Kettle River; Falls above the Sandstone Dam, which were exposed when the dam was removed in 1995. With the removal of the Sandstone Dam, the Kettle River is now 'free-flowing' and is a tributary to the St. Croix River.

Minnesota Stream Quantification Tool and Debit Calculator User Manual (Version 1.0)

US Army Corps of Engineers®
St. Paul District

BOARD OF WATER AND SOIL RESOURCES

MINNESOTA POLLUTION CONTROL AGENCY

DEPARTMENT OF NATURAL RESOURCES

StreamMechanics

Ecosystem Planning & Restoration

Minnesota Stream Quantification Tool and Debit Calculator User Manual (Version 1.0)

July 2019

Citation:

Minnesota Stream Quantification Tool Steering Committee (MNSQT SC). 2019. Minnesota Stream Quantification Tool and Debit Calculator (MNSQT) User Manual, Version 1.0. U.S. Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds (Contract # EP-C-17-001), Washington, D.C.

Acknowledgements

The Minnesota Stream Quantification Tool (MNSQT) and supporting materials are adapted for Minnesota from the Wyoming Stream Quantification Tool v1.0 (USACE, 2018) and the Colorado Stream Quantification Tool beta version (CSQT SC 2019). The regionalization of this tool for Minnesota was funded by USEPA Region 5 and USEPA Headquarters through a contract with Ecosystem Planning and Restoration (contract # EP-C-17-001).

The Minnesota Stream Quantification Tool (MNSQT) is the collaborative result of agency representatives, Stream Mechanics, and Ecosystem Planning and Restoration (EPR), collectively referred to as the MNSQT Steering Committee (MNSQT SC). Members include:

Will Harman, Stream Mechanics
LeeAnne Lutz, Ecosystem Planning and Restoration
Kerryann Weaver, U.S. Environmental Protection Agency, Region 5
Melanie Burdick, U.S. Environmental Protection Agency, Region 5
Jill Bathke, U.S. Army Corps of Engineers, St. Paul District
Leslie Day, U.S. Army Corps of Engineers, St. Paul District
Ken Powell, Minnesota Board of Water and Soil Resources
Doug Norris, Minnesota Department of Natural Resources
Tom Hovey, Minnesota Department of Natural Resources
Jen Oknich, Minnesota Pollution Control Agency

Many other provided valuable contributions to the Minnesota documents, including: Karl Koller (MN DNR) and Ian Chisholm (MN DNR), who provided valuable input, review and comment throughout regionalization and document development, Nathan Mielke (MPCA) who provided input on fish and macroinvertebrate metrics and assemblage data, Jesse Anderson who provided input on water quality parameter metrics and associated data, and Nick Proulx (MN DNR), David Demmer (MN BWSR), Mike Miller (WI DNR), Leslie Day (USACE), and Amy James (EPR). Valuable peer review on draft versions of this document were provided by Julia McCarthy (EPA Region 8). Valuable peer review and contract support was provided by Brian Topping (EPA Headquarters).

Table of Contents

List of Figures

List of Tables

List of Examples

Preface

Document History

The Minnesota Stream Quantification Tool (MNSQT) and Debit Calculator were developed from the Wyoming Stream Quantification Tool (WSQT) v1.0. The MNSQT User Manual (this document) was developed using the Colorado Stream Quantification Tool (CSQT) Beta version documentation as a template. All documents have been edited from the WSQT v1.0 and the CSQT Beta version for use in Minnesota.

Document Availability and Revisions

A digital copy of the MNSQT and associated documents can be obtained on the Regulatory In-lieu fee and Bank Information Tracking System (RIBITS) website under Assessment Tools for Minnesota:

https://ribits.usace.army.mil/

Or at the Stream Mechanics website:

https://stream-mechanics.com/stream-functions-pyramid-framework/

A copy may also be requested from any of the USACE Regulatory Offices in Minnesota.

The following spreadsheets and documents are available:

- MNSQT Workbook – Microsoft Excel Workbook described in detail in the User Manual (this document).
- Debit Calculator Workbook – Microsoft Excel Workbook described in detail in the St. Paul District Stream Mitigation Guidance (USACE Date pending) and the User Manual (this document).
- Minnesota Stream Quantification Tool and Debit Calculator Version 1.0 User Manual (User Manual) – This manual describes the MNSQT and Debit Calculator workbooks, all calculations performed by the workbooks, and how to collect data and calculate input for the MNSQT.
- Scientific Support for the MNSQT (MNSQT SC Date pending) – A comprehensive review of the function-based parameters and metrics, reference standards, stratification methods, scoring and references used in the MNSQT. The Scientific Support for the MNSQT also includes a list of metrics summarizing this information.
- St. Paul District Stream Mitigation Guidance (USACE Date pending) – USACE procedures for using the MNSQT and Debit Calculator workbooks to calculate credits and debits.

Future versions will be updated and revised periodically as additional data are gathered and reference curves and metrics are refined. Field data supporting refinement of reference curves and evaluation of metrics are appreciated.

The MNSQT architecture is flexible and can accommodate additional parameters and metrics that are accompanied by reference curves. If a user is interested in proposing additional parameters or metrics for incorporation into the tool, they should provide a written proposal for consideration. The written proposal should include a justification and rationale (e.g., data sources and/or literature references) and should follow the framework for identifying threshold values and index scores that is outlined in the Scientific Support for the MNSQT (MNSQT SC Date pending).

Send questions to: Technical Services Section, St. Paul District US Army Corps of Engineers, 108 5th Street East, Suite 700, St. Paul, Minnesota 55101 or call (651) 290-5525. More information on the SQT and District mitigation guidance can be found at https://www.mvp.usace.army.mil/Missions/Regulatory/.

DISCLAIMER

The Minnesota Stream Quantification Tool and Debit Calculator, including workbooks and supporting documents, are intended for the evaluation of Clean Water Act Section 404 (CWA 404) and Rivers and Harbors Act Section 10 (RHA Section 10) compensatory mitigation projects and impact sites and their departure from reference conditions in terms of functional loss or lift, respectively. The metrics are scored based on their current condition as compared to a reference standard. Consultation with the local USACE office is recommended prior to the use of this tool related to any CWA 404 or RHA Section 10 activities. The MNSQT can also be applied to restoration projects outside of the CWA 404 or RHA Section 10 regulatory context. Coordination with the appropriate State agency is recommended prior to data collection. In part, or as a whole, the function-based parameters, metrics, and index values are not intended to be used as the basis for engineering design criteria. The U.S. Army Corps of Engineers assumes no liability for engineering designs based on these tools. Designers should evaluate evidence from hydrologic and hydraulic monitoring, modeling, nearby stream morphology, existing stream conditions, sediment transport requirements, and site constraints to determine appropriate restoration designs.

Acronyms

BEHI/NBS – Bank Erosion Hazard Index / Near Bank Stress
BHR – Bank Height Ratio
BMP – Best Management Practice
CFR – Code of Federal Register
Corps – United States Army Corps of Engineers (also, USACE)
CSQT – Colorado Stream Quantification Tool
CWA 404 – Section 404 of the Clean Water Act
DNR – Department of Natural Resources
DO – Dissolved Oxygen
ECS – Existing Condition Score
EPA – United States Environmental Protection Agency (also, USEPA)
ER – Entrenchment Ratio
FF – Functional Feet
HUC – Hydrologic Unit Code
IBI – Index of Biotic Integrity
IHA – Indicators of Hydrologic Alteration
LWD – Large Woody Debris
LWDI – Large Woody Debris Index
MIDS – Minimal Impact Design Standards
MNSQT – Minnesota Stream Quantification Tool
MNSQT SC – Minnesota Stream Quantification Tool Steering Committee
MPCA – Minnesota Pollution Control Agency
MWR – Meander Width Ratio
NLCD – National Land Cover Database
NRCS – Natural Resource Conservation Service
PCS – Proposed Condition Score
RHA Section 10 – Section 10 of the Rivers and Harbors Act
R_v – Site Runoff Coefficient
SEM – Stream Evolution Model
SFPF – Stream Function Pyramid Framework
TMDL – Total Maximum Daily Load
TSS – Total Suspended Solids
USACE – United States Army Corps of Engineers (also, Corps)
USEPA – United States Environmental Protection Agency (also, EPA)
USGS – United States Geologic Survey
UT – Unnamed Tributary
WDR – Width Depth Ratio
WHAF – Watershed Health Assessment Framework
WSQT – Wyoming Stream Quantification Tool
WSTT – Wyoming Stream Technical Team

Glossary of Terms

Alluvial Valley – Valley formed by the deposition of sediment from fluvial processes.

Catchment – Land area draining to the downstream end of the project reach.

Colorado Stream Quantification Tool (CSQT) – The CSQT user manual and scientific support documents have been adapted and modified for use in Minnesota.

Colluvial Valley – Valley formed by the deposition of sediment from hillslope erosion processes. Colluvial valleys are typically confined by terraces or hillslopes.

Condition – The relative ability of an aquatic resource to support and maintain a community of organisms having a species composition, diversity, and functional organization comparable to reference aquatic resources in the region. (see 33CFR 332.2)

Condition Score – Metric-based index values are averaged to characterize condition for each parameter, functional category, and overall project reach.

ECS = Existing Condition Score

PCS = Proposed Condition Score

Credit – A unit of measure (e.g., a functional or areal measure or other suitable metric) representing the accrual or attainment of aquatic functions at a compensatory mitigation site. The measure of aquatic functions is based on the resources restored, established, enhanced, or preserved. (see 33CFR 332.2)

Debit – A unit of measure (e.g., a functional or areal measure or other suitable metric) representing the loss of aquatic functions at an impact or project site. The measure of aquatic functions is based on the resources impacted by the authorized activity. (see 33CFR 332.2)

Debit Calculator workbook – A Microsoft-Excel workbook used to evaluate change in condition at permitted impact sites.

Debit Tool worksheet – The debit tool worksheet is included in the Debit Calculator workbook and is used to calculate the functional loss due to proposed impacts.

Field Value – A field measurement or calculation input into the MNSQT for a specific metric. Units vary based on the metric or measurement method used.

Functional Capacity – The degree to which an area of aquatic resource performs a specific function. (see 33CFR 332.2)

Functions – The physical, chemical, and biological processes that occur in ecosystems. (see 33CFR 332.2)

Functional Category – The organizational levels of the stream quantification tool: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology. Each category is defined by functional statement(s).

Functional Feet (FF) – Functional feet is the primary unit for communicating functional lift and loss. The functional feet for a stream reach is calculated by multiplying an overall reach condition score by the stream reach length. The change in functional feet (ΔFF) is the difference between the Existing FF and the Proposed FF.

Function-Based Parameter – A structural measure which characterizes a condition at a point in time, or a process (expressed as a rate) that describes and supports the functional statement of each functional category.

Index Values: Dimensionless values between 0.00 and 1.00 that express the relative condition of a metric field value compared with reference standards. These values are derived from reference curves for each metric. Index values are combined to create parameter, functional category, and overall reach scores.

Impact Severity Tiers – The Debit Tool worksheet provides estimates of proposed condition based upon the magnitude of proposed impacts, referred to as the impact severity tier. Higher tiers impact more stream functions.

Measurement Method – A specific tool, equation or assessment method used to inform a metric. Where a metric is informed by a single data collection method, metric and measurement method are used interchangeably (see Metric).

Metric – A specific tool, equation, measured values or assessment method used to evaluate the condition of a structural measure or function-based parameter. Some metrics can be derived from multiple measurement methods. Where a metric is informed by a single data collection method, metric and measurement method are used interchangeably (see Measurement Method).

Minnesota Stream Quantification Tool (MNSQT) – The MNSQT consists of two workbooks, the MNSQT workbook and the Debit Calculator workbook. The MNSQT workbook is a spreadsheet-based calculator that scores stream condition before and after restoration or impact activities to determine functional lift or loss, respectively (see MNSQT workbook). The MNSQT can also be used to determine restoration potential, develop monitoring criteria and assist in other aspects of project planning. The Debit Calculator workbook is a spreadsheet-based calculator that determines the functional loss due to proposed impacts (see Debit Calculator workbook).

Minnesota Stream Quantification Tool Steering Committee (MNSQT SC) – The group who worked on the development of the MNSQT and contributed to various aspects of this document.

MNSQT workbook – The Microsoft-Excel workbook file used to evaluate change in condition at a mitigation or restoration site.

Performance Standards – Observable or measurable physical (including hydrological), chemical and/or biological attributes that are used to determine if a compensatory mitigation project meets its objectives. (see 33 CFR 332.2)

Project Area – The geographic extent of a project. This area may include multiple project reaches where there are variations in stream physical characteristics and/or differences in project designs within the project area.

Project Reach – A homogeneous stream reach within the project area, i.e., a stream segment with similar valley morphology, stream type (Rosgen 1996), stability condition, riparian vegetation type, and bed material composition. Multiple project reaches may exist in a project area where there are variations in stream physical characteristics and/or differences in project designs.

Reference Aquatic Resources – A set of aquatic resources that represent the full range of variability exhibited by a regional class of aquatic resources as a result of natural processes and without anthropogenic disturbances. (see 33 CFR 332.2)

Reference Curves – A relationship between observable or measurable metric field values and dimensionless index values. These curves take on several shapes, including linear, polynomial, bell-shaped, and other forms that best represent the degree of departure from a reference standard for a given field value. These curves are used to determine the index value for a given metric in a project reach.

Reference Standard – The subset of reference aquatic resources that are least disturbed and exhibit the highest level of function. In the MNSQT, this condition is considered functioning for the metric being assessed, and ranges from minimally impacted to unaltered or pristine condition.

Representative Sub-Reach – A length of stream within a project reach that is selected for field data collection of parameters and metrics. The representative sub-reach is typically 20 times the bankfull width or two meander wavelengths (Leopold 1994).

Riparian Area Width – The percentage of the historic or expected riparian corridor that currently contains riparian vegetation and is free from utility-related, urban, or otherwise soil disturbing land uses. The riparian corridor corresponds to (Merritt et al. 2017):

Substrate and topographic attributes -- the portion of the valley bottom influenced by fluvial processes under the current climatic regime,

Biotic attributes -- riparian vegetation characteristic of the region and plants known to be adapted to shallow water tables and fluvial disturbance, and

Hydrologic attributes -- the area of the valley bottom flooded at the stage of the 100-year recurrence interval flow.

Riparian Vegetation – Plant communities contiguous to and affected by shallow water tables and fluvial disturbance.

Stream Functions Pyramid Framework (SFPF) – The Stream Functions Pyramid is comprised of five functional categories stratified based on the premise that lower-level functions support higher-level functions and that they are all influenced by local geology and climate. The SFPF includes the organization of function-based parameters, metrics (measurement methods), and performance standards (reference standards) to assess the functional categories of the Stream Functions Pyramid (Harman et al. 2012).

Stream Restoration – The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource (33 CFR 332.2). The term is used in this document to represent stream compensatory mitigation methods including re-habilitation, re-establishment, and enhancement.

Threshold Values – Criteria used to develop the reference curves for each metric. These criteria differentiate between three condition categories: functioning, functioning-at-risk, and not functioning and relate to the Performance Standards as defined above.

Wyoming Stream Quantification Tool (WSQT) – The WSQT is the Stream Quantification Tool from Wyoming that has been adapted and modified for use in Minnesota.

Wyoming Stream Technical Team (WSTT) – The group who worked on the development of the WSQT and associated documents.

Overview

The Minnesota Stream Quantification Tool and Debit Calculator (MNSQT) are spreadsheet-based tools designed to inform permitting and compensatory mitigation decisions within the Clean Water Act Section 404 (CWA 404) and Rivers and Harbors Act Section 10 (RHA Section 10) programs. When used within the context of these programs, coordination with the US Army Corps of Engineers and other state or local regulatory authorities on tool use and parameter selection is recommended prior to data collection. The MNSQT can also be applied to restoration projects outside of the CWA 404 or RHA Section 10 regulatory context. Coordination with the appropriate State agency is recommended prior to data collection. These Microsoft Excel Workbooks have been developed to characterize stream ecosystem functions by evaluating a suite of indicators that represent structural or compositional attributes of a stream and its underlying processes. Indicators in the MNSQT represent parameters that are often impacted by authorized projects or affected (e.g. enhanced or restored) by mitigation actions undertaken by restoration providers. The MNSQT has been modified from the Wyoming Stream Quantification Tool Version 1.0 (WSQT v1.0; USACE 2018a) and regionalized for use in Minnesota. Many of the parameters, metrics and reference curves within the MNSQT Version 1.0 are similar to or identical to those in the WSQT v1.0 (USACE 2018a). Other stream quantification tools and user manuals have been developed for use in other states and regions, including North Carolina (Harman and Jones 2017), Tennessee (TDEC 2018), Georgia (USACE 2018b), and Colorado (CSQT SC 2019). Some metrics from these quantification tools were considered when developing the metrics for the MNSQT.

The MNSQT is an application of the Stream Functions Pyramid Framework (SFPF; Harman et al. 2012) and uses function-based parameters and metrics to assess five functional categories: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology. The MNSQT integrates multiple indicators from these functional categories into a reach-based condition score that is used to calculate the change in condition before and after impact or restoration activities are implemented. Restoration refers to the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource (33 CFR 332.2). The term is used in this document to represent compensatory mitigation methods including re-habilitation, re-establishment, and enhancement as defined in the 2008 Compensatory Mitigation for Losses to Aquatic Resources; Final Rule (2008 Rule).

The main goal of the MNSQT is to produce objective, verifiable, and repeatable results by consolidating well-defined procedures for objective and quantitative measures of defined stream variables. The MNSQT includes 24 metrics within 12 parameters that can be evaluated at a project site. A basic set of metrics within 5 parameters is required at all project sites evaluated for CWA 404 or RHA Section 10 purposes to provide consistency between impacts and compensatory mitigation and allow for more consistent accounting of functional change. Users can include additional parameters and metrics on a project-specific basis (see Section 2.3 on Parameter Selection). This User Manual provides data collection methods related to each metric. For some metrics, methods include both rapid and more detailed forms of data collection, allowing the tool to be used for rapid or more comprehensive site assessment.

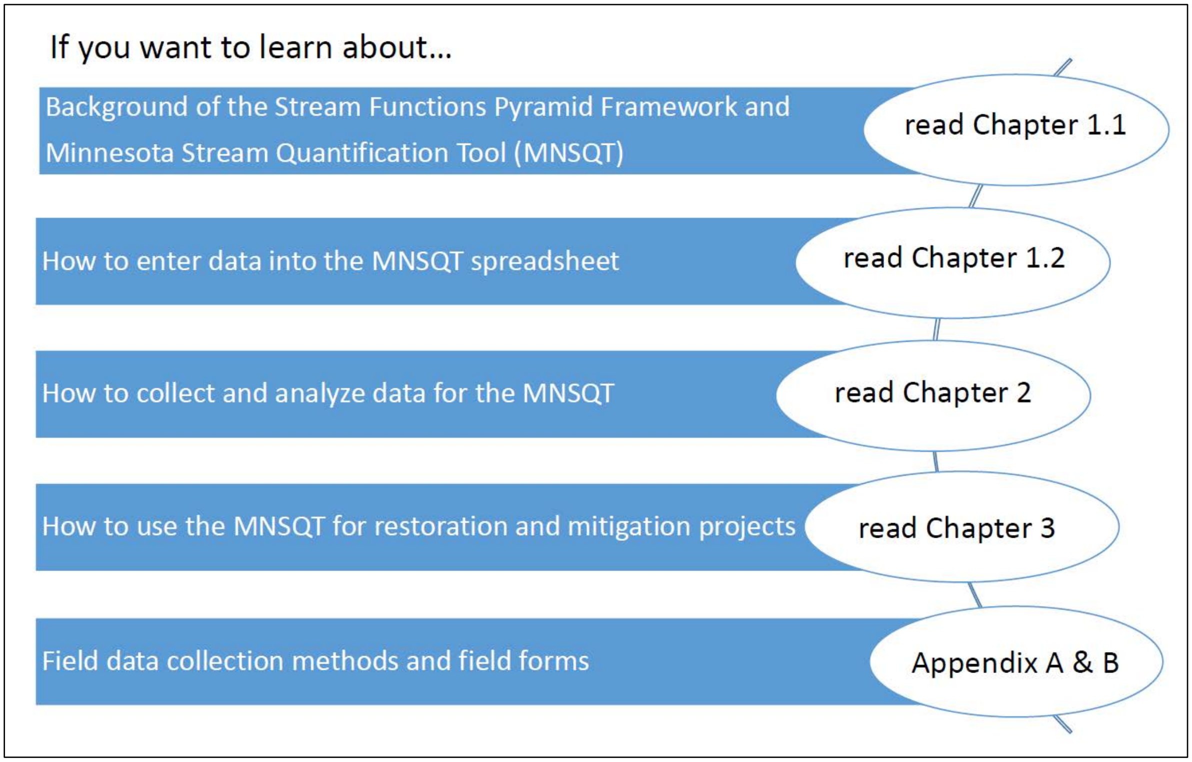
This manual describes the MNSQT and Debit Calculator workbooks and how to collect and analyze data entered into these workbooks. Companion documents include the St. Paul District Stream Mitigation Guidance (USACE Date pending) which provides policy direction for how and when the MNSQT will be used for the CWA 404 or RHA Section 10 regulatory programs and how tool results are translated into credits and debits; and the Scientific Support for the MNSQT, which provides rationale for scoring in the MNSQT and describes how measured stream conditions were converted into dimensionless index scores (MNSQT SC Date pending).

PURPOSE AND USE OF THE MNSQT

The purpose of the MNSQT is to evaluate change in stream ecosystem functions at a mitigation or restoration site and to inform permitting and compensatory mitigation decisions within the CWA 404 and RHA Section 10 programs. The MNSQT can also be applied to restoration projects outside of the CWA 404 or RHA Section 10 regulatory context. The tools are calculators to quantify functional change between an existing and future stream condition. The future stream condition can be a proposed for an active stream restoration project or a proposed stream impact requiring a CWA 404 permit. For a stream restoration project, this functional change can be estimated during the design or mitigation plan phase and verified during post-construction monitoring events in the MNSQT workbook. For a stream impact, functional loss can be estimated several ways using the Debit Calculator workbook. Estimates of functional lift and functional loss can inform CWA 404 and RHA Section 10 permitting and mitigation decisions; the application of the MNSQT in these regulatory programs in Minnesota is outlined in the St. Paul District Stream Mitigation Guidance (USACE Date pending). Debit and credit determination methods are not included in this manual but are outlined in the St. Paul District Stream Mitigation Guidance (USACE Date pending). Users are strongly encouraged to contact the Corps and other state or local regulatory authorities to obtain project-specific direction. Not all portions of the MNSQT or Debit Calculator workbooks will be applicable to all projects.

The MNSQT can also help determine if a proposed site has the potential to be considered for a stream restoration or mitigation project and provides a framework to guide restoration planning. The catchment assessment and restoration potential process accompanying the MNSQT (described in Chapter 3) can be used to help determine factors that limit the potential lift achieved by a stream restoration or mitigation project. This information can be used to develop project goals that match the restoration potential of a site. Quantifiable objectives, performance standards, and monitoring plans can be developed that link restoration activities to measurable changes in stream functional categories and function-based parameters assessed by the tool. Figure 1 can assist in navigating this User Manual for specific project types.

Figure 1: Manual Directory



KEY CONSIDERATIONS

The MNSQT and supporting documentation have been developed to meet the function-based approaches set forth in the 2008 Rule. Therefore, the following concepts are critical in understanding the applicability and limitations of this tool:

- The parameters and metrics in the tool were selected due to their sensitivity in responding to reach-scale changes associated with the types of activities commonly encountered in the CWA 404 or RHA Section 10 programs and commonly used in stream restoration. These parameters do not comprehensively characterize all structural measures or processes that occur within a stream.
- The MNSQT is designed to assess the same parameters at a site over time, thus providing information on the degree to which the condition of the stream system changes following impacts or restoration activities. We refer to the MNSQT as a change tool for this reason – it is intended to detect change at a site over time. Unless the same parameters and metrics are used across all sites, it would inappropriate to compare scores.
- The MNSQT itself does not score or quantify watershed condition. Watershed condition reflects the external elements that influence functions within a project reach and may affect project site selection or restoration potential (see Chapter 3).
- The MNSQT is not a design tool. Many function-based parameters are critical to a successful restoration design but sit outside the scope of the MNSQT. The MNSQT measures the physical, chemical, and biological responses or outcomes related to a project design at a reach scale.

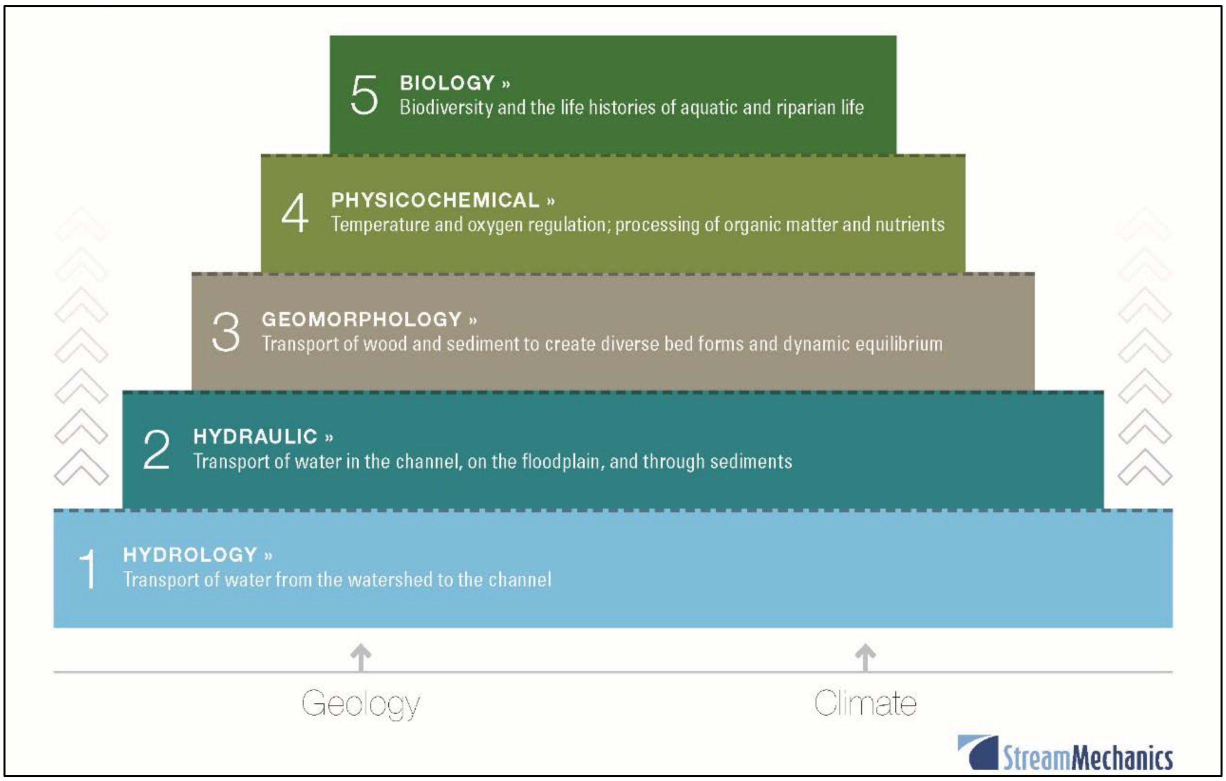
Chapter 1. Background and Introduction

The Minnesota Stream Quantification Tool and Debit Calculator spreadsheets are an application of the Stream Functions Pyramid Framework (SFPF). Therefore, to understand the structure of the MNSQT, it is important to first understand the SFPF. This chapter provides a brief overview of the SFPF followed by an overview of the elements included in the MNSQT and Debit Calculator workbooks.

1.1. Stream Functions Pyramid Framework (SFPF)

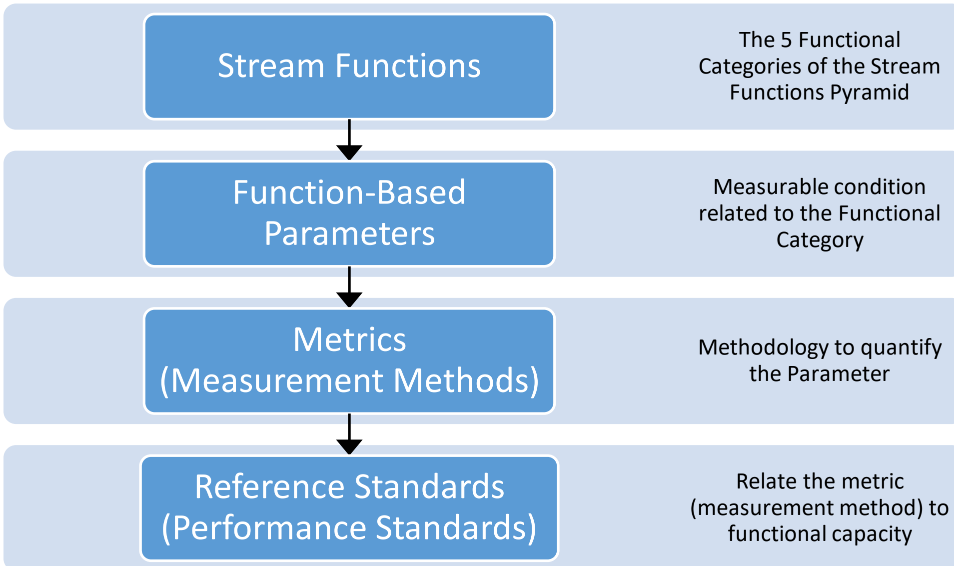
The Stream Functions Pyramid (Figure 2), includes five functional categories: Level 1: Hydrology, Level 2: Hydraulics, Level 3: Geomorphology, Level 4: Physicochemical, and Level 5: Biology. The Pyramid organization recognizes that lower-level functions generally support higher-level functions (although the opposite can also be true) and that all functions are influenced by local geology and climate. Each functional category is defined by a functional statement.

Figure 2: Stream Functions Pyramid (Image from Harman et al. 2012)



The SFPF illustrates a hierarchy of stream functions but does not provide specific mechanisms for addressing functional capacity, establishing performance standards, or communicating functional change. The diagram in Figure 3 expands the Pyramid concept into a more detailed framework to quantify functional capacity, establish performance standards, evaluate functional change, and establish function-based goals and objectives.

Figure 3: Stream Functions Pyramid Framework



This comprehensive framework includes more detailed forms of analysis to quantify stream functions and functional indicators of underlying stream processes. In this framework, function-based parameters describe and support the functional statements of each functional category, and the metrics (measurement methods) are specific tools, equations, and/or assessment methods that are used to characterize site condition and inform function-based parameter scores. Reference standards (performance standards) are measurable or observable end points of stream restoration.

1.2. Minnesota Stream Quantification Tool and Debit Calculator (MNSQT)

Following the SFPF, function-based parameters and metrics were selected to quantify stream condition across various ecoregions and stream types. Each metric is linked to reference curves that relate measured field values to a regional reference condition. In the MNSQT, field values for a metric are assigned an index value (0.00 – 1.00) using the applicable reference curves. The numeric index value range was standardized across metrics by determining how field values relate to functional capacity, i.e., functioning, functioning-at-risk, and not-functioning conditions (Table 1). The reference curves in the MNSQT are tied to specific benchmarks (thresholds) that represent the degree to which the aquatic resources are functioning and/or the degree to which condition departs from reference standard.[1]

[1] Additional detail on function-based parameters and metrics, along with specific information on stratification and reference curve development is provided in the Scientific Support for the MNSQT (MNSQT SC, Date pending).

Table 1: ***Functional Capacity Definitions Used to Define Threshold Values and Develop Reference Curves for the MNSQT***

Functional Capacity	Definition	Index Score Range
Functioning	A functioning score means that the metric is quantifying or describing the functional capacity of one aspect of a function-based parameter in a way that supports aquatic ecosystem structure and function at a reference standard condition. A score of 1.00 does not represent the best attainable condition, but an unaltered or pristine system. A score of 0.70 represents a system that is attaining a high level of function but may no longer be pristine.	0.70 to 1.00
Functioning-at-risk	A functioning-at-risk score means that the metric is quantifying or describing one aspect of a function-based parameter in a way that can support aquatic ecosystem structure and function. In many cases, this indicates the function-based parameter is adjusting in response to changes in the reach or the catchment. The trend may be toward lower or higher function. A functioning-at-risk score indicates that the aspect of the function-based parameter, described by the metric, is between functioning and not- functioning.	0.30 to 0.69
Not-functioning	A not-functioning score means that the metric is quantifying or describing one aspect of a function-based parameter in a way that does not support aquatic ecosystem structure and function. A score of 0.29 represents a condition that is severely altered or impaired relative to reference conditions, and a score of 0.00 represents a condition that is indicative of no functional capacity.	0.00 to 0.29

The MNSQT workbook (MNSQTv1.0.xlsx) is a Microsoft Excel Workbook comprised of 9 worksheets. There are no macros in the workbook and all formulas are visible, though some worksheets are locked to prevent editing. One workbook should be assigned to each project reach within a project area. Each of the following worksheets is described in this Section.

The MNSQT worksheets include:

- Project Assessment
- Catchment Assessment
- Major Flow Variability Metrics
- Measurement Selection Guide
- Quantification Tool (locked)
- Monitoring Data (locked)
- Data Summary (locked)
- Reference Curves (locked)

- Pull Down Notes – This worksheet is hidden and contains all the inputs for drop down menus throughout the workbook.

The Debit Calculator workbook (MNSQT Debit Calculator v1.0.xlsx) is a Microsoft Excel Workbook comprised ofseven worksheets. There are no macros in the workbook and all formulas are visible, though some worksheets are locked to prevent editing. One workbook can be used to score multiple project reaches within a project area. Each of the following worksheets is described in this Section.

The Debit Calculator worksheets include:

- Project Assessment
- Debit Calculator (locked)
- Measurement Selection Guide
- Existing Conditions (locked)
- Proposed Conditions (locked)
- Reference Curves (locked and hidden)
- Pull Down Notes – This worksheet is hidden and contains all the inputs for drop down menus throughout the workbook.

1.2.A. PROJECT ASSESSMENT WORKSHEET

The Project Assessment worksheet allows for a description of the project reach, the proposed project, and its effect on the stream within the project area. This worksheet is included in both MNSQT and Debit Calculator workbooks, but contains different components, as described below.

In the MNSQT workbook this worksheet will communicate the goals of the project and its associated restoration potential. For projects with multiple reaches (and thus multiple workbooks), the project information on this worksheet may be the same across workbooks except for a unique reach-specific description. Information on delineating project reaches is provided in Chapter 2.

COMPONENTS OF THE PROJECT ASSESSMENT WORKSHEET

Programmatic Goals (MNSQT only) – Programmatic goals represent big-picture goals that are often broader than function-based goals and are determined by the project owner or funding entity. A drop-down menu is provided with the following options: Mitigation – Credits, TMDL, Grant, or Other.

Reach Description (MNSQT) – Space is provided to describe the project reach, including the individual reach ID, location (latitude/longitude), and reference stream type. If there are multiple project reaches within the project area, this section should include a description of the characteristics that separate it from other reaches. Guidance on identifying project reaches and selecting reference stream type is provided in Section 2.4.

Reach Description (Debit Calculator) – Space is provided in a table to assign each reach a Stream ID, briefly describe proposed impact for each reach, and identify the location (latitude/longitude) for up to 10 reaches. Information regarding the project name, applicant and project ID and/or permit numbers can be documented on the worksheet.

Aerial Photograph of Project Reach (MNSQT only) – Provide a current aerial photograph of the project reach. The photo could include labels indicating where work is proposed, the project area boundaries and/or proposed/existing easement, and any important features within the project site.

Latitude/Longitude (MNSQT and Debit Calculator) – Provide the latitude and longitude at the downstream limit of the project reach.

Reference Stream Type (MNSQT only) – Provide the reference stream type that should occur in a given landscape setting given the hydrogeomorphic processes occurring at the watershed and reach scales. Channel evolution scenarios should be used to inform the reference stream type.

Restoration Approach (MNSQT only) – In Box 1, the user should explain programmatic goals (see Example 1).

Box 2 should be used to explain the connection between the restoration potential and the programmatic goals. The restoration potential can be classified as partial or full restoration, and this classification comes from the Catchment Assessment worksheet (see below).

Box 3 should be used to describe the function-based goals and objectives of the project. More information on restoration potential and developing goals and objectives is provided in Chapter 3.

Example 4: Restoration Approach

If the programmatic goal is to create mitigation credits, then the first text box could provide more information about the type and number of credits desired.

If the restoration potential is partial restoration, then the second text box would explain how improvements to hydrology and hydraulics, and/or geomorphology would create the necessary credits and identify the constraints and stressors that are limiting restoration of physicochemical and biological functions.

The goals of the project would match the restoration potential, e.g., target reference standard habitat condition and partial restoration of biological condition. Accompanying objectives could identify parameters to be restored and which metrics will be used to monitor restoration progress.

1.2.B. Catchment Assessment Worksheet

This worksheet is included within the MNSQT workbook but not the Debit Calculator workbook. The Catchment Assessment worksheet assists in characterizing watershed processes and stressors that exist outside of the project reach but affect functions within the reach. It also highlights factors necessary to consider or address during the project design to maximize the likelihood of a successful project. This worksheet contains 15 categories to be rated as Good, Fair, or Poor. Fourteen of the categories are related to specific Minnesota Department of Natural Resources (DNR) Watershed Health Assessment Framework (WHAF) Index Scores or values that can be obtained from WHAF Charts and Reports. The specific WHAF index or value that relates to each category is listed in Column I. Information on the WHAF and index descriptions are provided at the DNR WHAF website (https://www.dnr.state.mn.us/whaf/index.html).

Most of the categories describe potential stressors upstream of the project reach since the contributing catchment has the most influence on the project reach's hydrology, water quality, and biological condition. Based on the category ratings, the user should provide an overall watershed condition and determine the restoration potential for the reach. The user should refer to Section 3.2.a for determining the Restoration Potential for the reach.

1.2.c. Major Flow Variability Metrics

This worksheet is present in the MNSQT workbook, but not the Debit Calculator workbook. This worksheet is a reference that provides the Flow Variability Rate and Frequency of Change metric and the Frequency and Duration of High/Low Pulses metric for the HUC-8 watershed in which the stream restoration project is located. These two metrics are evaluated for the Flashiness Index (Hydrology) category IHA analysis. *This worksheet is included for reference purposes and does not require any data entry.*

1.2.d. Measurement Selection Guide

This worksheet is present in the MNSQT workbook and the Debit Calculator workbook. The measurement selection guide is included to assist users in selecting the appropriate parameters and metrics for the project reach.

1.2.e. Quantification Tool Worksheet

This worksheet is included in the MNSQT workbook. The Existing Conditions and Proposed Conditions Debit worksheets within the Debit Calculator workbook are similar and will be discussed this section. In both workbooks, the quantification tool calculates the condition score based on data entry describing the existing and proposed conditions of the project reach. In the MNSQT workbook, the Quantification Tool worksheet contains three areas for data entry: Site Information and Reference Selection, Existing Condition Assessment field values, and Proposed Condition Assessment field values.

In the Debit Calculator workbook, the user can score the existing and proposed conditions for 10 reaches in the Existing Conditions and Proposed Conditions worksheets, respectively. The user provides site information for each reach in the Reach Information and Reference Standard Stratification table above each condition assessment.

