Wisconsin Stream Quantification Tool and Debit Calculator

User Manual (BETA)

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Beta Version, 2023

Lead Agencies:

United States Environmental Protection Agency, Region 5

United States Army Corps of Engineers, St. Paul District

Wisconsin Department of Natural Resources

Contractors:

Ecosystem Planning and Restoration

Stream Mechanics

McCarthy Ecology

Contributing Agencies:

Land and Water Resources Department, Dane County, WI

United States Geological Survey

Wisconsin Department of Natural Resources:
Office of Great Waters – Great Lakes and Mississippi River

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The WISQT is the collaborative result of agency representatives, collectively referred to as the WISQT Steering Committee (WISQT SC) and WISQT Technical Committee (WISQT TC).

Steering committee members include:

Melissa Blankenship, EPA Region 5
James Brodzeller, Land and Water Resources Department, Dane County, WI
Leslie Day, St. Paul District U.S. Army Corps of Engineers (USACE)
Marie Kopka, St. Paul District USACE
April Marcangeli, St. Paul District USACE
Tom Nedland, WDNR
Kerryann Weaver, EPA Region 5

Technical committee members include:

Jill Bathke, St. Paul District USACE
James Brodzeller, Land and Water Resources Department, Dane County, WI
Kevin Denn, St. Paul District USACE
Matt Diebel, United States Geological Survey
Eric Hanson, St. Paul District USACE
Faye Healy, St. Paul District USACE
Madeline Magee, Office of Great Waters – Great Lakes and Mississippi River, WDNR
April Marcangeli, St. Paul District USACE
Mike Miller, WDNR
Tom Nedland, WDNR
Eric Norton, St. Paul District USACE
Kurt Rasmussen, WDNR
Bradd Simms, WDNR
Jon Simonsen, WDNR
Kerryann Weaver, EPA Region 5

Many others provided valuable contributions to the WISQT, Debit Calculator, and Wisconsin documents, including: Alex Latzka, Amy Minser, Phil Kaufmann, Matt Mitro, Jennifer Gibson, and Alex Chapla who provided valuable input, review, and comment throughout regionalization and document development. Will Harman (Stream Mechanics, EPR) Paxton Ramsdell (EPR), Beth Allen (EPR), Cidney Jones (EPR) and Julia McCarthy (McCarthy Ecology) provided technical support and regionalization support under EPA IDIQ contract no. 68HERC21D0008. Peer review and contract support was provided by Amy James (EPR).

Table of Contents

List of Figures

List of Tables

Preface

Document History

The Wisconsin Stream Quantification Tool (WISQT) and Debit Calculator were developed using the Minnesota Stream Quantification Tool v2.0 (MNSQT SC 2020) as a template, while also incorporating updates and lessons learned from other SQTs. All documents have been edited for use in Wisconsin.

Document Availability and Revisions

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

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

Or at the Stream Mechanics website:

https://stream-mechanics.com/stream-quantification-tool/

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

The following WISQT workbooks and documents are available:

- WISQT 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 Procedures (USACE 2023) and the User Manual (this document).
- Wisconsin Stream Quantification Tool and Debit Calculator BETA User Manual (User Manual) – This manual describes the SQT and Debit Calculator workbooks, all calculations performed by the workbooks, and how to collect data and calculate inputs for the WISQT.
    - Appendix A provides information to assist users in preparing for and collecting data for the metrics found in the WISQT workbook and Debit Calculator workbook.
    - Appendix B provides field forms. These forms are available in Microsoft Excel workbook format in addition to being included with the User Manual in PDF format.
- Scientific Support for the WISQT (WISQT SC, *in draft*) – This document provides the rationale for selecting the function-based parameters and metrics, developing the reference curves, determining stratification, an overview of scoring, and references used in the WISQT.
- St. Paul District Stream Mitigation Procedures – USACE (2023) procedures for using the WISQT and Debit Calculator workbooks to calculate credits and debits.

Future versions of the workbooks and manuals will be updated and revised periodically as additional data are gathered and reference curves and metrics are applied to local projects. Field data supporting refinement of reference curves and evaluation of metrics are appreciated.

The WISQT 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 WISQT (WISQT SC, *in draft*).

Send questions and proposals to: Technical Services Branch, St. Paul District US Army Corps of Engineers, 332 Minnesota Street, Suite E1500, St. Paul, Minnesota 55101 or call (651) 290-5525; or email StPaulSQT@usace.army.mil. More information on the SQT and District mitigation guidance can be found at https://www.mvp.usace.army.mil/Missions/Regulatory/.

DISCLAIMER

The WISQT and Debit Calculator, including workbooks and supporting documents, may be used for a variety of regulatory and non-regulatory applications. The WISQT is intended to inform permitting and compensatory mitigation decisions within the Clean Water Act Section 404 (CWA § 404) and Rivers and Harbors Act Section 10 (RHA § 10) programs. The metrics are scored based on a site's 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 § 10 activities. The WISQT can also be applied to restoration projects outside of the CWA § 404 or RHA § 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 USACE 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.

Version

WISQT Version	**Date finalized**	**Description**
BETA	May 19, 2023	Draft version for review and comment.