Cells that allow input are shaded gray and all other cells are locked. Each section of the MNSQT Quantification Tool worksheets is discussed below.

Site Information and Reference Selection

In the MNSQT workbook Quantification Tool worksheet, the Site Information and Reference Selection section consists of general site information and classifications to determine which reference curve(s) to apply in calculating index values for relevant metrics (Figure 4). Information on each input field and guidance on how to select values are provided in Section 2.4.

In the Debit Calculator workbook, the corresponding section is located above each reach condition assessment in the Existing Conditions and Proposed Conditions workbook and is called Reach Information and Reference Selection. Similar general site information and classifications that determine which reference curve(s) apply are input in this section for each reach. Two inputs (outstanding resource waters and proposed BMPs) are specific to the Debit

Calculator. The Debit Calculator also requires more specific location information (latitude and longitude of the upstream and downstream extent of the reach) in lieu of the drainage area input.

In the MNSQT workbook, Quantification Tool worksheet, the restoration potential field is linked to the input cell on the Catchment Assessment worksheet and the reference stream type is linked to the input cell on the Project Assessment worksheet.

Figure 4: Example Site Information and Reference Selection Input Fields

Site Information and Reference Selection	
Project Name:	Restoration Project
Reach ID:	1
Restoration Potential:	Full
Existing Stream Type:	C
Reference Stream Type:	Bc
Woody Vegetation Natural Component:	Yes
Use Class:	2A
River Nutrient Regions:	North
Drainage Area (sq.mi.):	10
Proposed Bed Material:	Gravel
Existing Stream Length (ft):	1000
Proposed Stream Length (ft):	1200
Macroinvertebrate IBI Class:	Northern Forest Rivers
Fish IBI Class:	Northern Rivers
Valley Type:	Confined Alluvial

EXISTING AND PROPOSED CONDITION ASSESSMENT DATA ENTRY

Once the Site Information and Reference Selection section has been completed, the user can input data into the field value column of the Existing and Proposed Condition Assessment tables (Figure 5).

A user will rarely input data for all metrics or parameters within the tool. Guidance on parameter selection is provided in Chapter 2.3. The function-based parameters and metrics are listed by functional category, starting with Hydrology. Multiple tables in the MNSQT are color-coded to show the delineation between functional categories: light blue for hydrology, dark blue for hydraulics, orange for geomorphology, yellow for physicochemical, and green for biology.

The Existing Condition Assessment field values are derived from data collection and analysis methods outlined in Chapter 2 and Appendix A. An existing condition score relies on baseline data collected from the project reach before any work is completed. For some metrics, methods include both rapid and more detailed forms of data collection; field values can be calculated using data from either rapid or more comprehensive site assessment.

The Proposed Condition Assessment field values should consist of reasonable values for restored conditions. For the Proposed Condition Assessment, the user should rely on available data to estimate the proposed condition field values. Proposed field values that describe the physical post-project condition of the stream reach should be based on project design studies and calculations, drawings, field investigations, and best available science. Parameters and metrics that are assessed in the Existing Condition Assessment must also be used to determine the proposed post-impact condition score. (Note: field value, as used here, refers to the location in the condition assessment table of the worksheet where data are entered and not the actual collection of field data to yield a field value).

Figure 5: Example Field Value Data Entry in the Condition Assessment Table

Functional Category	Function-Based Parameter	Metric	Field Value
Hydrology	Reach Runoff	Land Use Coefficient	80
		BMP MIDS Rv Coefficient	
		Concentrated Flow Points / 1,000 feet	3
Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.2
		Entrenchment Ratio	3
Geomorphology	Large Woody Debris	LWD Index	184
		No. of LWD Pieces / 100 meters	
	Lateral Migration	Dominant BEHI/NBS	H/M
		Percent Streambank Erosion (%)	20
		Percent Armoring (%)	
	Bed Material Characterization	Size Class Pebble Count Analyzer (p-value)	0.01
	Bed Form Diversity	Pool Spacing Ratio	2.4
		Pool Depth Ratio	2.1
		Percent Riffle (%)	30
		Aggradation Ratio	1.2
	Riparian Vegetation	Riparian Buffer Width (%)	60
		Canopy Cover (%)	50
		Herbaceous Vegetation Cover (%)	40
		Woody Stem Basal Area (sqm/hectare)	50
Physicochemical	Temperature	Summer Average (°C)	14
	Dissolved Oxygen	DO (mg/L)	7
	Total Suspended Solids	TSS (mg/L)	11
Biology	Macroinvertebrates	Macroinvertebrate IBI	55
	Fish	Fish IBI	40

Scoring Functional Lift and Loss

Scoring occurs automatically as field values are entered into the Existing Condition Assessment or Proposed Condition Assessment tables. A metric field value will correspond to an index value ranging from 0.00 to 1.00. Where more than one metric is used per parameter, these index values are averaged to calculate parameter scores. Similarly, multiple parameter scores within a functional category are averaged to calculate functional category scores. Functional category scores are weighted and summed to calculate overall scores that are used to calculate functional change.

Index Values – The reference curves available for each metric are visible in the Reference Curves worksheet. When a field value is entered for a metric on the Quantification Tool worksheet, these reference curves are used to calculate an index value.

As a field value is entered in the Quantification Tool worksheet, the neighboring index value cell should automatically populate with an index value (Example 2a). If the index value cell returns FALSE instead of a numeric index value, the Site Information and Reference Selection section may be missing data. In Example 2b, the proposed stream type was not selected in the Site Information and Reference Selection causing the Index Value to return a FALSE because the tool could not determine which reference curve to use.

Example 9: Populating Index Values in the MNSQT

(eeeee) Index values automatically populate when field values are entered.

Metric	Field Value	Index Value
Pool Spacing Ratio	5	1.00
Pool Depth Ratio		
Percent Riffle (%)	60	1.00
Aggradation Ratio		

(fffff) If FALSE, check the Site Information and Reference Selection section of the worksheet.

Metric	Field Value	Index Value
Pool Spacing Ratio	5	FALSE
Pool Depth Ratio		
Percent Riffle (%)	60	FALSE
Aggradation Ratio		

If the worksheet does not return a numeric index value, the user should check the Site Information and Reference Selection for data entry errors and then check the stratification for the metric in the Reference Curve worksheet. Note that incorrect information in the Site Information and Reference Selection section may result in applying reference curves that are not suitable for the project.

Scoring – In the MNSQT, scores are averaged within each level of the stream functions pyramid framework. Metric index values are averaged to calculate parameter scores; parameter scores are averaged to calculate category scores (Figure 6). The category scores are then weighted and summed to calculate overall scores; overall score weighting by category is shown in Table 2. Category scores are additive, so a maximum overall score of 1.00 is only possible when parameters within all five categories are evaluated. For example, if only Hydrology, Hydraulics and Geomorphology parameters are evaluated, the maximum overall score is 0.60.

In the Debit Calculator, scores for parameters that are not determined from studies, field investigations or best available science, will default to a score of 0.90 for state listed outstanding resource waters (prohibited or restricted) or 0.80 for all other waters. Because the metrics are not being assessed, the tool assumes these metrics are functioning. This approach acknowledges it is possible some metrics can and often score high where other values may be functioning at a lower capacity.

Figure 6: Scoring Example

Functional Category	Function-Based Parameter	Parameter	Category	Category
Hydrology	Reach Runoff	0.58	0.58	Functioning At Risk
Hydraulics	Floodplain Connectivity	0.57	0.57	Functioning At Risk
Geomorphology	Large Woody Debris	0.42	0.52	Functioning At Risk
	Lateral Migration	0.60		
	Bed Material Characterization			
	Bed Form Diversity	0.55		
	Riparian Vegetation	0.50		
Physicochemical	Temperature	0.21	0.31	Functioning At Risk
	Dissolved Oxygen	0.21		
	Total Suspended Solids	0.50		
Biology	Macroinvertebrates	0.00	0.00	Not Functioning
	Fish	0.00		

Table 2: Functional Category Weights

Functional Category	Weight
Hydrology	0.20
Hydraulics	0.20
Geomorphology	0.20
Physicochemical	0.20
Biology	0.20

<u>Calculating Functional Feet</u> – The change at an impact or mitigation site is the difference between the existing (pre-project) and proposed (post-project) overall scores. Existing and proposed condition scores are multiplied by stream length to calculate the change in functional feet (ΔFF).

The Quantification Tool worksheet calculates change in units of functional feet (FF) using stream length and the existing and proposed reach condition scores (ECS and PCS respectively) as follows:

1. $Existing\ FF = ECS * Existing\ Stream\ Length$
2. $Proposed\ FF = PCS * Proposed\ Stream\ Length$
3. $\text{Change in FF } (\Delta FF) = Proposed\ FF - Existing\ FF$

Functional lift is generated when the existing condition is more functionally impaired than the proposed condition and the third equation above yields a positive value. A negative value would represent a functional loss.

<u>Color Coded Scoring</u> – When index values are populated in the Quantification Tool worksheet, cell colors will automatically change color to identify where on the reference curve the field value lies (Figure 6). Green coloring indicates field values and index scores that represent a functioning (reference standard) range of condition; yellow indicates field values and index scores that represent a functioning-at-risk range of condition; and, red indicates field values and index scores that represent a not-functioning range of condition (see Table 1 for definitions). This color-coding is provided as a communication tool to illustrate the relative condition of the various metrics and parameters assessed. This is particularly useful when comparing existing to proposed condition, as well as reviewing the summary tables and monitoring data included in the MNSQT workbook (both are described below). Note that color coding is not provided for the overall score, as the overall score is not representative of an overall site condition unless parameters within all categories are evaluated. For example, if only Hydrology, Hydraulics and Geomorphology parameters are evaluated, the maximum overall score will be 0.60.

FUNCTIONAL LIFT AND LOSS SUMMARY TABLES

The Quantification Tool worksheet in the MNSQT workbook summarizes the scoring at the top of the worksheet, next to and under the Site Information and Reference Selection section. There are four summary tables: Functional Change Summary, Mitigation Summary, Functional Category Report Card, and Function-Based Parameters Summary.

<u>Functional Change Summary</u> – This summary (Figure 7) provides the overall scores from the Existing Condition Assessment and Proposed Condition Assessment sections, calculates the functional change occurring at the project site, and incorporates the length of the project to calculate the overall change in functional feet (∆FF).

The change in functional condition is the difference between the proposed condition score (PCS) and the existing condition score (ECS). It is a measure of the quality difference between existing and proposed condition irrespective of stream length. The summary includes the existing and proposed stream lengths to calculate and communicate functional feet (FF). A functional foot is the product of a condition score and the stream length (see equations in Calculating Functional Feet above). Since the condition score is 1.00 or less, the functional feet of a stream reach are always less than or equal to the actual stream length.

The change in functional feet (Proposed FF – Existing FF) is the amount of functional lift or loss resulting from the project. For projects that include multiple reaches, the change in functional feet can be summed to calculate the total change in functional feet for an entire project. This value can be used as a credit. Functional change is also expressed as the percent change in functional feet for a project reach:

$$Percent\ Change\ in\ FF = \frac{Proposed\ FF - Existing\ FF}{Existing\ FF} * 100$$

Percent change is provided for the functional feet scores. For stream restoration activities creating functional lift, the percent change will be positive. If functional loss occurs, the percentage will be negative. Stream restoration projects that increase stream length as part of a restoration activity will have a greater percent increase in functional feet.

The final summary value shown is the Functional-Foot Yield (FF Yield) (FF/FT). This value is calculated as:

$$FF\ Yield = \frac{Proposed\ FF - Existing\ FF}{Proposed\ Stream\ Length}$$

This value shows how many functional feet have been generated for every foot of channel being restored. For example, a value of 0.28 means that 0.28 functional feet are being created for every linear foot of restoration work. When the proposed stream length equals the existing stream length, the FF Yield equals the Proposed Condition Score minus the Existing Condition Score.

Figure 7: Example Functional Change Summary Table

FUNCTIONAL CHANGE SUMMARY	
Existing Condition Score (ECS)	0.45
Proposed Condition Score (PCS)	0.65
Change in Functional Condition (PCS - ECS)	0.20
Existing Stream Length (ft)	1000
Proposed Stream Length (ft)	1200
Change in Stream Length (ft)	200
Existing Functional Feet (FF)	450
Proposed Functional Feet (FF)	780
Proposed FF - Existing FF	330
Percent Change in FF (%)	73%
FF Yield	0.28

Functional Category Report Card – This summary presents a side-by-side comparison of the functional category scores based on the existing and proposed condition scores from the Condition Assessment sections of the worksheet (Figure 8). This table provides a general overview of the functional changes pre- and post-project to illustrate where the change in condition is anticipated. The color coding within this table is described in the Scoring Functional Lift and Loss Section above.

Figure 8: Example Functional Category Report Card

FUNCTIONAL CATEGORY REPORT CARD			
Functional Category	**ECS**	**PCS**	**Functional Change**
Hydrology	0.47	0.85	0.38
Hydraulics	0.65	0.99	0.34
Geomorphology	0.64	0.76	0.12
Physicochemical	0.49	0.67	0.18
Biology	0.00	0.08	0.08

Function-Based Parameters Summary – This summary provides a side-by-side comparison of the individual parameter scores (Figure 9). Values are pulled from the Condition Assessment sections of the worksheet. This table can be used to better understand how the category scores are determined and serves as a quality control check to see if a parameter was assessed for both the existing and proposed condition assessments. For example, the parameter summary table illustrates which parameters within the geomorphology functional category were assessed and contributing to the overall lift at the site. The color coding within this table is described in the Scoring Functional Lift and Loss Section above.

Figure 9: Example Function-Based Parameters Summary Table

FUNCTION BASED PARAMETERS SUMMARY			
Functional Category	**Function-Based Parameters**	**Existing Parameter**	**Proposed Parameter**
Hydrology	Reach Runoff	0.47	0.85
Hydraulics	Floodplain Connectivity	0.65	0.99
Geomorphology	Large Woody Debris	0.40	0.64
	Lateral Migration	0.66	0.99
	Bed Material Characterization	0.00	0.65
	Bed Form Diversity	0.60	0.75
	Riparian Vegetation	0.44	0.66
Physicochemical	Temperature	0.70	0.97
	Dissolved Oxygen	0.21	1.00
	Total Suspended Solids	0.00	0.00
Biology	Macroinvertebrates	0.00	0.00
	Fish	0.12	0.21

1.2.F. MONITORING DATA WORKSHEET

This worksheet is included in the MNSQT workbook, but not the Debit Calculator workbook. The Monitoring Data worksheet contains 11 condition assessment tables identical to the Existing and Proposed Condition Assessment sections in the Quantification Tool worksheet (Figure 5, page 18). The first table on the Monitoring Data worksheet is identified as the As-Built condition followed by 10 condition assessment tables for monitoring. The user can enter the monitoring date and year at the top of each condition assessment table, e.g., 1 for the first growing season post-project. The methods for calculating index values and scoring are identical to the Quantification Tool worksheet (Section 1.2.e).

In order to calculate functional change, the same parameters and the same metrics must be included in each condition assessment. If a value is entered for a metric in the Existing Condition Assessment, a field value must also be entered for the As-Built Condition and for each monitoring event in the Monitoring Data worksheet. Field values in the Monitoring Data worksheet should be entered for each monitoring event as they occur. A condition assessment is not likely to be completed every calendar year.

1.2.G. DATA SUMMARY WORKSHEET

This worksheet is included in the MNSQT workbook, but not the Debit Calculator. This worksheet provides a summary of project data from the existing condition, proposed condition, as-built condition, and monitoring assessments, as pulled from the Quantification Tool and Monitoring Data worksheets. The Data Summary worksheet features a function-based parameter summary, a functional category report card, and four plots showing this information graphically. *This worksheet is included for information purposes and does not require any data entry.*

1.2.H. REFERENCE CURVES WORKSHEET

The Reference Curves worksheet contains the reference curves used to convert metric field values into index values in the Quantification Tool and Monitoring Data worksheets. This worksheet is present in both the MNSQT and Debit Calculator workbooks. For information on reference curves, refer to Section 1.2. *This worksheet is included for information purposes and does not require any data entry. This worksheet is locked to protect the calculations used to convert field values to index values.*

The numeric index value range (0.00 to 1.00) was standardized across metrics by determining how field values relate to functional capacity, i.e., functioning, functioning-at-risk and not-functioning conditions (Table 1, page 13). Reference curves are tied to specific benchmarks (thresholds) that represent the degree to which the reach condition departs from reference standard as described in Table 1. On this worksheet, reference curves are organized into columns based on functional category and appear in the order they are listed on the Quantification Tool worksheet. One metric can have multiple curves depending on how the reference curves were stratified. For example, the dissolved oxygen metric is stratified by use class. All reference curves and their stratification are described in the Scientific Support for the MNSQT (MNSQT SC Date pending).

There may be instances where better data to inform reference standard and index values are available for a project. The Corps can approve an exception to using the reference curves and index values for a metric within the MNSQT where sufficient data are available to identify reference standards.

1.2.I. DEBIT CALCULATOR WORKSHEET

This worksheet is only present in the Debit Calculator workbook, and not in the MNSQT workbook. The Debit Calculator worksheet is where users enter data describing the impacts to each reach by selecting an impact severity tier. Functional loss is then quantified. The worksheet consists of an input table, explanatory information on the proposed impact factors and activity modeling, and a summary of the results from the Existing and Proposed Conditions worksheet within the Debit Calculator workbook. Cells that allow input are shaded grey and most other cells are locked. Each section of the Debit Calculator worksheet is discussed below.

COMPONENTS OF THE DEBIT CALCULATOR WORKSHEET

Permit Number – Provide the name of the project and any permit or application number assigned. This information will be automatically populated from the Project Assessment worksheet.

The Debit Tool Table (Figure 10) is the calculator where users enter data, describe the impact type and severity, and establish the existing condition for each stream reach in the project. This information, along with stream length is how resource value functional loss is quantified.

Figure 10: Debit Tool Table Example

Stream ID by Reach	Impact Description	Debit Option	Existing Stream Length	Existing Condition Score	Proposed Length	Impact Severity Tier	Proposed Condition Score	Change in Functional Feet
STRM 1 R1	100 LF Minor channelization	3	500	0.27	400	Tier 3	0.14	-79.0
STRM 1 R2	75 LF Arch culverts	2	390	0.79	400	Tier 4	0.18	-236.1
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
0	0							
							Total Functional Loss (Debits in FF):	**-315.1**

Stream ID by Reach – Applicants enter each impact site by reach. This information will be automatically populated from the Project Assessment worksheet. The user can score up to 10 reaches within each Debit Calculator workbook. If the project contains more than 10 reaches, more than one Debit Calculator workbook will need to be used.

Impact Description – Describe the impact proposed. This activity can range from culvert installations to bank armoring, or full channel fill and replacement. This information will automatically be populated from the Project Assessment worksheet.

Debit Option – There are three options for determining the existing and proposed site conditions. Users should select Debit Option 1, 2 or 3 from the dropdown menu. The existing and proposed conditions scores from the Existing Conditions and Proposed Conditions worksheets are automatically summarized in the ECS and PCS Summary Table. For projects that involve the complete removal or piping of a stream, the proposed condition score is 0.

For all Debit Options, it is important that any reach names used in the Existing Conditions and Proposed Conditions worksheets match the reach names used in the Project Assessment worksheet. These options are described below and summarized in Table 3; additional detail is provided in the St. Paul District Stream Mitigation Guidance (USACE, Date pending).

1. Option 1 requires the applicant to use the Existing Conditions and Proposed Conditions worksheets of the Debit Calculator workbook to calculate the existing and proposed condition scores by quantitatively assessing required parameters. Parameter selection should be determined based on coordination with the appropriate regulatory agencies. The user will enter the existing scores for each reach into the Debit Tool Table. The proposed score will automatically populate with the proposed conditions score from the ECS and PCS Summary Table.

2. Option 2 is for permit applicants that choose to use the Existing Conditions worksheet with existing conditions data collected or modeled for the site for selected parameters and use the standard score for all other parameters. The parameter selection and standard score selection will be determined based on coordination with the appropriate regulatory agencies. The proposed condition score will be calculated by the Debit Tool based on the Impact Severity Tier that is selected.

3. Option 3 allows permit applicants to use a standard existing condition score for all required parameters. The existing conditions score will default to 0.90 for state listed outstanding

resource waters (prohibited or restricted) or 0.80 for all other waters. The proposed condition score will be calculated by the Debit Tool based on the Impact Severity Tier that is selected.

For all options, if the existing scores calculated from the Existing Condition worksheet are less than 0.30, the user will enter 0.30 into the Existing Conditions Score column of the Debit Tool table. The minimum allowable existing condition score is 0.30 and the debit calculator will highlight the cell if the existing score entered is less than 0.30.

Table 3: Summary of Debit Options

Debit Option	Existing Condition Score (ECS)*	Proposed Condition Score (PCS)
1	Assess existing condition using Existing Conditions worksheet for required parameters	Estimate proposed condition using Proposed Conditions worksheet for required parameters
2	Assess existing condition using Existing Conditions worksheet for selected parameters and use standard scores for all other parameters	Use Debit Calculator
3	Assess existing condition using Existing Conditions worksheet using standard scores for all parameters (0.90 for state listed outstanding resource waters (prohibited or restricted) and 0.80 for other waters as a default value)	Use Debit Calculator

** ECS cannot be below 0.30 for any of the options.*

<u>Existing Stream Length</u> – Calculate the length of the stream that will be directly impacted by the permitted activity. Stream length should be measured along the centerline of the channel, for example, measuring the channel length of the stream before a culvert is installed.

<u>Proposed Stream Length</u> – Calculate the length of stream channel after the impact has occurred. For pipes, the proposed length is the length of the pipe at a minimum. If the stream will be straightened by the permitted activity, the proposed length will be less than the existing length. Proposed stream lengths should not be longer than the impact length. Streams cannot be lengthened by pipes. Therefore, a 300-foot pipe along 275 feet of stream will only impact 275 linear feet of stream. The debit calculator will highlight the cell if the existing stream length is shorter than the proposed stream length.

<u>Impact Severity Tier</u> – Determination of an impact severity tier is needed to calculate a proposed condition score. The impact severity tier is a categorical determination of the amount of adverse impact to stream functions, ranging from no loss to total loss from a proposed activity. Impact Severity Tier categories were developed by comparing the habitat conditions that would likely exist at an impact site in the altered reach versus the conditions existing in a non-impacted stream. These factors were based on projected functional loss and grouped by common impact activities with similar functional loss.

Impact Severity Tiers range from 0 – 5 where 0 represents no appreciable permanent loss of stream functions and therefore would not require compensatory mitigation, while a 5 would result in total loss of stream functions. Table 4 lists the impact severity tiers along with a description of impacts to key function-based parameters and example activities that may lead to those impacts. Note that some activities could be in multiple tiers depending on the magnitude of the impact and efforts taken to minimize impacts using bioengineering techniques or other low-impact practices.

Once the Impact Severity Tier has been selected, the proposed condition score and proposed functional feet will automatically calculate in the Debit Calculator. A description of how functional feet are calculated can be found in Section 1.2.e The absolute value of the total change in functional feet is equal to the base debits required to offset the proposed impacts. However, it is not the only information needed to determine the total amount of debits assessed in a project. This information is detailed in the St. Paul District Stream Mitigation Guidance (USACE Date pending), or the most recent applicable guidance.

Multiple stream impacts can be reported on a single spreadsheet. The spreadsheet will automatically total the base debits.

ECS and PCS Summary Table – Summarizes the overall existing condition scores and overall proposed condition scores of all stream reaches from the Existing Conditions and Proposed Conditions worksheets in a table located below the Debit Tool Table. If the existing condition score calculated from the Existing Conditions worksheet is less than 0.30, the score in the Summary Table will default to 0.30. Therefore, applicants can easily transfer overall existing condition scores from the summary table to the Debit Tool Table. The overall proposed conditions score will automatically populate in the Debit Tool Table when Debit Option 1 is selected.

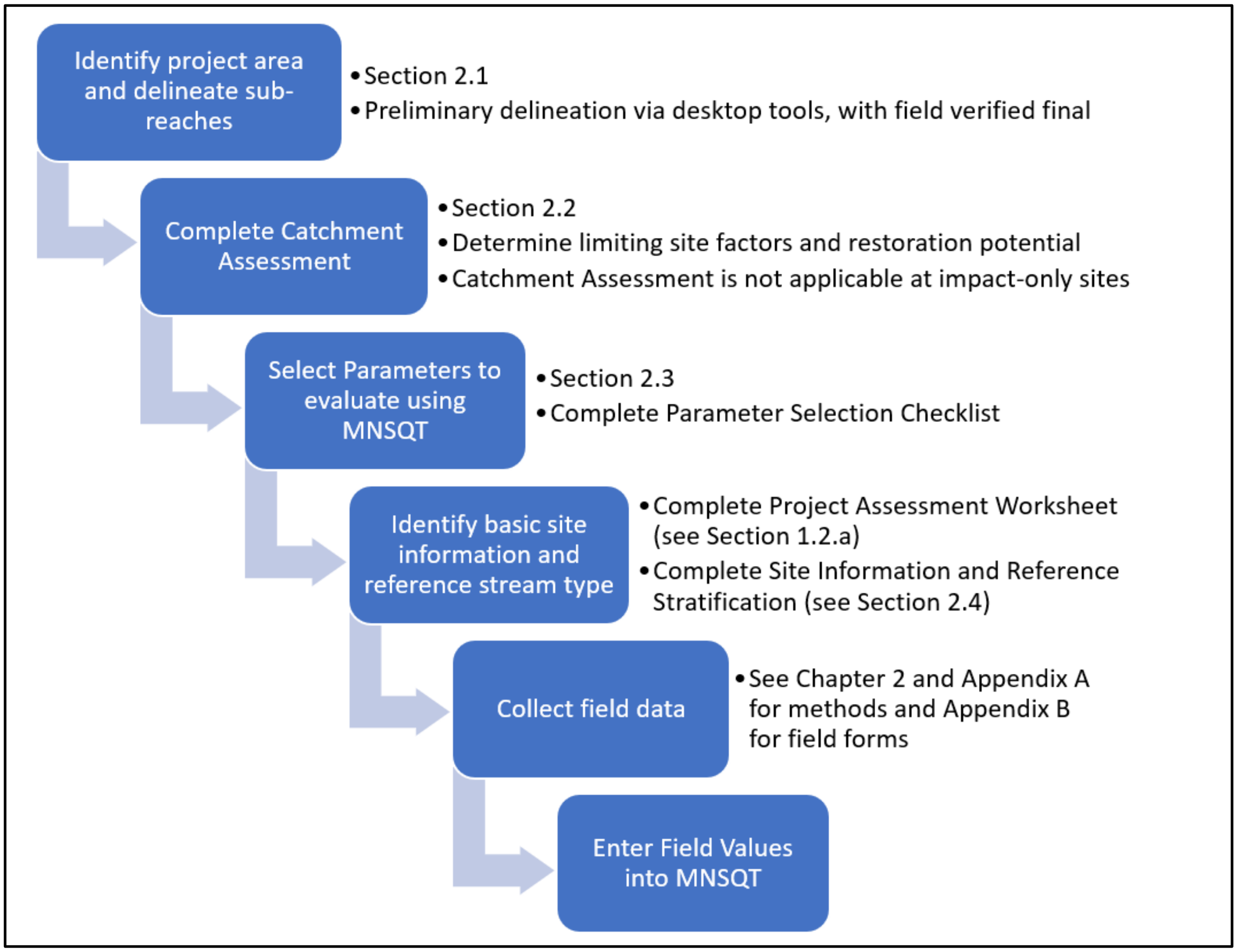
Table 4: Impact Severity Tiers and Example Activities

Tier	Description (Impacts to function-based parameters)	Example Activities
0	No permanent impact on any of the key function-based parameters	Bio-engineering of streambanks, stream restoration
1	Impacts to riparian vegetation and/or lateral migration	Bank stabilization, two-stage ditch, utility crossings.
2	Impacts to riparian vegetation, lateral migration, and bed form diversity	Utility crossing, two-stage ditch, bridges, bottomless arch culverts
3	Impacts to riparian vegetation, lateral migration, bed form diversity, and floodplain connectivity	Bottomless arch culverts, minor channelization
4	Impacts to riparian vegetation, lateral migration, bed form diversity, and floodplain connectivity. Potential impacts to temperature, processing of organic matter, and macroinvertebrate and fish communities	Channelization, box culverts, short length pipe culverts, weirs/impoundments/flood, and minor relocations
5	Removal of all aquatic functions	Piping, relocation, removal or complete fill of channel

Chapter 2. Data Collection and Analysis

This chapter provides instruction on how to collect and analyze data used in the MNSQT and Debit Calculator workbooks. Figure 11 provides a flow chart of the typical process. Individuals collecting and analyzing these data should have experience and expertise in botany, ecology, hydrology, and geomorphology. Interdisciplinary teams with a combination of these skill sets are beneficial to ensure consistent and accurate data collection and analysis. Field training in the methods outlined herein, as well as the Stream Functions Pyramid Framework, are recommended to ensure that the methods are executed correctly and consistently. Additionally, the analysis for the BMP Minimal Impact Design Standards (MIDS) R_v Coefficient requires training and experience with hydrologic modeling and analyses, although this is an optional metric within the MNSQT.

Figure 11: MNSQT Process Flow Chart



This chapter includes methods for metrics that can be evaluated in the office, steps for calculating metrics, as well as a summary of field methods. For some metrics, multiple field methods are provided that will allow for either rapid or more comprehensive site assessment. Detailed field procedures are provided in Appendix A. Few metrics are unique to the MNSQT, and data collection procedures are often consistent with other instruction manuals or literature. Where appropriate, this chapter and Appendix A will reference the original methodology to provide technical explanations and make clear any differences in data collection or calculation methods needed for the MNSQT.

2.1. Reach Delineation and Representative Sub-Reach Selection

The MNSQT is informed by reach-based assessment methods, and each reach is input into the tool separately. A large project may be subdivided into multiple project reaches (each requiring their own workbook), as stream condition or character can vary widely from the upstream end of a project to the downstream end.

Delineating stream reaches within a project area occurs in two steps. The first step is to identify whether there is a need to separate the project area into multiple reaches based on variations in stream physical characteristics and/or differences in project designs or magnitude of impacts. Once project reaches are determined, the user selects a representative sub-reach within each reach to assess various metrics. The processes to define project reaches and representative sub-reaches are described in detail below in Sections 2.1.a and 2.1.b respectively.

2.1.a. Delineation of Project Reach(es)

The user should determine whether their project area encompasses a single homogeneous reach, or multiple potential reaches. For this purpose, a reach is defined as a stream segment with similar valley morphology, stream type (Rosgen 1996), stability condition, riparian vegetation type, and bed material composition. Reaches within a project site may vary in length depending on the variability of the physical stream characteristics within the project area.

Practitioners can use aerial imagery, NHD data and other desktop tools to determine preliminary reach breaks; however, these delineations should be verified in the field. Practitioners should provide justification for the final reach breaks in the Reach Description section of the Project Assessment worksheet. Specific guidance is provided below to assist in making consistent reach identifications:

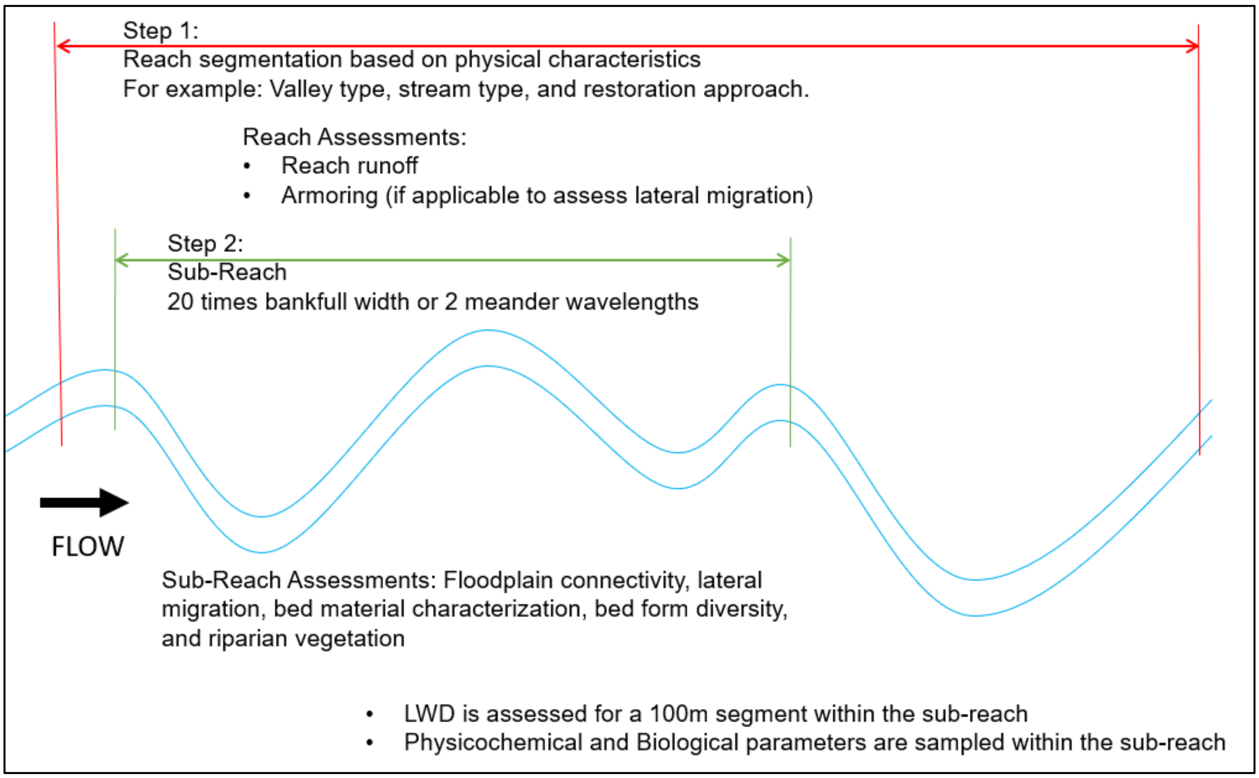
- Separate streams, e.g. tributaries vs. main stem, are considered separate project reaches.
- A tributary confluence should lead to a reach break. Where a tributary enters the main stem, the main stem should be split into two project reaches - one upstream and one downstream of the confluence. Small tributaries, as compared to the drainage area of the main stem channel, may not require a reach break.
- Reach breaks should occur where there are changes to valley morphology, stream type (Rosgen 1996) or bed material composition.
- Reach breaks should occur where there are diversion dams or other flow modification structures on the stream, with separate reaches upstream and downstream of the structure. The diversion dam or structure would also be its own reach.
- Reach breaks should occur where there are distinct changes in the level of anthropogenic modifications, such as narrowed riparian width from road embankments, concrete lined channels, dams, stabilization, or culverts/pipes. For example, a culvert's footprint would be evaluated as a separate project reach from the reaches immediately up and downstream of the culvert.

- Multiple project reaches are needed where there are differences in the magnitude of impact or mitigation approach (e.g., enhancement vs. restoration) within the project area. For example, restoration approaches that reconnect stream channels to their original floodplain versus bank stabilization activities.

2.1.B. Representative Sub-Reach Determination

Some metrics will be evaluated along an entire project reach length, some will be evaluated at a specific point within the project reach and other metrics will be evaluated in a representative sub-reach (Figure 12). Selecting a representative sub-reach is necessary to avoid having to quantitatively assess very long stream lengths with similar physical conditions. The representative-sub reach is 20 times the bankfull width or two meander wavelengths (Leopold 1994), whichever is longer. If the entire reach is shorter than 20 times the bankfull width, then the entire project reach should be assessed. Guidelines are provided below for each functional category.

Figure 12: Reach and Sub-Reach Segmentation



Hydrology Functional Category:

- Reach runoff metrics are evaluated within the entire project reach.

Hydraulics Functional Category:

- Floodplain connectivity is assessed within the representative sub-reach.

Geomorphology Functional Category:

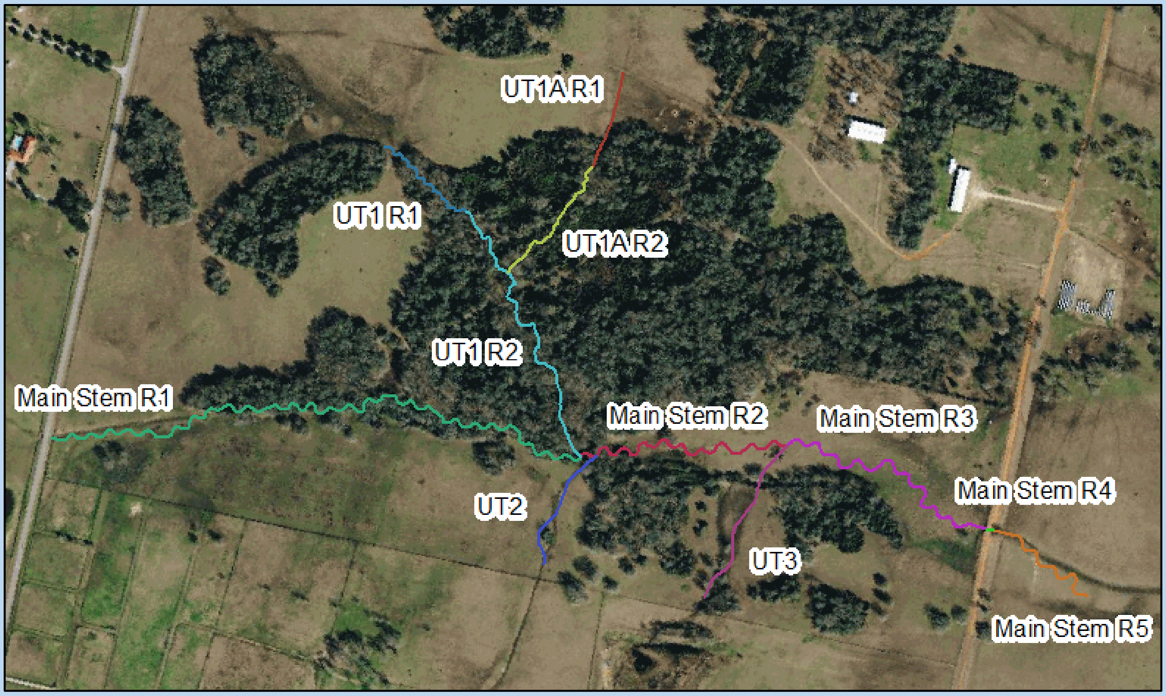
- Large woody debris (LWD) is assessed within a 328-foot (100 meter) segment located, whenever possible, within the representative sub-reach. If the project reach is less than 328 feet, the LWD assessment should extend proportionally into the adjacent upstream and downstream segments to achieve the required stream length.
- Lateral migration, bed material characterization, bed form diversity, and riparian vegetation are assessed within the representative sub-reach. There is one exception. Armoring, which is a metric under lateral migration, is assessed along the entire project reach.

Physicochemical and Biology Functional Categories:

- Sampling should occur within the project reach, but specific locations will vary by metric, and are described in the metric sections in this Chapter and in Appendix A.

Example 17: Project Reach Delineation

The following is an example showing how project reaches are identified based on physical observations. Work was proposed on five streams. The main-stem channel was delineated into five reaches, two unnamed tributaries (UT) were delineated into two reaches each, and the remaining two UTs as individual project reaches. This project has a total of 11 project reaches and an MNSQT Excel Workbook would need to be completed for each.



Reach	Reach Break Description
Main Stem R1	Beginning of project to UT1 confluence where drainage area increases by 25%.
Main Stem R2	To UT3 confluence where there is a change in slope.
Main Stem R3	To culvert. Bed material is finer and bed form diversity is impaired below culvert.
Main Stem R4	40 feet through the culvert.
Main Stem R5	From culvert to end of project.
UT1 R1	Property boundary to the last of a series of headcuts caused by diffuse drainage off the surrounding agricultural fields.
UT1 R2	To confluence with Main Stem. Restoration approach differs between UT1 R1 where restoration is proposed to address headcuts and this reach where enhancement is proposed.
UT1A R1	Property boundary to edge of riparian vegetation. Reach is more impaired than UT1A R2, restoration is proposed.
UT1A R2	To confluence with UT1. Enhancement is proposed to preserve riparian buffer.
UT2 & UT3	Beginning of project to confluences with Main Stem. Reaches are actively downcutting and supplying sediment to the main stem.

2.2. Catchment Assessment

The primary purpose of the Catchment Assessment is to assist in determining restoration potential for restoration and mitigation projects (described in Section 3.2.a.). It is a decision-support tool rather than a quantitative scoring tool. Therefore, results from the Catchment Assessment are not scored in the MNSQT but are used to help inform a restoration potential decision. The Catchment Assessment worksheet is included in the MNSQT workbook, but not the Debit Calculator workbook.

The Catchment Assessment worksheet includes descriptions of processes and stressors that exist outside of the project reach or conservation easement and may limit functional lift. The Catchment Assessment does not pertain to stressors occurring within the project reach/easement area that can be addressed as part of the restoration activities. The Catchment Assessment evaluates conditions primarily upstream, but sometimes downstream of the project reach. Instructions for collecting data and describing each process and stressor are provided in this section.

There are 14 defined categories, with space for an additional user-defined category to identify and document any stressor observed in the catchment that could limit the restoration potential or impair the functioning of the project reach. There are three choices to rate the catchment condition for each category: Good, Fair, and Poor.

The Catchment Assessment relies on data available from the MN DNR's WHAF that can be obtained online (https://www.dnr.state.mn.us/whaf/index.html). The specific WHAF index or value that relates to each category is listed in Column I. Information on the WHAF and index descriptions are provided at the DNR WHAF website (https://www.dnr.state.mn.us/whaf/index.html).

The score for the indicators of hydrologic alteration (IHA) analysis used in the Flashiness Index (Hydrology) category is derived from the Rate and Frequency of Change metric and the Frequency and Duration of High/Low Pulses metric (metric values are listed in the Major Flow Variability Metrics worksheet provided in the SQT).

The data used to evaluate each category should be documented and provided as supporting data. Once all categories of the Catchment Assessment are completed, the user should provide an overall watershed condition, based on their best professional judgement, and determine the restoration potential for the reach. The user should refer to Section 3.2.a for determining the Restoration Potential for the reach.

2.3. Parameter Selection

The MNSQT and Debit Calculator workbooks include 24 metrics used to quantify 12 parameters. Not all metrics and parameters will need to be evaluated at each site. The user should consider landscape setting, function-based goals/objectives and restoration potential when selecting parameters.

IMPORTANT CONSIDERATIONS:

- For CWA 404 and RHA Section 10 projects, the Corps has discretion over which field methods, metrics, and parameters are used for a project; therefore, users should consult with the Corps prior to data collection on a project. In addition, the Corps strongly encourages applicants or bank sponsors consult with the District and other state or local regulatory authorities prior to data collection on a project to avoid costly delays and unnecessary data collection. Not all field methods, metrics, and parameters may be required for all projects.

- The same parameters must be used in the existing condition and all subsequent condition assessments (i.e., proposed, as-built, and monitoring) within a project reach, otherwise the relative weighting between metrics and parameters changes and the overall scores are not comparable over time.
- For metrics that are not selected (i.e., a field value is not entered), the metric is not included in the scoring. It is NOT counted as a zero.
- The overall scores should not be compared or contrasted between sites when parameters and metric selection varies between project sites. To evaluate multiple sites, the same suite of parameters and metrics would need to be collected at all sites.
- The reach runoff, floodplain connectivity, lateral migration, riparian vegetation, and bed form diversity parameters must be evaluated at all sites. These parameters are important indicators of the stability and resiliency of stream systems. The Quantification Tool worksheet in the MNSQT workbook will display a warning message above the Functional Category Report Card reading, *"WARNING: Data are not provided for Reach Runoff, Floodplain Connectivity, Lateral Migration, Riparian Vegetation, and Bed Form Diversity Parameters.",* if data are not entered for these parameters.
- Field methods in Appendix A are generally focused on single-thread wadeable streams, except for fish, which can be sampled in wadeable and non-wadeable streams. Some metrics may be difficult to sample in non-wadeable or multi-thread systems and may require alternate field methodologies. For CWA 404 or RHA Section 10 projects, sampling plans in these systems should be discussed with the Corps and other state or local regulatory authorities prior to data collection efforts.
- Reference curves to assign index values have been primarily derived from data within perennial, wadeable, single-thread stream systems. When applying metrics in other stream situations, such as multi-thread systems or ephemeral channels, the user should note this and select only applicable parameters and metrics (Table 5). While a parameter and associated metrics may be applicable to ephemeral and multi-thread channels, the user should understand that the reference curves are not from these systems. Therefore, more focus should be placed on the difference in stream condition rather than the absolute value.

Table 5: Applicability of metrics across flow type and in multi-thread systems. An 'x' denotes that one or more metrics within a parameter is applicable within these stream types.

Applicable Parameters	Perennial	Intermittent	Ephemeral	Multi-thread Channels
Reach Runoff	x	x	x	x
Floodplain Connectivity	x	x	x	x
Large Woody Debris	x	x	x	x

Applicable Parameters	Perennial	Intermittent	Ephemeral	Multi-thread Channels
Lateral Migration	x	x	x	x
Bed Material Characterization	x	x	x	x
Bed Form Diversity	x	x		
Riparian Vegetation	x	x	x	x
Temperature	x	Where baseflows extend through index period		x
Dissolved Oxygen	x			x
TSS	x			x
Macroinvertebrates	x			x
Fish	x			x

SPECIFIC GUIDANCE ON PARAMETER SELECTION:

Reach Runoff Parameter: This parameter should be evaluated at all project sites. Users should evaluate the land use coefficient metric and the concentrated flow points metric together. These two metrics are used in rural environments and urban environments without stormwater best management practices (BMPs). The BMP MIDs R_v coefficient is an optional metric that should be used only when BMPs are proposed on land adjacent to the stream restoration project. If the BMP MIDS R_v coefficient is used, the land use coefficient and concentrated flow points metrics are not used.

Floodplain Connectivity: BHR and ER Metrics: This parameter should be evaluated at all project sites. The BHR and ER metrics are complimentary, as each of these metrics contributes differently to an overall understanding of floodplain connectivity; therefore, they should be applied together. The only exception is in multi-thread systems, where the BHR should be applied but not the ER.

Large Woody Debris (LWD) Parameter: This parameter should be evaluated at project sites where trees/wood is a natural component of the riparian corridor. Users can evaluate either the Large Woody Debris Index (LWDI) or large wood piece count metric, but not both. The LWDI metric better characterizes the complexity of large wood in streams but takes more time to assess.

Lateral Migration Parameter: This parameter should be evaluated at all project sites. The percent armoring metric is optional. Additional guidance on metric selection follows:

1. The dominant BEHI/NBS and percent erosion metrics are applicable in single-thread channels. These metrics are not recommended in systems that are naturally in disequilibrium, like some braided streams, ephemeral channels, alluvial fans, or other systems with naturally high rates of bank erosion.

2. The percent armoring metric is applicable only when armoring techniques are present or proposed in the project reach. If a user is proposing to armor an eroding bank, the user would substitute this metric for dominant BEHI/NBS in calculating the proposed condition score; the user would not apply the BEHI/NBS metric to an armored bank.

Bed Material Characterization Parameter: This parameter is optional and is recommended for alluvial or confined stream reaches where altered sediment transport processes have shifted the grain-size distribution away from the reference condition. This parameter is only applicable in gravel and cobble bed streams. Selection and sampling of a reference reach is required.

Bed Form Diversity Parameter: This parameter should be evaluated at all single-thread perennial and intermittent project sites. Users must evaluate pool spacing ratio, pool depth ratio, and percent riffle metrics together. The aggradation ratio metric is optional. Additional guidance on metric selection follows:

1. The pool spacing ratio metric should be evaluated at all sites except natural bedrock systems, ephemeral streams, or multi-thread systems, where the metric is not applicable.
2. The pool depth ratio and percent riffle metrics should be evaluated together at all sites except ephemeral streams or multi-thread channels.
3. The aggradation ratio metric is recommended for meandering single-thread stream types where the riffles are exhibiting signs of aggradation.

Riparian Vegetation Parameter: This parameter should be evaluated at all project sites. However, the woody stem basal area metric should only be used if woody vegetation is determined to be a natural component of the riparian buffer.

Temperature, Dissolved Oxygen, and Total Suspended Solids[2]: These parameters are optional and are recommended for projects with goals and objectives related to water quality improvements or projects where improvements to these parameters are anticipated based on restoration potential. One or more parameters can be applied at a project site.

Macroinvertebrates Parameter: This parameter is optional and is recommended for wadeable perennial and intermittent stream projects with goals and objectives related to biological improvements or projects where improvements in biological condition are anticipated based on restoration potential.

Fish Parameter: This parameter is optional and is recommended for wadeable and non-wadeable perennial projects with goals and objectives related to biological improvements or projects where improvements in biological condition are anticipated based on restoration potential.

2.4. Data Collection for Site Information and Reference Selection

The Quantification Tool worksheet quantifies the change in condition using reference curves to translate measured field values into index scores. For some metrics, these curves are stratified by physical stream characteristics like stream type and vegetation attributes. The Site Information and Reference Selection section of the Quantification Tool worksheet consists of general site information and classifications to determine which reference curves are used to calculate index values for relevant metrics. It may not be necessary to complete all fields in this

[2] Without evaluating the physicochemical and biological parameters, the maximum overall score in the MNSQT will be 0.60. Selecting and assessing parameters in both of these functional categories will increase the maximum overall score to 1.0 in the MNSQT.

section, depending on parameter selection. Metrics will not be scored or may be scored incorrectly if necessary data are not provided in this section.

In the Debit Calculator workbook, similar information for each reach is included in the Reach Information and Reference Selection section above each condition assessment in the Existing Conditions and Proposed Conditions worksheets. Metrics will not be scored or may be scored incorrectly if necessary data are not provided in this section.

Information on each field and guidance on how to select values is described below.

For fields with drop-down menus, if a certain variable is not included in the drop-down menus, then data to inform stratified index values for a specific physical stream characteristic is not yet available for Minnesota. Additional information on how reference curves are stratified is included in the Scientific Support for the MNSQT (MNSQT SC Date pending).

Project Name – Enter the name of the project.

Reach ID – Each project reach within a project area should be assigned a unique identifier (see Section 2.1 for guidance on delineating project reaches).

Restoration Potential (restoration and mitigation projects only) – Restoration potential should be determined for the reach (not the sub-reach) using the stepwise process described in Section 3.2.a. This cell is automatically populated by the restoration potential selected by the user on the Catchment Assessment worksheet.

Existing Stream Type – The existing stream type is determined through a field survey of the project reach. This stream classification system and the basic fluvial landscapes in which the different stream types typically occur are described in detail in *Applied River Morphology* (Rosgen 1996). The broad-level stream type is determined using entrenchment ratio, width depth ratio, sinuosity, and slope (Figure 13). The existing stream type is not used to select the appropriate reference curve or determine index values but is provided for communication and to inform channel evolution scenarios and restoration potential, refer to Section 3.2.

In the Debit Calculator workbook, the existing stream type is used to select the appropriate reference curve, so the existing stream type should be entered for both existing and reference stream type. Note: if the existing stream type is degraded (e.g., a G or F), a stable reference stream type will need to be selected.

Figure 13: Rosgen Stream Classification Summary (Rosgen 1996)

Quick Rosgen Stream Classification Guide (Rosgen 1996)					
ER < 1.4			1.4 < ER < 2.2	ER > 2.2	
WDR < 12		WDR > 12	WDR > 12	WDR < 12	WDR > 12
K<1.2	K>1.2	F	B	E	C
A	G	ER = Entrenchment Ratio; WDR = Width Depth Ratio; K = Sinuosity			

Reference Stream Type – The MNSQT relies on the stream type to stratify reference curves for the entrenchment ratio, pool spacing ratio, and percent riffle metrics.

Reference stream type is the stream type that should occur in a given landscape setting given the hydrogeomorphic processes occurring at the watershed and reach scales. Channel evolution scenarios should be used to inform the reference stream type in the MNSQT, and this information can be further supported with information from the design process, where available (see Example 4). The Rosgen Channel Succession Scenarios (Rosgen 2006) or other stream evolution models (Cluer and Thorne 2013) can be used as a guide for determining the reference stream type. In the MNSQT workbook, this cell is automatically populated by the reference stream type selected by the user on the Project Assessment worksheet. Space is provided on the Project Assessment worksheet to describe the rationale used to select the reference stream type.

Example 24: Reference Stream Type Identification

Existing stream type: Gc
This stream type will often evolve into an F and then a C stream type (Table 3). If the reach is in a wide alluvial valley, the reference stream type would likely be a C, E, or DA. These are all common in wide, low gradient, alluvial valleys.

However, it may sometimes evolve into a Bc stream type if the forces resisting lateral migration are greater than the driving forces of water and sediment discharge.

Historic, geomorphic, and even stratigraphic evidence and research may be needed to determine reference stream type. For example, DA (stream/wetland) complexes were historically common in alluvial valleys with low energy and sediment supply (Cluer and Thorne 2013) while alluvial valleys with gravel/cobble bed streams and sediment supply were likely single-thread C or E stream types (Rosgen 2006). Information from the design process (e.g., fluvial landscape, historic channel conditions, watershed hydrology, sediment transport, and/or anthropogenic constraints) can also be used to inform reference stream type. It will require experience and expertise from a multi-disciplinary team to determine the reference stream type.

Woody Vegetation Natural Component – The MNSQT uses this stratifier to select the correct reference curves for the Canopy Cover and Woody Stem Basal Area metrics. Methodology for determining if trees and shrubs are a natural component of the riparian zone is described in the

Canopy Cover Data Collection section in Appendix A. In cases where woody vegetation is a natural component of the riparian zone, the user will select yes from the drop-down menu. This condition should represent the vegetation community that would naturally occur at the site if the reach were free of anthropogenic alteration and impacts.

Use Class – A water body's use class is determined by the Minnesota Pollution Control Agency (MPCA) and is tied to dissolved oxygen (DO) concentrations, as shown below:

- Class 2A. Not less than 7 mg/L as a daily minimum.
- Class 2Bd, 2B, 2C. Not less than 5 mg/L as a daily minimum.
- Class 2D. Maintain background.
- Class 7. Not less than 1 mg/L as a daily average, provided that measurable concentrations are present at all times.

The use class is used to stratify the reference curves for both the DO and Total Suspended Solids (TSS) parameters. Use classes are provided in Minnesota Administrative Rules[3,4].

River Nutrient Regions – The river nutrient region is used to stratify reference curves for the TSS parameter. Figure 14 shows the nutrient regions delineated for MN and Table 6 sets out standards for TSS developed by the MPCA by nutrient region or reach.

[3] https://www.revisor.mn.gov/rules/7050.0470/
[4] https://www.revisor.mn.gov/rules/7050.0430/ (unlisted waters)

Figure 14: River Nutrient Regions in Minnesota (MPCA 2018a)

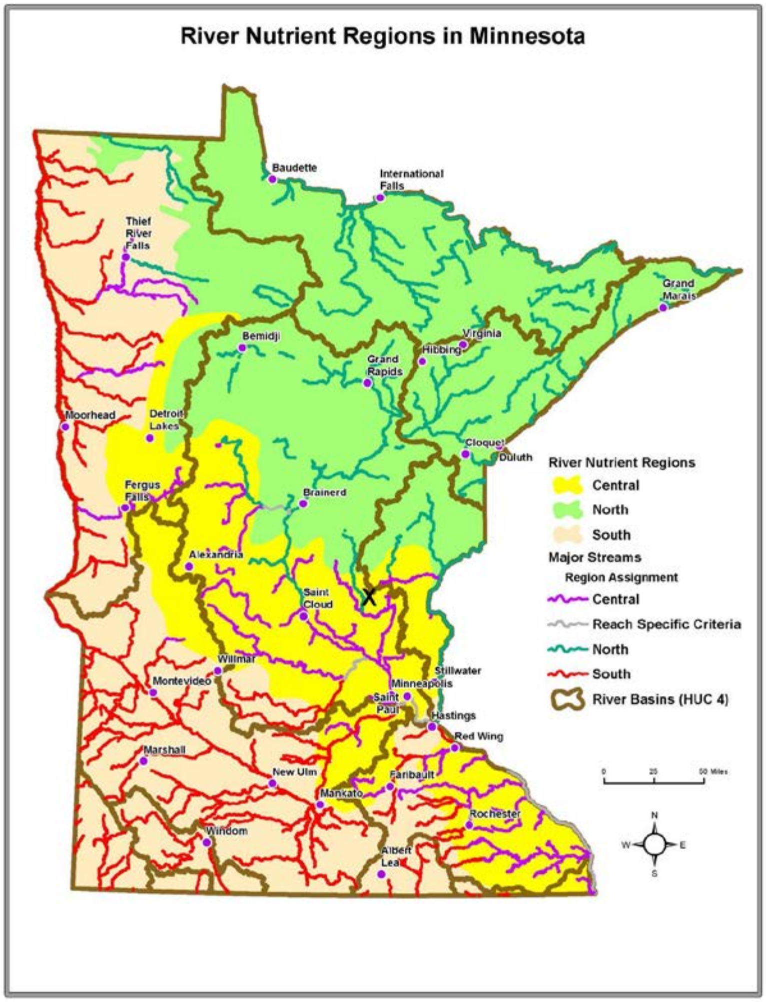


Table 6: Minnesota's TSS (mg/L), Secchi tubes (S-tube[cm]), and site-specific standards for named river reaches (adapted from MPCA 2018a)

Region or River	TSS	S-tube Exceeds	S-tube Meets
All Class 2A Waters	10	55	95
Northern River Nutrient Region as Modified for TSS	15	40	55
Central River Nutrient Region as Modified for TSS	30	25	35
Southern River Nutrient Region as Modified for TSS	65	10	15
Red River Nutrient Region as Modified for TSS	100	5	10
(Assessment season for above waters is April through September)			
Lower Mississippi Mainstem – Pools 2-4	32		
Lower Mississippi Mainstem below Lake Pepin	30		
(Assessment season for Lower Mississippi is June through September)			

Drainage Area (sq.mi.) – The drainage area is the land area draining water to the downstream end of a project reach and is delineated using available topographic data (e.g., StreamStats, USGS maps, LiDAR or other digital terrain data). The drainage area is not used to stratify any reference curves but is important information to include for a project site. This input is not included in the Debit Calculator workbook.

Proposed Bed Material – The bed material characterization metric in the MNSQT is only applicable to gravel or cobble bed streams. Otherwise, the proposed bed material is not used to stratify any reference curves but is important information to include for a project site. Instructions for performing a pebble count is provided in Appendix A.

Existing Stream Length (ft) – Project reach stream length extends from the upstream to the downstream end of the project reach. This can be determined by surveying the profile of the stream, stretching a tape in the field, or remotely by tracing the stream centerline pattern from aerial imagery. Stream length is not used for reference curve stratification but is used to calculate functional feet. Note the user provides this input in the Debit Calculator worksheet of the Debit Calculator workbook rather than the Site Information and Reference Selection section.

Proposed Stream Length (ft) – Project reach stream length extends from the upstream to the downstream end of the project reach. The proposed length can be estimated from project design documents, and later verified using as-built conditions using the approaches described in Existing Project Reach Stream Length above. Where stream length does not change post-project, the same value can be entered for the Existing and Proposed Project Stream Length. Stream length is used to calculate the functional feet, so both existing and proposed stream length must be recorded. Note the user provides this input in the Debit Calculator worksheet of the Debit Calculator workbook rather than the Site Information and Reference Selection section.

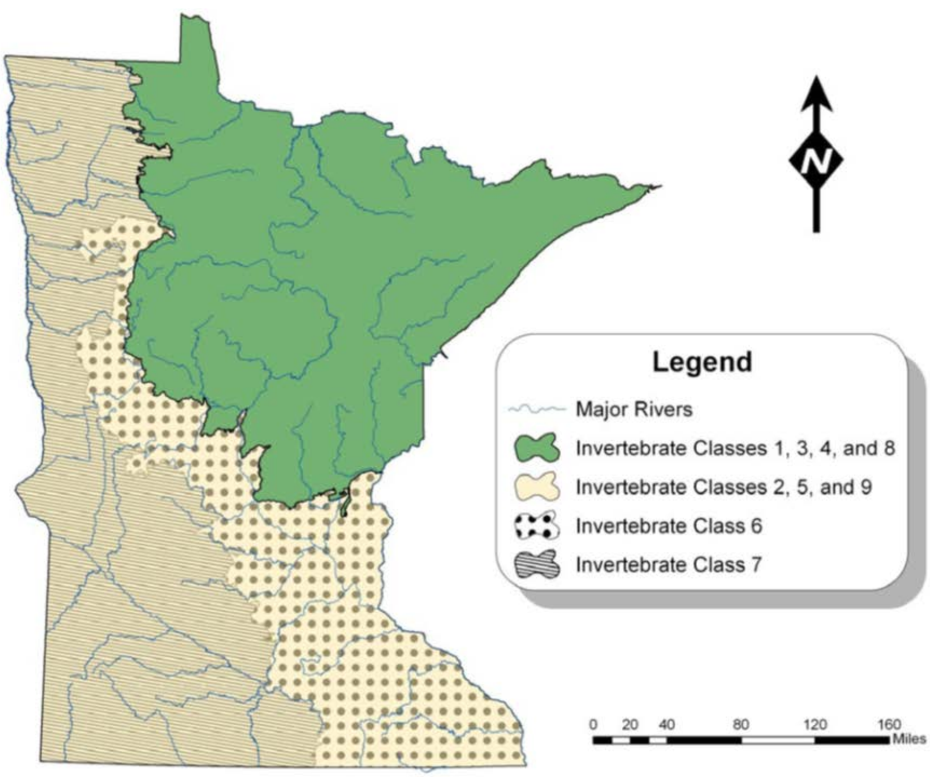
Macroinvertebrate Index of Biological Integrity (IBI) Class – The MPCA recognizes nine different macroinvertebrate IBI classes based on stream type and the expected natural macroinvertebrate community associated with each. Stream types are defined using drainage area, geographic region, thermal regime, and gradient. Table 7 presents the different classes and their criteria while Figure 15 shows the geographic distribution of each class.

Table 7: Macroinvertebrate IBI Classes in Minnesota (adapted from MPCA 2014a)

Stream Type/Class	Description	Drainage Area
1 - Northern Forest Rivers	Rivers in the Laurentian Mixed Forest province	>=500 Sq. Miles
2 - Prairie and Southern Forest Rivers	Rivers in the Eastern Broadleaf Forest, Prairie Parklands, and Tall Aspen Parklands ecological provinces	>=500 Sq. Miles
3 - Northern Forest Streams, Riffle-Run (RR)	High gradient streams in the Laurentian Mixed Forest ecological province	< 500 Sq. Miles
4 - Northern Forest Streams, Glide-Pool (GP)	Low gradient streams in the Laurentian Mixed Forest ecological province	< 500 Sq. Miles

Stream Type/Class	Description	Drainage Area
5 – Southern Stream RR	High gradient Streams in the Eastern Broadleaf Forest, Prairie Parklands, and Tall Aspen Parklands ecological provinces, as well as streams in HUC 07030005	< 500 Sq. Miles
6 – Southern Forest Streams GP	Low gradient streams in the Eastern Broadleaf Forest, as well as streams in HUC 07030005	< 500 Sq. Miles
7 – Prairie Streams GP	Low gradient Streams in the Prairie Parklands, and Tall Aspen Parklands ecological provinces	< 500 Sq. Miles
8 – Northern Coldwater	Coldwater streams in northern portions of Minnesota characterized by the Laurentian Mixed Forest ecological province	N/A
9 – Southern Coldwater	Coldwater streams in southern portions of Minnesota characterized by the Eastern Broadleaf Forest, Prairie Parklands, and Tall Aspen Parklands ecological provinces	N/A

Figure 15:   Map of Macroinvertebrate IBI Classes in Minnesota (MPCA 2014a)



Fish IBI Class – Similar to macroinvertebrates, the MPCA has developed a comprehensive, statewide IBI to assess the biological integrity of riverine fish communities in Minnesota. IBI classes were first defined using watershed lines that reflect post-glacial barriers to movement, resulting in ‘north’ and ‘south’ streams (Figure 16). These two classes were further refined into nine total classes based on stream/watershed size, thermal regime, and gradient (Table 8). Figure 17 shows the general geographic distribution of each class. It is important to note that the map is for display purposes only; classification of individual sampling locations should utilize site-specific attributes as outlined in Table 8.

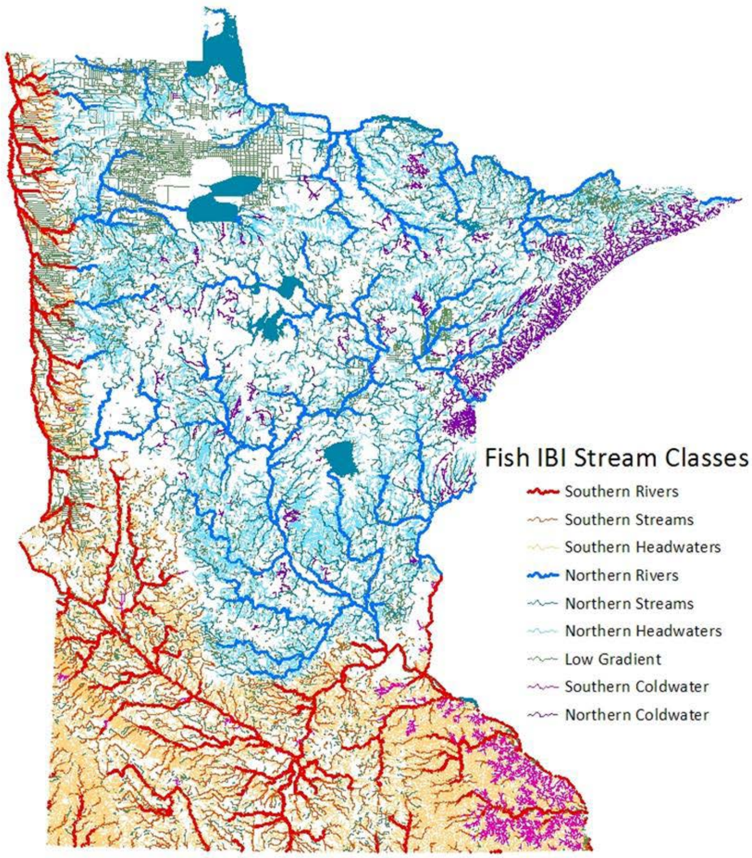
Figure 16: Map of 'north' and 'south' streams defined for the MN fish IBI (MPCA 2014b)

Table 8: Fish IBI Classes in Minnesota (adapted from MPCA 2014b)

Fish IBI Class*	Drainage Area	Gradient
Northern Rivers	>500 sq. miles[+]	N/A
Northern Streams	>50 sq. miles	
Northern Headwaters	<50 sq. miles	>0.50 m/km
Northern Coldwater	N/A	N/A
Southern Rivers	>300 sq. miles	
Southern Streams	>30 sq. miles	
Southern Headwaters	<30 sq. miles	>0.50 m/km
Southern Coldwater	N/A	N/A
Low Gradient	<50 sq. miles (north) <30 sq. miles (south)	<0.50 m/km (north) <0.30 m/km (south)

*All classes are warmwater, except for northern and southern coldwater classes
[+]Drainage area cutoff for rivers in the Red River basin is >350 sq. miles

Figure 17: Map of fish IBI classes in Minnesota (MPCA 2014b)



<u>Valley Type</u> – Valley type is used to stratify reference curves for riparian width. The valley type options are unconfined alluvial, confined alluvial or colluvial/v-shaped:

Unconfined Alluvial Valleys: Wide, low gradient (typically less than 2% slope) valleys that support meandering and anastomosed stream types (e.g., C, E, DA). In alluvial valleys, rivers adjust pattern without intercepting hillslopes. These valleys typically have a valley width ratio greater than 7.0 (Carlson 2009) or a meander width ratio (MWR) greater than 4.0 (Rosgen 2014).

Confined Alluvial Valleys: Valleys that support transitional stream types between step-pool and meandering or where meanders intercept hillslopes (e.g., C, Bc). These valley types typically have a valley width ratio less than 7.0 and a MWR between 3 and 4.

Colluvial/V-shaped Valleys: Valleys that are confined and support straighter, step-pool type channels (e.g., A, B, Bc). These valley types typically have a valley width ratio less than 7.0 and a MWR less than 3.

Outstanding Resource Waters – Outstanding resource waters determination information is provided in Minnesota Administrative Rules[5]. This input is only in the Debit Calculator workbook and is not included in the MNSQT workbook. This input is not used to stratify any reference curves but impacts the default standard scores associated with metrics in the Debit Calculator.

Proposed BMPs – Enter yes if the project includes BMPs to treat runoff from the lateral drainage area. This input is only in the Debit Calculator workbook and is not included in the MNSQT workbook. This input is not used to stratify any reference curves but impacts which metric(s) are used to assess reach runoff in the Debit Calculator.

Latitude/Longitude – In the Debit Calculator workbook, enter the latitude and longitude of the upstream and downstream extent of the reach)

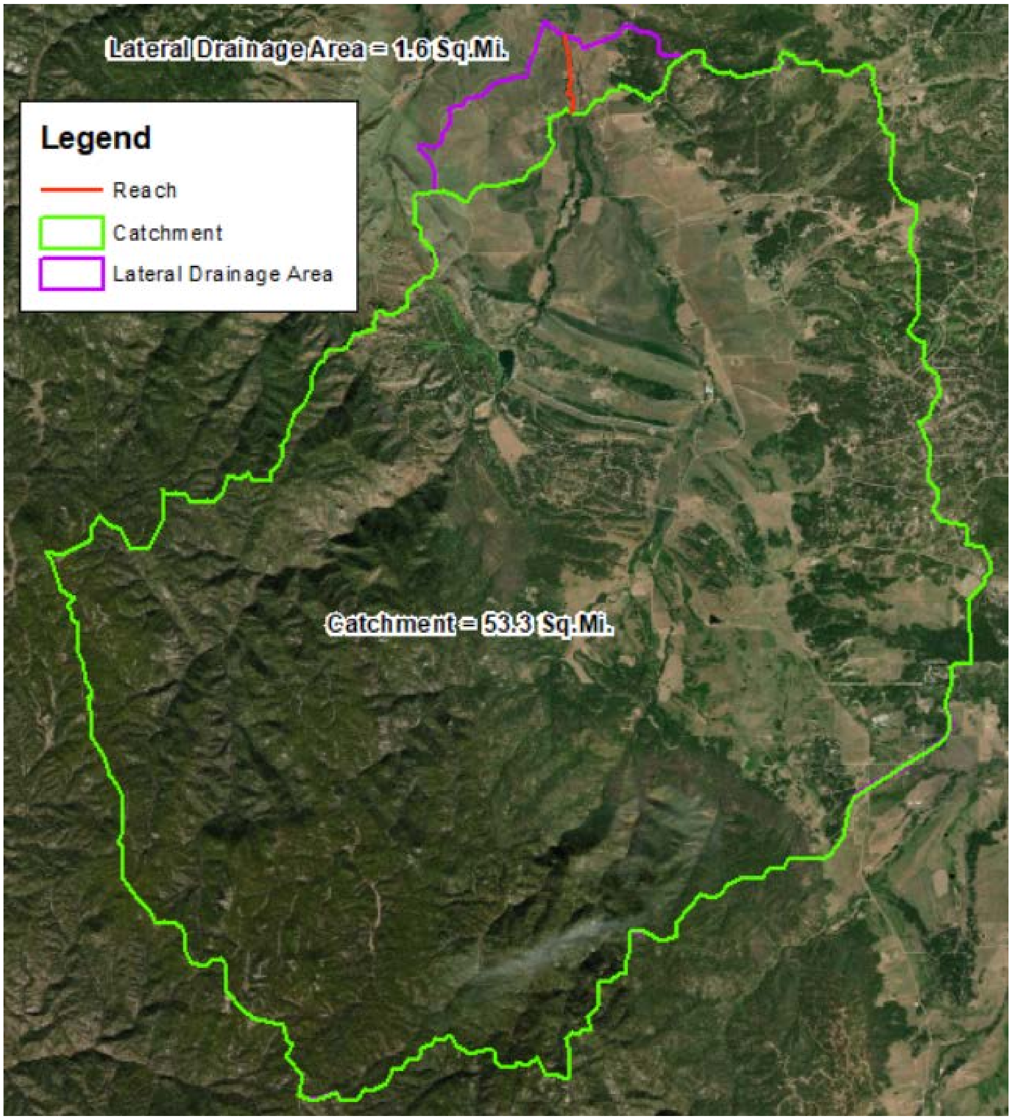
2.5. Hydrology Functional Category Parameters and Metrics

There is one function-based parameter to assess reach-scale hydrology functions: reach runoff. There are three metrics to assess reach runoff: land use coefficient, BMP MIDS R_v coefficient, and concentrated flow points. The land use coefficient and concentrated flow are used together to assess Reach Runoff. The BMP MIDS R_v coefficient metric is used in urban environments when BMPs are applied to adjacent uplands. The land use coefficient and concentrated flow points are not measured if the BMP MIDS R_v coefficient is used.

Reach runoff metrics are assessed in the lateral drainage area for the project reach. The lateral drainage area (Figure 18) is the portion of the reach catchment that drains directly to the reach from adjacent land uses.

[5] https://www.revisor.mn.gov/rules/7050.0335/

Figure 18: ***Lateral Drainage Area for Reach Runoff.*** *The purple line delineates the upgradient extent of the land draining to the project reach (i.e., 1.6 mi²).*



LAND USE COEFFICIENT

The land use coefficient metric evaluates the infiltration and runoff processes of the land that drains laterally into the stream reach. This metric, an area weighted land use coefficient, serves as an indicator of runoff potential from land uses draining into the project reach between the upstream and downstream end points. Land use coefficients are shown in Table 9. Higher values, nearer 100, indicate more runoff potential while lower values, nearer 0, indicate less runoff.

Table 9: Land Use Descriptions and Associated Land Use Coefficients. Adapted from NRCS (1986).

Land Use Description (From TR-55)	Land Use Coefficient
Urban Areas Land Uses	
Open Space (lawns, parks, golf courses, cemeteries, etc.)	61
Impervious areas	98
Gravel Roads	85
Dirt Roads	82
Commercial and business districts	92
Industrial districts	88
Residential districts by average lot size: 1/8 acre or less (town houses) 1/4 acre 1/3 acre 1/2 acre 1 acre 2 acres	 85 75 72 70 68 65
Agricultural Lands/Natural Land Cover	
Pasture, grassland, or range – continuous forage for grazing	61
Meadow – continuous grass, protected from grazing and generally mowed for hay	58
Brush – brush-weed-grass mixture with brush major element	48
Woods – grass combination (orchard or tree farm)	58
Farmsteads – buildings, lanes, driveways, and surrounding lots	74
Woods--disturbed by heavy grazing	66
Woods—forested areas protected from grazing and w/adequate litter and brush covering the soil	55

Data Collection Method:

1. Delineate the lateral drainage area between the upstream and downstream project reach limits. This will include land area on both sides of the stream (see Figure 18).
2. Using the USGS National Land Cover Database (NLCD), delineate the different land use types within the lateral drainage area and calculate the area occupied by each type.
3. Using Table 9, assign each land use type a land use coefficient value.
4. Calculate an area-weighted land use coefficient. For each land use type, multiply the land use coefficient by the area of that land use type; sum all products and divide by the total lateral drainage area (see equation below).

$$Land\ Use\ Coefficient_{Area\ Weighted} = \frac{\sum(Area_i * \ Land\ Use\ Coefficient_i)}{Area_{total}}$$

Concentrated Flow Points

Example 31: Concentrated Flow Points

An agricultural ditch draining water from an adjacent field into a project reach.

Anthropogenic impacts can lead to concentrated flows that erode soils and transport sediment into receiving stream channels. This metric assesses the number of concentrated flow points that enter the project reach per 1,000 linear feet of stream. For this metric, concentrated flow points are defined as erosional features, such as swales, gullies or other channels, that are created by anthropogenic impacts. Anthropogenic causes of concentrated flow may include agricultural drainage ditches, impervious surfaces, storm drains, and others (see Example 5).

Stream restoration projects can reduce concentrated flow entering the channel by dispersing flow in the floodplain and increasing ground cover near the channel. Combining multiple concentrated flow points into a single concentrated flow point does not count as an improvement. The restoration activity must diffuse or capture the runoff. Example activities include filling ditches, removing pipes, routing concentrated flow into created oxbow ponds, and stormwater BMP's.

Development can negatively impact stream channels by creating concentrated flow points such as stormwater outfalls. Proposed grading and stormwater management plans for development should be consulted to determine whether, and how many, concentrated flow points are likely to result from the proposed development.

Data Collection Method:

Concentrated flow points are evaluated in the field; methods are outlined in Appendix A.

BMP MIDS Rv Coefficient

The BMP MIDS R_v coefficient is assessed for projects that will include stormwater BMPs adjacent to the stream restoration project. The MPCA MIDS calculator accounts for percent impervious in the site runoff coefficient (R_v). The site runoff coefficient is a weighted coefficient based on user input of land use and soil type (Table 10). The R_V is used to calculate annual volume. To assess BMP runoff, the user must use the MIDS calculator[6] to calculate the existing runoff coefficient (R_v) and then calculate the effective R_v for the proposed condition.

[6] The MIDS calculator, web-based manual, and supporting information is available at https://stormwater.pca.state.mn.us/index.php/MIDS_calculator

Table 10: R_v Coefficients by Land Use and Soil Type (adapted from MPCA 2014c)

R_v coefficients	A soils	B soils	C soils	D soils
Forest/Open space	0.02	0.03	0.04	0.05
Managed turf (disturbed soils)	0.15	0.20	0.22	0.25
Impervious cover	0.95	0.95	0.95	0.95

<u>Data Collection Method</u>:

1. Determine the existing land use and impervious cover for the area that drains to the proposed BMP(s).
2. Using the MIDS calculator, the user inputs existing land use and impervious cover. The Existing R_v coefficient is not displayed in the MIDS GUI interface but can be found in the Site Information and Summary worksheet in the associated MIDS calculator Excel workbook (Figure 19). The Existing R_v coefficient is entered into SQT for existing conditions.

Figure 19: Rv coefficient in MIDS calculator Excel workbook. The red box highlights the Existing Rv coefficient in the example below.