Acronyms

BEHI – Bank Erosion Hazard Index
BHR – Bank Height Ratio
BMP – Best Management Practice
CFP – Concentrated Flow Point
CFPI – Concentrated Flow Point Index
CFR – Code of Federal Register
CWA § 404 – Section 404 of the Clean Water Act
d50 – Median particle size
DBH – Diameter at Breast Height
DPI – Diatom Phosphorus Index
ECS – Existing Condition Score
EPA – United States Environmental Protection Agency
ER – Entrenchment Ratio
FF – Functional Feet
FFS – Functional Feet Score
fIBI – Fish Index of Biotic Integrity
HBI – Hilsenhoff Biotic Index
HUC – Hydrologic Unit Code
IBI – Index of Biotic Integrity
LDA – Lateral Drainage Area
LWD – Large Woody Debris
LWDI – Large Woody Debris Index
mIBI – Macroinvertebrate Index of Biotic Integrity
MWR – Meander Width Ratio
NBS – Near Bank Stress
NHD – National Hydrography Dataset
NLCD – National Land Cover Database
NRCS – Natural Resource Conservation Service
O/E – Observed divided by expected
PCS – Proposed Condition Score
QT – Quantification_Tool (refers to the worksheet in the WISQT workbook)
RHA § 10 – Section 10 of the Rivers and Harbors Act
SFPF – Stream Function Pyramid Framework
SQT – Stream Quantification Tool
SWDV – Surface Water Data Viewer
USACE – United States Army Corps of Engineers (also, Corps)
UT – Unnamed Tributary
W/D – Width Depth Ratio
WDNR – Wisconsin Department of Natural Resources
WDRS – Width Depth Ratio State
WISQT – Wisconsin Stream Quantification Tool
WISQT SC – Wisconsin Stream Quantification Tool Steering Committee
WISQT TC – Wisconsin Stream Quantification Tool Technical Committee

Glossary of Terms

Absolute cover - Total vegetative areal cover (by a species, group of species or sum of all species present).

Areal cover – Areal cover is the degree to which above ground portions of plants (not limited to those rooted in a sample plot) cover the ground surface.

Alluvial valley – Valley formed by the deposition of sediment from fluvial processes. See also definitions for confined alluvial valley and unconfined alluvial valley.

Armoring – 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 bankfull 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.

Bankfull – Bankfull is a discharge that forms, maintains, and shapes the dimensions of the channel as it exists under the current climatic regime. The bankfull stage or elevation represents the break point between channel formation and floodplain processes (Wolman and Leopold 1957).

Catchment – Land area draining to a common outlet (see also Watershed).

Colluvial valley – Valley formed by the deposition of sediment from hillslope erosion processes. Colluvial valleys are bowl-shaped and typically confined by terraces or hillslopes. Colluvium is material that originates on the hillslopes and moves down slope through mass wasting processes to the valley bottom. These valleys are confined and support straighter, step-pool type channels (e.g., A, B, Bc, F). These valley types typically have a valley width ratio less than 7.0 and a meander width ratio (MWR) ratio less than 3.

Concentrated Flow Point (CFP) – An ephemeral, erosional feature, such as a swale, gully, or other constructed channel or drainage feature that alters or concentrates runoff directly into a stream. Examples include ditches, storm drains, and drain tiles. Additionally, CFPs include channels that have formed where a pipe or other drainage feature discharges to open ground that has subsequently eroded to form a channelized feature. Natural ephemeral channels, spring outlets, outlets from properly functioning best management practices, and natural streams impacted by channelization or other man-made activities are not considered CFPs.

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 33 CFR 332.2).

Condition score – A score from 0.00 to 1.00 that represents the condition or quality of a metric based on the departure from a reference condition. The metric index values are averaged to characterize the condition for each parameter, functional category, and overall project reach.

ECS - Existing Condition Score

PCS - Proposed Condition Score

Confined alluvial valley – Valley formed by the deposition of sediment from fluvial processes, typically confined by terraces or hillslopes that support transitional stream types between step-pool and meandering, or where meanders often intercept hillslopes (e.g., C, Bc). These valley types typically have a valley width ratio less than 7.0 and a meander width ratio (MWR) between 2 and 4.

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 33 CFR 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 33 CFR 332.2).

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

Effective riparian area – The area adjacent to and contiguous with the stream channel that supports the dynamic equilibrium of the stream. It is typically a corridor associated with a project reach where, under natural conditions, the valley bottom is influenced by fluvial processes under the current climatic regime; riparian vegetation characteristic of the region and plants known to be adapted to shallow water tables and fluvial disturbance are present; and the valley bottom is flooded at the stage of the 100-year recurrence interval flow (Merritt et al. 2017).

Effective vegetated riparian area – The portion of the effective riparian area that currently supports riparian vegetation and is free from utility-related, urban, or other soil disturbing land uses.

Field value – A field or desktop measurement or calculation from an existing assessment method that is input into the SQT for a specific metric. Units vary based on the assessment method used.

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

Functional capacity – The degree to which an area of aquatic resource performs a specific function (see 33 CFR 332.2). In the WISQT, index scores for functional capacity are presented in "functioning", "functioning-at-risk" or "not-functioning" ranges.

Functional category – The organizational levels of the stream quantification tool, adopted from the Stream Functions Pyramid Framework (Harman et al. 2012): 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 project reach are calculated by multiplying an overall reach condition score by the stream length. The change in functional feet (ΔFF) is the difference between the Existing FF and the Proposed FF.

Functional lift – The difference in the condition score or functional feet before and after a project, which results in improved function.

Functional loss – The difference in the condition score or functional feet before and after a project, which results in a loss of function.

Functional Loss worksheet – This is a worksheet in the Debit Calculator workbook and is used to calculate the functional loss due to proposed impacts.

Function-based parameter – A measure which characterizes a condition at a point in time, or a process (expressed as a rate) that describes and supports the functional statement for a given functional category (Harman et al. 2012).

Geomorphic pools – Geomorphic pools are associated with large planform features and generally remain intact over time and across a range of flow conditions. In meandering streams, geomorphic pools are located in the meander bend. These pools are also called lateral-scour pools. In step-pool streams, geomorphic pools are found immediately downstream from cascades or steps.

Index values – Dimensionless values between 0.00 and 1.00 that express the functional capacity and the relative condition of a metric field value compared with reference condition. Index values convert the different units used in the assessment methods to one scale. These values are derived from reference curves for each metric.

Impact severity tiers – The Functional Loss 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.

Large Woody Debris – Dead wood, standing or fallen, over 3.28 feet (1m) in length and at least 3.94 inches (10 cm) in diameter at the largest end. The wood must be within the bankfull channel or spanning the bankfull channel.

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 (Harman et al. 2012) (see Metric).