Summary Information

Total impervious cover (acres)	0.50
Total watershed area (acres)	2.50
Site runoff coefficient, Rv	0.30
% Impervious	20%

3. The user will run MIDs with proposed BMP(s) using the existing land use and impervious cover to determine the Proposed Annual Volume.
4. The user will use the calculated Proposed Annual Volume and the equation below to back-calculate the effective R_v. The equation below is the Annual Volume equation from the MIDS calculator that has been rearranged to solve for the Effective R_v. The effective R_V is entered into the SQT for proposed conditions.

$$Effective\ R_V = \left(\frac{Proposed\ Annual\ volume(acft)}{0.9 \times Total\ Area\ (acres)}\right) \times \left(\frac{12\ {}^{in}/_{ft}}{Annual\ Rainfall(in)}\right)$$

Equation inputs:

- Annual Rainfall determined by project zip code (determined by MIDS calculator)
- 0.9 = Fraction of annual rainfall events that produce runoff (constant)
- Proposed Annual Volume (determined by MIDS calculator from Step 3)
- Total Area (acres) area that drains to the BMP(s)

2.6. Hydraulics Functional Category Parameter and Metrics

There is one function-based parameter to assess hydraulic functions: floodplain connectivity. There are two metrics to assess floodplain connectivity: bank height ratio (BHR) and entrenchment ratio (ER). Entrenchment ratio characterizes the horizontal extent of the floodplain while BHR indirectly characterizes the frequency of floodplain inundation. Entrenchment ratio is not applicable to multi-thread systems. Every single-thread project reach must assess floodplain connectivity using bank height ratio and entrenchment ratio.

Bank Height Ratio (BHR)

The BHR is a measure of channel incision and an indicator of whether flood flows can access and inundate the floodplain. This metric is described in detail by Rosgen (2014). The bank height ratio compares the low bank height to the maximum bankfull riffle depth. The lower the ratio, the more frequently water can access the floodplain. The low bank height is defined as the left or right streambank that has a lower elevation, indicating the minimum water depth necessary to inundate the floodplain. The most common calculation for the BHR, and the one used in the MNSQT, is low bank height divided by the maximum bankfull riffle depth (D_{max}). Typically, the minimum bank height ratio is 1.0 meaning that bankfull is equal to the top of the streambank.

$$BHR = \frac{Low\ Bank\ Height}{Dmax}$$

To improve consistency and repeatability, this measurement is taken at the approximate mid-point of every riffle within the representative sub-reach. The approximate mid-point is stated to provide some flexibility in the specific location with the intent being to select a location where the BHR best represents the full length of the riffle. The riffle length corresponding to the BHR is also measured and the weighted BHR is calculated and input into the MNSQT. To calculate the weighted BHR, use the measurements for low bank height, thalweg depth, and riffle length for every riffle feature within the representative sub-reach and calculate using the weighted BHR equation below (also see Example 7). The weighted BHR should then be entered in the MNSQT.

$$BHR_{weighted} = \frac{\sum_{i=1}^{n}(BHR_i * RL_i)}{\sum_{i=1}^{n} RL_i}$$

Where, RL_i is the length of the riffle where BHR_i was measured.

Example 38: Weighted BHR Calculation in an assessment segment with four riffles

Riffle ID	Length (RL)	BHR	BHR * RL
R1	25	1.0	25
R2	200	1.5	300
R3	75	1.4	105
R4	40	1.2	36
Total	**340 ft**	**Total**	**466**
Weighted BHR = 466/340 = 1.4			

Data Collection Methods:

BHR data are collected within the representative sub-reach using the longitudinal profile or the rapid survey method. Field methods are described in Appendix A.

ENTRENCHMENT RATIO (ER)

Floodplain connectivity and width vary naturally by stream and valley type, with some streams more naturally constrained than others. An entrenchment ratio characterizes the vertical containment of the river by evaluating the ratio of the flood prone width to the bankfull width (Rosgen 1996). The ER is a measure of approximately how far the 2-percent-annual-probability discharge (50-year recurrence interval) will laterally inundate the floodplain (Rosgen 1996).

Entrenchment ratio is calculated by dividing the flood prone width by the bankfull width of a channel, measured at a riffle cross section. The flood prone width is measured perpendicular to the valley and at the same location as the riffle cross section. The flood prone width is the cross-section width at an elevation of two times the bankfull max depth.

$$ER = \frac{Flood\ Prone\ Width}{Bankfull\ Width}$$

The ER should be measured at each riffle to calculate the weighted ER (see equation below and Example 7). However, if the valley width is uniform, it is unnecessary to assess every riffle. The ER should be measured at the midpoint of the riffle, halfway between the head of the riffle and the head of the run or pool if there is not a run. A weighted ER is calculated as follows:

$$ER_{weighted} = \frac{\sum_{i=1}^{n}(ER_i * RL_i)}{\sum_{i=1}^{n} RL_i}$$

Where, RL_i is the length of the riffle where ER_i was measured.

Example 45: Weighted ER Calculation in an assessment segment with four riffles

Riffle ID	Length (RL)	ER	ER * RL
R1	25	1.2	30
R2	200	2.1	420
R3	50	1.6	80
R4	30	1.8	54
Total	**305 ft**	**Total**	**584**
Weighted ER = 305/584 = 1.9			

Data Collection Methods:

ER data are collected within the representative sub-reach using cross-sectional survey methods or the rapid survey method. Field methods are described in Appendix A.

2.7. Geomorphology Functional Category Metrics

The MNSQT contains the following function-based parameters to assess the geomorphology functional category: large woody debris, lateral migration, bed material characterization, bed form diversity, and riparian vegetation. Not all geomorphic parameters will be evaluated for all projects. Refer to Section 2.3 of this manual for guidance on parameter and metric selection.

2.7.A. Large Woody Debris

There are two metrics used to assess large woody debris (LWD), including a LWD piece count and a large woody debris index (LWDI). Either metric can be used to inform this parameter but both metrics should not be used at a single reach. LWD should be assessed for all projects that are in ecoregions that support forested riparian areas.

LWD is defined as dead and fallen wood over 3.28 feet (1m) in length and at least 3.9 inches (10 cm) in diameter at the largest end.[7] The wood must be within the stream channel or touching the top of the streambank. LWD that lies in the floodplain but is not at least partially in the active channel is not counted. Both metrics use data from a LWD assessment reach of 328 feet (100 meters). This reach should be located within the representative sub-reach and should represent the portion of the sub-reach that will yield the highest score.

LWDI

The Large Woody Debris Index (LWDI) is used to evaluate large woody debris within or touching the active channel of a stream. This index was developed by the USDA Forest Service Rocky Mountain Research Station (Davis et al. 2001). Guidance on calculating the LWDI score is included in the *Application of the Large Woody Debris Index: A Field User Manual Version 1* (Harman et al. 2017). When data are entered digitally into the field form workbook, the LWDI score calculates automatically. The LWDI score is entered as the field value in the MNSQT.

Data Collection Method:

Data collection methods and field forms are provided in the *Application of the Large Woody Debris Index: A Field User Manual Version 1* (Harman et al. 2017).

Piece Count

For this metric, all pieces of LWD within the 328 feet (100 meters) LWD assessment reach are counted. For debris dams, each piece within the dam that qualifies as LWD is counted as a piece. The number of pieces observed is the field value input for the MNSQT. No additional calculation is required.

Data Collection Method:

The field procedure is outlined in Appendix A; data is recorded on the Project Reach form (Appendix B).

[7] Note: Standing dead material is not included as LWD. In willow-dominated systems, willow branches that form debris jams are included in the LWDI assessment even if they do not meet the minimum piece size. Additional discussion is provided in the LWDI manual.

2.7.B. LATERAL MIGRATION

Lateral migration is a parameter that assesses the degree of streambank erosion relative to natural rates of erosion and is recommended for all projects. There are three metrics for this parameter: dominant bank erosion hazard index /near bank stress (BEHI/NBS), percent streambank erosion, and percent armoring. When using the BEHI/NBS assessment, the percent of bank erosion is also assessed. The dominant BEHI/NBS characterizes the magnitude of bank erosion and the percent of erosion characterizes the extent of bank erosion within a reach. Percent armoring is used when armoring techniques are present or proposed.

DOMINANT BANK EROSION HAZARD INDEX/NEAR BANK STRESS (BEHI/NBS)

The Bank Erosion Hazard Index (BEHI) is a method used to estimate the tendency of a given stream bank to erode based on factors such as bank angle, riparian vegetation, rooting depth and density, surface protection, and bank height relative to bankfull height. Near Bank Stress (NBS) is an estimate of shear stress exerted by flowing water on the stream banks. Together, BEHI and NBS are used to populate the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model and produce cumulative estimates of stream bank erosion rates for surveyed reaches (Rosgen 2014). In the MNSQT, the BEHI/NBS assessment is used to determine the dominant BEHI/NBS category within the representative sub-reach. Evaluation of BEHI/NBS should be completed for **every** outside meander bend. The outside of the meander bend is assessed whether or not it is eroding. In addition to all meander bends, any other bank that is actively contributing sediment is also assessed. Depositional zones, such as point bars, or other areas that are not actively eroding should not be evaluated (Rosgen 2014). Additionally, riffle sections that are not eroding and have low potential to erode are excluded from the dominant BEHI/NBS survey.

Banks that are armored should not be assessed with the dominant BEHI/NBS metric. If armoring is present or proposed, this metric does not apply.

The dominant BEHI/NBS is the category that represents the greatest cumulative bank length; it does not need to describe over 50% of the assessed banks. For each bank, the BEHI/NBS category percent is calculated by summing the length of each bank and then dividing that length by the total assessed length. The total percent for each BEHI/NBS category is calculated by summing the percentage for each category (see Example 8). If there is a tie between more than one BEHI/NBS category, the category representing the highest level of bank erosion should be selected.

To enter the field value in the MNSQT, a drop-down list of BEHI/NBS categories is provided in the Quantification Tool worksheet.

Example 52: Calculation of Dominant BEHI/NBS

In this example, data were collected in the field for 1100 feet of bank (including left and right banks). Actively eroding banks and those with a strong potential to erode were assessed using the BEHI/NBS methods.

Bank ID (Left and Right)	BEHI/NBS	Length (Feet)	Percent of Total (%)
L1	Low/Low	50	50 / 155 = 32
L2	High/High	12	8
R1	Mod/High	22	14
R2	High/High	31	20
L3	Low/Mod	9	6
R4	High/High	31	20
Total Length		**155**	**100**

There are four BEHI/NBS categories present: Low/Low, High/High, Mod/High, and Low/Mod. The length of each bank was summed and divided by the assessed bank length; the total percent is then calculated for each category (e.g., High/High = 8%+20%+20% = 48%). The dominant BEHI/NBS category is High/High since that score is greater than the other three BEHI/NBS categories.

Data Collection Method:

Field methods are included in Appendix A and datasheets are included in Appendix B. Detailed field procedures are not provided for the BEHI/NBS method but can be found in the following references: Appendix D of the *Function-Based Rapid Field Stream Assessment Methodology* (Starr et al. 2015), or *River Stability Field Guide, Second Edition* (Rosgen 2014).

Percent Streambank Erosion

The percent streambank erosion is measured as the length of streambank that is actively eroding divided by the total length of bank (left and right) in the project reach. All banks with a BEHI/NBS score indicating an actively eroding bank (Table 11) should be summed together to calculate this metric.

Table 11: BEHI/NBS Stability Ratings that Represent Actively Eroding and Non-eroding Banks

Non-eroding Banks	*Actively Eroding Banks*
VL/VL, VL/L, VL/M, VL/H, VL/VH, VL/Ex, L/VL, L/L, L/M, L/H, L/VH, L/Ex, M/VL, M/L	M/M, M/H, M/VH, M/Ex, H/L, H/M, H/H, H/Ex, VH/VL, VH/VH, Ex/VL, Ex/L Ex/M, Ex/H, Ex/VH, Ex/Ex

VL = Very Low, L=Low, M = Moderate, H = High, VH = Very High, Ex = Extreme

This metric is calculated by dividing the total length of eroding bank by the total length of streambank within the sub-reach, refer to Example 9. The total length of streambank is the sum of the left and right bank lengths within the sub-reach (approximately twice the channel length).

$$Percent\ Streambank\ Erosion = \frac{Length\ of\ Eroding\ Bank}{Total\ length\ of\ Streambank\ in\ Reach} * 100$$

Data Collection Method:

Data from the BEHI/NBS assessment method and reach length determination are used to calculate percent erosion. Methods are included in Appendix A and datasheets are included in Appendix B. Additional resources to use in the field include: Appendix D of the *Function-Based Rapid Field Stream Assessment Methodology* (Starr et al. 2015), or *River Stability Field Guide, Second Edition* (Rosgen 2014).

Example 59: Calculation of Percent Erosion

This example uses the same BEHI/NBS results as Example 8. In the table below, actively eroding banks are identified in bold per Table 11. These bank lengths are added together (12+22+31+31) and divided by the total bank length (1100 feet including left and right banks). The total percent streambank erosion is 8.7%.

Bank ID (Left and Right)	BEHI/NBS	Length (Feet)
L1	Low/Low	50
L2	**High/High**	**12**
R1	**Mod/High**	**22**
R2	**High/High**	**31**
L3	Low/Mod	9
R4	**High/High**	**31**

Percent Armoring

Bank armoring is any rigid human-made stabilization practice that permanently prevents lateral migration processes. Examples of armoring include rip rap, gabion baskets, concrete, boulder toe and other engineered materials that covers the entire bank height. Bank stabilization practices that include toe protection to reduce excessive erosion are not considered armoring if the stone or wood does not extend from the streambed to an elevation that is beyond one-third the bank height and the remainder of the bank height is vegetated.

This metric should only be used if bank armoring is present or proposed in the project reach. If banks are not armored in the project reach, a field value should not be entered. To calculate the armoring field value, measure the total length of armored banks (left and right) within the project reach and divide by the total length of bank (left and right). Multiply by 100 to report as a percentage of bank armoring. Enter the field value into the MNSQT.

$$Percent\ Armoring = \frac{Length\ of\ Armored\ Bank}{Total\ length\ of\ Streambank\ in\ Reach} * 100$$

Data Collection Method:

Collect along entire project reach length using the field method described in Appendix A.

2.7.c. Bed Material Characterization

Bed material is a parameter recommended for projects in gravel bed streams with sandy banks where fining of the bed material is occurring due to bank erosion or where activities are proposed that could lead to fine sediment deposition over gravel bed material. Projects that implement bank stabilization practices along a long project reach or restore flushing flows may be able to show a reduction in fine sediment deposition. Bed material is characterized using a Wolman Pebble Count procedure and the Size-Class Pebble Count Analyzer (v1; Potyondy and Bunte 2007).[8]

The field value for this metric is informed by a comparison between the project reach and a reference reach. Bevenger and King (1995) provide a description of how to select and potentially combine reference reaches for bed material characterization. Note, reference reach stratification may include Rosgen stream classification, catchment area, gradient, and lithology. When possible, the reference reach should be located upstream of the project reach and upstream of the source of sediment imbalance. For example, a stable C stream type with a forested catchment upstream of an unstable C4 or Gc/F4 stream type would represent a good reference reach. If a reference reach cannot be located, this metric cannot be calculated. The location of the reference and project reaches should be mapped and provided.

Steps for calculating this metric:

1. Download the Size-Class Pebble Count Analyzer and read the Introduction tab.
2. Read and complete the Sample Size worksheet. Note, keeping the sample size the same between the reference and project reach is recommended. At least 100 samples should be collected for both reaches. Keep the default values for Type I and Type II errors, which are 0.05 and 0.2 respectively. Set the study proportion to 0.25.
3. Complete a Representative Pebble Count at the project and reference reaches.

[8] www.fs.fed.us/biology/nsaec/assets/size-classpebblecountanalyzer2007.xls

4. Enter the results for the reference and project reaches in the Data Input tab in the Size-Class Pebble Count Analyzer. Run the analyzer.
5. Review the contingency tables to determine if the project reach is statistically different from the reference condition for the 4mm and 8mm size classes. Depending on the size of gravel in your project area and the reference reach, change the size class if appropriate for your site.
6. The p-value from the contingency tables for the selected size class (typically either 4 mm or 8 mm) should be entered as the field value for the existing condition assessment. A non-statistically significant value, such as 0.5, can be entered as the proposed condition assuming that the project will reduce the supply of fine sediment to the project reach.

Data Collection Method:

Bed material data should be collected using pebble count procedures described in Bevenger and King (1995).

2.7.D. Bed Form Diversity

Bed forms include the various channel features that maintain heterogeneity in the channel form, including riffles, runs, pools, and glides (Rosgen 2014). Together, these bed features create important habitats for aquatic life. The location, stability, and depth of these bed features are responsive to sediment transport processes acting against the channel boundary conditions. Therefore, if the bed forms are representative of a reference condition, it can be assumed that the sediment transport processes are in equilibrium within the system. There are four metrics for this parameter: pool spacing ratio, pool depth ratio, percent riffle, and aggradation ratio.

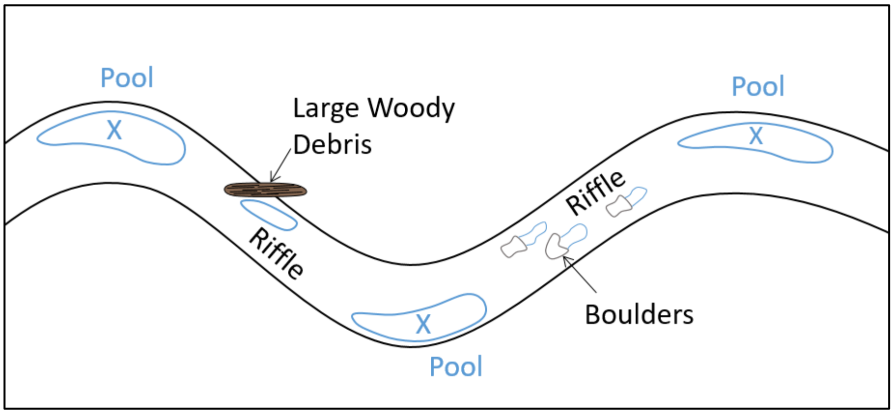
Pool Spacing Ratio

Pool-to-pool spacing is essentially a measure of how many geomorphic pools are present within a given reach and can be indicative of the channel stability and geomorphic function. For this metric, pools should only be included if they are geomorphic pools; micro-pools within riffles are not counted using this metric. Geomorphic pools are associated with planform features that create large pools that remain intact over many years and flow conditions. Examples include pools associated with the outside of a meander bend and downstream of a large cascade or step. Micro pools are small, typically less than half the width of the channel, and may not last for a long period of time or after a large flow event. An example is a scour pool downstream of a single piece of large woody debris. It is important that users accurately characterize pools, and thus guidance for identifying pools in different valley types is provided below. Note, pool identification is slightly different for pool depth and percent riffle.

Identifying Geomorphic Pools in Alluvial-Valley Streams:

Pools should only be included if they are located along the outside of the meander bend. Figure 20 provides an illustration of what is and is not counted as a pool (pools are marked with an ‘X’). The figure illustrates a meandering stream, where the pools located in the outside of the meander bend are counted for the pool spacing measurement, and the ‘X’ marks the approximate location of the deepest part of the pool. The pools associated with the large woody debris and boulder clusters in this figure are not counted because they are small pools located within the riffle. Compound pools that are not separated by a riffle within the same bend are treated as one pool. However, compound bends with two pools separated by a riffle are treated as two pools. Rosgen (2014) provides illustrations for these scenarios.

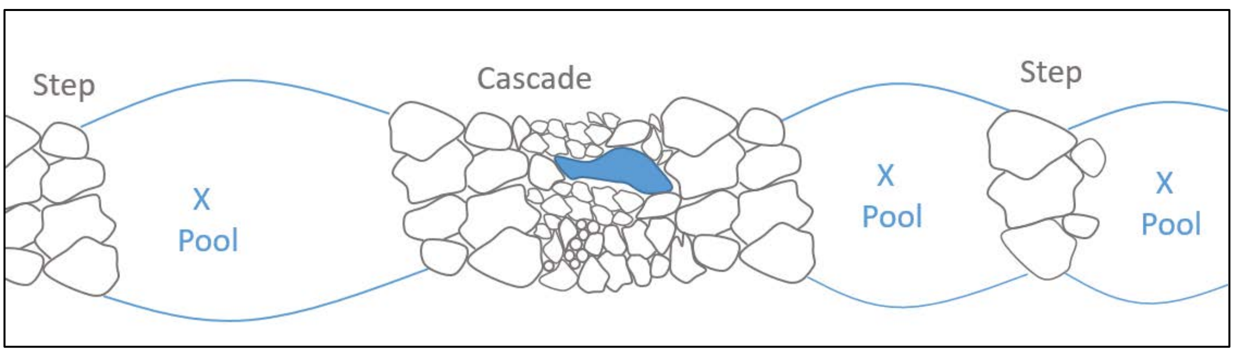
Figure 20: Pool Spacing in Alluvial Valley Streams



Identifying Geomorphic Pools in Colluvial and V-Shaped Valleys

Pools in colluvial or v-shaped valleys should only be counted if they are downstream of a step, riffle, or cascade. Pools within a riffle or cascade are not counted, just like pools within a riffle of a meandering stream are not counted. An example of pool spacing in a colluvial or v-shaped valley is shown in Figure 21. For these bed forms, pools are only counted at the downstream end of the riffle or cascade, micro pools within the feature are not included.

Figure 21: Pool Spacing in Colluvial and V-Shaped Valleys



The pool spacing ratio is the distance between sequential geomorphic pools divided by the bankfull riffle width determined from the representative riffle cross section.

$$Pool\ Spacing\ Ratio = \frac{Distance\ between\ sequential\ pools}{Riffle\ Bankfull\ Width}$$

The pool spacing ratio is calculated for each pair of sequential pools in the representative sub-reach. The field value entered in the MNSQT should be a median value based on at least three pool spacing measurements.

Data Collection Method:

Field methods are described in Appendix A. Pool-to-pool spacing is the distance between the deepest point of two pools, and these data can be collected using either longitudinal profile or the rapid survey method. Bankfull riffle width data is collected using the Representative Riffle Survey method.

POOL DEPTH RATIO

The pool depth ratio is a measure of pool quality with deeper pools scored higher than shallow pools. All significant pools (geomorphic and pools associated with wood, boulders, convergence, and backwater) are assessed. If a pool is not associated with a geomorphic or planform feature (i.e., meander bend or riffle/step), it should still meet the following criteria to classify as a pool: the pool must be deeper than the riffle, have a concave shaped bed surface and a water surface slope that is flatter than the riffle, and a width that is at least one-third the width of the channel.

$$Pool\ Depth\ Ratio = \frac{D_{max\ pool}}{D_{mean\ riffle}}$$

The pool depth ratio is calculated by dividing the maximum bankfull pool depth by the mean bankfull riffle depth. The pool depth ratio is calculated for each pool in the representative sub-reach. The minimum, maximum, and average values are then calculated. However, only the average value is input into the MNSQT.

Data Collection Method:

Field methods are described in Appendix A. Pool depth represents the elevational difference between the deepest points of each pool and the bankfull elevation. These data can be collected using either longitudinal profile and cross-sectional survey methods or the rapid survey method. Mean bankfull riffle depth is calculated using the Representative Riffle Survey method.

PERCENT RIFFLE

The percent riffle is the proportion of the representative sub-reach containing riffle bed form features. Riffle length is measured from the head (beginning) of the riffle downstream to the head of the pool. Run features are included within the riffle length. Glide features should be classified as pools. A run is a transitional feature from the riffle to the pool and the glide transitions from the pool to the riffle (Rosgen 2014). If the pools are not associated with a planform feature (i.e., meander bend or riffle/step), it should still be large enough to qualify as a pool. The criteria used to classify a pool includes: the pool must be deeper than the riffle, have a concave shaped bed surface and a water surface slope that is flatter than the riffle, and a width that is at least one-third the width of the channel. Percent riffle is calculated by dividing the total length of riffles within the representative sub-reach by the total sub-reach length.

Data Collection Method:

Field methods are described in Appendix A. Percent riffle data can be collected using either longitudinal profile survey methods or the rapid survey method.

AGGRADATION RATIO

Channel instability can result from excessive deposition that causes channel widening, lateral instability, and bed aggradation. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections. The aggradation ratio is the bankfull width at the widest riffle within the representative sub-reach divided by the mean bankfull riffle depth at that riffle. This ratio is then divided by a reference width depth ratio (WDR).

$$Aggradation\ Ratio = \frac{W_{max\ riffle}}{D_{mean\ riffle}} \Big/ Reference\ WDR$$

Since the WDR can play a large role in the design process and is often linked to slope and sediment transport assessments, the reference WDR is selected by the practitioner. The reference WDR can come from the representative riffle cross section at, or adjacent to the project reach or through the design process. Justification for the selected WDR should be provided.

<u>Data Collection Method</u>:

Data can be collected using either cross-sectional survey methods or the rapid survey method. Both methods are outlined in Appendix A. It is recommended to measure this metric at multiple riffle cross sections with aggradation features to ensure that the widest value for the sub-reach is obtained and to document the extent of aggradation throughout the project reach.

2.7.E. RIPARIAN VEGETATION

For purposes of the MNSQT, riparian vegetation is a parameter in the geomorphic category of the stream functions pyramid emphasizing its role in supporting the dynamic equilibrium of the stream channel. Dynamic equilibrium is part of the geomorphology functional statement. Riparian vegetation is supported by the hydrology and hydraulic functions. For example, non-incised streams have more overbank flooding and shallower depths to the water table, which affect riparian vegetation composition. Moving up the pyramid, riparian vegetation supports physicochemical functions like denitrification and supports various life stages of aquatic organisms.

There are four metrics for riparian vegetation: riparian buffer width (%), canopy cover (%), herbaceous vegetation cover (%) and woody stem basal area (sqm/hectare). Woody stem basal area is required only if woody vegetation has been determined to be a natural component of the riparian buffer.

RIPARIAN BUFFER WIDTH

This metric is the average width of vegetated buffer (excluding all artificial vegetation that is periodically harvested/removed such as crops, sod, tree farms, etc.) contiguous with the stream and uninterrupted by human-related disturbances/structures (roads, buildings, utility lines, etc.) expressed as a percentage of the reference expectation (the expected vegetated area width).

The expected vegetated area width is calculated based on the channel size and valley type. The average vegetated buffer is the portion of the expected vegetated area width that currently contains riparian vegetation and is free from development, as described above. These values should first be estimated using aerial imagery interpretation prior to validating in the field.

Riparian width (%) is the field value entered into the MNSQT and is calculated using the following equation:

$$Riparian\ Width = \frac{Average\ Vegetated\ Area\ Width}{Expected\ Vegetated\ Area\ Width} * 100$$

Data Collection Method:

The riparian buffer width metric relies on a combination of desktop and field observation methods as described in Appendix A. A figure that shows the location of where the Expected Vegetated Area Width was determined and that shows the measurement locations used to determine the Average Vegetated Area Width should be provided.

The expected vegetated area width is determined based on the valley type and bankfull width as described below for the defined stream reach.

Expected Vegetated Area Width:

1. Determine valley type (alluvial, confined alluvial or colluvial).
2. Determine bankfull width (feet).
3. Multiply bankfull width by the typical MWR based on the valley type (Table 12). Add additional width for the outside meander bends (see equation below and Figure 21)

$$Expected\ Vegetated\ Area\ \ Width = \ W_{Bankfull} * MWR + 2 * W_{additional}$$

Table 12: MWR by Valley Type adapted from Harman et al. (2012) and Rosgen (2014)

Valley Type	MWR	Additional Width (ft) $W_{additional}$
Alluvial Valley	4	25
Confined Alluvial	3	15
Colluvial	2	10

4. Use the Expected Vegetated Area Width calculated in step 3 and apply it to the stream reach using the procedure in Appendix A to determine if the expected vegetated area width should be adjusted based on observable indicators of floodplain and/or active fluvial processes.

Average Vegetated Area Width:

Once the expected vegetated area width is defined for the stream reach, the average vegetated area width is determined as follows:

1. Within the expected vegetated area width, use aerial imagery to identify and delineate areas of riparian vegetation (excluding all artificial vegetation that is periodically harvested/removed such as crops, sod, tree farms, etc.) that are contiguous with the stream channel. Do not include areas that are interrupted by any human-related

disturbances/structures (roads, buildings, utility lines, etc.). Field verification may be necessary, but this step should primarily be based on aerial imagery interpretation.

2. Measure the width of the buffer from one side of the expected vegetated area width to the other at a minimum of 10 locations for the entire reach. A minimum of 2 measurements are required in each sub-reach.
3. Average the measurements from Step 2, this is the average vegetated area width.
4. Apply the average vegetated area buffer width to the stream reach using the same method as for the expected vegetated area width as described in Appendix A. Note that the application of the average vegetated area buffer to the stream reach will not involve the adjustments for topography and observable fluvial/floodplain processes described in the procedure for determining the expected vegetated area width.
5. Determine the area (in square kilometers or meters) of the expected and average vegetated area buffer width. Divide the average vegetated area width by the expected vegetated area width and multiply by 100 to calculate the riparian width metric field value.

CANOPY COVER

This metric characterizes the canopy cover provided by the leaves and branches of trees and shrubs in the riparian zone. Canopy cover is determined by separately assessing the relative areal cover of the shrub and tree vegetation strata and then adding those values together. The shrub strata is defined as woody vegetation greater than 1.37 meters high and less than 7.62 cm diameter breast height, and the tree strata is woody vegetation greater than 1.37 meters high and 7.62 cm or greater diameter breast height. This metric uses the data from the riparian sampling plots collected according to the instructions provided in Appendix A.

In certain ecological sections of the state, trees and shrubs are not a significant natural component of the riparian zone of some stream reaches. In those instances, high canopy cover can be detrimental to natural stream functioning by suppressing or otherwise altering the underlying herbaceous vegetation layer. Methodology for determining if trees and shrubs are a natural component of the riparian zone is described in the Canopy Cover Data Collection section in Appendix A.

<u>Data Collection Method</u>:

Canopy cover is determined by averaging the relative cover values collected for each sampling plot as described in Appendix A.

HERBACEOUS VEGETATION COVER

This metric characterizes herbaceous vegetation cover, which is important for bank stability, water quality, and habitat, particularly in systems where woody vegetation is not prevalent. The herbaceous strata is defined as all herbaceous vegetation as well as all woody vegetation less than one 1.37 meters high (breast height). A higher relative areal cover in the herbaceous strata provides more leaf and stem surfaces to intercept precipitation. Areas that are devoid of herbaceous cover expose the riparian zone to potential erosive forces. This metric uses the data from the riparian sampling plots collected according to the instructions provided in Appendix A.

Data Collection Method:

See Data Collection Method for Herbaceous Vegetation Cover are described in Appendix A.

Woody Stem Basal Area

This metric is an estimate of the average amount of the riparian zone occupied by woody stems. Woody stems intercept and slow flood and overland flows to protect against associated erosive forces. A higher basal area of woody stems will provide more attenuation of flows and protect the stream channel. For purposes of the MNSQT, woody stem basal area is determined by sampling woody stems that are greater than 1.37 meters high. The resulting sampling values are expressed as an area (m^2) per hectare and averaged across sampling plots for the reach. This metric uses the data from the riparian sampling plots collected according to the instructions provided in Appendix A.

In certain ecological sections of the state, trees and shrubs are not a significant natural component of the riparian zone of some stream reaches. In those instances, this metric should not be used. Methodology for determining if trees and shrubs are a natural component of the riparian zone is described in the Canopy Cover Data Collection section in Appendix A.

Data Collection Method:

Woody stem basal area is determined using sampling methods described in Appendix A.

2.8. Physicochemical Functional Category Metrics

The MNSQT contains three function-based parameters to assess the physicochemical functional category: temperature, dissolved oxygen, and total suspended solids.

2.8.A. Temperature

This parameter evaluates summer average temperature measured in degrees Celsius, which plays a key role in aquatic life cycles. High water temperatures, or rapid increases of temperature above ambient temperatures, can be very detrimental to fish.

Data Collection Method:

Placement and use of in-water temperature sensors should follow *Procedure for Temperature Logger Deployment at Stream Monitoring Sites* (MPCA 2015). This procedure is provided in Appendix B and describes equipment selection, deployment methodologies, data QAQC and includes a temperature logger form.

2.8.B. Dissolved Oxygen

This parameter evaluates dissolved oxygen (DO), which plays a key role in supporting aquatic life. There is one metric included in the MNSQT for this parameter, the dissolved oxygen concentration, measured in milligrams per liter (mg/L). DO standards differ depending on the use class of the water as described in the *Guidance Manual For Assessing the Quality of Minnesota Surface Waters* (MPCA 2018a).

Data Collection Method:

Measuring dissolved oxygen concentration should be conducted according to the *Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component* document (MPCA 2018b). The standard for DO is expressed in terms of daily minimums and concentrations generally following a diurnal cycle. Consequently, measurements in open-water months (April through November) should be made before 9:00 a.m. Sampling events may coincide with biological sampling where sampling periods overlap.

2.8.C. TOTAL SUSPENDED SOLIDS

Total suspended solids (TSS) consist of soil particles, algae, and other materials that are suspended in water and cause a lack of clarity. Excessive TSS can harm aquatic life, degrade aesthetic and recreational qualities, and make water more expensive to treat for drinking. Total suspended solids (TSS) standards differ depending on the use class of the water as described in the *Guidance Manual For Assessing the Quality of Minnesota Surface Waters* (MPCA 2018a). There is one metric included in the MNSQT for this parameter, the TSS concentration, measured in milligrams per liter (mg/L).

Data Collection Method:

Measuring total suspended solids should be conducted according to methods described in the *Guidance Manual For Assessing the Quality of Minnesota Surface Waters* (MPCA 2018a) and *Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component* document (MPCA 2018b). The State also uses turbidity as a surrogate for TSS. The protocol for turbidity sampling is described in *Turbidity TMDL Protocol Guidance and Submittal Requirements* (MPCA 2007).

2.9. Biology Functional Category Metrics

The function-based parameters included in the MNSQT for the biology functional category are macroinvertebrates and fish. The presence of a healthy, diverse, and reproducing aquatic community is a good indication that the aquatic life beneficial use is being supported by a lake, stream, or wetland. The aquatic community integrates the cumulative impacts of pollutants, habitat alteration, and hydrologic modification on a water body over time. Monitoring the aquatic community, or biological monitoring, is therefore a relatively direct way to assess aquatic life use-support. Interpreting aquatic community data is accomplished using an index of biological integrity or IBI. The IBI incorporates multiple attributes of the aquatic community, called “metrics,” to evaluate a complex biological system (MPCA 2018a). MPCA has developed fish (MPCA 2014b) and macroinvertebrate (MPCA 2014a) IBIs to assess the aquatic life use of rivers and streams statewide in Minnesota.

2.9.A. MACROINVERTEBRATES

Macroinvertebrates are an integral part of the food web and are commonly used as indicators of stream ecosystem condition. The MPCA recognizes nine different macroinvertebrate IBI classes based on stream type and the expected natural macroinvertebrate community associated with each. Stream types are defined using drainage area, geographic region, thermal regime, and gradient. Table 7 presents the different classes and their criteria while Figure 15 shows the geographic distribution of each class.

Data Collection Method:

Macroinvertebrate sampling should be conducted following the guidance in *Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017b).

2.9.B. FISH

Fish are an integral part of functioning river ecosystems. Similar to macroinvertebrates, the MPCA has developed a comprehensive, statewide IBI to assess the biological integrity of riverine fish communities in Minnesota. IBI classes were first defined using watershed lines that reflect post-glacial barriers to movement, resulting in 'north' and 'south' streams (Figure 16). These two classes were further refined into nine total classes based on stream/watershed size, thermal regime, and gradient (Table 8). Figure 17 shows the general geographic distribution of each class. It is important to note that the map is for display purposes only; classification of individual sampling locations should utilize site-specific attributes as outlined in Table 8.

Data Collection Method:

Fish sampling should be conducted following the guidance in *Fish Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017a) and *Water Chemistry Assessment Protocol for Stream Monitoring Sites* (MPCA 2014d).

Chapter 3. Calculating Functional Lift

This chapter outlines the process and concepts that should be considered during restoration project planning using the MNSQT, including projects providing mitigation under CWA 404 or RHA Section 10 (i.e., mitigation banks, in-lieu fee projects, or on-site/off-site permittee responsible mitigation projects). The sections of the MNSQT workbook that should be completed for restoration and mitigation projects are summarized in Table 13. See Section 1.2.e. for information on how the MNSQT calculates functional lift.

Table 13: MNSQT Worksheets Used for Restoration Projects

Worksheets	Relevant Sections
Project Assessment (Section 1.2.a)	• Reach Description • Aerial Photograph of Project Reach • Restoration Approach
Catchment Assessment (Section 1.2.b)	• Complete entire form • Determine restoration potential
Major Flow Variability Metrics	No data entry in this worksheet
Measurement Selection Guide	No data entry in this worksheet
Quantification Tool (Section 1.2.e)	• Site Information and Reference Selection • Existing Condition field values* • Proposed Condition field values*
Monitoring Data (Section 1.2.f)	• As-Built Condition field values* • Field values for up to 10 monitoring events*
Data Summary	No data entry in this worksheet
Reference Curves	No data entry in this worksheet

**Guidance on parameter selection is provided in Section 2.3. and detailed instructions for collecting and analyzing field values for all metrics are provided in Chapter 2 and Appendix A.*

3.1. Site Selection

The MNSQT can be used to assist with selecting or ranking the priority of a potential stream restoration or mitigation site. While there are many other elements to include in a thorough site-selection process (ELI 2016; Starr and Harman 2016); this section only illustrates the role of the MNSQT.

In the MNSQT, functional lift is estimated from the difference in pre- and post-project condition scores, scaled to project length and expressed as an overall change in functional feet. Therefore, if the user is deciding between multiple sites, the MNSQT can be used to rank sites based on the amount of functional lift available. Due to time constraints, the user may want to evaluate potential mitigation or restoration project sites using rapid methods available for some metrics (see Chapter 2 and Appendix A). At this stage, a user will likely have to estimate post-project condition using best professional judgement. The user could model a variety of design approaches to see how much lift is reasonable for each parameter. While evaluating different sites, it is generally recommended to focus on whether a proposed site can achieve the following post-project condition scores:

1. An index score of 0.70 or higher for floodplain connectivity, bed form diversity, and lateral migration; and
2. An index score of 0.60 or higher for riparian vegetation (recognizing that riparian vegetation may take multiple years to reach full potential).

If the purpose of the project is to provide mitigation under CWA 404 or RHA Section 10, the user should also refer to the St. Paul District Stream Mitigation Guidance (USACE Date pending) or consult with the Corps for further guidance on site selection.

3.2. Restoration or Mitigation Project Planning

3.2.A. Restoration Potential

Users will need to complete the Catchment Assessment Form and determine the restoration potential of the project reach. Once the restoration potential has been determined, the results are provided in the Site Information and Reference Selection section of the Quantification Tool worksheet. The Catchment Assessment worksheet is described in Sections 1.2 and 2.2 of this manual. The information below provides guidance on how to determine restoration potential using the results from the Catchment Assessment.

Restoration potential is the highest level of restoration that can be achieved based on an assessment of the contributing catchment, reach-scale constraints, and the results of the reach-scale function-based assessment (Harman et al. 2012). Restoration potential is determined by the degree to which physical, chemical, and biological processes at both watershed and reach scales are maintained or restored. The “highest level” refers to the functional categories in the Stream Functions Pyramid, and whether a project can restore functional capacity within each of the categories to a reference standard. A project with full restoration potential would restore the functional capacity within all categories to a reference standard. Partial restoration would improve some, but not all functions to reference standard. For example, partial restoration might mean restoring stability and aquatic habitat to a reference standard by implementing activities that manipulate processes in the Hydrology, Hydraulics and Geomorphology categories, but not restoring temperature or fish communities to a reference standard due to watershed stressors (Beechie et al. 2010; Harman et al. 2012).

Full Restoration Potential – The project has the potential to restore functions within all categories, including Biology, to a reference standard (see Table 1, page 14). This is consistent with the ‘full-restoration’ concept identified by Beechie et al. (2010), where actions restore habitat-forming processes and return the site to its natural or reference standard range of biological conditions and dynamics.

Partial Restoration Potential – The project has the potential to improve some functions compared with pre-project or baseline conditions. One or more functional categories may be restored to conditions typical of or approaching reference standard, but some catchment stressors or reach-scale constraints are preventing the site from reaching full potential.

Partial restoration is the most common restoration-potential level for stream restoration projects. Watershed processes and reach-scale constraints influencing a project site may allow for some functions, such as floodplain connectivity, dynamic equilibrium, and in-stream habitat to be restored but may limit the restoration of physicochemical and/or biological functions to reference standard. For partial restoration projects, improvements in all functional categories may be observed, but these improvements may not reflect a reference standard.

There are likely situations where even partial restoration is not possible due to the severity of catchment stressors and project constraints that may be outside the control of the practitioner. For example, flow alteration (a catchment-scale stressor) may modify the hydrologic and sediment transport processes to such a degree that partial-restoration is not feasible. Some stressors and constraints limit restoration potential to such a degree that the site may not be suitable for restoration activities.

Procedure for Determining Restoration Potential:

1. Determine the project reach limits and delineate the catchment area to the downstream end of the project reach (see reach delineation in Chapter 2).

2. Complete the Catchment Assessment worksheet (see Section 2.2 of this manual). Review the scores for each category to determine if an identified stressor can be overcome or if it will prevent the project reach from achieving even partial restoration. A stressor that prohibits partial restoration may constitute a "deal breaker" that could affect site selection until catchment-scale stressors can be improved.

    a. Upon completing the Catchment Assessment worksheet, the user should determine if restoration activities can overcome any or all of the catchment perturbations. Refer to the individual category ratings in the Catchment Assessment Form. Can the fair or poor ratings for each individual category be overcome by the scale of the project or by doing additional work in the catchment? If individual category ratings can change from fair or poor to good, then full restoration may be possible.

    b. Compare the reach size to the catchment size (length and/or area). Can the scale and type of restoration overcome the catchment stressors? At the reach scale, practitioners should consider several factors, including the scale of the restoration project in relation to the watershed. For small catchments where the length or area of the restoration project is large compared to the total stream length or catchment area, reach-scale activities may be able to overcome the stressors and perturbations.

    c. Consider whether catchment-scale efforts, in combination with a restoration project, are feasible and could overcome catchment perturbations/stressors. Broad-scale efforts could include managing sources of sediment imbalances within the contributing watershed, improving stormwater management practices, restoring more natural hydrology, removing connectivity barriers, etc. Note: evaluating and addressing stressors to underlying hydrologic or sediment transport processes will require additional design and/or modeling analyses that are outside the scope of this tool.

3. Identify reach-scale human-caused constraints. Explain how they could limit restoration potential. Constraints are human-caused conditions, structures and land uses that inhibit restoration activities at the reach scale and are outside of the control of the practitioner. A constraint is different than a stressor which occurs at the catchment-scale outside of the project reach. Constraints can negatively affect processes needed to support full restoration potential (and in extreme cases can even prohibit partial restoration).

   Common constraints include land uses within the floodplain or valley bottom that minimize stream-corridor width (e.g., roads, utility easements, levees/berms, etc.) and prevent streambed elevation changes during design. Note that natural conditions are not constraints. For example, while hillslopes constrain the lateral extent of meandering, that is not a constraint, as defined here. Hillslopes are a natural condition of the catchment. The presence of bedrock can limit changes to bed elevation and even prevent some aquatic species from migrating upstream. However, these are natural conditions that create habitat diversity. They are not considered constraints in this methodology and would therefore not limit the restoration potential.

4. Use the Quantification Tool worksheet to determine the baseline, existing condition of the reach. The Quantification Tool worksheet will quantify functional capacity by parameter and functional category.

5. Determine the current and future potential Stream Evolution Model (SEM) or Rosgen Channel Succession Stage (Table 14). Is the stream trending towards greater or lesser functionality? What is the realistic final Stage or Stream Type as compared to the previously undisturbed Stage or Stream Type? Note: this information is also used to determine the Reference Stream Type in the MNSQT and is described in Chapter 2.

   The future SEM stage (Cluer and Thorne 2013) or Rosgen Stream Type (Rosgen 1996) can be determined by considering the reach-scale constraints, Catchment Assessment results in combination with the baseline existing condition data. The SEM and Rosgen Channel Succession Stages are not described in this manual and users should consult the source material in applying these methods. The SEM provides more detail for systems that historically started as stream/wetland complexes or multi-thread systems than the Rosgen method and provides functional descriptions for each stage. Table 15 provides a crosswalk to assist the user in determining the SEM from the existing stream type for the project reach. The Rosgen approach includes channel evolution changes in a wider range of valley types than the SEM and responses to a wider range of disturbances.

Table 14: Crosswalk Linking Stream Evolution Model Stages to Rosgen Stream Type Succession

Stream Evolution Model Stages (Cluer and Thorne 2013)	Corresponding Rosgen Stream Types
Stage 0 - Anastomosing	DA
Stage 1 – Sinuous Single Thread	C, E
Stage 2 - Channelized	C, E, → Gc
Stage 3 - Degradation	Gc
Stage 3a – Arrested Degradation	Gc → F → Bc
Stage 4 – Degradation and Widening	Gc → F
Stage 5 – Aggradation and Widening	F → C
Stage 6 – Quasi Equilibrium	C, E
Stage 7 – Laterally Active	C, E, F
Stage 8 - Anastomosing	DA

Based on Steps 1-5, describe the restoration potential as Full or Partial. Explain the reasons for your selection. Identify which parameters/functions could be restored to a functioning condition (reference standard) and which may not. The restoration potential of the project reach is recorded on the Catchment Assessment worksheet and described on the Project Assessment worksheet. Results are also entered in the Site Information and Reference Selection section of the Quantification Tool worksheet.

3.2.B. FUNCTION-BASED DESIGN GOALS AND OBJECTIVES

After the restoration potential has been determined, users should develop function-based goals and objectives. This information is also entered into the MNSQT Workbook on the Project Assessment worksheet. Guidance on developing function-based goals and objectives is provided below.

Design goals are statements about *why* the project is needed at the specific project site and outline a general intention for the restoration project. These goals communicate the reasons behind the project's development. Design objectives explain *how* the project will be completed. Objectives are specific, tangible and can be validated with monitoring and performance standards. Objectives, in combination with the stated goals, describe what the practitioner will do to address the functional impairment. Typically, objectives will explain how key function-based parameters like floodplain connectivity, bed form diversity, lateral migration, and riparian vegetation will be changed to meet the goals. Design goals and objectives can be used to inform parameter selection within the MNSQT (see Examples 10 and 11).

The design goals should be cross referenced with the restoration potential of the project site to ensure that the goals do not exceed the restoration potential. For example, restoring wild trout biomass is not feasible if the restoration potential is limited due to the level of catchment development and higher water temperatures entering the project reach. In this example, the design goal could be revised to restore physical habitat for trout, a partial restoration goal that matches the restoration potential. If wild trout populations in the project reach are to be monitored, increasing wild trout biomass could be possible even with partial restoration potential; however, restoring wild trout biomass to reference standard would not be expected or possible. If catchment-level improvements are implemented to address stormwater runoff and temperature issues, full restoration could be achieved. This outcome would require reach-scale *and* catchment-scale restoration efforts.

Example 63: Project with Partial Restoration Potential

Partial Restoration Potential: The catchment draining to the project is mostly farmland. The overall catchment health is fair and biological improvements are limited by flow alteration.

Goals: Improve aquatic habitat for native fish communities and reduce sediment supply from bank erosion.

Objectives: Fence out cattle and replant riparian vegetation to stabilize banks, reconstruct portions of channel to improve bed form diversity (habitat).

Possible Parameter List:

- Reach Runoff
- Floodplain Connectivity
- Large Woody Debris
- Lateral Migration
- Bed Form Diversity
- Riparian Vegetation
- Macroinvertebrates
- Fish

Monitoring is included for metrics within the Biology category because the project is expected to show some improvement. However, the project is not expected to restore macroinvertebrates and fish parameters to a reference standard.

Example 11: Project with Full Restoration Potential

Full Restoration Potential: The project is located on a headwater stream where the catchment draining to the project is recovering from historical cattle grazing and farming. The overall existing catchment health is fair but expected to improve due to the changes in land use. The stream has been channelized and is incised due to agricultural land use practices.

Goals: Improve aquatic habitat for native fish communities and reduce sediment supply from bank erosion.

Objectives: Replant riparian vegetation to stabilize banks, reconstruct the entire channel to improve floodplain connectivity and bed form diversity (habitat).

Possible Parameter List:

- Reach Runoff
- Floodplain Connectivity
- Large Woody Debris
- Lateral Migration
- Bed Form Diversity
- Riparian Vegetation
- Temperature
- Dissolved Oxygen
- Total Suspended Solids
- Macroinvertebrates
- Fish

Due to the changes in upstream land use practices, it is expected to restore temperature, dissolved oxygen, total suspended solids, macroinvertebrates, and fish parameters to a reference standard.

Chapter 4. References

Beechie TJ, Sear DA, Olden JD, Pess GR, Buffington JM, Moir H, Roni P, Pollock MM. 2010. Process-based principles for restoring river ecosystems. BioScience. 60(3):209-222. https://doi.org/10.1525/bio.2010.60.3.7

Bevenger GS, King RM. 1995. A pebble count procedure for assessing watershed cumulative effects. US Department of Agriculture Forest Service Research Paper RM-RP-319. Fort Collins (CO): Rocky Mountain Forest and Range Experiment Station. https://www.fs.fed.us/rm/pubs_rm/rm_rp319.pdf

Carlson EA. 2009. Fluvial riparian classifications for national forests in the Western United States [thesis]. [Fort Collins (CO)]: Colorado State University.

Cluer B, Thorne C. 2013. A Stream Evolution Model Integrating Habitat and Ecosystem Benefits. River Research and Applications. 30(2):135-154. https://pdfs.semanticscholar.org/97b5/7edce62571b00897b0ba5c182076772cf92a.pdf

Colorado Stream Quantification Tool Steering Committee (CSQT SC). 2019. Colorado Stream Quantification Tool and Debit Calculator User Manual, Beta Version. Washington (DC): US Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds (Contract # EP-C-17-001).

Davis JC, Minshall WG, Robinson CT, Landres P. 2001. Monitoring Wilderness Stream Ecosystems. General Technical Report RMRS-GTR-70. Fort Collins (CO): US Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://www.fs.fed.us/rm/pubs/rmrs_gtr070.pdf

Environmental Law Institute (ELI), Stream Mechanics, The Nature Conservancy. 2016. Stream mitigation: Science, policy, and practice. https://www.eli.org/sites/default/files/eli-pubs/stream-mitigation-science-policy-and-practice-final-report.pdf

Harman WA, Barrett TB, Jones CJ, James A, Peel HM. 2017. Application of the large woody debris index: a field user manual version 1. Raleigh (NC): Stream Mechanics and Ecosystem Planning & Restoration. https://stream-mechanics.com/wp-content/uploads/2017/12/LWDI-Manual_V1.pdf

Harman WA, Jones CJ. 2017. Calculating functional loss using the stream quantification tool and debit calculator. Prepared for Environmental Defense Fund. https://stream-mechanics.com/wp-content/uploads/2017/08/Debit-Tool-White-Paper_Final-Draft.pdf

Harman WA, Jones CJ. 2016. Functional lift quantification tool for stream restoration projects in North Carolina: Spreadsheet user manual version 2. Raleigh (RC): Environmental Defense Fund.

Harman WA, Jones CJ. 2017. North Carolina stream quantification tool: spreadsheet user manual, NC SQT v3.0. Raleigh (NC): Environmental Defense Fund. https://www.edf.org/sites/default/files/Quantification-Tool-User-Manual.pdf

Harman W, Starr R, Carter M, Tweedy K, Clemmons M, Suggs K, Miller C. 2012. A function-based framework for stream assessment and restoration projects. EPA 843-K-12-006.

Washington (DC): US Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds. https://www.epa.gov/sites/production/files/2015-08/documents/a_function_based_framework_for_stream_assessment_3.pdf

Leopold LB. 1994. A View of a River. Cambridge (MA): Harvard University Press, Harvard University.

Merritt DM, Manning ME, Hough-Snee N, editors. 2017. The National Riparian Core Protocol: A riparian vegetation monitoring protocol for wadeable streams of the conterminous United States. General Technical Report RMRS-GTR-367. Fort Collins (CO): US Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://www.fs.fed.us/rm/pubs_series/rmrs/gtr/rmrs_gtr367.pdf

Minnesota Pollution Control Agency (MPCA). 2007. Turbidity TMDL Protocols and Submittal Requirements. Document number wq-iw1-07. St. Paul, MN.

MPCA. 2014a. Development of a macroinvertebrate-based Index of Biological Integrity for assessment of Minnesota's rivers and streams. Document number wq-bsm4-01. Environmental Analysis and Outcomes Division, St. Paul, MN.

MPCA. 2014b. Development of a fish-based Index of Biological Integrity for assessment of Minnesota's rivers and streams. Document number wq-bsm2-03. Environmental Analysis and Outcomes Division, St. Paul, MN.

MPCA. 2014c. Runoff coefficients by land use and soil type [Internet]. Minnesota Stormwater Manual,; 2014 Sep 8, 13:45 UTC [cited 2019 Jul 10]. Available from:https://stormwater.pca.state.mn.us/index.php?title=Runoff_coefficients_by_land_use_and_soil_type&oldid=15349.

MPCA. 2014d. Water Chemistry Assessment Protocol for Stream Monitoring Sites. Biological Monitoring Program, St. Paul, MN.

MPCA. 2015. Procedure for Temperature Logger Deployment at Stream Monitoring Sites. Biological Monitoring Program, St. Paul, MN.

MPCA. 2017a. Fish Data Collection Protocols for Lotic Waters in Minnesota. Document number wq-bsm3-12b. St. Paul, MN.

MPCA. 2017b. Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota. Document number wq-bsm3-12a. St. Paul, MN.

MPCA. 2018a. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List, March 2018. Document number wq-iw1-04j. Environmental Analysis and Outcomes Division, St. Paul, MN.

MPCA. 2018b. Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component. Document number wq-s1-18. St. Paul, MN.

Minnesota Stream Quantification Tool Steering Committee (MNSQT SC). Date pending. Scientific Support for the Colorado Stream Quantification Tool, Version 1.0. Washington (DC): US Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds (Contract # EP-C-17-001).

Natural Resources Conservation Service (NRCS). 1986. Urban hydrology for small watersheds. Technical Release No. 55. Washington (DC): US Department of Agriculture Natural Resources Conservation Service, Conservation Engineering Division. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf

Potyondy J, Bunte K. 2007. Size-class pebble count analyzer v1 2001, updated September 2007. US Forest Service. https://www.fs.fed.us/biology/nsaec/assets/size-classpebblecountanalyzer2007.xls

Rosgen, D. 1996. Applied river morphology. Fort Collins (CO): Wildland Hydrology Books.

Rosgen, D. 2006. A watershed assessment for river stability and sediment supply (WARSSS). Fort Collins (CO): Wildland Hydrology Books.

Rosgen, D. 2014. River stability field guide. 2nd ed. Fort Collins (CO): Wildland Hydrology Books.

Starr R, Harman W, Davis S. 2015. Final draft function-based rapid field stream assessment methodology. CAFE S15-06. Annapolis (MD): US Fish and Wildlife Service, Chesapeake Bay Field Office. https://www.fws.gov/chesapeakebay/stream/StreamsPDF/FinalDraftFunctionBasedRapidStreamAssessmentMethodologyandAppendices5-29-15.pdf

Starr R, Harman W. 2016. Draft final function-based stream restoration project process guidelines. CBFO S16-03. Annapolis (MD): US Fish and Wildlife Service, Chesapeake Bay Field Office. https://www.fws.gov/chesapeakeBay/stream/StreamsPDF/DraftFinalFunctionBasedStreamRestorProcessGuidelines6-17-2016Appendices.pdf

Tennessee Department of Environment and Conservation (TDEC). 2018. Tennessee stream quantification tool: spreadsheet user manual. TN SQT v1.0. Nashville (TN): Tennessee Department of Environment and Conservation. https://www.tn.gov/content/dam/tn/environment/water/documents/ppo_water_arap-tn-sqt-spreadsheet-user-manual-DRAFT.PDF

US Army Corps of Engineers (USACE). 2018a. Scientific support for the Wyoming stream quantification tool. Version 1.0. Cheyenne (WY): USACE Omaha District, Wyoming Regulatory Office. https://usace.contentdm.oclc.org/digital/api/collection/p266001coll1/id/8062/download

USACE. 2018b. Georgia interim stream quantification tool and user manual. In: 2018 Standard Operating Procedures for Compensatory Mitigation. Burford (GA): USACE Savannah District, Georgia Regulatory Branch. https://www.sas.usace.army.mil/Portals/61/docs/Regulatory/Mitigation%20Documents/SOP.pdf?ver=2018-07-03-144058-600

USACE. Date pending. Stream Mitigation Guidance. USACE St. Paul District, Minnesota Regulatory office.

APPENDIX A:

Field Data Collection Methods for the
Minnesota Stream Quantification Tool and Debit Calculator
Version 1.0

Table of Contents

1. Introduction and Purpose

The purpose of this document is to provide a compendium of field methods that can be used to collect data for the Minnesota Stream Quantification Tool and Debit Calculator (MNSQT). Individuals collecting and analyzing these data should have experience and expertise in ecology, hydrology, and geomorphology. Interdisciplinary teams with a combination of these skill sets are beneficial to ensure consistent and accurate data collection and analysis. Field trainings in these methods and the Stream Functions Pyramid Framework are recommended to ensure that the methods are executed consistently.

This Appendix serves as a compliment to Chapter 2 of the User Manual, which provides information on how to select parameters, and calculate metric field values from field data. The MNSQT and Debit Calculator are not themselves assessment methods, but instead consolidate data and results from many methods and use them to calculate changes in stream condition and determine functional lift and loss. Methods are provided in this Appendix for reference and use in the field. Few measurements are unique to the MNSQT, and data collection procedures are often detailed in other instruction manuals or literature. Where appropriate, this appendix will reference the original methodology and explain differences in data collection or calculation methods needed for the MNSQT. This document is based on the Field Document Collection Methods for the Colorado SQT (CSQT) Beta Version (CSQT SC 2019 Appendix A) and has been edited for Minnesota with input from the Minnesota Stream Quantification Tool Steering Committee (MNSQT SC). The CSQT Beta Version user manuals served as the basis for the MNSQT Version 1.0 and many Chapters in this document are reproduced with minor edits from CSQT SC (2019) Appendix A.

A Parameter Selection Checklist and the data forms referenced in the relevant sections below are included in Appendix B. There is a shading key on some of the field forms that indicates which cells are intended to be filled out in the office versus the field, and which cells perform calculations. The calculation cells will automatically calculate values from provided field data in the workbook version. These cells can also be filled out on a printed field form. Prior to fieldwork, the user should complete the Parameter Selection Checklist, which will assist in determining the field methods and forms needed for data collection. Guidance on selecting appropriate parameters and metrics is provided in Chapter 2 of the User Manual. Several of the data forms are available as Microsoft Excel Workbooks where data can be entered upon returning from the field.[1] Other data processing tools, such as Mecklenberg (2004) and RIVER*Morph* software program (http://www.rivermorph.com) can be used to process field data and calculate metric values.

Note: One optional metric in the MNSQT requires data collection at a reference site *in addition* to data collection within the project area. For the bed material characterization metric, Bevenger and King (1995) provide a description of how to select and potentially combine reference reaches. For this metric, the reference reach should be located within the same stream and valley type, with a similar catchment area, gradient, and lithology. When possible, reference

[1] Microsoft Excel version of the field forms and the Mecklenburg (2004) Reference Reach Spreadsheet tool are available from the Stream Mechanics website: https://stream-mechanics.com/stream-functions-pyramid-framework/

reaches should be located upstream of the project reach and upstream of the source of sediment imbalance.

At a minimum, the following field gear will be needed:

- Field forms and maps
- Waders
- Stadia rod
- Standard survey equipment or hand level/line level depending on selected method
- Metric ruler
- 100' tape (note: a tape with feet on one side and metric on the other is recommended)
- Enough 300' tapes for the assessment reach length (note: a tape with feet on one side and metric on the other is recommended)
- GPS unit (helpful with lateral migration and sinuosity field measurements)
- Calipers large enough to measure 50 cm diameter logs (helpful for the LWD assessment and DBH measurments)

For evaluating the following parameters and metrics, field methods are described briefly in this Appendix, however, users should be familiar with the following procedures and should review the following references prior to field sampling if that parameter will be assessed:

- Pebble Count:
    - River Stability Field Guide, Second Edition (Rosgen 2014)
    - A Pebble Count Procedure for Assessing Watershed Cumulative Effects (Bevenger and King 1995)
- Large Woody Debris Index:
    - Application of the Large Woody Debris Index: A Field User Manual Version 1 (Harman et al. 2017).
- Bank Erosion Hazard Index/Near Bank Stress:
    - Appendix D of Function-Based Rapid Field Stream Assessment Methodology (Starr et al. 2015), or
    - River Stability Field Guide, Second Edition (Rosgen 2014)
- Temperature:
    - Procedure for Temperature Logger Deployment at Stream Monitoring Sites (MPCA 2015)
    - Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List (MPCA 2018a)

   - Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component (MPCA 2018b)
   - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)
   - Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams (USEPA 2014)

- Dissolved Oxygen:
   - Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List (MPCA 2018a)
   - Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component (MPCA 2018b)
   - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)
- Total Suspended Solids:
   - Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List (MPCA 2018a)
   - Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component (MPCA 2018b)
   - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)
   - Turbidity TMDL Protocols and Submittal Requirements (MPCA 2007)
- Macroinvertebrates:
   - Development of a Macroinvertebrate-Based Index of Biological Integrity for Minnesota’s Rivers and Streams (MPCA 2014a)
   - Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota (MPCA 2017a)
   - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)
- Fish:
   - Development of a Fish-Based Index of Biological Integrity for Minnesota’s Rivers and Streams (MPCA 2014b)
   - Fish Data Collection Protocols for Lotic Waters in Minnesota (MPCA 2017b)
   - Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations (MPCA 2018c)

- Standard Methods for Sampling North American Freshwater Fishes (Bonar et al. 2009)

2. Reach and Representative Sub-Reach Assessments

Prior to field work, the user must determine whether the project area should be delineated into multiple project reaches (see Section 2.1 of the User Manual). The following sequence of steps is recommended for all evaluations. Based on parameter selection (Section 2.3 of the User Manual), not all steps will need to be completed for all projects. The Parameter Selection Checklist can be used to indicate which parameters are included within the field evaluation.

Additionally, before going in the field check any sampling windows or index periods for field data collection. The procedure below outlines a comprehensive assessment of most metrics in the MNSQT that can be completed in a single day or visit, but multiple days or visits may be required, depending on the metrics selected for analysis.

Procedure:

1. Conduct necessary pre-field desktop activities (see Chapter 2 of the User Manual). Complete the Parameter Selection Checklist and the Site Information section of the Project Reach form. All values in these sections should be filled in prior to completing fieldwork.
2. Walk along the stream throughout the project area to verify the delineation of project reaches. Determine whether additional segmentation is needed based on field conditions. Record the GPS location at the downstream end of the reach in Section I of the Project Reach form.
3. Within each project reach, walk along the stream length to view the locations and character of riffles, presence of beaver dams or other impoundments, and bankfull indicators.
    a. Measure difference between bankfull stage and water surface elevation at multiple points along the project reach (See Bankfull Elevation – Field Identification section on page A-7). These data can be recorded in the Project Reach form. Use these data to come to a consensus on the difference between the bankfull (BKF) elevation and water surface (WS) elevation and record the value in Section II of the Project Reach form.
    b. Consider possible locations for the representative riffle cross section (see Representative Riffle Survey on page A-10). The preference is for the riffle to be located within the representative sub-reach. However, in disturbed settings, this cross section may be located upstream or downstream of the sub-reach.
    c. Record number of concentrated flow points and length of any armored sections of bank in Section II of the Project Reach form (see Concentrated Flow Points and Armoring sections below).
    d. Measure slope and sinuosity for stream classification purposes (See Rosgen Stream Classification).
4. If the project reach is long, determine the location of the representative sub-reach. The sub-reach is at least two meander cycles or 20 bankfull widths in length, whichever is longer.

The sub-reach should be representative of the typical bed form diversity in the project reach and should include the stretch of channel with the greatest amount of large woody debris.

5. Record the GPS location at the downstream end of the representative sub-reach in Section III of the Project Reach form.
6. Select the location within the sub-reach for biological sampling (if applicable). Refer to *Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017b) and *Fish Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017a) for information on selecting a sample location.
7. Sample macroinvertebrates (see Macroinvertebrate Sampling in Section 9). Processed samples should be immediately preserved in sample containers with a final alcohol concentration of at least 70% and stored in a cool, shaded area for the remainder of data collection.
8. Sample fish (see Fish Sampling in Section 9). All fish that are alive after processing should be immediately returned to the stream. Considerable effort should be expended to minimize handling mortality, such as using a live well, quickly sorting fish into numerous wet containers, and replacing their water supply.
9. Survey the representative riffle cross section (see Representative Riffle Survey methods below). If located within the sub-reach, the same riffle used for biological sampling may be used for the cross section survey, or an alternative representative riffle can be selected. If the same riffle is used, locate the cross section in a portion of the riffle not substantially disturbed from biological sampling. Locate bankfull indicators using the Bankfull Elevation - Field Identification methods.
10. Conduct the Longitudinal Profile (see Section 3) or Rapid Survey (Section 4) for bed form diversity and floodplain connectivity data.
    a. Where a longitudinal profile is performed, additional cross section surveys may be required to quantify the entrenchment ratio.
11. Conduct a large woody debris assessment (Section 5), lateral migration evaluations (Section 6), pebble counts, and riparian vegetation survey (Section 7), as applicable based on parameter selection.
12. Install temperature sensors and dissolved oxygen sensors (Section 8) as applicable based on parameter selection and complete the Temperature Logger and Sensor Log form, respectively.

Concentrated Flow Points

This metric assesses the number of concentrated flow points caused by anthropogenic impacts that enter the project reach and is normalized per 1,000 linear feet of stream. Anthropogenic causes of concentrated flow include agricultural drainage ditches, impervious surfaces, storm drains, land clearing, and others.

Procedure:

1. During the initial reach walk, any observed concentrated flow points should be tallied and recorded on the Project Reach form. The reach walk should extend along the entire project reach and include both sides of the stream channel.
    - Field calculation: The number of concentrated flow points is normalized to a count per 1,000 linear feet of stream. Divide the count by the reach length provided in Section 1 of the form and multiply the result by 1,000 linear feet. Space is provided for this calculation in Section II.B of the form; the workbook version of the form will automatically calculate this value.

Percent Armoring

Percent armoring is a metric that must be assessed on reaches where armoring is present or proposed. If armoring is not present or proposed this metric is not assessed. Examples of armoring include rip rap, gabion baskets, concrete, and other engineered materials that prevent streams from meandering and are located within the channel banks. Typically, toe wood with transplants or bioengineering is not counted as armoring. However, if toe wood or stone-toe used for bioengineering extends from the bed to more than one-third the bank height, it is counted as armoring. Engineered log jams that are mechanically anchored to the bed/banks and extend to the top of the streambank are considered armoring. Armoring should be measured along the entire project reach and include both sides of the stream channel.

Procedure:

1. During the initial reach walk, measure and record the length of each bank that is armored and record that length on the Project Reach form. The reach walk should extend along the entire project reach and include both sides of the stream channel.

Bankfull Elevation – Field Identification

Multiple parameters in the MNSQT require bankfull dimensions to calculate metrics, including floodplain connectivity, large woody debris, lateral migration, and bed form diversity. Bankfull dimensions are also needed to determine the Rosgen stream type. Prior to making field measurements for these parameters and determining stream type, the user should identify and verify the bankfull stage and associated dimensions. Methods to establish and verify bankfull elevation in the field can be found in the *Fisheries Stream Survey Manual* (MN DNR 2007) and the Bankfull Elevation – Field Identification section of the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ/WQD 2018). The text from the WDEQ/WQD manual (2018) is duplicated here with minor modifications; photographs from the original reference are not included.

Quality Control: Appropriate use of bankfull elevation indicators requires adherence to the following principles which can also serve as quality control for this method:

1. Seek indicators appropriate for specific Rosgen stream types.
2. Know the recent flood and drought history of the area to avoid being misled by spurious indicators. This includes conducting site reconnaissance during bankfull discharge events.
3. Use multiple indicators wherever possible as reinforcement of a common stage or elevation.

4. Exercise caution when identifying bankfull elevation in reaches of the stream that are subject to frequent inundation caused by beaver dams, diversion structures, etc.
5. Bankfull elevation above and below hydrologic anomalies that influence the entire active channel such as natural controls (boulders, bedrock), headcuts, dams, and similar features will likely be different. These breaks in bankfull elevation should be accounted for at all site visits.
6. Except in cases noted above, bankfull indicators should be at a consistent elevation relative to the water surface along an individual stream reach.
7. Reachwide bankfull slope should be similar to the reachwide water surface slope, assuming both variables were measured on the same day and rapid aggradation or degradation is not occurring. This can be determined from the longitudinal profile and difference in measurements between the bankfull indicator and water surface.
8. Bankfull indicators along pools, particularly along the outside of meander bends, may be at a higher elevation than indicators at riffles. However, there should still be consistency in elevation of bankfull indicators along the entire reach. The flat surface along the top of a point bar is often a good bankfull indicator. Point bars are depositional features found along the inside of a meander bend.
9. Where possible, calibrate field-determined bankfull stage elevation and corresponding bankfull channel dimensions to known recurrence interval discharges (refer to Section 2.6.c in Chapter 2 of the User Manual) and/or with applicable regional curves. In using regional curves to verify bankfull, the bankfull area is typically used for the comparison. Lines E, F, and G of Section III of the Project Reach form should be populated with the bankfull area, width, and mean depth as calculated from these resources before going out in the field.
10. Persistent long-term drought conditions may create a false “bankfull” elevation that does not correspond to the actual bankfull elevation under the current climatic regime. See step 9.

Introduction: Bankfull discharge is a frequently occurring peak flow whose corresponding stage or elevation often represents the incipient point of flooding associated with a return period of 1-2 years. Bankfull elevation (and its associated discharge) serves as a consistent reference point which can be related to the formation, maintenance, and dimensions of the channel as it exists under the current climatic regime. Bankfull elevation often represents the break point between processes of channel and floodplain formation. Correctly identifying bankfull elevation is crucial and serves as the foundation for all subsequent geomorphic methods used in the determination of channel classification, dimension, pattern, and profile.

Bankfull discharge can occur at any time during the year. Because site visits are often not conducted during a bankfull event, bankfull indicators must be relied on to correctly identify bankfull elevation. There are several bankfull indicators though no one indicator is suitable in all circumstances. Use the following common bankfull indicators to identify bankfull elevation, many of which have been adapted from Rosgen (2008). In all cases, multiple bankfull indicators should be used to identify bankfull elevation. Primary indicators should always be sought out at the site; secondary indicators should be used only as supplemental information to support primary indicators as described in the *Fisheries Stream Survey Manual* (MN DNR 2007) or the

Manual of Standard Operating Procedures for Sample Collection and Analysis (WDEQ/WQD 2018).

Primary Indicators:

1. Floodplains – Bankfull elevation is often associated with the point at which water begins to spread out onto the floodplain. This may or may not be the top of the bank. This is one of the best indicators of bankfull elevation for use on Rosgen C, D, DA and E stream types which often have well-developed floodplains. Floodplain indicators do not apply to entrenched Rosgen A, F and G stream types which generally do not have floodplains. Moderately entrenched streams (B stream types) have bankfull or floodplain benches. Most streams in alluvial/colluvial valleys have three distinct terraces. Do not confuse the low terrace with the floodplain, which may be close in elevation. The low terrace is an abandoned floodplain often characterized by upland or a mixture of upland and facultative riparian vegetation.

2. Breaks in Slope – A change in slope from a near vertical bank to a more horizontal bank is often the best indicator of the incipient point of flooding, or the transition from the bankfull channel to a floodplain. Such changes in slope often correspond to the “bankfull bench”. However, streams that have undergone physical alterations in the past or are actively degrading or aggrading can have multiple slope breaks that represent abandoned floodplains or terraces, rather than the bankfull elevation. For incised channels with near vertical banks, the first substantial break in slope (example: transitioning from 90° to 45°) at the bottom of the near vertical bank can be the bankfull elevation.

3. Scour Lines – A scour line at a consistent elevation along a reach that lies below an intact soil layer can represent bankfull elevation. Scour lines may or may not have exposed root hairs.

4. Undercuts – On bank sections where the perennial vegetation forms a dense root mat, the upper extent or top of the undercut is normally slightly below bankfull elevation. Undercuts are best used as indicators in channels lacking obvious floodplains.

5. Depositional Features – The elevation on top of the highest depositional feature (point bar or mid-channel bar) within the active channel is often associated with the bankfull elevation. However, in streams that have experienced recent record flood events, the tops of the highest depositional features may be above bankfull elevation. In streams that are rapidly degrading (downcutting), the tops of the highest depositional features may also be above the bankfull elevation.

6. Particle Size Demarcation – The point at which there is a distinct change in particle size of the active channel bed at a consistent elevation along a reach is often associated with bankfull elevation. Changes in particle size can be from coarse to fine or from fine to coarse and may also correspond to a break in slope or the top of a depositional feature.

Secondary Indicators:

1. Vegetation - Using vegetation to identify bankfull elevation must be done cautiously. When vegetation is used as a sole indicator, bankfull is frequently underestimated. Riparian species common for each ecological province can be used as supplemental indicators of bankfull elevation in Minnesota streams. Generally, bankfull elevation is located at or just

under the base of riparian vegetation often associated with a scour line. Saplings of species such as willow (*Salix* sp.) and cottonwood (*Populus* sp.) should not be used as indicators as they can colonize within the bankfull channel. Mature woody species are generally found above the bankfull elevation and should not be used. Vegetation generally is not an appropriate indicator in streams where active degradation such as bank sloughing is occurring.

2. Lichens or Mosses – A noticeable change in color, pattern and/or species of lichens or mosses on boulders or bedrock at a consistent elevation along a reach may represent bankfull elevation.
3. Debris Lines - The top of a debris line consisting of leaf and woody litter, dead algae, fecal material, trash or other floating debris at a consistent elevation along a reach may represent bankfull elevation. However, do not confuse debris deposited by flow events larger than bankfull to represent bankfull elevation.

Procedure:

1. Determine whether hydrologic anomalies such as natural controls (boulders, bedrock), headcuts, dams, and similar features exist in the reach and account for their influence on bankfull elevation accordingly.
2. Using the bankfull indicators described above, walk the entire length of the reach, multiple times if needed, and identify primary and secondary bankfull indicators where applicable. Care should be taken to use only the best bankfull indicators that provide the strongest evidence of bankfull elevation.
3. Mark the locations of both primary and secondary bankfull indicators with pin flags.
4. Use a pocket rod or stadia rod to measure the distance from the current water surface to the estimated bankfull elevation at each of the best bankfull indicators. Bankfull indicators should follow a generally consistent elevation relative to the water surface throughout the reach. As such, distances from the current water surface to the estimated bankfull elevation should be similar among all measurements. Outlying distances will be evident and should be removed or revisited and verified.
5. Use a weighted (primary indicators have greater weight than secondary indicators) average distance between water surface and bankfull elevation as a reference point when conducting subsequent geomorphic survey procedures such as cross sections and longitudinal profiles on the same day the average value was measured.
6. If desired for future reference, photo document the location of the bankfull elevation using the pin flags as reference points, making sure the entire bankfull channel is visible in the photograph. If a measurement tape has been stretched longitudinally along the entire reach, record the distance along the tape where the bankfull indicator in the photograph is located.

Representative Riffle Survey

A representative riffle should be surveyed to calculate the bankfull dimensions of area, width, and mean depth and to determine the Rosgen Stream Classification type (see following section). Bankfull dimensions from the representative riffle should be compared to estimated bankfull dimensions from other references such as return interval analysis or bankfull regional curves to verify the bankfull indicator (see Bankfull Elevation – Field Identification, Quality Control section above). The bankfull width and mean depth from the representative riffle survey are used to calculate pool spacing and pool depth ratios. These are the primary reasons for surveying the representative riffle and the selection of the representative riffle should keep these objectives in mind.

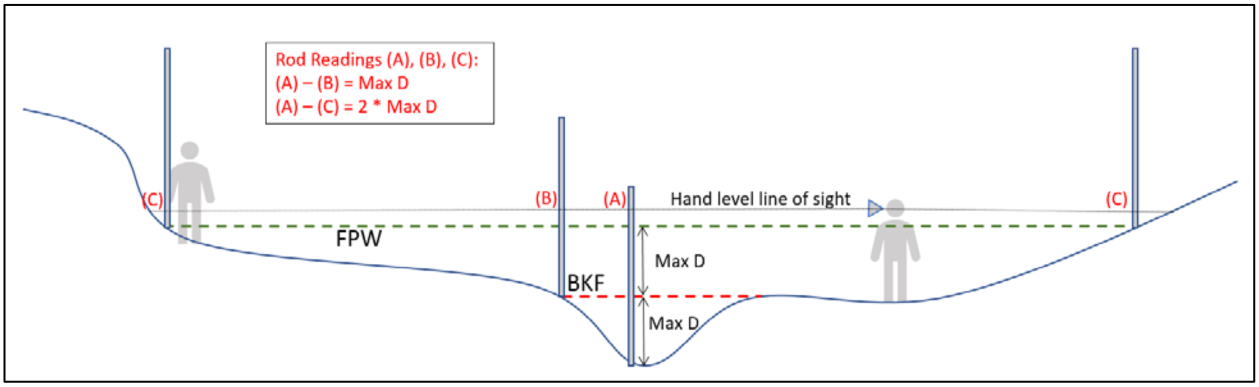
Two representative riffle cross sections may be required in severely degraded systems where the first cross section is a different stream type than the assessment reach. In this case, the two cross sections should be measured following the procedures below. The first is used for bankfull verification and to calculate dimensionless ratios for the bed form diversity parameter. The second riffle is measured within the assessment reach to characterize the existing Rosgen stream type[2].

The representative riffle survey can be completed with either standard survey equipment or a stadia rod and level tape for rapid surveys. Methods to set up and measure the representative riffle cross section using standard surveying equipment are derived from the *Fisheries Stream Survey Manual* (MN DNR 2007) or Channel Cross Section Survey methods outlined in the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ/WQD 2018). Text from the WDEQ/WQD (2018) manual is duplicated here with minor modifications; information on quality control and photographs from the original reference are not included. A rapid method using a tape and stadia rod follow.