Metric – A specific tool, equation, measured value, 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 workbooks, user manual and scientific support documents (MNSQT SC 2020a; MNSQT SC 2020b).

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 reaches where there are variations in stream physical characteristics and/or differences in project activities 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, 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 activities.

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 anthropogenic disturbances. Reference aquatic resources represent the full range of functional capacity characterized by SQT condition scores.

Reference condition – The relative functional capacity of reference standard resources, characterizing the range of natural variability under undisturbed to least disturbed condition and representing the subset of reference aquatic resources that exhibit the highest level of function. In the SQT, this condition is considered functioning, culturally unaltered, or pristine for the metric being assessed (see Reference Standard).

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 (see Reference Condition).

Relative cover – The proportional areal cover by vegetation type; the total across all types should not exceed 100%.

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

Restoration Potential – 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).

Riffle – Riffles are shallow, steep-gradient channel segments typically located between pools. Riffles are the river's natural grade control feature (Knighton 1998) and are sometimes referred to as fast-water channel units (Hawkins et al. 1993, Bisson et al. 2017). For purposes of the SQT, in meandering streams, riffles broadly represent the section between lateral-scour pools known as a crossover, regardless of bed material size. Therefore, the term riffle is also used in the crossover section of a sand bed channel. Riffles are measured from head of riffle to head of pool; thus, runs are considered riffles and glides are considered pools.

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

Significant pool – Significant pools are pools not classified as geomorphic pools. They are often associated with wood, boulders, convergence, and backwater in the main channel. Significant pools must be deeper than the riffle, have a concave shaped bed surface and a width that is at least one-third the width of the channel. The pool may also have a flatter water surface slope than the riffle; however, this is not always the case, e.g., a pool downstream of a log in a steep-gradient channel.

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 rehabilitation, re-establishment, and enhancement.

Stream type – Stream type reflects the Rosgen stream type classification system and the basic fluvial landscapes where they typically occur (Rosgen 1996, NRCS 2007). Four stream types are applied in the WISQT (see Section 4.2), and each of these stream type characterizations provides information on the project reach to inform the restoration potential determination, project goals and objectives, reach-specific performance standards and/or reference curve selection. The following stream types are used in this document:

Existing Stream Type - the stream type before impact or restoration activity. It is determined using existing condition data.

Design Stream Type - the stream type that will be constructed as part of a project design (i.e., the as-built stream type). It is determined from the design process and other factors as described in Section 4.2.

Proposed Stream Type - the stream type that is expected to form (evolve to) by the end of the monitoring period (i.e., the restoration target stream type at project closeout). It is informed by factors described in Section 4.2 and should be consistent with the estimated conditions identified in the proposed condition assessment.

Reference Stream Type - the stream type that would naturally occur given the valley morphology and absent from anthropogenic influences. The WISQT relies on the reference stream type to stratify reference curves for the entrenchment ratio, pool spacing ratio, and percent riffle metrics.

Stream/wetland complex – A stream channel or channels with adjacent riverine wetlands located within the floodplain or riparian geomorphic setting, where overbank flow from the channel(s) is the primary wetland water source (Brinson et al. 1995). Stream types may be single-thread or anastomosed. Common stream types for stream/wetland complexes include Rosgen E, Cc-, and DA.

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 index values, as defined previously.

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 unconfined alluvial valleys, rivers adjust pattern without intercepting hillslopes. These valleys typically have a valley width ratio greater than 7.0 or a meander width ratio (MWR) greater than 4.0 (Rosgen 2014).

Watershed – Land area draining to a common outlet (see also Catchment).

Wisconsin Stream Quantification Tool (WISQT) - The WISQT is a spreadsheet-based tool used to evaluate change in condition. The WISQT consists of two workbooks, the WISQT workbook and the Debit Calculator workbook (see WISQT workbook and Debit Calculator workbook).

WISQT Steering Committee (WISQT SC) – The group who worked on the development of the WISQT and contributed to various aspects of this document.

WISQT Technical committee (WISQT TC) – The group that provided technical direction on the metrics and reference curves included in the WISQT.

WISQT workbook – The Microsoft-Excel workbook file used to evaluate change in condition before and after restoration or impact activities to determine functional lift or loss, respectively. The WISQT workbook can also be used to determine restoration potential, develop monitoring criteria and assist in other aspects of project planning. Also referred to as the SQT workbook.

Chapter 1. Introduction

The Wisconsin Stream Quantification Tool and Debit Calculator (WISQT) are spreadsheet-based tools primarily 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 § 10) programs. When used within the context of these programs, coordination with the US Army Corps of Engineers (USACE) and other state or local regulatory authorities is recommended prior to data collection. The WISQT can also be applied to restoration projects outside of the CWA § 404 or RHA § 10 regulatory context; for instance, stream crossing and habitat restoration projects that will benefit northern pike or trout. When applied to a non-mitigation project, WISQT users should coordinate with the appropriate state agency prior to data collection.

The WISQT workbook and Debit Calculator workbook were 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 represent parameters that are often impacted by authorized projects or affected (e.g., enhanced or restored) by mitigation actions undertaken by restoration providers. The WISQT has been developed using existing SQTs and regionalized for use in Wisconsin. Many of the parameters, metrics, and reference curves within the WISQT BETA Version are similar or identical to those in the MNSQT v2.0 (MNSQT SC 2020a). 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), Wyoming (USACE 2018a), Georgia (USACE 2018b), Colorado (USACE 2020), Michigan (MI EGLE 2020), South Carolina (South Carolina Steering Committee 2021) and Alaska (Alaska Stream Quantification Tool Steering Committee 2021). Some concepts, metrics and reference curves from these quantification tools were considered when developing the WISQT.

SQTs are an application of the Stream Functions Pyramid Framework (SFPF; Harman et al. 2012) and use function-based parameters and metrics to assess five functional categories: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology. SQTs integrate 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 rehabilitation, re-establishment, and enhancement as defined in the Compensatory Mitigation for Losses to Aquatic Resources; Final Rule (USACE & EPA 2008).