Note: The flood prone width should be recorded for all riffle cross sections and measured perpendicular to the fall line of the valley. Entrenchment ratio is a metric in the MNSQT for the floodplain connectivity parameter and is necessary to determine the stream type. Independent of whether the representative riffle is surveyed following the WDEQ/WQD procedure, rapid survey methods, or Minnesota state specific stream data collection protocols, the cross section flood prone width is required. This means that either the cross section should extend far enough into the floodplain to capture the flood prone width OR the distance from the channel bank to the elevation that is twice the max bankfull depth should be recorded for each side of the channel. Where it is not feasible to survey the entire flood prone width, the cross section should span a width that is at least 3 times the width of the channel. Figure A.1 demonstrates how to measure the flood prone width with a hand level.

[2] The second riffle can also be used to characterize reach conditions for the return interval, average depth, and average velocity metrics if applicable. Additional cross sections may be necessary, refer to the User Manual instructions for these metrics.

Figure A.1. Surveying Flood Prone Width



Procedure (WDEQ/WQD 2018):

Identify the riffle within the project area that will be used as the representative riffle. Where possible, the representative riffle should be located within the representative sub-reach. However, in a highly degraded reach, a stable riffle cross section from an adjoining upstream or downstream sub-reach may be used.

1. Following the procedure in Bankfull Elevation–Field Identification, identify bankfull elevation in the reach.
2. Determine the location of the cross section within the representative riffle. Cross sections should not be placed over riffles or other features that have been substantially disturbed by biological sampling, animal or human activity or similar causes. Avoid placement of the cross section at the top or bottom of a riffle feature. In streams with active physical degradation and/or aggradation, features may migrate longitudinally within the reach from one year to another. Place the cross section across the mid-point of the feature to increase the likelihood that the facet type you measure will be the same type you measure in subsequent years. Make sure that the cross section is perpendicular to the direction of flow at bankfull. Where possible, cross section endpoints should be located above the bankfull elevation and preferably above the flood prone elevation (twice the maximum bankfull depth, see Figure A.1).
3. If possible, establish permanent markers at the cross section endpoint locations by driving rebar vertically in the ground. Attach either plastic or metal end caps on the tops of rebar for identification. This step is only needed if repeat surveys are anticipated.
4. Stretch the measurement tape or tag line (tape) across the channel with zero always beginning on the left bank as you are facing downstream. The zero mark on the tape should be placed over the left cross section endpoint. The tape can be secured to the ground with range pins. Make sure to stretch and secure the tape tight between both endpoints; sagging tapes are unacceptable. During windy conditions, flagging ribbon can be attached at regular intervals on the cross section tape to minimize tape “waving”.
5. Record the station ID of the cross section using the tape stretched along the length of the representative sub-reach (see Longitudinal Profile and Rapid Bed Form Survey Method) and sketch the cross section location as part of the site map with associated landmarks.

Document as much information as possible about the cross section location on the datasheet so it can be relocated for future surveys or site visits.

6. Starting with the top of the left endpoint at 0, begin the cross section survey. Proceed with rod readings at breaks in slope; record important features such as terraces, top of bank, low bank, bankfull, edge of water, inner berm, and thalweg. If undercuts are present, use a combination of the stadia rod and pocket rod to accurately characterize the undercut. Otherwise, take survey readings at regular intervals of generally one to five feet, with wider intervals used for wider channels. Record any features along the cross section tape in the notes section of the datasheet. Complete the survey by taking rod readings at the right endpoint. Record all features on the datasheet next to their corresponding rod readings.

Rapid Cross Section Survey Procedure:

1. Follow steps 1-3 in the above procedure.
2. Stretch a tape from the left bankfull indicator to the right bankfull indicator. Use the primary bankfull indicator or the difference between water surface elevation and bankfull that has been recorded on the Project Reach form as the control.
3. Record the bankfull width. Space is provided on the Project Reach form.
4. Level the tape by attaching a line level or by measuring the distance from the water surface to the tape at the left and right edge of water surface; the location where the water meets the streambank. The distance should be the same on both sides.
5. Working from left to right, record the station from the tape and the depth from the tape to the ground using a stadia rod. Include bankfull, major breaks in slope, the thalweg, and other points along the channel bottom. Record this data on the Project Reach form.
6. Space is provided on the Project Field form to calculate the bankfull mean depth and area. These calculations are automatically performed in the Microsoft Excel Workbook version of the Project Reach form. A rough estimate of the mean depth can be calculated by adding all the depth measurements (except for zeros at bankfull) and dividing by the number of observations.
7. Compare the bankfull width, mean depth, and area to the regional curve values on the field form.
8. Measure the flood prone width on either side of the bankfull channel as shown in Figure A.1. The flood prone width should be measured perpendicular to the fall line of the valley.

Rosgen Stream Classification

The MNSQT requires that the existing stream type be determined according to the Rosgen classification system (Rosgen 1996). Stream classification is based on entrenchment ratio, width depth ratio, sinuosity, slope, and channel material. Section V of the Project Reach form provides space to collect these data based on measurements from the sub-reach assessment.

Methods to determine Rosgen Stream Classification are derived from the Rosgen Stream Classification section in the *Manual of Standard Operating Procedures for Sample Collection and Analysis* (WDEQ/WQD 2018). The text below is modified from this reference. This section is included in the field data collection methods to ensure that sufficient data are collected to classify the existing stream type. As shown in the procedures below, determining the stream type is based on values derived from data collected as described elsewhere in this appendix. As such, determining the stream type can be done in the office after the data are collected and processed.

Field Measurements:

1. Entrenchment Ratio (ER): Unitless measure of flood prone area width (Wfpa) divided by bankfull width (Wbkf).
    a. Values are measured or calculated from the Representative Riffle Survey.
2. Width to Depth Ratio (Wbkf / dbkf): Unitless measure of bankfull width (Wbkf) divided by bankfull mean depth (dbkf).
    a. Values are measured or calculated from the Representative Riffle Survey.
3. Channel Sinuosity. Unitless measure of channel length divided by valley length.
4. Channel Materials (Particle Size Index) (D50): Perform a pebble count procedure following guidance in Rosgen (2014) or Harrelson et al. (1994). For the rapid assessment, a visual inspection is sufficient for determining the bed material category (e.g. gravel, sand) if the determination is only used for stream classification purposes. However, experience performing quantitative grain-size distributions is required in order to make accurate estimates.
5. Water Surface Slope (S): Measure of water surface slope from the top of a riffle to the top of another riffle at least twenty bankfull widths in length. This measurement is a surrogate for the water surface slope at bankfull stage. Measure in ft/ft.
    a. See Longitudinal Profile and Rapid Survey Methods.
    b. Note if baseflow is not present, the bottom of the channel should be used. However, care must be taken to not create large elevation changes due to localized scour or fill. One method to avoid localized scour or fill is to use the edge of channel rather than the thalweg. In both cases (with and without baseflow), the measurements should be made at the top of a feature, e.g. the top or beginning of a riffle.

3. Longitudinal Profile

This method will provide data to inform the floodplain connectivity and bed form diversity parameters within the MNSQT. Additionally, data from the longitudinal profile can be used to calculate average reach slope.

There are two methods that can be used to collect bed form diversity and floodplain connectivity data for the MNSQT, the Longitudinal Profile (described in this section) and the Rapid Survey (described in Section 4). For CWA Section 404 or RHA Section 10 projects, it is recommended the user coordinate with the Corps and other state or local regulatory authorities prior to selecting between these methods. The rapid survey techniques for collecting the bed form diversity and floodplain connectivity data are considered more rapid than surveying the longitudinal profile and require little post-processing of the field data.

Field forms for the longitudinal profile include the Longitudinal Profile form and the Cross Section form and are provided in Appendix B. Data collected using these forms will require post-processing to calculate MNSQT metric field values for pool spacing ratio, pool depth ratio, percent riffle, and bank height ratio. Data analysis should follow the methods described in Chapter 2 of the User Manual. The Reference Reach Spreadsheet version 4.3 developed by Dan Mecklenburg with the Ohio Department of Natural Resources (DNR) is a free, user-friendly tool for entering survey and pebble count data and can be used to calculate these metrics.[3] The RIVER*Morph* software program (http://www.rivermorph.com) can also be used to calculate these metrics. Users should provide the raw survey data, longitudinal profile plots at legible scales, and bed form identification callouts that indicate where measurements were taken to calculate field values.

Quality Control: Following the process described in Harrelson et al. (1994), no longitudinal profile is complete without checking the accuracy of the survey with a survey closure. To close the survey, take a foresight reading at the benchmark, compute the elevation, and compare the difference to the original benchmark elevation at the start of the survey. Typically, a closure of no more than 0.05 feet is acceptable when conducting stream surveys. The survey closure error shall be documented on the longitudinal profile datasheet.

Introduction: The longitudinal profile documents the existing water surface, bankfull, low bank, terrace, and thalweg elevations of a stream reach. Longitudinal profile data is used to calculate average bankfull and water surface slopes of a reach, along with maximum, minimum, and average slopes of features such as riffles, runs, pools, and glides (also known as facet slopes). Maximum, minimum, and average bankfull depths and spacing measures are obtained from longitudinal profile data. These data are useful in geomorphic assessments of streambed stability and sediment supply and may be useful for design objectives. Longitudinal profiles require basic surveying skills and equipment. Survey basics such as establishing benchmarks, foresights, positioning the level, turning points, and others are not covered here. For more information on survey basics consult Harrelson et al. (1994).

[3] The spreadsheet is no longer available from the DNR web page, but is available at https://stream-mechanics.com/resources/under spreadsheet tools.

Procedure:

1. Establish a representative sub-reach within the project reach, generally at least two meander cycles or 20 bankfull widths in length. The sub-reach should be representative of the typical bed form diversity in the project reach and should include the stretch of channel with the greatest amount of large woody debris.
2. Beginning at the upstream end of the sub-reach, stretch the tapes along either the left or right bank as close to the edge of the channel as possible and should be threaded through riparian vegetation or other obstructions if necessary. Tape(s) can be secured to the ground with survey pins, vegetation, or rocks. Stationing of features will be obtained from the tape.
3. If desired, establish permanent markers at the beginning and end of the longitudinal profile tape by driving rebar vertically in the ground. Attach either plastic or metal end caps on top of the rebar for identification.
4. The position of the longitudinal profile tape should be included on the site map along with associated landmarks, stream channel cross sections, and other relevant features. If desired, triangulate the top and bottom of the longitudinal profile between the benchmark and another permanent feature and record on the datasheet. GPS locations of the top and bottom of the longitudinal profile can be used in place of triangulation. Document as much information as possible about the longitudinal profile tape location on the datasheet so it can be relocated for future surveys.
5. Follow the procedure in Bankfull Elevation – Field Identification section above to identify bankfull elevation in the reach.
6. Follow the process described by Harrelson et al. (1994) to establish a benchmark and height-of-instrument.
7. Begin the longitudinal profile survey at station 0 on the longitudinal profile tape. Record (at a minimum) rod readings of water surface, thalweg and low bank. Only take rod readings of bankfull where indicators are present. Record the quality of the bankfull indicator(s) (good, fair, etc.) and the type of feature in the notes column of the datasheet.
8. Continue the survey, working in a downstream direction. Collect readings at the top and mid-point of each riffle, run, and glide feature along with any other major bed features (dams, weirs, etc.). For pools, take a reading at the top and maximum depth location and note whether the pool is a geomorphic pool (refer to Pool Identification below). For streams with long features or a homogeneous bed, take rod readings at regular intervals, generally spaced no more than one to three bankfull widths.
9. Note the stationing of all cross section locations (if present) on the longitudinal profile tape and record on the datasheet. Take rod readings at the tops of all cross section endpoints located along the bank with the longitudinal profile tape and record on the datasheet.
10. Close the survey according to the process described in the Longitudinal Profile Quality Control section of this document.

Pool Identification

Geomorphic pools are a term used in the Stream Quantification Tool to differentiate between major and minor pools. Geomorphic pools are associated with planform features that create large pools and patterns that remain intact over many years and flow conditions. Examples include pools associated with the outside of a meander bend and downstream of a large cascade or step. These pools are included in the pool spacing ratio metric. Micro pools within riffles are small, typically between one-third and half the width of the channel and may not last for a long period of time or after a large flow event. An example is a scour pool downstream of a single piece of large woody debris. These pools are not included in the pool spacing ratio metric.

If a pool is not associated with a meander bend or cascade/step, it should still meet the following criteria: the pool must be deeper than the riffle, have a concave bed surface, have a water surface slope that is flatter than the riffle, and a width that is at least one-third the width of the channel.

Cross Section Surveys

Data should be collected from cross sections at multiple riffles within the representative sub-reach to inform MNSQT metric field values. A Cross Section form is provided in Appendix B to collect these data. Data collected using these forms will require post-processing to calculate MNSQT metric field values. Cross sections should be collected following the procedures described in the Representative Riffle Survey section above. The detailed (surveyed) or rapid cross section survey method, or a combination of the two, can be used based on best professional judgement.

- For the entrenchment ratio, it is recommended that the entrenchment ratio be measured at each riffle unless the valley width is consistent throughout the representative sub-reach. If the width of the valley is uniform, then one entrenchment ratio value can be used to represent the project reach. The flood prone width should be measured perpendicular to the fall line of the valley.
- For the aggradation ratio, it is recommended to measure this metric at multiple riffle cross-sections with aggradation features to ensure that the widest value for the sub-reach is obtained and to document the extent of aggradation throughout the project reach. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections.

Users should provide the raw survey data, cross section plots at legible scales, and callouts for feature that indicate where measurements were taken to calculate field values.

4. Rapid Survey

This section outlines rapid survey methods to collect data to inform floodplain connectivity and bed form diversity parameters. There are two methods that can be used to collect bed form diversity and floodplain connectivity data for the MNSQT, the Longitudinal Profile (described in Section 3) and the Rapid Survey (described in this section). For CWA Section 404 or RHA Section 10 projects, it is recommended the user coordinate with the Corps and other state or local regulatory authorities prior to selecting between these methods. The rapid survey techniques for collecting the bed form diversity and floodplain connectivity data are considered more rapid than surveying the longitudinal profile and require little post-processing of the field data.

The Rapid Survey form is provided in Appendix B. There is a shading key on the field form that indicates which cells are intended to be filled out in the office versus the field, and which sections are for performing field calculations. The calculation cells can be filled out on a printed field form. In the workbook version, these cells will automatically calculate values from provided field data. Field values that can be entered directly into the Quantification Tool worksheet from this field form are bolded. These include: weighted BHR, weighted ER, maximum WDR, percent riffle, average pool depth ratio, and median pool spacing ratio.

Procedure:

1. Establish a representative sub-reach within the project reach, generally at least two meander cycles or 20 bankfull widths in length, whichever is longer. The sub-reach should be representative of the typical bed form diversity in the project reach and should include the stretch of channel with the greatest amount of large woody debris.
2. Beginning at the upstream end of the sub-reach, stretch tapes along either the left or right bank as close to the edge of the channel as possible, and should be threaded through riparian vegetation or other obstructions if necessary. Tape(s) can be secured to the ground with survey pins, vegetation, or rocks. Stationing of features will be obtained from the tape. Begin and end the representative sub-reach at the head of a riffle feature.
3. Record sub-reach length in Rapid Survey form.
4. Measure the slope of the sub-reach (see Reach Slope section below).
5. Working from upstream to downstream, take measurements at every riffle and pool within the sub-reach using a stadia rod and a hand level. A line level can be used instead of a hand level for small streams. Note: Review pool identification instructions provided below and in Section 2.6.d of the User Manual.
    a. Measure the following at every riffle within the sub-reach and record values in the Rapid Survey form. These data are used to calculate the bank height ratio, entrenchment ratio, aggradation ratio, and percent riffle metrics.
        i. Measure the length of the riffle, including runs, if present. Riffle length is measured by taking a station reading from the tape at the head (beginning) of the riffle and another station reading downstream at the head of the pool.

Field calculation: Percent riffle can be calculated by adding the length of all riffles within the sub-reach (total riffle length) and dividing by the total sub-reach length. Total riffle length is also used to calculate weighted entrenchment ratio and weighted bank height ratio below.

ii. Identify the middle of the riffle feature and bankfull elevation (see Bankfull Elevation – Field Identification section above).

iii. From mid-riffle, measure the difference in stadia rod readings from the thalweg to the top of the lower of the two streambanks. Record this value as the Low Bank Height on the rapid survey form. The low bank height is the lower of the left and right streambanks, indicating the minimum water depth necessary to inundate the floodplain.

iv. From mid-riffle, measure the difference in stadia rod readings from the thalweg to the bankfull indicator, and record this value as the bankfull maximum depth on the Rapid Survey form. Alternatively, measure the difference in stadia rod readings from the thalweg to the water surface then add the value recorded for the difference between bankfull stage and water surface (Section II on the Project Reach form).

Field calculation: bank height ratio can be calculated by dividing the low bank height by the bankfull maximum depth. Space is also provided to calculate the weighted bank height ratio: multiply the bank height ratio by the riffle length at each riffle and divide by the total length for the sub-reach.

v. From mid-riffle, measure the bankfull width and record this on the form.

vi. For sub-reaches with changes in valley width or a bank height ratio greater than 1.8, flood prone width should also be measured at each riffle. At mid-riffle, locate and flag the point along the cross section in the floodplain where the difference in stadia rod readings between the thalweg and that point is twice that of the bankfull maximum depth (see Figure A.1 for illustration). Record flood prone width on the rapid survey form.

Field calculation: entrenchment ratio can be calculated by dividing the flood prone width by the bankfull maximum depth. Space is also provided to calculate the weighted entrenchment ratio: multiply the entrenchment ratio by the riffle length at each riffle and divide by the total riffle length for the sub-reach.

vii. If evaluating the aggradation ratio, at the widest riffle in the sub-reach (or any riffle with aggradation features) the bankfull mean depth should also be measured and recorded. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections. At candidate riffle features, estimate the mean depth as the difference between the edge of channel and the bankfull stage. This is measured by placing a stadia rod at the edge of channel, which is the breakpoint between the streambed and streambank. Measure the stadia rod height at the bankfull elevation and record as the mean depth. Note: It is recommended to collect data from multiple riffle cross sections with aggradation features to ensure that the widest value for the sub-reach is obtained and to document the extent of aggradation throughout the project reach.

Field calculation: width depth ratio can be calculated by dividing bankfull width by bankfull mean depth. The largest width depth ratio within the sub-reach is considered the maximum width depth ratio.

b. Measure the following at every pool within the sub-reach and record values in the Rapid Survey form. These data are used to calculate the pool spacing and pool depth ratio metrics.

   i. Determine the deepest point of the pool and record the station number from the tape on the form.

   Field calculation: The pool spacing ratio can be calculated by determining the distance between each pair of pools and dividing this distance by the bankfull riffle width (from Section IV of the Project Reach form). Space is provided to record the median pool spacing ratio on the Rapid Survey form.

   ii. Measure the maximum bankfull pool depth by placing the stadia rod at the deepest point in the pool and recording the depth to bankfull elevation. Alternatively, measure the difference in stadia rod readings from the deepest point in the pool to the water surface and then add the value recorded for the difference between bankfull stage and water surface recorded in Section II of the Project Reach form.

   Field calculation: The pool depth ratio can be calculated by dividing the bankfull pool depth by the mean bankfull riffle depth (from Section IV of the Project Reach form). Space is provided to record the average pool depth ratio on the Rapid Survey form.

Pool Identification

Pool-to-pool spacing is an indirect measure of how many geomorphic pools are present within a given reach and can be indicative of channel stability and geomorphic function. For this metric, pools should only be included if they are geomorphic pools; micro-pools within riffles are not counted using this metric. Geomorphic pools are associated with planform features that create large pools and patterns that remain intact over many years and flow conditions. Examples include pools associated with the outside of a meander bend and downstream of a large cascade or step. Micro pools within riffles are small, typically between one-third and half the width of the channel and may not last for a long period of time or after a large flow event. An example is a scour pool downstream of a single piece of large woody debris.

For the pool depth ratio and percent riffle metrics, all significant pools (geomorphic and micro-pools associated with wood, boulders, convergence, and backwater) are assessed. If a pool is not associated with a planform feature (ex. meander bend or cascade/step), it should still meet the following criteria: the pool must be deeper than the riffle, have a concave bed surface, have a water surface slope that is flatter than the riffle, and a width that is at least one-third the width of the channel. If one or no geomorphic pools are observed in the representative sub-reach, the field value for this metric is 0.0.

Reach Slope

Average reach slope is part of stream classification and metric stratification. It is not used as a function-based parameter or metric. If a longitudinal profile is performed, slope can be calculated from that data and does not also need to be collected using the procedure below. If the rapid method is used, data should be collected using the following field procedure.

Procedure:

1. Take a stadia rod reading of the water surface elevation at the head of the first riffle and the head of the last riffle in the representative sub-reach. If limited by the line of sight and/or magnification of the hand level being used, take a stadia rod reading of the water surface elevation at the head of the first riffle and the head of the last riffle within a line of sight. Repeat as needed throughout project reach making sure that the total drop in elevation is recorded. Note, for streams with a uniform slope, a relatively short length of channel can be measured. For streams with large slope changes between riffles and pools, the entire sub-reach should be measured.

Field calculation: Calculate the difference in stadia rod readings, divide the difference in stadia rod readings by the channel length between these two points. Where multiple readings were taken, the sum of the elevation changes should be used in the numerator (total fall over the measured length). The denominator is the total stream length between the first and last measurement point. Space is available for calculations in the Project Reach form.

5. Large Woody Debris

Large Woody Debris Index
The Large Woody Debris Index (LWDI) is used to evaluate large woody debris within or touching the active channel of a stream. LWD that solely lies in the floodplain is not counted. Large woody debris is defined as dead and fallen wood over 1m in length and at least 10 cm in diameter at the largest end.[4] This index was developed by the USDA Forest Service Rocky Mountain Research Station (Pg. 73-77 in Davis et al. 2001). This method informs the large woody debris parameter in the MNSQT. It can be used instead of the large woody debris piece count. Both metrics should not be used at a site. The LWDI has a greater level of field effort but captures more information about large wood in the reach.

The Large Woody Debris Index data collection procedure is not included here. Users should download the *Application of the Large Woody Debris Index: A Field User Manual* prior to going out in the field (Harman et al. 2017).[5] Large Woody Debris Index data forms are included in Appendix B; or a fillable excel workbook that calculates LWDI is available with the User Manual.

Large Wood Piece Count
This method informs the large woody debris parameter in the MNSQT. It can be used instead of the LWDI metric. Both metrics should not be used at a site. The piece count has a reduced level of field effort but captures limited information about large wood in the reach.

Procedure:

1. Identify the 328-foot (100-meter) segment within the representative sub-reach that contains the most large woody debris. Record the station of the downstream end of the reach on the Project Reach form.
2. Count all pieces of large woody debris within this segment. Large wood is defined as dead wood over 3.3 feet (1m) in length and at least 3.9 inches (10cm) in diameter at the largest end. The wood must be within the stream channel or touching the top of the streambank. In a debris jam or dam, the number of individual pieces of large wood within the dam should be counted. The number of pieces should be tallied and totaled on the Project Reach form.

[4] Note: In willow-dominated systems, willow branches that form debris jams are included in the assessment even if they do not meet the minimum piece size. Additional discussion is provided in the LWDI manual.
[5] The manual is available here: https://stream-mechanics.com/wp-content/uploads/2017/12/LWDI-Manual_V1.pdf.

6. Lateral Migration

BEHI/NBS and Percent Streambank Erosion

The dominant BEHI/NBS and percent streambank erosion metrics within the lateral migration parameter are informed by an assessment of bank erosion hazard index (BEHI)/near bank stress (NBS). The BEHI/NBS is part of the Bank Assessment for Non-point Source Consequences of Sediment (BANCS) model (Rosgen 2014). Data forms are provided in Appendix B. **Detailed field procedures are not provided below**, but can be found in the following references:

- Appendix D of Function-Based Rapid Field Stream Assessment Methodology (Starr et al. 2015)
- River Stability Field Guide, Second Edition (Rosgen 2014)

Procedure:

1. Evaluate the outside bank of every meander bend whether or not it is eroding. In addition, assess all other areas of active erosion regardless of their location. Depositional zones and riffle sections that are not eroding should not be evaluated.
2. Give each study bank an ID, e.g. L1 for left side, bank number 1. Determine the BEHI/NBS rating for each study bank. Record data on the Lateral Migration form.
3. Measure and record the length of each bank assessed using the station numbers from the tape(s) stretched along the sub-reach for the Longitudinal Profile or Rapid Survey. A GPS unit can also be used to map assessed banks.

Data can be recorded on the Lateral Migration form found in Appendix B. These data can be used to determine the field values following the instructions in Chapter 2 of the User Manual for the following metrics: dominant BEHI/NBS and percent streambank erosion.

Note: If a bank is armored, do not apply the dominant BEHI/NBS metric. Instead, assess using the percent armoring metric, which is described in Section 2 of Appendix A.

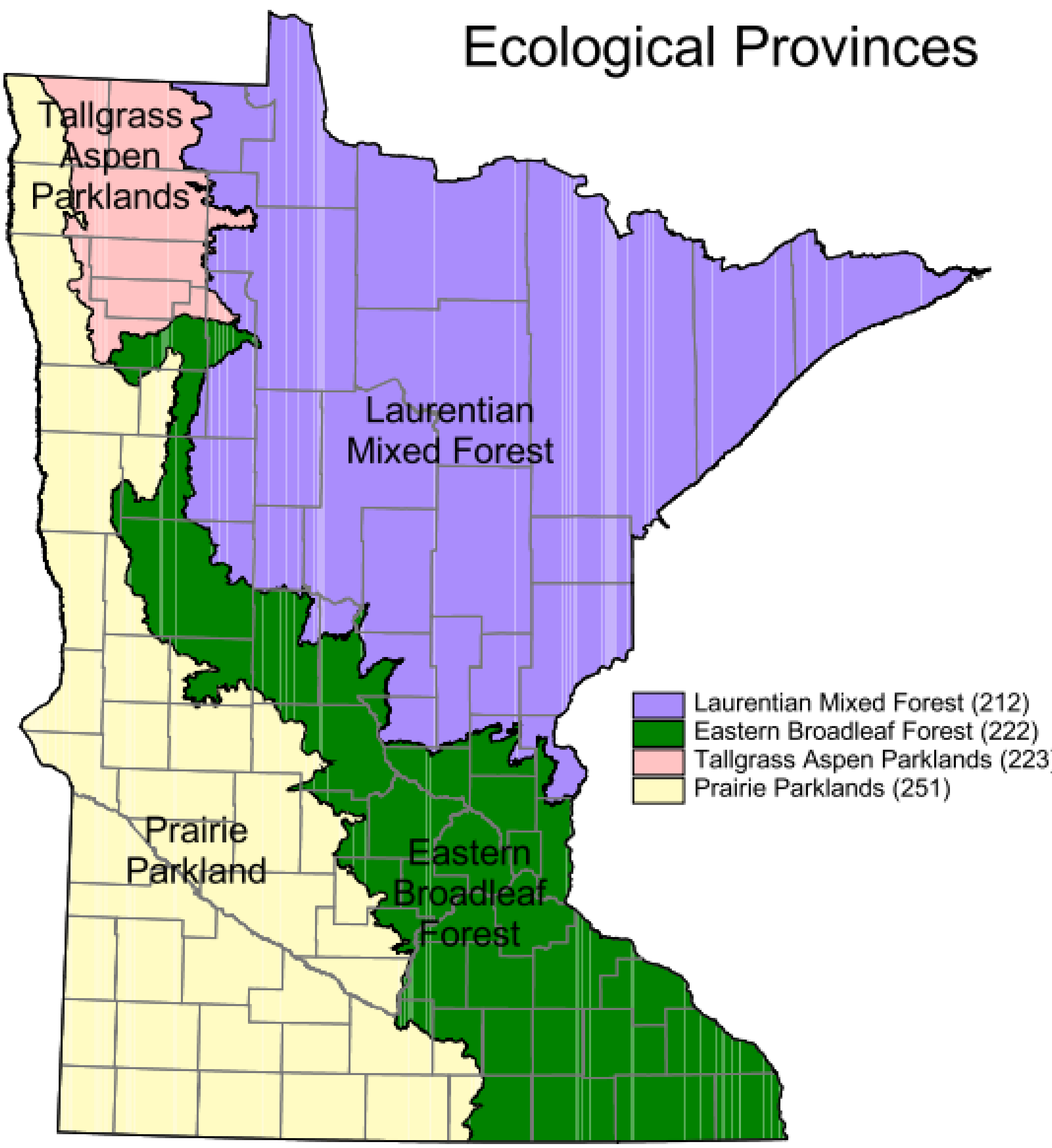
7. Riparian Vegetation

There are four metrics to assess the riparian vegetation parameter in the MNSQT: riparian buffer width, canopy cover, herbaceous vegetation cover, and woody stem basal area. Field data for canopy cover, herbaceous vegetation cover, and woody stem basal area should be collected during the growing season at the same time of year for pre- and post-project evaluations. A Riparian Width and Riparian Vegetation form is provided to record data (Appendix B).

Canopy cover and woody stem basal area are stratified based on whether woody vegetation is a significant natural component of the riparian zone or not. The procedure for determining whether vegetation is a significant natural component of the riparian zone is described below.

1. Determine if woody vegetation is a significant natural component of the riparian zone. This can be determined by examining appropriate reference reaches in the area. Otherwise, use the *Field Guides to the Native Plant Communities of Minnesota* (MN DNR, 2003, 2005a, 2005b) for the project specific ecological province to help make this determination. To use a field guide:
    a. First, select the field guide associated with the ecological province the stream reach is located in. The ecological provinces are shown in Figure A.2.

Figure: A.2 MN Ecological Provinces (MN DNR website)



b. Second, use the map on the inside cover of the field guide to determine the ecological section the stream reach is located in and consult the associated key for that section (Keys A through D).

c. Third, determine which system is associated with the riparian zone of the stream reach based on field properties, soil and hydrological properties, landform affinity and plant indicators as described in the key.

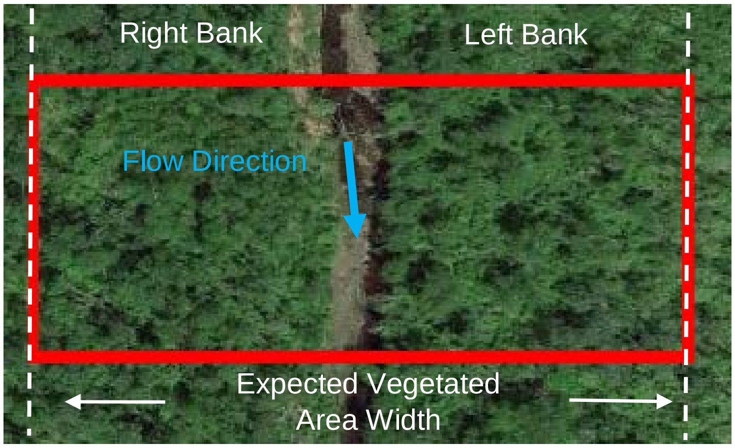
d. Based on the vegetation structure and composition description of the system or applicable subsystem as well as the natural history description, determine if woody vegetation is a significant natural component of the riparian zone of the stream reach.

Canopy cover, herbaceous vegetation cover, and woody stem basal area are assessed at vegetation plots. Field values will need to be averaged across plots before entering into the Quantification Tool spreadsheet (see Section 2.6.e in Chapter 2 of the User Manual). The user should provide a figure that shows the location and extent of the vegetation plot grid layout and identification of the sampled plots. To begin, the location of the vegetation plot must be determined using the following procedure:

Procedure:

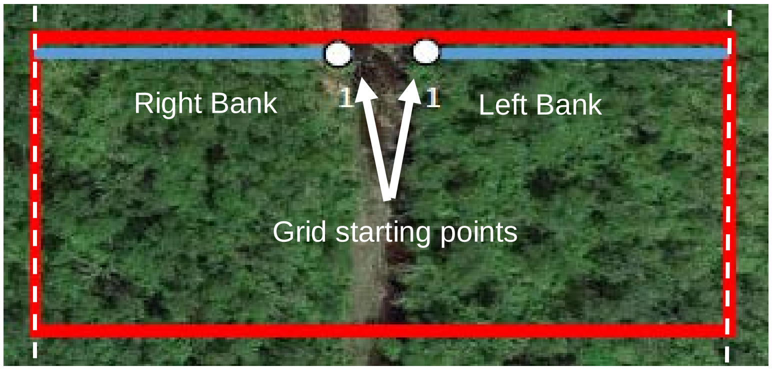
1. Determine the expected riparian area as described in Section 2.7.e of the User Manual. On an aerial image, plot a rectangle that represents the upstream and downstream limits of the defined stream reach and the landward left and right bank limits of the expected riparian area as shown in Figure A.3. Left bank and right bank orientation are determined looking in the downstream direction. This rectangle is the area for establishing a sampling grid.

Figure A.3. Stream Reach with Expected Riparian Area



2. Establish the grid starting points on the right and left channel bank, beginning at the upstream end of the reach. Establish initial transect by drawing a straight line from each grid starting point extending perpendicular to the expected riparian limit as shown in Figure A.4.

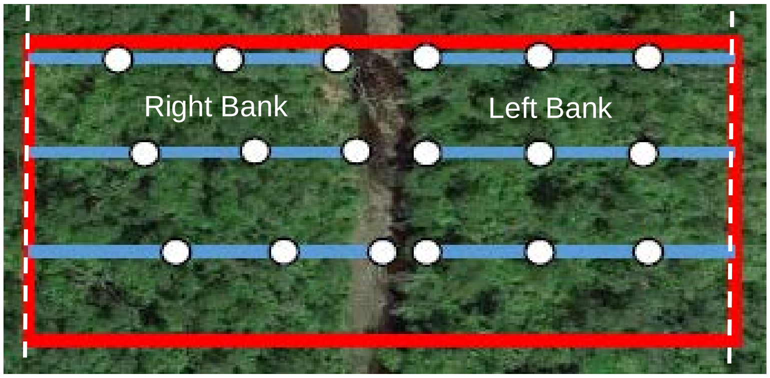
Figure A.4. Grid Starting Points



3. Establish additional parallel transects progressively downstream every 10 meters for both right and left banks. The last transect cannot be closer than 10 meters from the downstream end of the stream reach. Begin each transect by establishing initial plot anchor points on the

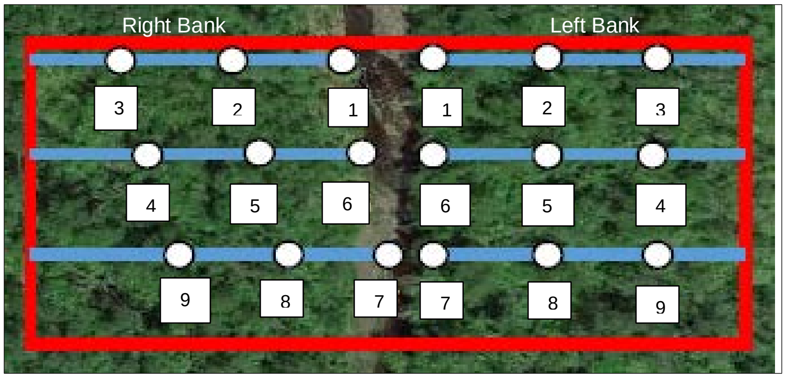
right and left channel bank. Mark additional plot anchor points every 10 meters along each transect, starting from the channel edge and moving towards the expected riparian boundary (Figure A.5). The last anchor point cannot be closer than 10 meters from the expected riparian limit. In Figure A.5, the white circles are plot anchor points and the blue lines are transects.

Figure A.5. Anchor Points and Transects



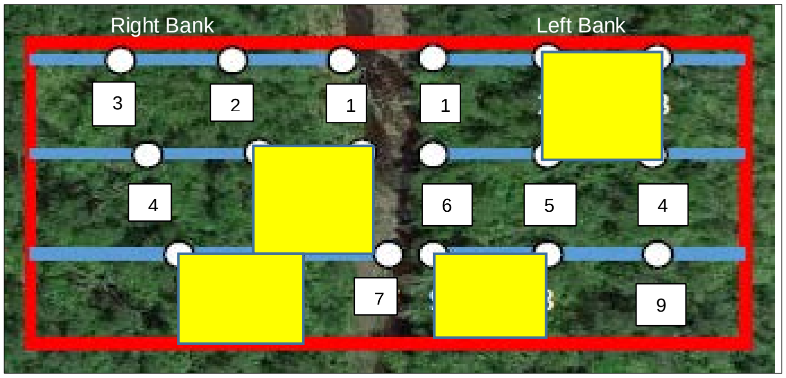
4. For each side separately (right and left banks) number the grid points sequentially starting from the grid anchor point at the channel and proceeding landward. Then continue the labeling down to next transect, then toward channel, down to next transect and repeat until complete (Figure A.6).

Figure A.6. Grid Point Labels



5. Use a random number table or generator to randomly select grid point numbers. The randomly selected grid points identify the top left corner of the grid that will be sampled (as viewed in plan view). A minimum of 2 plots per side is required. For example, grids L2, L7, R5, and R9 are shown in Figure A.7. Continue selecting grid numbers until the sampling area is equal to a minimum of 2% of the overall sampling area (area identified by red rectangle in figures). To calculate the percent sampling area, multiply the number of plots by 100 square meters and divide the result by the total area (in square meters) of the expected riparian zone for the applicable bank (right or left), then convert to a percentage. Do not include the stream channel in the total area calculation. If there is considerable variation in the composition of the riparian zone vegetation which is not adequately captured by the randomly selected sample plots, consider adding additional plots and/or establishing sub-reaches for separate sampling using the same procedures.

Figure A.7. Random Grid Selection



6. Locate the randomly selected plots in the field using appropriate measurement methods. Mark plot corners and subplot locations as applicable and begin sampling. Label plots with R and L plus the number to distinguish right and left bank samples (i.e. L2, R5, etc.). Attach a figure to the MNSQT riparian vegetation data forms showing the grid layout and selected sample plots (see Figure A.7) with labels.

Riparian Buffer Width

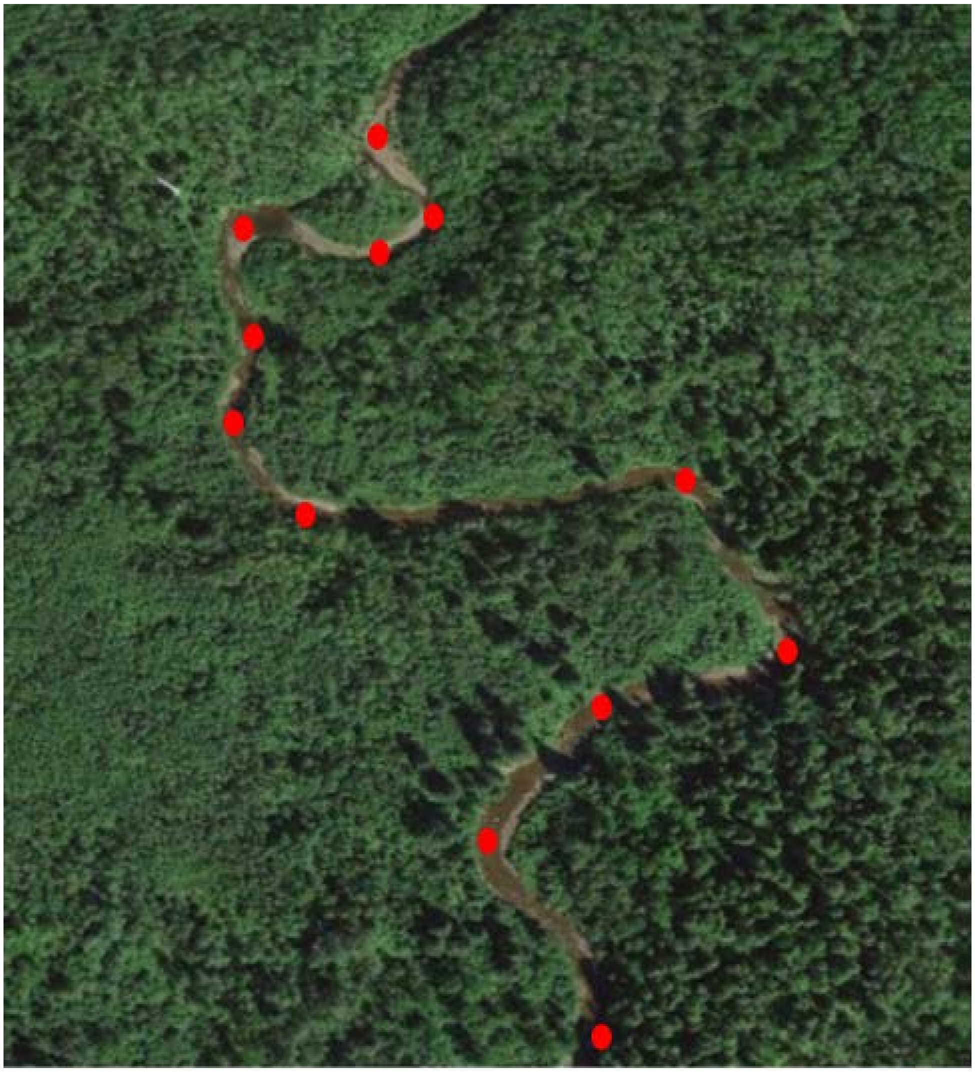
The method to determine the expected riparian width (based on bankfull and MWR) and average riparian area width is described in Section 2.6.f of the User Manual.

The expected vegetated area width that was determined using the method Section 2.6.f of the User Manual, is applied to the stream reach as described in the process below.

Procedure:

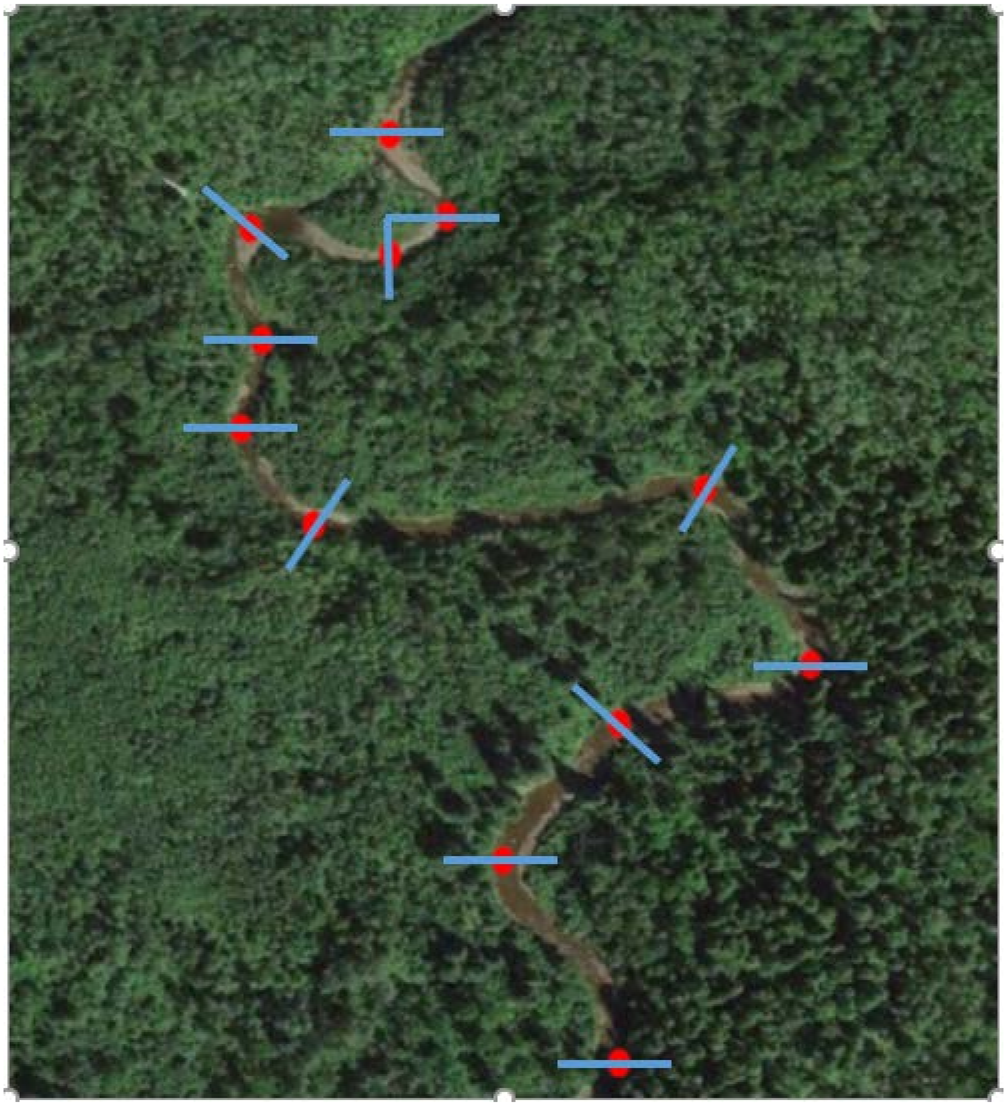
1. Using an aerial image of the reach, mark the center of the stream channel at the farthest landward point of each outside meander bend on both sides (Figure A.8). Long meander bends will require two points to capture stream sinuosity.

Figure A.8. Points identifying the stream channel at farthest landward point of each meander bend



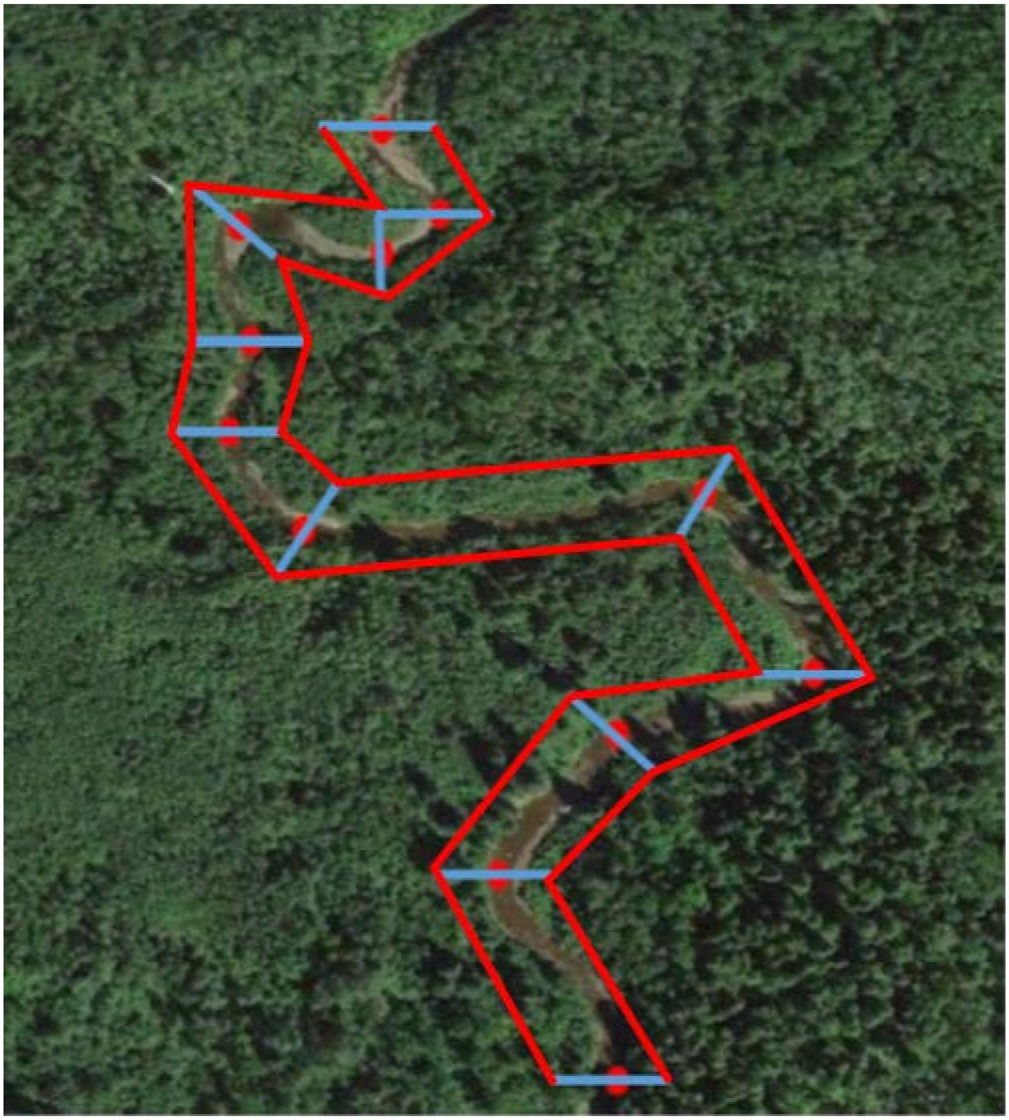
2. At each point, draw a line equivalent to the calculated expected vegetated area width (calculated using methods from Section 2.6.f of the User Manual) perpendicular to the direction of flow within the channel centered on the point (Figure A.9).

Figure A.9. Expected vegetated area width draw at each point



3. Connect the endpoints of the lines on each side (Figure A.10).

Figure A.10. Connect the end points of the expected vegetated area width lines



4. Identify any areas in the zone that are narrower than the expected vegetated area width. Indicated with arrows in Figure A.11.

Figure A.11. Arrows indicate areas narrower than the expected vegetated area width

5. Make adjustments in identified areas to maintain the minimum calculated expected vegetated area width (Figure A.12).

Figure A.12. Areas adjusted to maintain the minimum calculated expected vegetated area width

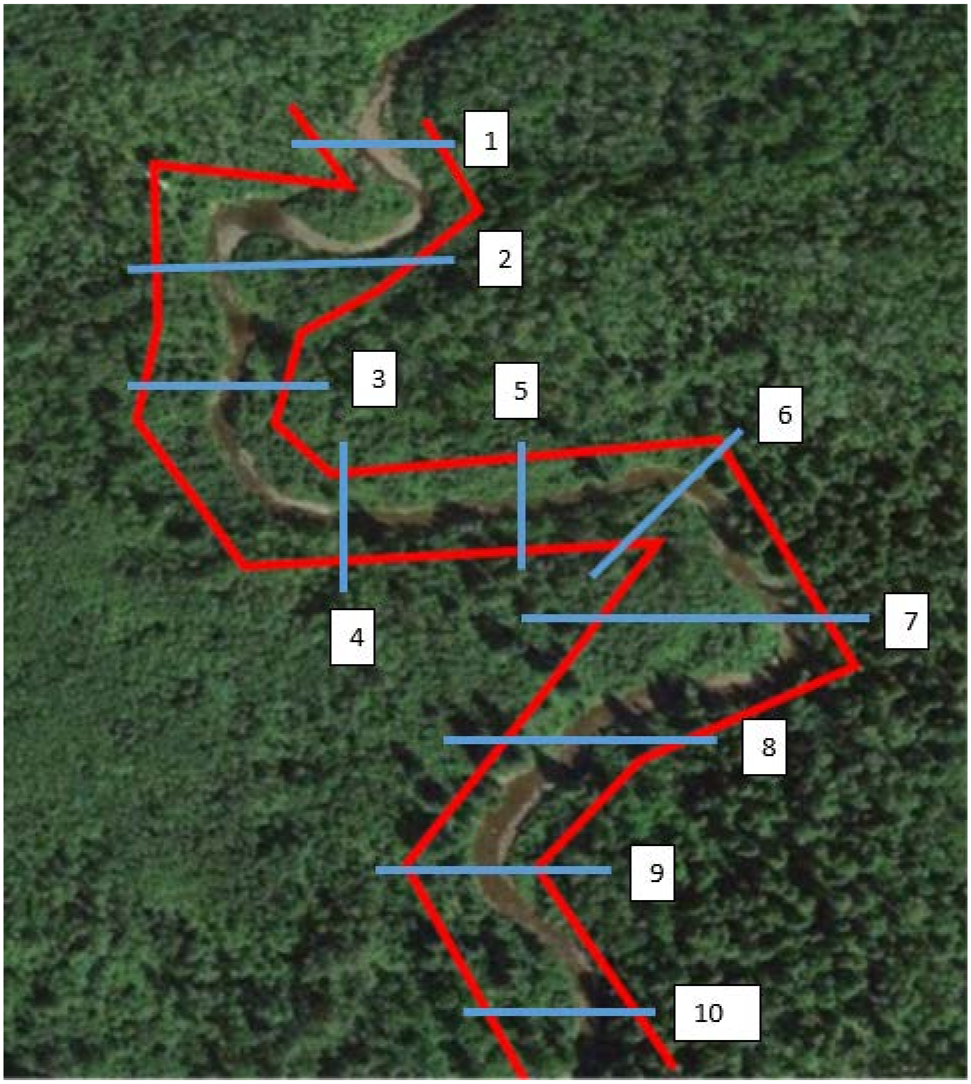
6. The riparian zone established using this procedure should be narrowed in any areas that overlap a hillslope which is clearly above the expected stage of the 100-year recurrence interval flow. Overlay the 100-year floodplain mapped zone with topographic data to confirm and adjust as necessary.

   Conversely, the zone should be widened in areas where it does not fully encompass the stream valley bottom where there is a mapped 100-year floodplain and/or there are observable indicators of floodplain and the influence of fluvial processes. Such indicators include fluvial sediments, bar deposition, water staining and water marks.

   The riparian zone should be inspected for these field indicators at a minimum of 10 locations spaced evenly throughout the reach on both sides of the stream. This involves locating the zone limits at each chosen location in the field using GPS points and inspecting the area landward from the limits for at least 10 meters. These field verification points should be indicated and labeled on the riparian zone figure with results noted for each (Figure A.13).

In the example shown in Figure A.13, for locations 1 – 6, 9, and 10 no indicators were identified beyond the mapped expected vegetated area width. At locations 7 and 8, bar deposition and sediments were observed approximately 10 meters landward from mapped expected vegetated area width. The expected vegetated area width is expanded 10 meters from halfway between points 6 and 7 to halfway between points 8 and 9.

Figure A.13. Field inspection locations



The Riparian Width field form in Appendix B can be used to document field measured riparian buffer width. The field form provides a list of indicators that may be used to identify the edge of the expected vegetated area width.

Field verification may be necessary for the average vegetated area width. Identify and delineate areas of riparian vegetation (excluding all artificial vegetation that is periodically harvested/removed such as crops, sod, tree farms, etc.) in the riparian zone (aka expected vegetated area width) that are contiguous with the stream channel. Do not include areas that are interrupted by any human-related disturbances/structures (roads, buildings, utility lines, etc.).

Canopy Cover

Canopy cover is determined by assessing the relative areal cover of the shrub and tree vegetation strata. Data can be recorded on the Riparian Vegetation form found in Appendix B. This data can be used to determine the field values following the instructions in Chapter 2 of the User Manual for Canopy Cover. The data collection method provided below is based on the *CVS-EEP Protocol for Recoding Vegetation* (Lee et al. 2008) and modified for use in Minnesota.

Procedure:

1. Visually estimate the percent of the relative areal cover provided by the shrub strata (woody vegetation less than 1.37 m in height with a diameter at breast height (dbh) less than 7.62 cm). The relative areal cover is the proportional cover provided by the shrub vegetation strata as a percentage of the total plot, ranging from 0 - 100%. Use the cover class ranges in Table A.1 for the estimates. Enter the cover midpoint estimate in the Riparian Vegetation Form. Fill out one Riparian Vegetation form for each sampling plot.

2. Estimate the percent of the relative areal cover provided by the tree vegetation strata (woody vegetation greater than or equal to 1.37 m in height with a dbh greater than or equal to 7.62 cm). The relative areal cover is the proportional cover provided by the tree vegetation strata as a percentage of the total plot, ranging from 0 - 100%. Use the cover class ranges in Table A.1 for the estimates. Enter the cover midpoint estimate in the Riparian Vegetation Form.

Table A.1 Cover Class Descriptions

Cover Class Range	Midpoint
>95 - 100%	97.5%
>75 - 95%	85%
>50 - 75%	62.5%
>25 - 50%	37.5%
>5 - 25%	15%
>1 - 5%	3%
>0 - 1%	0.5%

3. Determine the canopy cover for each plot by adding the shrub strata and tree strata midpoint values.

4. Average the canopy cover estimates across all plots.

Herbaceous Vegetation Cover

Visually estimate the percent of the relative areal ground cover that is covered by the herbaceous vegetation strata in the plot. This includes all above ground plant material (leaves, branches, stems) less than 1.37 m in height. The relative areal cover is the proportional cover provided by the tree vegetation strata as a percentage of the total plot, ranging from 0 - 100%.

Use the cover class ranges in Table A.1 for the estimates. Enter the cover midpoint estimate in the Riparian Vegetation Form (Appendix B). Fill out one Riparian Vegetation form for each sampling plot.

Woody Stem Basal Area

For purposes of the MNSQT, woody stem basal area is determined by sampling woody stems that are greater than 1.37 meters high. The resulting sampling values are expressed as an area (m^2) per hectare and averaged across sampling plots for the reach. The data collection method provided below is based on the *CVS-EEP Protocol for Recoding Vegetation* (Lee et al. 2008) and modified for use in Minnesota.

Procedure:

1. Determine if the entire plot (10 by 10 meters) will be sampled or if subsampling within the plot is appropriate. Subsampling involves stem counts and measurements along a one meter wide strip along the right and left sides of the 10 by 10 meter plot as opposed to sampling the entire plot. If stem densities are relatively high and somewhat uniform within the plot, subsampling within the plot can be conducted, however, subsampling cannot be used to estimate basal area of planted trees and shrubs for a post-project assessment.

2. Count and record the dbh of all woody stems within the plot and/or subplots. Stems must be from woody, perennial species and at least 1.37 meters high. Height refers to the length of the stem (rather than the actual height above ground) and should be determined based on the length from the ground to the end of the terminal bud. Multiple stems from the same plant are not counted if they split above 1.37 meters high. For stems up to 30.5 cm dbh, use the following dbh classes in Table A.2 to determine the midpoint value. Measure and record the exact dbh of all woody stems exceeding 30.5 cm dbh.

Table A.2: DBH Classification

DBH (cm)	DBH Midpoint (cm)
0 – 2.5	1.25
2.5 – 5	3.75
5 – 7.5	6.75
7.5 – 12.5	10
12.5 – 20.5	16.5
20.5 – 30.5	25.5
>30.5	Measure

3. Determine the sum of all dbh measurements by adding the total centimeters for all stems less than 30.5 cm (number of stems multiplied by the midpoint) to the measured dbh for all stems greater than 30.5 cm. Add these values for all the plots, convert to square meters, and divide by the total plot area to determine woody stem basal area in m^2/hectare.

8. Physicochemical Parameters

Temperature

Placement and use of in-water temperature sensors should follow *Procedure for Temperature Logger Deployment at Stream Monitoring Sites* (MPCA 2015). This procedure covers equipment selection, deployment methodologies, temperature logger form, and data QAQC. **Methods are not provided in this section.**

Record the time and date of temperature sensor deployment on the Sensor Log form in Appendix B.

Dissolved Oxygen

This metric is a direct measure of the concentration of dissolved oxygen (mg/L) in in the project reach collected according to procedures outlined in the *Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component* (MPCA 2017b). **Methods are not provided in this section.**

Record the time and date of dissolved oxygen sensor deployment on the Sensor Log in Appendix B. As noted in the User Manual, measurements in open-water months (April through November) should be made before 9:00 a.m. Please refer to the assessment guidance manual (*Guidance Manual For Assessing the Quality of Minnesota Surface Waters* (MPCA 2018a)) regarding the importance of dissolved oxygen measurements collected before 9:00 a.m. (e.g. to measure impact from streams impacted by eutrophication). The MPCA can provide recommendations for suitable Sonde deployment sites.

Total Suspended Solids (TSS)

This metric is a direct measure of the concentration of total suspended soilds (mg/L) in the project reach collected according to procedures outlined in the *Guidance Manual For Assessing the Quality of Minnesota Surface Waters* (MPCA 2018a), and *Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component* (MPCA 2018c). The State also uses turbidity as a surrogate for TSS. The protocol for turbidity sampling is described in *Turbidity TMDL Protocol Guidance and Submittal Requirements* (MPCA 2007).document (https://www.pca.state.mn.us/sites/default/files/wq-iw1-07.pdf)

Methods are not provided in this section.

Record the time and date of the sample collection on the Sensor Log in Appendix B.

9. Biological Parameters

Macroinvertebrate Sampling

Detailed macroinvertebrate surveys should be conducted using *Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017). **Specific macroinvertebrate sampling procedures are not provided in this section.**

Record information related to macroinvertebrate sampling on the Stream Invertebrate Visit Form, Stream Sample External Label, and Physicochemical and Macroinvertebrate Sampling Sorting Bench Sheet forms in Appendix B.

Fish Sampling

Detailed fish surveys should be conducted using *Fish Data Collection Protocols for Lotic Waters in Minnesota* (MPCA 2017a) and standard methods (Bonar et al. 2009). **Specific fish sampling procedures are not provided in this section.**

Record information related to fish sampling on the Fish Survey Record form in Appendix B. In addition, the visit summary form found in the *Water Chemistry Assessment Protocol for Stream Monitoring Sites* (MPCA 2014c), which summarizes sampled stream condition/water quality information, should be filled out. This form is also included in Appendix B.

10. References

Bevenger GS, King RM. 1995. A pebble count procedure for assessing watershed cumulative effects. US Department of Agriculture Forest Service Research Paper RM-RP-319. Fort Collins (CO): Rocky Mountain Forest and Range Experiment Station. https://www.fs.fed.us/rm/pubs_rm/rm_rp319.pdf

Bonar SA, Hubert WA, Willis DW, editors. 2009. Standard methods for sampling North American freshwater fishes. Published by American Fisheries Society.

Colorado Stream Quantification Tool Steering Committee (CSQT SC). 2019. Colorado Stream Quantification Tool and Debit Calculator User Manual, Beta Version. Washington (DC): US Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds (Contract # EP-C-17-001).

Davis JC, Minshall WG, Robinson CT, Landres P. 2001. Monitoring Wilderness Stream Ecosystems. General Technical Report RMRS-GTR-70. Fort Collins (CO): US Department of Agriculture, Forest Service, Rocky Mountain Research Station. https://www.fs.fed.us/rm/pubs/rmrs_gtr070.pdf

Harman WA, Barrett TB, Jones CJ, James A, Peel HM. 2017. Application of the large woody debris index: a field user manual version 1. Raleigh (NC): Stream Mechanics and Ecosystem Planning & Restoration. https://stream-mechanics.com/wp-content/uploads/2017/12/LWDI-Manual_V1.pdf

Harrelson CC, Rawlins CL, Potyondy JP. 1994. Stream channel reference sites: an illustrated guide to field technique. General Technical Report RM-245. Fort Collins (CO): US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. https://www.fs.fed.us/biology/nsaec/fishxing/fplibrary/Harrelson_1994_Stream_Channel_Reference_Sites_An_Illustrated.pdf

Lee, Michael T., R.K. Peet, S.D. Roberts and T.R. Wentworth, 2008. CVS-EEP Protocol for Recording Vegetation, Version 4.2 (http://cvs.bio.unc.edu/methods.htm).

Mecklenberg D. 2004. The reference reach spreadsheet for channel survey data management, A STREAM Module: spreadsheet tools for river evaluation, assessment and monitoring. Version 4.01L. Ohio Department of Natural Resources.

MN Department of Natural Resources (MN DNR). 2003. Field Guide to the Native Plant Communities of Minnesota: The Laurentian Mixed Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program. St. Paul, MN.

MN DNR. 2005a. Field Guide to the Native Plant Communities of Minnesota: The Eastern Broadleaf Forest Province. Ecological Land Classification Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program. St. Paul, MN.

MN DNR. 2005b. Field Guide to the Native Plant Communities of Minnesota: The Prairie Parkland and Tallgrass Aspen Parkland Provinces. Ecological Land Classification

Program, Minnesota County Biological Survey, and Natural Heritage and Nongame Research Program. St. Paul, MN.

MN DNR. 2007. Fisheries Stream Survey Manual: Stream Survey Methods, V 2.1. Special Publication No. 165. Division of Fish and Wildlife, St. Paul, MN.

Minnesota Pollution Control Agency (MPCA). 2007. Turbidity TMDL Protocols and Submittal Requirements. Document number wq-iw1-07. St. Paul, MN.

MPCA. 2014a. Development of a fish-based Index of Biological Integrity for assessment of Minnesota's rivers and streams. Document number wq-bsm2-03. Environmental Analysis and Outcomes Division, St. Paul, MN.

MPCA. 2014b. Development of a macroinvertebrate-based Index of Biological Integrity for assessment of Minnesota's rivers and streams. Document number wq-bsm4-01. Environmental Analysis and Outcomes Division, St. Paul, MN.

MPCA. 2014c. Water Chemistry Assessment Protocol for Stream Monitoring Sites. Biological Monitoring Program, St. Paul, MN.

MPCA. 2015. Procedure for Temperature Logger Deployment at Stream Monitoring Sites. Biological Monitoring Program, St. Paul, MN.

MPCA. 2017a. Fish Data Collection Protocols for Lotic Waters in Minnesota. Document number wq-bsm3-12b. St. Paul, MN.

MPCA. 2017b. Macroinvertebrate Data Collection Protocols for Lotic Waters in Minnesota. Document number wq-bsm3-12a. St. Paul, MN.

MPCA. 2018a. Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b)Report and 303(d) List, March 2018. Document number wq-iw1-04j. Environmental Analysis and Outcomes Division, St. Paul, MN.

MPCA. 2018b. Standard Operating Procedures, Intensive Watershed Monitoring – Stream Water Quality Component. Document number wq-s1-18. St. Paul, MN.

MPCA. 2018c. Standard Operating Procedures, Water Quality Monitoring in Aquatic Invasive Species Infested Locations. Document number wq-s1-68. St. Paul, MN.

Rosgen DL. 1996. Applied river morphology. Fort Collins (CO): Wildland Hydrology Books.

Rosgen DL. 2008. River stability field guide. Fort Collins (CO): Wildland Hydrology Books.

Rosgen DL. 2014. River stability field guide. 2nd ed. Fort Collins (CO): Wildland Hydrology Books.

Starr R, Harman W, Davis S. 2015. Final draft function-based rapid field stream assessment methodology. CAFE S15-06. Annapolis (MD): US Fish and Wildlife Service, Chesapeake Bay Field Office. https://www.fws.gov/chesapeakebay/stream/StreamsPDF/FinalDraftFunctionBasedRapidStreamAssessmentMethodologyandAppendices5-29-15.pdf

US Environmental Protection Agency (USEPA). 2014. Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams. Global Change Research Program, National Center for Environmental Assessment, Washington, D.C; EPA/600/R-13/170F.

WDEQ/WQD. 2018. Manual of standard operating procedures for sample collection and analysis. Cheyenne (WY): Wyoming Department of Environmental Quality, Water Quality Division, Watershed Program. http://deq.wyoming.gov/wqd/qaqc/resources/manual/

Project:
Reach ID:

Minnesota Stream Quantification Tool
Parameter Selection Checklist

	Function-Based Parameter	Metric(s)	Datasheets for Field-based Metrics
☐	Reach Runoff*	☐ Land Use Coefficient (D) **AND** Concentrated Flow Points (F)	Project Reach Form Section II(B)**
		or	
		☐ BMP MIDS Rv Coefficient (D)	
☐	Floodplain Connectivity*	☐ Bank Height Ratio* **AND** Entrenchment Ratio* (F)	Rapid Survey Form** **OR** Cross Section **AND** Longitudinal Survey Forms
☐	Large Woody Debris (LWD)	☐ LWD Index (F)	LWDI Form
		or	
		☐ No. of LWD Pieces/ 100 meters (F)	Project Reach Form Section VI**
☐	Lateral Migration*	☐ Dominant BEHI/NBS* **AND** Percent Streambank Erosion* (F)	Lateral Migration Form**
		or	
		☐ ***Optional:*** Percent Armoring (F)	Project Reach Form Section II(C)**
☐	Bed Material Characterization	☐ ***Optional:*** Size Class Pebble Count Analyzer (F)	Pebble Count Form
☐	Bed Form Diversity*	☐ Pool Spacing Ratio* **AND** Pool Depth Ratio* **AND** Percent Riffle* (F)	Longitudinal Survey **OR** Rapid Survey Form**
		☐ ***Optional:*** Aggradation Ratio (F)	Cross Section Form **OR** Rapid Survey Form**
☐	Riparian Vegetation*	☐ Riparian Width* (D/F) **AND** Canopy Cover* (F) **AND** Herbaceous Vegetation Cover* (F) **AND** Woody Stem Basal Area[1] (F)	Riparian Width and Vegetation Forms**
☐	Temperature	☐ ***Optional:*** Summer Average (F)	Temperature Logger SOP Form
☐	Dissolved Oxygen	☐ ***Optional:*** Dissolved Oxygen Concentration (F)	Sensor Log
☐	Total Suspended Solids	☐ ***Optional:*** Total Suspended Solids Concentration (F)	Sensor Log
☐	Macroinvertebrates	☐ ***Optional:*** Macroinvertebrate IBI (F)	Macroinvertebrate Sample Sorting Bench Sheet **AND** Stream Invertebrate Visit Form
☐	Fish	☐ ***Optional:*** Fish IBI (F)	Fish Survey Record Form **AND** Visit Summary Form

* Include in all assessments
** Field values can be entered directly from field forms into MNSQT; all other metrics require additional post-processing or analysis to
(D) indicates metrics are calculated using desktop methods
(F) indicates metrics are calculated or verified using field methods
[1] Include Woody Stem Basal Area only if woody vegetation is determined to be a signification natural component of the riparian zone.

Date:
Investigators:

Minnesota Stream Quantification Tool
Project Reach Form

I. Site Information

Project Name:	
Reach ID:	
Drainage Area (sq. mi.):	
Use Class:	
River Nutrient Region:	
Valley Type:	
Stream Reach length (ft):	
Latitude:	
Longitude:	

Shading Key
Desktop Value
Field Value
Calculation

II. Reach Walk

A.

Difference between bankfull (BKF) stage and water surface (WS) (ft)							
Difference between BKF stage and WS (ft) *Average or consensus value from reach walk.*							

B.

Number Concentrated Flow Points	
Concentrated Flow Points/ 1,000 L.F.	

C.

Length of Armoring on banks (ft)							
Total (ft)							
Percent Armoring (%)							

D.

Valley length (ft)	
Stream Length (ft)	
Sinuosity	

III. Identification of Representative Sub-Reach

Representative Sub-Reach Length At least 20 x the Bankfull Width	
Latitude of downstream extent:	
Longitude of downstream extent:	

20*Bankfull Width	

Sub-Reach Survey Method

□ Longitudinal Profile & Cross Section
□ Rapid Survey

IV. Bankfull Verification and Representative Riffle Cross Section

Is Cross Section located within Representative Sub-Reach? □ Yes □ No

If no, explain why:

A.	Bankfull Width (ft)	
B.	Bankfull Mean Depth (ft) = Average of cross-section depths	
C.	Bankfull Area (sq. ft.) Width * Mean Depth	
D.	Regional Curve Bankfull Width (ft)	
E.	Regional Curve Bankfull Mean Depth (ft)	
F.	Regional Curve Bankfull Area (sq. ft.)	
G.	Curve Used	

Cross Section Measurements Depth measured from bankfull			
Station	Depth	Station	Depth

NOTE: Space is provided here to survey a cross section using rapid survey methods. A cross section form is also available for cross section surveys.

V. Stream Classification

A.	Width Depth Ratio (ft/ft) Bankfull Width / Bankfull Mean Depth	
B.	Bankfull Max Riffle Depth	
C.	Floodprone Area Width (ft)	
D.	Entrenchment Ratio (ft/ft) Floodprone Area Width /Bankfull Width	
E.	Slope Estimate (%)	
F.	Channel Material Estimate	
G.	Stream Type	

Average slope from the representative sub-reach will be measured and calculated. Pebble count forms are available to aid in this determination.

VI. Large Woody Debris (100m (328 ft) assessment length within Sub-Reach)

A.	Number of Pieces	

NOTE: Complete this section only if the LWDI is not being used. Otherwise complete the LWDI Field Form.

VII. Representative Sub-Reach Sketch

VIII. Notes

Minnesota Stream Quantification Tool
Longitudinal Profile Form

Date:	Rod Team:
Stream Name:	Instrument Team:
Reach I.D.	Notes Team:
Team Number:	

Longitudinal Profile Field Form

Key Codes:

Head of Riffle	R	Bankfull	BKF	Benchmark	TBM
Head of Run	N	Top of Bank	TOB	Turning Point	TP
Head of Pool	P	Edge of Channel	EC	Backsight	BS
Head of Glide	G	Inner Berm	IB	Foresight	FS
Thalweg	TW			Height of Instrument	HI

Survey:			**Thalweg**		**Water Surface**		**Bankfull**		**Top of Low Bank**			
Station	**BS (+)**	**HI**	**FS (-)**	**Elevation**	**FS (-)**	**Elevation**	**FS (-)**	**Elevation**	**FS (-)**	**Elevation**	**FS (-)**	**Elevation**

Minnesota Stream Quantification Tool
Longitudinal Profile Form

Survey:			Thalweg		Water Surface		Bankfull		Top of Low Bank			
Station	BS (+)	HI	FS (-)	Elevation	FS (-)	Elevation	FS (-)	Elevation	FS (-)	Elevation	FS (-)	Elevation

Minnesota Stream Quantification Tool

Cross Section Form

Date:	Rod Team:
Stream Name:	Instrument Team:
Reach I.D.	Notes Team:
Team Number:	

Key Codes:

Head of Riffle	R	Bankfull	BKF	Benchmark	TBM
Head of Run	N	Top of Bank	TOB	Turning Point	TP
Head of Pool	P	Edge of Channel	EC	Backsight	BS
Head of Glide	G	Inner Berm	IB	Foresight	FS
Thalweg	TW			Height of Instrument	HI

Cross Section Field Form

Station	BS (+)	HI	FS (-)	Elevation	Notes

Date:
Investigators:

Minnesota Stream Quantification Tool
Rapid Survey Form

Reach ID:

I. Riffle Data (Floodplain Connectivity & Bed Form Diversity)

A.	Representative Sub-Reach Length		20*Bankfull Width	

B. Bank Height & Riffle Data: Record for each riffle in the Sub-Reach

	R1	R2	R3	R4	R5	R6	R7	R8
Begin Station								
End Station								
Low Bank Height (ft)								
BKF Max Depth (ft)								
BKF Mean Depth (ft)								
BKF Width (ft)								
Flood Prone Width (ft)								
Riffle Length (ft) *Including Run*								
Bank Height Ratio (BHR) Low Bank H / BKF Max D								
BHR * Riffle Length (ft)								
Entrenchment Ratio (ER)								
ER * Riffle Length (ft)								
WDR BKF Width/BKF Mean Depth								

C.	Total Riffle Length (ft) *Excludes Additional Pool Lengths*	
D.	**Weighted BHR** $\frac{\Sigma(Bank\ Height\ Ratio_i \times \text{Riffle Length}_i)}{\Sigma Riffle\ Length}$	
E.	**Weighted ER**	
F.	**Maximum WDR**	
G.	**Percent Riffle (%)**	

Shading Key
Field Value
Calculation

Date:
Investigators:

Minnesota Stream Quantification Tool
Rapid Survey Form

II. Pool Data (Bed Form Diversity)

A. Pool Data: Record for each pool within the Sub-Reach

	P1	P2	P3	P4	P5	P6	P7	P8
Geomorphic Pool?								
Station								
P-P Spacing (ft)	X							
Pool Spacing Ratio Pool Spacing/BKF Width	X							
Pool Depth (ft) Measured from BKF								
Pool Depth Ratio Pool Depth/BKF Mean Depth								

B.	**Average Pool Depth Ratio**		C. **Median Pool Spacing Ratio**	

III. Slope

	Begin	End	Difference	Slope (ft/ft)
Station along tape (ft)				
Stadia Rod Reading (ft)				

IV. Notes

LARGE WOODY DEBRIS FIELD FORM

Date Revised: 10/19/2016

Investigator(s)		State		Forest Type	Deciduous Evergreen Mixed Other
Date		County		Forest Age (yrs)	
Stream Name		Phys. Province		Latitude (dd)	
Reach ID		Drainage Area (mi^2)		Longitude (dd)	
Watershed Name		Dominant Species			

Survey Length (ft)	328	Survey Length = 328 ft/100 m	BKF Width (ft)		Slope (ft/ft)	
Stream Classification	Ephemeral Intermittent Perennial		BKF Mean Depth (ft)		Bed material	
Stream Condition	Degraded Restored Reference Managed		Floodprone Width (ft)		Rosgen Type	
Field Notes:						

SCORE	1		2		3		4		5		
CATEGORY	*** PIECES ***										**TOTAL PIECES**
Length/BKF Width	0 to 0.4		0.4 to 0.6		0.6 to 0.8		0.8 to 1.0		> 1.0		
Diameter (cm)	10 to 20		20 to 30		30 to 40		40 to 50		>50		
Location	**Zone 4** (Above BKF/Extending into Channel)				**Zone 3** (Above BKF/Within Streambanks)		**Zone 2** (Above WS/Below BKF)		**Zone 1** (Below WS)		
Type	Bridge				Ramp		Submersed		Buried		
Structure	Plain		Plain/Int		Intermediate		Int/Sticky		Sticky		
Stability	Moveable		Mov/Int		Intermediate		Int/Sec		Secured		
Orientation (deg)	0 to 20		20 to 40		40 to 60		60 to 80		80 to 90		
Total											

CATEGORY	**** DEBRIS DAMS ****										**TOTAL DAMS**
Length (% of BKF Width)	0 to 20		20 to 40		40 to 60		60 to 80		80 to 100		
Height (% of BKF Depth)	0 to 20		20 to 40		40 to 60		60 to 80		80 to 100		
Structure	Coarse		Coarse/Int		Intermediate		Int/Fine		Fine		
Location	Partially high flow		In high flow		Partially low flow		Mid low flow		In low flow		
Stability	Moveable		Mov/Int		Intermediate		Int/Sec		Secured		
								Total		LWDI	

* Pieces - Non-living wood that has a large end diameter ≥ 10 cm and has a length ≥ 1 m. ** Debris Dams - Three (3) or more pieces touching.