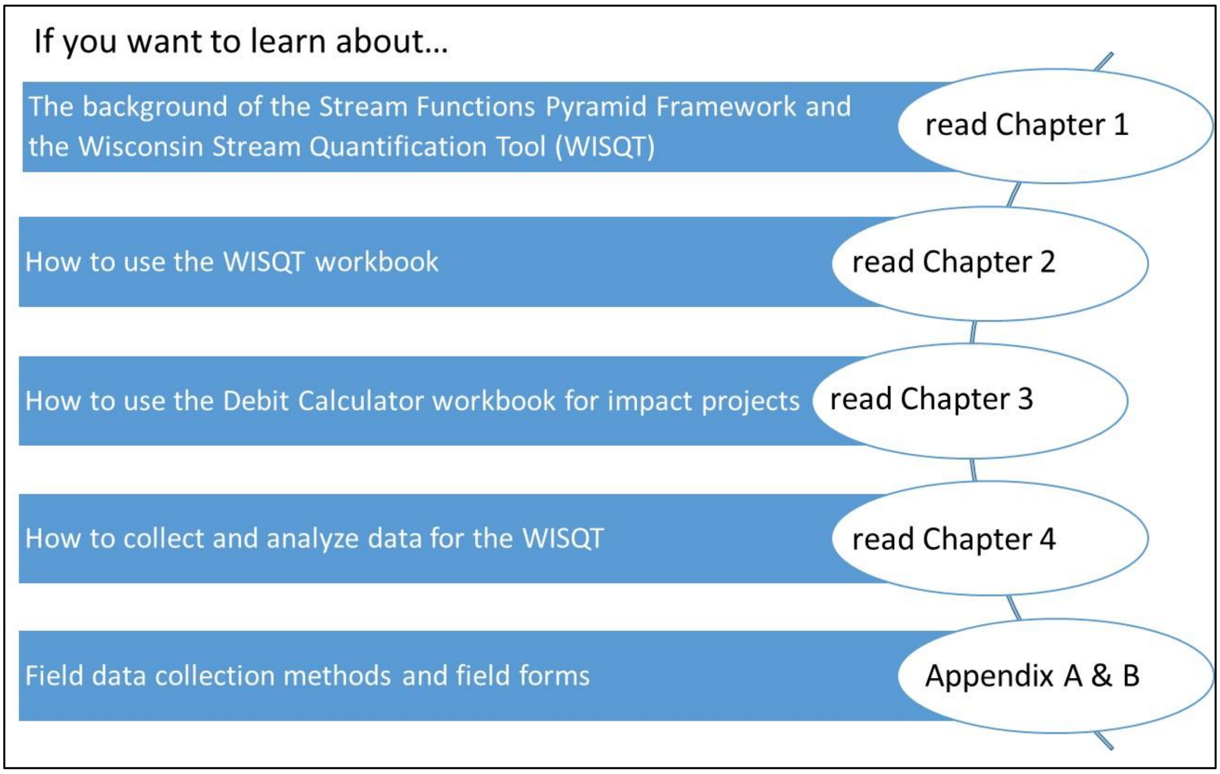
The main goal of the WISQT is to produce objective, verifiable, and repeatable results by consolidating well-defined, quantitative, measures of defined stream variables. The WISQT includes 28 metrics within 14 parameters that can be evaluated at a project site. A basic set of metrics within 7 parameters is recommended at all project sites evaluated for CWA § 404 or RHA § 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 4.3). This User Manual and Appendices outline data collection and analysis 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 WISQT workbook (Chapter 2), the Debit Calculator workbook (Chapter 3), and how to collect and analyze data entered into these workbooks (Chapter 4). Companion documents include the St. Paul District Stream Mitigation Procedures which provides policy direction for how and when the WISQT will be used for the CWA § 404 or RHA § 10 regulatory programs and how tool results are translated into credits and debits (USACE 2023); and the Scientific Support for the WISQT, which provides rationale for scoring in the WISQT and describes how field values are converted into dimensionless index scores (WISQT SC, *in draft*).

1.1. Purpose and Use of the WISQT

The purpose of the WISQT and Debit Calculator workbooks is to evaluate change in stream condition (including riparian condition) at an impact, mitigation, or restoration site and to inform permitting and compensatory mitigation decisions within the CWA § 404 and RHA § 10 programs. The WISQT workbook can also be applied to restoration projects outside of the CWA § 404 or RHA § 10 regulatory context. The workbooks are calculators to quantify change between an existing and future stream condition. The future stream condition can be proposed for an active stream restoration project or a proposed stream impact. 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 WISQT 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 § 10 permitting and mitigation decisions; the application of the WISQT in these regulatory programs in Wisconsin, as well as debit and credit determination methods, are outlined in the St. Paul District Stream Mitigation Procedures (USACE 2023). Not all portions of the WISQT workbook or Debit Calculator workbook will be applicable to all projects. Figure 1 can assist in navigating this User Manual for specific project types.

Figure 1: Manual directory.



The WISQT workbook 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 (Table 1). The Catchment Assessment and restoration potential process accompanying the WISQT workbook (described in Chapter 2) 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 function-based parameters assessed by the tool.

Table 1: Overview of the typical restoration process with associated WISQT worksheets.

Phase and Task(s)	Associated WISQT Worksheets
Site Selection based on Programmatic Goals	
Identify programmatic goals. Consider sites that could meet these goals.	Project_Summary
Delineate the project area(s) and determine project reaches.	Project_Summary
Assess catchment(s) to understand watershed context and potential constraints.	Restoration_Potential
Collect reach-specific information to determine reach-scale constraints, current condition, and the likely trajectory of stream condition. Determine existing, design, proposed and reference stream type. Estimate potential lift and proposed condition.	Quantification_Tool
Project Initiation	
Verify reach breaks and set function-based goals and quantifiable objectives for each reach.	Project_Summary
Refine responses for Catchment Assessment. Record overall catchment condition and select the site's restoration potential.	Restoration_Potential
Collect additional data to characterize the existing condition.	Quantification_Tool
Design	
Evaluate the proposed condition based on the proposed design or compare design alternatives. The SQT is not a design tool; however, design alternatives can be modeled in the SQT to identify and select the restoration design that will result in the greatest functional lift. Practitioners should **not** assume that a 1.00 can be achieved for each metric. This would mean that an unaltered or pristine stream is being restored, which is generally not possible.	Quantification_Tool
Monitoring	
Collect as-built and monitoring data to characterize post-project condition.	Quantification_Tool
The proposed field values predicted during the design phase can be used to develop performance standards. If the proposed field values are not obtained during monitoring and the trend is not towards the predicted value, an adaptive management plan may be needed. Note, regulatory agencies may require additional performance standards beyond what is used in the SQT.	Quantification_Tool

1.2. Key Considerations

The WISQT and supporting documentation have been developed to meet the function-based approaches set forth in the Compensatory Mitigation for Losses to Aquatic Resources; Final Rule (USACE & EPA 2008). Therefore, the following concepts are critical in understanding the applicability and limitations of this tool:

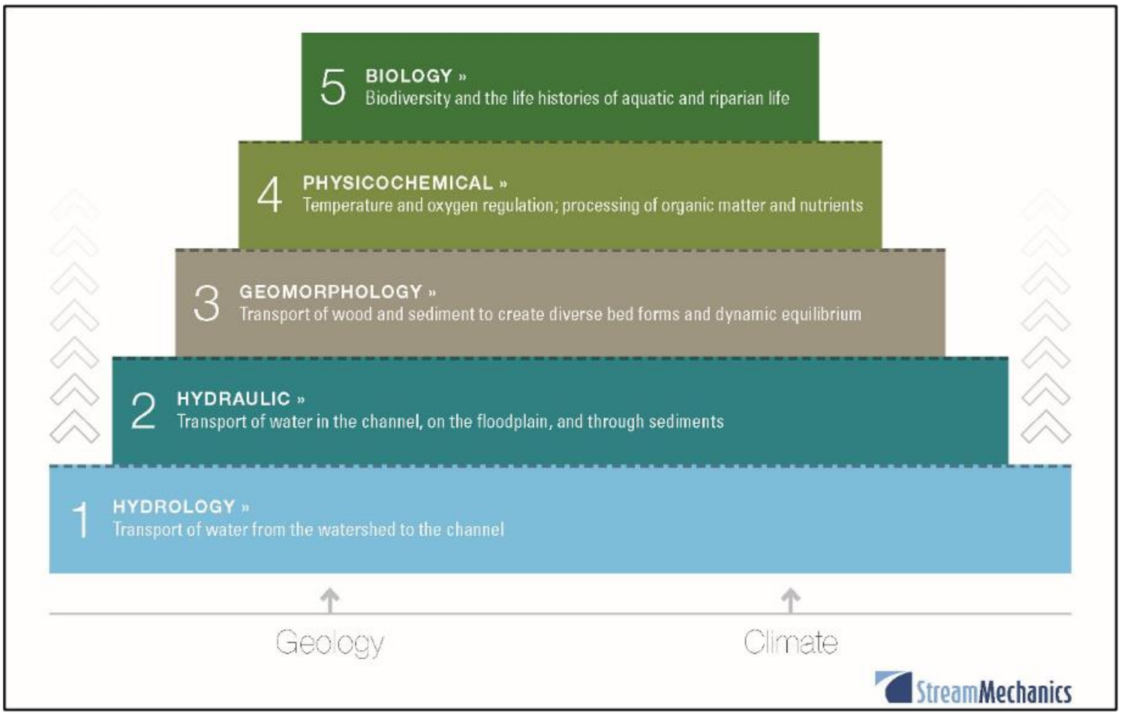
- The parameters and metrics in the tool were selected due to their sensitivity in responding to reach-scale changes associated with the types of activities commonly encountered in the CWA § 404 or RHA § 10 programs. These parameters do not comprehensively characterize all structural measures or processes that occur within a stream.
- SQTs are designed to assess the same parameters and metrics 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 WISQT as a change, or delta, 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 be inappropriate to compare scores.
- The WISQT 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 Section 2.2).
- The WISQT is not a design tool. 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 WISQT measures the physical, chemical, and biological responses or outcomes related to a project design at a reach scale.
- Not all parameters and metrics in the tool will be applicable to stream/wetland complexes, especially those with multiple channels. Practitioners working in these resource types should consult with agencies to determine the most applicable parameters to be used (Section 4.3).

1.3. Stream Functions Pyramid Framework (SFPF)

The Wisconsin Stream Quantification Tool and Debit Calculator workbooks are an application of the Stream Functions Pyramid Framework (SFPF). Therefore, to understand the structure of the WISQT, it is important to first understand the SFPF.