Date:
Investigators:

Minnesota Stream Quantification Tool
Lateral Migration Form

Reach ID:
Valley Type:
Bed Material:

			Bank Erosion Hazard Index								
Station ID	**Bank Length (Ft)**	**Study Bank Height (ft)**	**BKF Height (ft)**	**Root Depth (ft)**	**Root Density (%)**	**Bank Angle (degrees)**	**Surface Protection (%)**	**Bank Material Adjustment**	**Stratification Adjustment**	**BEHI Total/ Category**	**NBS Ranking**

Date:

Investigators:

Minnesota Stream Quantification Tool

Lateral Migration Form

Summary Table

BEHI/NBS Ranking	Enter bank Length from all rows on p.1 with same ranking									Length (Feet)	Percent of Total
Ex/Ex											
Ex/VH											
Ex/H											
Ex/M											
Ex/L											
Ex/VL											
VH/Ex											
Vh/VH											
VH/H											
VH/M											
VH/L											
VH/VL											
H/Ex											
H/VH											
H/H											
H/M											
H/L											
H/VL											
M/Ex											
M/VH											
M/H											
M/M											
M/L											
M/VL											
L/Ex											
L/VH											
L/H											
L/M											
L/L											
L/VL											
									Total Length:		
									Eroding Length:		

Date:
Investigators:

Minnesota Stream Quantification Tool
Riparian Width Form

Reach Name: ____________
Reach Length: ____________

Plot ID:							
Measured Channel Width:		Measured (L Bank):		Measured (R Bank):		Measured Width[1] (Ft):	0
Check Indicators noted in field:							
	Valley Edge		Slope break/Terrace	Notes:			
	Change in Sediment		Other:				
	Evidence of Flooding						
	Change in Vegetation						

[1] Measured Width is the sum of the field measured channel width, left riparian width, and right riparian width

Plot ID:							
Measured		Measured		Measured		Measured Width[1] (Ft):	0
Check Indicators noted in field:							
	Valley Edge		Slope break/Terrace	Notes:			
	Change in Sediment		Other:				
	Evidence of Flooding						
	Change in Vegetation						

[1] Measured Width is the sum of the field measured channel width, left riparian width, and right riparian width

Plot ID:							
Measured		Measured		Measured		Measured Width[1] (Ft):	0
Check Indicators noted in field:							
	Valley Edge		Slope break/Terrace	Notes:			
	Change in Sediment		Other:				
	Evidence of Flooding						
	Change in Vegetation						

[1] Measured Width is the sum of the field measured channel width, left riparian width, and right riparian width

Plot ID:							
Measured		Measured		Measured		Measured Width[1] (Ft):	0
Check Indicators noted in field:							
	Valley Edge		Slope break/Terrace	Notes:			
	Change in Sediment		Other:				
	Evidence of Flooding						
	Change in Vegetation						

[1] Measured Width is the sum of the field measured channel width, left riparian width, and right riparian width

Shading Key
Field Value
Calculation

Project/Reach Name: ___________________

Plot ID# Circle one **- Left** or **Right** side of stream (orientation determined facing downstream)

Relative Areal Cover[1] by Strata	**Cover Midpoint**
Herb Strata (all veg <1.37m in height[2])	
Shrub Strata (woody veg <1.37m in height and <7.62cm dbh[3])	
Tree Strata (woody veg ≥1.37m in height and ≥7.62 cm dbh)	
Canopy Cover (sum of shrub and tree strata cover midpoints)	
Notes:	

Range	**Midpoint**
>95-100%	97.5%
>75-95%	85.0%
>50-75%	62.5%
>25-50%	37.50%
>5-25%	15%
>1-5%	3%
>0-1%	0.50%

[1]Relative Areal Cover is the proportional cover by vegetation as a percentage of the total plot, ranging from 0-100%.

[2]Height is the length of the woody, perennial stem (rather than the height above the ground) measured to the terminal bud of longest woody stem.

[3]Dbh is measured in centimeters at a height of 1.37m above ground.

Plot ID# Circle one - **Full Plot** or **Subplot[2]**

Woody Stem Basal Area at dbh[1]			
DBH Range	**Number**	**Midpoint**	**Total Centimeters by Range[3]**
0 - 2.5cm		1.25	
>2.5 - 5cm		3.75	
>5 - 7.5cm		6.75	
>7.5 - 12.5cm		10	
>12.5 - 20.5cm		16.5	
>20.5 - 30.5cm		25.5	
>30.5cm (enter dbh to nearest cm)		N/A	
		Total:	

[1]Dbh is measured in centimeters at a height of 1.37m above ground.

[2]Subplot is a one meter wide strip along right and left sides of 10 x 10m plot. Cannot be used for post-project assessment if woody plantings present.

[3]Number of stems multiplied by midpoint. Add measured dbh for stems >30.5cm.

Shading Key
Field Value
Calculation

PEBBLE COUNT DATA SHEET

SITE OR PROJECT:	
REACH/LOCATION:	
DATE COLLECTED:	
FIELD COLLECTION BY:	
DATA ENTERED BY:	

			PARTICLE CLASS			Reach Summary	
MATERIAL	PARTICLE	SIZE (mm)	Riffle	Pool	Total	Class %	% Cum
	Silt / Clay	< .063					
	Very Fine	.063 - .125					
	Fine	.125 - .25					
	Medium	.25 - .50					
	Coarse	.50 - 1.0					
	Very Coarse	1.0 - 2.0					
	Very Fine	2.0 - 2.8					
	Very Fine	2.8 - 4.0					
	Fine	4.0 - 5.6					
	Fine	5.6 - 8.0					
	Medium	8.0 - 11.0					
	Medium	11.0 - 16.0					
	Coarse	16 - 22.6					
	Coarse	22.6 - 32					
	Very Coarse	32 - 45					
	Very Coarse	45 - 64					
	Small	64 - 90					
	Small	90 - 128					
	Large	128 - 180					
	Large	180 - 256					
	Small	256 - 362					
	Small	362 - 512					
	Medium	512 - 1024					
	Large-Very Large	1024 - 2048					
	Bedrock	> 2048					

Totals

Date:
Investigators:

Minnesota Stream Quantification Tool
Sensor Log

Stream Name:
Sub-reach Name:

Dissolved Oxygen Logger Deployed? ☐ **Yes** ☐ **No**

Date Deployed:	
Date Retreived:	

Frequency of data: ☐ Daily ☐ Other: _______
Timing of data: ☐ 1-3pm ☐ Other: _______

Describe sensor location within reach:

Total Suspended Solids Sample Obtained? Sample Type:

Date Obtained:	

Describe location within reach:

Other Sensor Deployed? Sensor Type:

Date Deployed:	
Date Retreived:	

Frequency of data (if applicable): _______

Describe location within reach:

ALSO IDENTIFY ALL SENSOR LOCATIONS ON SUB-REACH SKETCH ON PROJECT REACH FORM

-MPCA Biological Monitoring Program-

Macroinvertebrate Sample Sorting Bench Sheet

Field Number	Sample Date	Sample Type *	# Sample Bottles	Sample Sorting Date		# Organisms Picked	# Squares Picked**	L/R (y/n)	Chiro toVial (y/n)
				Begin	End				

* QMH, QR, HD, WTL

** Applies only to samples being subsampled

-MPCA Biological Monitoring Program-

Macroinvertebrate Sorting QC Form

Sample Field Number	Sampling Date	Sample Type	Initials of QC Sorter	# Organisms found in QC	# Organisms originally found in sample	Sorting Efficiency	Date QC Sort Completed

-MPCA Biological Monitoring Program-

Macroinvertebrate Identification Lab Bench Sheet

Field Number	**Sample Date**
Site Name	**Taxonomist:**
Sample Type QMH* QR HD other____________	**Date of Sample ID:** _____/_____/_____

*A processed QMH sample consists of 2 parts, the subsample(ss) and large/rare (l/r), both parts must be identified

Order/Family	Genus	Species/Notes	ss	l/r
Ephemeroptera				
Baetiscidae	Baetisca			
Caenidae	Bracycercus			
	Caenis			
Ephemerellidae	Attenella			
	Ephemerella			
	Serratella			
Ephemeridae	Ephemera			
	Hexagenia			
Leptohyphidae	Tricorythodes			
Leptophlebiidae	Leptophlebia			
	Paraleptophlebia			
Polymitarcidae	Ephoron			
Potamanthidae	Anthopotamus			
Heptageniidae	Epeorus			
	Heptagenia			
	Stenacron			
	Stenonema			
Isonychiidae	Isonychia			
Ametropodidae	Ametropus			
Baetidae	Acerpenna			
	Baetis			
	Callibaetis			
	Heterocloeon			
notes/additional taxa				
Plecoptera				
Leuctridae				
Taeniopterygidae				
Perlidae	Acroneuria			
	Agnetina			
	Attaneuria			
	Neoperla			
	Paragnetina			
	Perlinella			
Perlodidae				
Pteronarcyidae	Pteronarcys			
notes/additional taxa				
Lepidoptera				
Pyralidae	Paraponyx			
	Petrophila			
notes/additional taxa				
Megaloptera				
Corydalidae	Chauliodes			
	Corydalus			
	Nigronia			
Sialidae	Sialis			
notes/additional taxa				
Isopoda				
Asselidae	Asselus			
notes/additional taxa				

Order/Family	Genus	Species/Notes	ss	l/r
Odonata				
Calopterygidae	Calopteryx			
	Hetaerina			
Coenagrionidae	Argia			
	Enallagma			
	Nehalennia			
Lestidae	Lestes			
Aeshnidae	Aeschna			
	Anax			
	Basiaeschna			
	Boyeria			
Cordulegastridae	Cordulegaster			
Corduliidae	Cordulia			
	Dorocordulia			
	Epitheca			
	Somatochlora			
Gomphidae	Dromogomphus			
	Gomphurus			
	Gomphus			
	Hagenius			
	Ophiogomphus			
	Phanogomphus			
	Progomphus			
notes/additional taxa				
Hemiptera				
Belostomatidae	Belstoma			
	Corixidae			
Corixidae	Hesperocorixa			
	Sigara			
	Trichocorixa			
Nepidae	Ranatra			
Notonectidae	Buenoa			
	Notonecta			
notes/additional taxa				
Amphipoda				
Talitridae	Hyallela	azteca		
Gammaridae	Gammarus			
notes/additional taxa				
Decapoda				
Cambaridae	Cambarus			
	Orconectes			
	Procambarus			
notes/additional taxa				
Pelecypoda				
Sphaeriidae				
Corbiculidae				
Unionidae				
notes/additional taxa				

entered into DataInverts by______ --- (initials) date_________

Order/Family	Genus	Species/Notes	ss	l/r	Order/Family	Genus	Species/Notes	ss	l/r
Trichoptera					**Diptera**				
Dipseudopsidae	Phylocentropus				Ceratopogonidae	Alluaudomyia			
Hydropsycidae	Ceratopsyche					Atrichopogon			
	Cheumatopsyche					Bezzia			
	Diplectrona					Ceratopogon			
	Hydropsyche					Culicoides			
	Potamyia					Nilobezzia			
Philopotamidae	Chimarra					Palpomyia			
	Dolophilodes					Probezzia			
Polycentropodidae	Cernotina					Sphaeromias			
	Cyrnellus				Chironomidae	G.			
	Neureclipsis				Dixidae	Dixa			
	Paranyctiophylax					Dixella			
	Polycentropus				Simuliidae	Simulium			
Psychomyiidae	Lype				Tipulidae	Antocha			
	Psychomyia					Dicranota			
Glossosomatidae	Agapetus					Hexatoma			
	Glossosoma					Limnophila			
	Protoptila					Limonia			
Hydroptilidae	Hydroptila					Pilaria			
	Leucotrichia					Tipula			
	Mayatrichia				Athericidae	Atherix			
	Oxyethira				Empididae	Hemerodromia			
	Orthotrichia				Tabanidae	Chrysops			
Rhyacophilidae	Rhyacophila					Tabanus			
Brachyecentridae	Brachycentrus				***notes/additional taxa***				
	Micrasema								
Helicopsychidae	Helicopsyche								
Lepidostomatidae	Lepidostoma								
Leptoceridae	Ceraclea				**Coleoptera**				
	Leptocerus				Dytiscidae	Agabus			
	Mystacides					Laccophilus			
	Nectopsyche					Liodessus			
	Oecetis				Gyrinidae	Dineutus			
	Trianodes					Gyrinus			
Limnephilidae	Limnephilus				Elmidae	Ancyronyx			
	Hydatophylax					Dubiraphia			
Molannidae	Molanna					Macronychus			
Phryganeidae	Phryganea					Optioservus			
	Ptilostomis					Stenelmis			
Sericostomatidae	Agarodes				Hydrophilidae	Berosus			
notes/additional taxa						Helocombus			
						Laccobius			
						Sperchopsis			
						Tropisternus			
Gastropoda									
Ancylidae	Ferrissia								
Planorbidae	Helisoma				**Annelida**	Oligochaeta			
	Promentus					Hirudinea			
	Planorbula				***notes/additional taxa***				
	Gyraulus								
Vivaparidae	Campeloma								
Lymnaeidae	Lymnaea								
	Bulimnea								
	Fossaria				Hydracarina (trombidoformes, acarina)				
Hydrobiidae	Amnicola				Nematoda				
Pleuroceridae	Pleurocera				*notes/additional taxa*				
Physidae	Physa								
notes/additional taxa									

entered into DataInverts by______ --- (initials) date__________

-MPCA Biological Monitoring Program-

Macroinvertebrate Identification QC Form

Field Number	Sample Date	Identifiers' Initials		Discrepancies		Comments	Total # of Conflicts	Total # of Taxa	Precision	
		Original ID	QC ID	Original Identification	QC Identification				Original ID	QC ID

MPCA Stream Monitoring Program

STREAM INVERTEBRATE VISIT FORM

Stream Name:		**Date:**	
Field Number:	**County:**	**Crew:**	
Water Chemistry	Tape Down: ___.____ (1/100ths ft) Location: ____________		

Time: (24 hr) ___:___ Air Temp:______ (ºC) Water Temp:______ (ºC) Conductivity: __________ (umhos@25ºC)

DO: __________(mg/L) DO % Saturation:____________ pH:_________ Secchi -Tube: __________ (cm)

Water Level: Normal Below _______ (m) Above _______ (m) Color _______________ (pcu)

*****If Flagging is not found or if establishing a new site, fill out GPS info*****

Coordinates	**LATITUDE**	**LONGITUTDE**	**Time:**
Field GPS:	_____ . _________	_____ . _________	**Name:**

Notes:

Stream Classification Information

Flow	Flow over riffle(s)	High / Med / Low / NA	Channel	Excavated, trapezoidal channel	%
Flow	Flow at reach constriction	High / Med / Low / NA	Channel	Shallow excavation, channelized wetland	%
Flow	Flow over run	High / Med / Low / NA	Channel	Natural channel	%
Flow	General flow pattern	High / Med / Low / NA	Vegetation	Emergent, aquatic vegetation in channel	Ext / Mod / Sparse / NA
Flow	Intermittent sections	Yes / No	Vegetation	Emergent, aquatic vegetation along bank	Ext / Mod / Sparse / NA
Habitat	Riffle (with flow) present in reach c		Vegetation	Floating or submerged aquatic vegetation	Ext / Mod / Sparse / NA
Habitat	Riffle (with flow) present outside of reach c		Vegetation	Loosely attached filamentous algae	Ext / Mod / Sparse / NA
Habitat	(riffles do not include riprap associated with bridges or bank stabilization)		Vegetation	Firmly attached algae or submerged veg	Ext / Mod / Sparse / NA
Habitat	Dominant invertebrate habitat (circle two) Riffle | Rocky Run-Pool | Aquatic Macrophyte | Bank-Overhanging Veg | Wood | Leaf				
Substrate	Dominant Run Substrate	bedrock / boulder / cobble / gravel / sand / silt			
Substrate	Dominant Pool Substrate	bedrock / boulder / cobble / gravel / sand / silt			
Substrate	Dominant Substrate receiving flow	bedrock / boulder / cobble / gravel / sand / silt			
Substrate	Dominant Substrate in reach	bedrock / boulder / cobble / gravel / sand / silt			

c Stream displays a typical riffle-run pool morphology c adequate flow to maintain riffle organisms c inadequate flow to maintain riffle organisms

c Stream has adquate flow to maintain riffle organism, but does not have suitable coarse substrate to support these assemblages (riffles, rock substrate in runs or pools)

c Stream has adquate flow to maintain riffle dwelling organism, woody debris has replaced rocks as primary coarse substrate

c Stream is low gradient, stream bed is predominately fine substrate, inadequate flow to maintain riffle organisms

Invertebrate Sample Information

Qualitative Multi-Habitat Sample (QMH)

Divide 20 samples equally among habitat types present in the reach. If three habitat types are present take 7 samples in each of the three dominant habitats (for a total of 21). If a habitat is present, but not in abundance to sample in equal proportion to other habitats, sample as much as possible and divide the remaining samples between the dominant habitat types.

a	Habitat			#Samples
c	rock riffle/run	Flow adequate to carry insects into net		
	rock substrate	Artificial flow needed to carry insect into net		
c	aquatic macrophyte			
c	undercut bank, overhanging veg			
c	snag, woody debris, root wad			
c	leaf pack			

Number of multihabitat containers: _____

Additional Biological Information

Presence of freshwater sponge ----------- yes / no

Presence of exotic species ---------------- yes / no

Name of exotic(s) if present:

(voucher a specimen if not present in sample)

Presence of mussels ----------------------yes / no

Description of mussel density and/or mussel bed location:

Notes

Pictures #: __ DD __ DU __ MD __ MU __ UD __ UU

Stream Sample External Label:

MPCA Bioassessment – Invertebrate Sample
Sample Preservative - 100% reagent alcohol / 10% formalin
Sample Type: QMH / RTH
Sample Composition: Riffle / Bank / Wood / Veg
Date ____/____/20___ (mm/dd/yyyy)
Station Name ____________________________
Station ID ___________________
Site Visit 1 / 2 Sample Jar ___ of ___
Collectors _____________________________

Stream Sample Internal Label:

Invertebrate Sample – sample type __________
Site Name:_______________________________
Field Number_____________________________
Date:_____/_____/_____ Bottle No. _____of____
Collected by: ____________________________
____

FISH SURVEY RECORD MPCA

Field Number:	Stream Name:
Date (mm/dd/yyyy):	Crew:
Gear Type (circle one): Backpack* Stream-electrofisher Boom-electrofisher Mini-Boom *Type of Backpack (circle one): Generator LR-24 Halltech	
Channel Position: Right Bank Mid-Channel Left Bank (circle one if boom-electrofisher site)	
Distance (m): Time Fished (sec): Identified By:	
Visit Comments:	

Species (common name)	Length Range (mm)	Weight (g)	Number	Anomalies or YOY	Voucher Number	Voucher Pics
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						
26.						
27.						
28.						

Anomalies: **A**-anchor worm; **B**-black spot; **C**-leeches; **D**-deformities; **E**-eroded fins; **F**-fungus; **G**-yellow grub; **L**-lesions; **N**-blind; **P**=parasites; **PL**-parasite lesion; **Y**-popeye; **S**-emaciated; **W**-swirled scales; **T**-tumors; **Z**-other. (Heavy [**H**] or Light [**L**] code may be combined with above codes).

(Cont.)

Species (common name)	Length Range (mm)	Weight (g)	Number	Anomalies or YOY	Voucher Number	Voucher Pics
29.						
30.						
31.						
32.						
33.						
34.						
35.						
36.						
37.						
38.						

INDIVIDUAL OR BATCH MEASUREMENTS

Species (common name)	Length Range (mm)	Weight (g)	Number	Anomalies or YOY	Voucher Number	Voucher Pics
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						
26.						
27.						
28.						
29.						
30.						
31.						
32.						

(Revised May 2015)

VISIT SUMMARY MPCA

VISIT INFORMATION ==

Field Number:______________________ Stream Name:____

Date (mm/dd/yy):___________________ Crew:____

Visit Result and Reason (check one in appropriate column):

Reportable
- ☐ Reportable: Sufficient and representative sample
- ☐ Reportable: Low sample size (<25 fish)

Non-reportable
- ☐ Non-reportable: Unsatisfactory taxis
- ☐ Non-reportable: Outside base flow, high

Replicate
- ☐ Replicate: Sufficient and representative sample
- ☐ Replicate: Low sample size (<25 fish)

Not sampled
- ☐ Non-sampleable: Insufficient flow
- ☐ Non-sampleable: Beaver dam – too deep/wide
- ☐ Non-sampleable: No definable channel
- ☐ Non-sampleable: Other (explain in comments)

If **GPS** coordinates taken during site visit:

DS FileName:________________ **X** FileName:________________ **US** FileName:________________

DS Lat:_____________________ **X** Lat:_____________________ **US** Lat:_____________________

DS Lon:_____________________ **X** Lon:_____________________ **US** Lon:_____________________

FIELD WATER CHEMISTRY===

Time (24 hr clock):_______________ Water Temp. (°C):______________ Air Temp. (°C):_____________

HACH Meter #:_________________ Conductivity (umhos@25°C):______________ pH:_____________

Dissolved Oxygen (DO)(mg/l):___________ %DO Saturation:__________ Secchi Tube:_______ /100cm

Water Level: ☐ Normal ☐ Below ________(m) ☐ Above ________(m)

Precipitation (if box(es) checked indicate intensity in comments) ☐ Currently raining ☐ Rain yesterday

LAB WATER CHEMISTRY ==

Chem. Sample ID (field sample):_______________ Chem. Sample ID (field duplicate):_______________

Collection Time (field sample):_________________ Collection Time (field duplicate):_________________

TAPE DOWN DISTANCE MEASUREMENT ==================================

Tape Down Length (100ths of ft):____

Location/Description of Reference Mark (if made):____

____

CHANNEL CHARACTERISTICS===

Transect Spacing (m):_______________ Station Length (m):________________

Channel Condition (check appropriate box): ☐ Natural Channel ☐ Recent Channelization ☐ Old Channelization

Visual Condition (refer to the ratings and codes on the backside of this form):

Appearance:________ Recreational Suitability:_________ Stream Condition:______ / ______ / ______

Does the site appear to be low gradient? ☐ No ☐ Yes (use checkboxes on back to describe observations)

COMMENTS/NOTES:____

____

____

____

(Revised April 2014)

Visual Condition - Ratings and Codes

RATING	APPEARANCE DEFINITION
1A	Clear – crystal, clear transparent water
1B	Tea-colored – transparent water, which has been colored by dissolved organic matter from upstream bogs or wetlands
2	Cloudy – not quite crystal clear; cloudy white, gray or light brown
3	Muddy – cloudy brown due to high sediment levels
4	Green – due to algae growth; indicative of excess nutrients released into stream
5	Muddy AND Green – a combination of cloudy brown from high sediment levels and green from algae growth

RATING	RECREATIONAL SUITABILITY DEFINITION
1	Beautiful, could not be better
2	Very minor aesthetic problems: excellent for body-contact recreation
3	Body-contact recreation and aesthetic enjoyment slightly impaired
4	Recreation potential and level of enjoyment of the stream substantially reduced (would not swim but boating/canoeing is okay)
5	Swimming and aesthetic enjoyment of the stream nearly impossible

STREAM CONDITION: **N**=Normal, **L**=Low, **Z**= No Flow, **D**=Dry, **I**=Interstitial, **H**=High
SW=Swift, **SL**=Slow, **MO**=Moderate
C=Clear, **M**=Muddy, **O**=Other

Low Gradient Site Characteristics (check all that apply) (note any comments):

- ☐ Flow velocity only slow, or slow and moderate
- ☐ Riffles absent or representing very low percentage of reach (typically <5%)
- ☐ Dominated (>80%) by fines (silt, sand, detritus), coarse substrate uncommon (<10%)
- ☐ Wetland vegetation (cattails, arum, water lily, etc.) in channel or riparian zone
- ☐ It looks like a low gradient stream

PROCEDURE FOR TEMPERATURE LOGGER DEPLOYMENT AT STREAM MONITORING SITES

updated 04/30/2015

I. PURPOSE

To describe the methods used by the Minnesota Pollution Control Agency's (MPCA) Biological Monitoring Program to place, check and retrieve temperature loggers that are placed at stream biological monitoring sites.

II. SCOPE/LIMITATIONS

This procedure applies to all sites where a temperature logger is placed.

III. GENERAL INFORMATION

Sites may be selected to have a temperature logger placed for a number of reasons including:

1) Site is a designated coldwater stream
2) Site is a 10x water chemistry site
3) Site is a Long Term Monitoring Reference site
4) Site thought to be coldwater, although not currently designated
5) Site is in coldwater/warmwater transition zone
6) Site is warmwater and chosen for further warmwater or climate change data collection

IV. REQUIREMENTS

A. Qualifications of crew leaders: The crew leader must be a professional aquatic biologist with a minimum of a Bachelor of Science degree in aquatic biology or closely related specialization. Field crew leaders should also possess excellent map reading skills and a demonstrated proficiency in the use of a GPS (Global Positioning System) receiver and orienteering compass.

B. Qualifications of field technicians/student interns: A field technician/student intern must have at least one year of college education and coursework in environmental and/or biological science.

C. General qualifications: All personnel conducting this procedure must have the ability to perform rigorous physical activity. It is often necessary to wade through streams and/or wetlands, canoe, or hike for long distances to reach a sampling site where a temperature logger may be placed.

V. RESPONSIBILITIES

A. Field crew leader: Implement the procedures outlined in the action steps and ensure that the data generated meets the standards and objectives of the Biological Monitoring Program.

B. Technicians/interns: Implement the procedures outlined in the action steps, including maintenance and stocking of equipment, data collection and recording.

VI. QUALITY ASSURANCE AND QUALITY CONTROL

A. Logger QA/QC: Every winter, all data loggers will be deployed and tested in a lab setting. All loggers will also be checked for battery life during data downloading in the fall.

B. Data QA/QC: All data collected by each temp logger each summer will be verified by trained staff to assure temperature logger was logging properly, and remained in the water, out of the sun, and did not become buried in sediment throughout the summer

VII. TRAINING

A. All inexperienced personnel will receive instruction from a trainer designated by the program manager. Major revisions in this protocol require that all personnel be re-trained in the revised protocol by an authorized trainer.

B. The field crew leader will provide instruction in the field and administer a field test to ensure personnel can execute this procedure.

VIII. ACTION STEPS

A. Equipment List: Verify that all necessary items are present before commencement of this procedure (Table 1).

B. Method: Sites that require temperature loggers can generally be put in during recon, but if high water persists may be put in at a later date, but no later than May 31st. If suitable deployment locations do not exist within the stream reach, temperature logger can be placed above or below the stream reach.

1) Record the Temperature Logger Serial Number on the Temp Logger form before deploying the logger.

2) Find a suitable location that the temperature logger can be placed.

   a. The logger should remain in the water column during the entire deployment and not exposed to the surface.

   b. The location should be: out of direct sunlight; in flowing water; intermediate depth.

   c. Logger should be placed no closer than 6 inches from the stream bottom to avoid siltation and burial.

   d. Measures should be taken to avoid backwaters, eddies, standing water, point source discharges, lake outlets, springs, groundwater seeps, beaver activity, wetlands and wetlands in stream margins.

   e. Measures should also be taken to choose a location that will protect the logger from future high velocities, substrate movement and debris that may dislodge the logger.

   f. Water should be well mixed. This can be verified by taking numerous temperature measurements near the deployment location. A 10 measurement cross-section can be taken looking at variable stream temperature, dissolved oxygen levels and conductivity. Variability in measurements may indicate sources of thermal variation. If this is true, find a new deployment location.

   g. Extra caution should be taken to place the temperature logger in a discrete location so they are not easily seen unless specifically looking for them. For watershed sites, locating the temperature logger at X, or further away from the road is preferred.

3) Attach the temperature logger to protective radiation shield.

   a. Deployment methodologies.

      i. Rebar – Adhere logger tightly to rebar with wire or heavy duty zip ties. In softer substrates this can be done by hand but in some areas hammers will help secure the rebar into the stream bed. Acceptable method in areas not heavily impacted by fine sediments (sand silt) or streams with unpredictable flows that may dislodge the rebar. Bent rebar can provide extra stability by securely anchoring the rebar into the substrate in two locations as well as allowing for easier deployment and retrieval.

      ii. Dog tie – Adhere logger tightly to end of triangle tie with wire or heavy duty zip tie. Screw tie down into side of stream bank within the channel. Logger should be placed no closer than 6 inches from the stream bank to avoid potential groundwater influence.

Acceptable method in streams dominated by fine sediments, not suitable for streams with unstable stream banks that may collapse during deployment.

iii. Airline Cable – Adhere wire to stable location (rebar on stream bank not prone to collapse, around a tree on stream bank not prone to falling into the stream during a high flow event, a large boulder (in stream laden with bed rock, only if no fine sediment are present), or a bridge pillar or pilon). Wire can be crimped using cable ferrules or wire rope clips. If wire is adhered to object on stream bank measures should be taken to hide evidence of the deployment from would be vandals or curious citizens by hiding exposed wire under vegetation or rocks.

4) Take a GPS waypoint of the temperature logger. Name the waypoint with the prefix “TL” followed by the logger serial number (eg.,TL644619). If the logger is later moved, and a new GPS point collected, label the new waypoint with the prefix “TL”, the logger serial number, followed by the letter “M” for “moved” (e.g., TL644619M).

5) If the logger is deployed in a low traffic area, consider documenting the logger’s location with a piece of flagging attached to a nearby tree or on the rebar stick.

6) Record the temperature of the water in the exact location of the logger. This should be done with a calibrated high precision electronic thermometer with a lead attached to the probe to get as close to the logger as possible.

7) Photograph the location of the logger by taking a photograph both upstream and downstream at deployment location and perpendicular to the stream towards the stream bank. Photographs will ease relocating the logger at future site visits and upon retrieval.

C. Temperature Logger Form

This form provides location, fish visit check, and retrieval notes for each temperature logger deployed. The form is completed upon placement of the temperature logger at the site.

C.1. Deployment Information

1) *Field Number* – A seven-digit code that uniquely identifies the station. The first two digits identify the year the station was established, the second two identify the major river basin, and the last three are numerically assigned in sequential order (example 02UM001). Assign the station an appropriate field number. For EMAP sites the last three digits should correspond to the sequential number provided by EPA for each site.

1) *Stream Name* – The name of the stream as shown on the most recent USGS 7.5” topographic map. Include all parts of the name (i.e. “North Branch”, “Creek”, “River”, “Ditch”, etc.).

2) *Date* – The date fish sampling is conducted in month/day/year format (MM/DD/YY).

2) *Crew* – The personnel who conducted the temperature logger deployment.

3) *Temp Logger Serial Number* – The unique identifier of the individual temperature logger.

4) *GPS Date* – The date that the final GPS file is taken in month/day/year format (MM/DD/YY).

5) *GPS Time* – The time of day (24-hour clock) that the GPS file is taken.

6) *Latitude* – The angular distance north or south of the equator. Record the latitude of the temperature logger as displayed on the GPS receiver in degrees, minutes, seconds format.

7) *Longitude* – The angular distance east or west of the prime meridian. Record the longitude of the temperature logger as displayed on the GPS receiver in degrees, minutes, seconds format.

8) *Placement Description* – Detailed description of where the temperature logger was placed in relation to all features of the stream (Riffle/Run/Pool) and location within the longitudinal reach (Upstream (US) / Mid

reach(X) / Downstream (DS) and the lateral reach left bank (LB) / right bank (RB) / mid channel (Mid). Special attention needs to be given so staff members are able to come back and retrieve the logger based on this description.

9) *Comments* – Written explanation of the temperature logger's location and placement. Special attention needs to be given so staff members are able to come back and retrieve the logger based on this description. Example: Temp logger 5 meters upstream from X flag in pool 3 feet off of right bank. Pounded rebar down in gravel until TL was 6" off bottom.

10) *Photographs of reach segments (frame #)* - In the first photograph, identify the site by writing the field number on a piece of paper held within the picture frame. Take two pictures (one facing upstream and one facing downstream) at the exact deployment location and a straight shot perpendicular to (or facing) the stream bank. Record the order the photos were taken or the frame numbers of each photograph to assist in identifying the pictures for each site after developing or downloading.

11) *Protective case* – Indicate type of radiation shield (case) utilized during deployment PVC or Metal.

12) *Precision thermometer #* - Identify meter utilized to take temperature during temperature logger deployment.

13) *Temperature (C)* – Temperature recorded during temperature logger launch. Temperature is tested with a calibrated thermometer.

14) *Time*: Indicate the time of day (24-hour clock) that the temperature is taken at deployment.

C.2. <u>Fish Visit Information</u>:

1) Site Visit 1

   a. *Date* – The date the temperature logger check was completed.

   b. *Crew* – The personnel who conducted the temperature logger check.

   c. *Was temp logger checked?* – A Yes/No option indicating whether or not the temperature logger was checked.

   d. *TL in good location?* – A Yes/No option indicating whether or not the temperature logger was in an appropriate location.

   e. *Comments* – Any additional comment about the condition the temp logger was found in.

   f. *Precision thermometer #* - Identify meter utilized to take temperature during temperature logger during site visit.

   g. *Temperature (C)* – Temperature recorded during site visit. Temperature is tested with a calibrated thermometer.

   h. *Time*: Indicate the time of day (24-hour clock) that the temperature is taken.

2) Site Visit 2

   a. *Date* – If there was a second visit, the date the temperature logger check was completed.

   b. *Crew* – If there was a second visit, the personnel who conducted the temperature logger check.

   c. *Was temp logger checked?* – If there was a second visit, a Yes/No option indicating whether or not the temperature logger was checked.

   d. *TL in good location?* – If there was a second visit, a Yes/No option indicating whether or not the temperature logger was in an appropriate location.

e. *Comments* – If there was a second visit, any additional comment about the condition the temp logger was found in.

f. *Precision thermometer #* - If there was a second visit, identify meter utilized to take temperature during site visit.

g. *Temperature (C)* – If there was a second visit, temperature recorded during site visit. Temperature is tested with a calibrated thermometer.

h. *Time:* If there was a second visit, indicate the time of day (24-hour clock) that the temperature is taken.

3) Site Visit 3

a. *Date* – If there was a third visit, the date the temperature logger check was completed.

b. *Crew* – If there was a third visit, the personnel who conducted the temperature logger check.

c. *Was temp logger checked?* – If there was a third visit, a Yes/No option indicating whether or not the temperature logger was checked.

d. *TL in good location?* – If there was a third visit, a Yes/No option indicating whether or not the temperature logger was in an appropriate location.

e. *Comments* – If there was a third visit, any additional comment about the condition the temp logger was found in.

f. *Precision thermometer #* - If there was a third visit, identify meter utilized to take temperature during site visit.

g. *Temperature (C)* – If there was a third visit, temperature recorded during site visit. Temperature is tested with a calibrated thermometer.

h. *Time*: If there was a third visit, indicate the time of day (24-hour clock) that the temperature is taken.

C.4. <u>If TL was moved…</u>

1) *Temp Logger Serial Number* – The unique identifier of the individual temperature logger.

2) *GPS Date* – The date that the final GPS file is taken in month/day/year format (MM/DD/YY).

3) *GPS Time* – The time of day (24-hour clock) that the GPS file is taken.

4) *Latitude* – The angular distance north or south of the equator. Record the latitude of the temperature logger as displayed on the GPS receiver in degrees, minutes, seconds format.

5) *Longitude* – The angular distance east or west of the prime meridian. Record the longitude of the temperature logger as displayed on the GPS receiver in degrees, minutes, seconds format.

6) *Placement Description* – Detailed description of where the temperature logger was placed in relation to all features of the stream (Riffle/Run/Pool) and location within the longitudinal reach (Upstream (US) / Mid reach (X) / Downstream (DS) and the lateral reach left bank (LB) / right bank (RB) / mid channel (Mid). Special attention needs to be given so staff members are able to come back and retrieve the logger based on this description.

C.5. <u>Retrieval Notes</u>:

i. *TL Retrieved* – Check box, indicates whether or not the temperature logger was collected.

j. *Date Attempted* – If an unsuccessful attempt to collect temperature logger was made, indicate date here.

k. *Crew* – The personnel who conducted the unsuccessful temperature logger check.

l. *Date Retrieved* – The date the temperature logger retrieval was completed.

m. *Retrieval Crew* - The personnel who conducted the successful temperature logger retrieval.

n. *Comments* – Any additional comments about where the temperature logger was found, especially noting if there were any issues with its location. If the temperature logger retrieval was unsuccessful indicate information about the search and whether or not additional attempts are warranted.

o. *Precision thermometer #* - Identify meter utilized to take temperature at temperature logger retrieval.

p. *Temperature (C)* –Temperature recorded during logger retrieval. Temperature is tested with a calibrated thermometer.

q. *Time:* Indicate the time of day (24-hour clock) that the temperature is taken at retrieval.

Table 1. Equipment List – This table identifies all equipment needed in order to deploy a temperature logger at a stream biological monitoring site.

Stream information sheet – for location of site

1:24,000 USGS topographical maps – for navigation to and from the sampling site

County Platte maps – for determining land ownership

Aerial photographs – for navigation to and from the sampling site

DeLorme atlas – for vehicular navigation to and from the sampling site

GPS receiver – to locate and document temperature logger location

Flagging – to mark the temperature logger location if needed

Pencil – for filling out forms

Permanent marker – to label flagging

Clipboard – to store forms/maps and record data

Waders – because it is necessary to enter the stream to place temperature logger

Cellular telephone – to contact landowners, to communicate between field crews, and for safety

Rebar – for anchoring temperature logger into the stream bed

Cable – for anchoring temperature logger to stable object

Dog ties – for anchoring temperature logger to side of stream bank

Cable Ferrules – for securing temperature logger to cable

Wire Cutter and Crimper – for cutting wire and securing cable ferrules to cable

Heavy duty Zip ties – for securing logger to rebar and dog ties

Hammer – to assist in getting rebar into the stream bed

Temperature Logger – to record temperature data

Wire – to attach temperature logger to rebar or dog tie

Temperature Logger Cases – radiation shields to protect temperature logger during deployment and (metal) enable deployment in streams with hard substrates (bedrock, cobble, boulder)

Water Chemistry Meter – to take DO and Conductivity measurements during deployment to insure water at deployment location is well mixed.

Calibrated Precision Thermometer – to record temperature at temperature logger deployment, site visits and temperature logger retrieval

Temperature Logger Form

(Revised 4/2015)

Deployment Information		
Field Number:	Stream Name:	
Date:	Crew:	
Temp Logger Serial Number	GPS Date	GPS Time
Field GPS	Latitude	Longitude
Decimal Degrees	_____.______________	_____.______________
Placed in a: Riffle Run Pool	Placed Near: US X DS / LB RB Mid	
Comments:		

Photos of Temp Logger Deployment			
Site number:	Logger looking DS:	Logger Looking US:	Straight on:
Case used : PVC or Metal	Deployment Method:		

Precision Thermometer		Temperature (C)		Time	

Visit information	
Date:	Crew:
Was temp logger checked?	TL in a good location (not at surface, or buried)?
Comments:	

Precision Thermometer #:		Temperature (C)		Time	

Date:	Crew:
Was temp logger checked?	TL in a good location (not at surface, or buried)?
Comments:	

Precision Thermometer #:		Temperature (C)		Time	

Date:	Crew:
Was temp logger checked?	TL in a good location (not at surface, or buried)?
Comments:	

Precision Thermometer #:		Temperature (C)		Time	

If TL was moved to a new location, please describe and include GPS Coordinates		
Temp Logger Serial Number	GPS Date	GPS Time
Field GPS	Latitude	Longitude
Decimal Degrees	_____.____________	_____.______________
Placed in a: Riffle Run Pool	Placed Near: US X DS LB RB Mid	
Comments:		

Retrieval Notes		
TL retrieved? ☐	If no, Date Attempted :	Crew:
Date retrieved:	Retrieval Crew:	
Comments: (At water surface, out of water, buried, no shade, surrounded by veg, looked good)		

Precision Thermometer #:		Temperature (C)		Time	