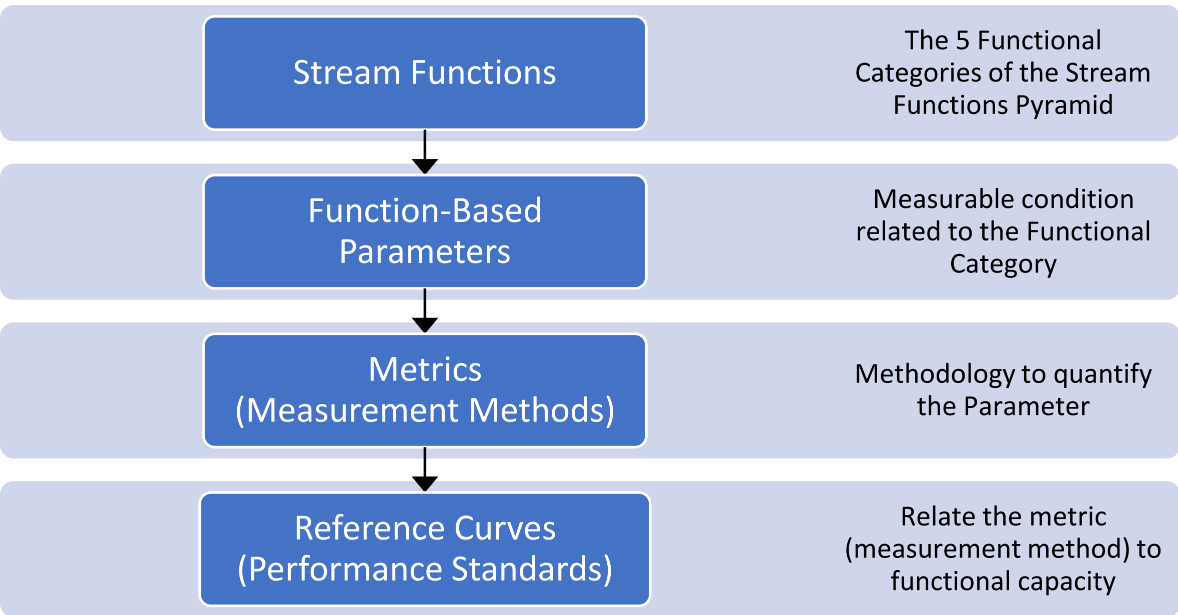
The Stream Functions Pyramid (Pyramid) is a conceptual framework developed to assist the stream restoration community (Harman et al. 2012). The Pyramid (Figure 2) includes five functional categories: Level 1: Hydrology, Level 2: Hydraulics, Level 3: Geomorphology, Level 4: Physicochemical, and Level 5: Biology. The Pyramid organization recognizes that lower-level functions generally support higher-level functions and that all functions are influenced by local geology and climate. Each functional category is defined by a functional statement. The general thought process is that if a goal is to restore a certain function, it is important to know the underlying, supporting functions that are necessary to meet the goal. For example, if the goal is to restore a native fish community (biology), then the limiting factors in physicochemical (e.g., water quality), geomorphology (e.g., sediment supply and habitat), hydraulics (e.g., flow dynamics), and hydrology (e.g., base flow condition) must be understood. If these underlying processes are impaired, they need to be addressed by restoration activities. If they can't be addressed by restoration activities, then the goal may need to change.

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



The SFPF expands the Pyramid's concept by adding function-based parameters, metrics, and reference curves (Figure 3). 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 assessment outcomes that provide the functional capacity of a given metric. Functional capacity is described by three potential outcomes: functioning (reference condition), functioning-at-risk, or not-functioning.

Figure 3: Stream Functions Pyramid Framework.



1.4. Wisconsin Stream Quantification Tool and Debit Calculator (WISQT)

Following the SFPF, a suite of 28 metrics within 14 function-based parameters 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. 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 2). The reference curves 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].

Table 2: Functional capacity definitions used to define threshold values and develop reference curves for the WISQT.

Functional Capacity	Definition	Index Score Range
Functioning	A functioning value 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. The reference standard concept aligns with the definition of reference condition for biological integrity (Stoddard et al. 2006). A score of 1.00 represents an un-altered or pristine condition (native or natural condition). A range of index values (0.70-1.00) accounts for the natural variability under undisturbed to least disturbed condition.	0.70 to 1.00
Functioning-at-risk	A functioning-at-risk value means that the metric is quantifying or describing one aspect of a function-based parameter in a way that may support aquatic ecosystem structure and function but does not reflect reference condition. Often, this indicates an adjustment or response to changes in the reach or the catchment towards lower or higher function. This range represents an intermediate area, where a resource is neither achieving reference condition nor is significantly degraded or impaired.	0.30 to 0.69
Not-functioning	A not-functioning value 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. An index value less than 0.30 represents an impaired or severely altered condition relative to reference standard, and an index value of 0.00 represents a condition that provides no functional capacity for that metric.	0.00 to 0.29

[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 WISQT (WISQT SC, *in draft*).

Chapter 2. Wisconsin Stream Quantification Tool Workbook

The WISQT workbook (WISQTvBETA.xlsx) is a Microsoft Excel Workbook comprised of 5 worksheets. There are no macros in the workbook and all formulas are visible, though worksheets are locked to prevent editing. The WISQT workbook is a project- or stream-based workbook that includes input for up to 10 reaches within a project area. Copies of the Quantification_Tool (QT) worksheet can be made for each reach on a stream or within a project area. These worksheets can be renamed; the title must not include spaces and must be entered as an exact match into Column A of the Reach Summary table in the Project Summary worksheet. If a project includes more than 10 reaches, additional WISQT workbooks will be needed.

Within each worksheet, users input values into the gray cells and select inputs from the drop-down menus in the blue cells; white cells are locked and will auto-populate with input provided on another worksheet.

The WISQT worksheets include:

- Project_Summary
- Restoration_Potential
- Quantification_Tool (QT)*
- Reference_Curves
- Pull Down Notes – This worksheet is hidden and contains all the inputs for drop down menus throughout the workbook.

> * Users can make copies of the QT worksheet to capture multiple project reaches within a project area. The Project Summary worksheet will summarize data from up to 10 QT worksheets. For projects with more than 10 reaches, more than one workbook will be needed.

2.1. Project Summary Worksheet

The Project Summary worksheet allows for a description of the proposed project and a summary of project reaches within the project area (Figure 4). This worksheet should be completed for all projects.

Figure 4: Example of Project Summary worksheet.

Programmatic Goals	
Select:	Mitigation - Credits
Expand on the programmatic goals of this project:	
Develop mitigation credits by improving habitat for native brook trout and reducing sediment supply from streambank erosion.	

Project Description	
Project Name:	Fox Creek
Project ID:	
Ecological Landscape:	Central Lake Michigan Coastal
River Basin:	Wolf River
12-digit HUC:	

Reach Summary

Worksheet Title	Reach ID	Reach Description	Reach Break Criteria	ECS	PCS	ΔFFS
QT_8	Reach 8-9			0.44	0.56	176.0 P2
QT_9	Reach 9-10			0.15	0.26	258.6 P2

<u>Programmatic Goals</u> – Programmatic goals are big-picture goals that generally represent the funding source or regulatory driver for the project. They are often broader than function-based design goals (described below) and are determined by the project owner or funding entity. Example programmatic goal statements include providing compensatory mitigation credit, meeting total maximum daily load (TMDL) requirements, addressing a watershed need like nutrient reduction, or addressing a species of concern. These goals tie back to the funding goals of a project but do not specifically tie to the reach-scale problem and solution.

A drop-down menu is provided with the following options: Mitigation – Credits, Mitigation – Debits, TMDL, Grant, or Other. A text box is also provided for the user to further explain their programmatic goals.

<u>Project Description</u> – Enter the following information, where applicable:

- <u>Project name</u>
- <u>Project ID</u> (e.g., permit number)
- <u>Ecological Landscape</u> – Select the ecological landscape in which the project reach is located from a drop-down menu (see *Ecological Landscapes of Wisconsin* [WDNR 2015]). Use the Wisconsin Department of Natural Resources (WDNR) Surface Water Data Viewer (SWDV)[2] to find your project location. Use the 'Ecoregions & Vegetation' -> 'Ecological Landscapes' layer to identify the ecological landscape for the project area.

[2] https://dnrmaps.wi.gov/H5/?Viewer=SWDV

- River Basin - Select the river basin in which the project reach is located from a drop-down menu. Use the WDNR SWDV 'Watershed Boundaries' -> 'DNR Water Management Units' layer to identify your project reach and river basin.
- 12-digit HUC – identify the sub-watershed for the project area. Use the WDNR SWDV 'Watershed Boundaries' -> 'Hydrologic Units (HUCs)' -> '12-digit HUCs (Subwatersheds)' layer to identify the sub-watershed.

Reach Summary – The following information is included for each project reach in the workbook:

- Worksheet title (if there are multiple project reaches) – enter the title for each relevant QT worksheet. The worksheet title must not include spaces and must be entered as an exact match into this cell (Figure 4). There is a pop up note in the WISQT with additional information about titles.
- Reach ID (will auto-populate from the relevant QT worksheet).
- Reach Description – describe each reach.
- Reach Break Criteria – describe the characteristics that separate it from the other reaches in the project area. Guidance on identifying project reaches is provided in Section 4.1.
- ECS, PCS, ∆FFS (will auto-populate from the relevant QT worksheet).

Aerial Photograph – There is space in the worksheet to insert an aerial photo of the project area. The imagery should label the upstream and downstream extent of each of the reaches (if there are multiple reaches).

Reach-scale Design Goals and Objectives - The first column includes space for Reach IDs, and the second column includes space for the user to explain their design goals and objectives for each reach. Design goals are statements about why the project is needed at the reach scale and describes a functional problem or desired solution. Design objectives explain how the project will be completed by listing which function-based parameters will be manipulated in order to achieve the goal. Design goals and objectives should be developed after the restoration potential has been determined (Section 2.2). Guidance on developing function-based goals and objectives, based on Harman et al. (2012), follows.

2.1.A. Developing Function-Based Design Goals and Objectives

Design goals are statements about *why* the project is needed at the reach scale and describes a functional problem or desired solution. Common function-based design goals include:

- Restore [insert native fish species] abundance to a reference condition.
- Improve habitat for [insert native fish species].
- Reduce sediment supply from eroding streambanks to improve channel stability.
- Reduce nitrogen and phosphorus loading from adjacent land uses.

Simple goal statements effectively communicate why the project is being done. Notice that these goal statements are specific, and do not simply state that the goal is to improve habitat and water quality. While improving habitat and water quality are common and needed goals, without a qualifier, they are too broad. A habitat only goal does not specify who the habitat is for, and different fish species require different habitats, e.g., coldwater versus warmwater fish. The same is true for water quality. Projects that address sediment as a water quality problem are common. However, if the water quality issue is from metals or other contaminants, an entirely different approach may be needed, and it might not involve reach-scale channel improvements.

TIE DESIGN GOALS TO RESTORATION POTENTIAL

Design goals should be cross referenced with the restoration potential of the reach to ensure that the goals do not exceed the restoration potential. Generally, goals that relate to channel stability and habitat can be achieved with a partial restoration potential result. Goals stating that there will be more fish, and certainly goals that anticipate restoring fish populations to reference condition, must have a full restoration potential result. The goal cannot exceed the restoration potential; a project cannot return a reach to reference condition without a full restoration potential result. However, a project with partial restoration potential could create large amounts of functional uplift.

In the first example function-based design goal, it states that a native fish species abundance will be restored to a reference condition. This goal could be expanded to include different life stages or species diversity, etc. Regardless, since the goal is stating that there will be a fish community in the project reach that matches reference condition, the results of the restoration potential process should equal “full,” meaning that the watershed condition along with the reach-scale restoration will support a reference condition fish community.

In the second example function-based design goal, it states that the habitat for a specific fish species will be improved. This goal could be achieved with a partial restoration potential because the goal does not relate to there being more (or any) fish in the reach after restoration construction is completed. In this framework, habitat is not biology. Biology includes the life histories of aquatic and riparian animal life. Habitat includes the water, bedforms, thermal regime, and other supporting processes on the Stream Functions Pyramid that support biology.

FUNCTION-BASED OBJECTIVES

Objectives explain *how* the project will be completed. Objectives are specific, tangible and can be validated with monitoring and performance standards. Design objectives, in combination with the stated design 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. Example objectives that also communicate functional uplift and state performance standards include the following:

- Improve floodplain connectivity by reducing bank height ratios from 2.0 to 1.0 and increasing entrenchment ratios from 1.2 to greater than 5.0.
- Improve bed form diversity by decreasing the pool spacing ratio from 10 to a range of 4 to 6, increasing the pool depth ratio from 1.5 to a range of 2 to 3, and decreasing the percent riffle from 95% to a range of 55 to 65%.
- Improve lateral migration by removing all armoring, changing the BEHI/NBS rating from high/high to low/high, and reducing the percent erosion from 30% to 5% or less.
- Improve riparian vegetation by increasing the observed effective vegetated riparian area to equal the expected effective vegetated riparian area, increasing the canopy cover from 0 to 50%, and increasing the woody stem basal area to 12 m^2/ha.

The above bullets are just examples. The final list of objectives should include all the function-based parameters and metrics that are shown in the proposed condition portion of the SQT. The values added to the objective statements should match the expected values at the end of the monitoring period only, and not the ultimate endpoint. For example, a restoration reach that starts as a cornfield will not have a reference standard riparian forest within a five-year monitoring period.

How Goals and Objectives Assist with Parameter Selection

Design goals and objectives, along with restoration potential, can also be used to inform parameter selection (Section 4.3). For projects that have a partial restoration potential with goals that focus on channel stability, users may not need to include parameters in the physicochemical and biology categories. For projects that have a partial restoration potential that focus on habitat, users may include parameters in physicochemical and biology if the watershed condition is good enough to see an increase in index scores. In this example, it is okay if the proposed functional capacity is not in the functioning range. For example, a project that is in a rural landscape setting with no or minor stressors in the catchment, and where the land use change is not trending towards more agriculture or urban, may show an improved biology from not-functioning to functioning-at-risk. For projects that have full restoration potential and goals that include returning biology to a reference standard, users should include parameters through biology.

2.2. Restoration Potential Worksheet

When applying the SQT at a mitigation or restoration site, users will need to determine the restoration potential for each reach within a project by completing the Restoration Potential worksheet in the WISQT workbook, which considers both watershed (catchment) and reach-scale factors that may influence the outcome of a project. The Restoration Potential worksheet outlines seven steps, including a Catchment Assessment, to assist in determining restoration potential for restoration and mitigation projects. These steps are duplicated in the Restoration Potential worksheet for users with mitigation or restoration sites in more than one watershed or catchment. When using more than one Restoration Potential worksheet, care should be taken to ensure that the information entered is associated with the proper watershed or catchment.

Once the Restoration Potential worksheet has been completed, Restoration Potential results will automatically display in the QT worksheet for each reach. *If using the WISQT workbook instead of the Debit Calculator for debit or impact projects, the Restoration Potential worksheet does not need to be completed.*

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 condition. A project with full restoration potential would restore the functional capacity within all categories back to a reference condition. Partial restoration would improve some, but not all functions, as compared to reference condition. For example, partial restoration might mean restoring stability and aquatic habitat to a reference condition by implementing activities that manipulate processes in the hydrology, hydraulics, and geomorphology categories, but not restoring temperature or fish communities to a reference condition 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 condition (see Table 1). 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 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 condition, but some catchment stressors or reach-scale constraints are preventing the site from reaching full restoration potential.

Partial restoration is the most common restoration-potential level for stream restoration and mitigation 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 condition. For partial restoration projects, improvements in all functional categories may be observed, but these improvements may not reflect a reference condition.

There are likely situations where even partial restoration is not possible due to the severity of catchment stressors and reach-scale constraints that may be outside the control of the practitioner. In these cases, restoration potential may be limited to such a degree that a site may not be suitable for restoration activities. 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.

2.2.A. STEPS FOR DETERMINING RESTORATION POTENTIAL

STEP 1 – CATCHMENT ASSESSMENT

The Restoration Potential worksheet includes seven steps to characterize restoration potential, including a Catchment Assessment. The Catchment Assessment is a decision-support tool rather than a quantitative scoring tool. Therefore, results from the Catchment Assessment are not scored in the WISQT but are used to help inform a restoration potential decision.

Users should consider stressors within the delineated contributing drainage area of the project (see Section 2.3.a for how to calculate drainage area). Note, typically one Catchment Assessment will be needed per project. However, there may be instances where more than one watershed-scale assessment is needed, for example, where two (or more) streams with different catchment conditions occur within a project area. If this is the case, additional copies of the Catchment Assessment are available at the bottom of the Restoration Potential worksheet and should be completed, as needed.

The Catchment Assessment includes a list of potential stressors that exist within the contributing watershed that may limit restoration potential. The Catchment Assessment does not pertain to stressors occurring within the project reach or 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, e.g., a dam.

There are 11 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 proposed condition score of the project reach. For each category, the user will determine whether the stressor is present (Yes) or not (No). Instructions for collecting data and describing each process and stressor are provided in this section. Once all categories of the Catchment Assessment are completed, the user should rely on the results to complete Steps 2-4 on the Restoration Potential worksheet to inform the restoration potential for the reach.

The Catchment Assessment relies on data available online from the EPA EnviroAtlas[3], the WDNR SWDV[4], and the WDNR Water Quantity Data Viewer[5]. The specific information that relates to each category is described below.

Urbanization – This category considers the percent of developed area within the upstream watershed. If 20% or more of the upstream watershed is considered developed or is rapidly urbanizing, the stressor is present. There are multiple options available to calculate the percentage of developed land upstream of a project site, including:

- EnviroAtlas' 'Land Cover: Type' layer. This layer requires an ArcGIS Online account.
- WDNR's SWDV's 'WHD-Plus Catchment' layer (see *Flashiness* below).
- Delineating the different land use types within the upstream catchment using USGS' National Land Cover Database (NLCD).
- Reviewing information from the Comprehensive Plan(s) for the encompassing county, city, village, town or regional planning commission, or other applicable urban planning projections, to help inform the degree to which the upstream watershed is urbanizing.

Road Density – This category considers the density of roads within the sub watershed. Using the EnviroAtlas 'Near-road Environments' layer, users should determine the road density (km/km^2) within the HUC-12 sub watershed. Additionally, when roads occur throughout much of the project area, i.e., within the length of the lateral drainage area, the project would have a high road density adjacent to the project reach. If road density is greater than or equal to 2.5 (km/km^2) in the sub-watershed OR there is high road density adjacent to the project reach, the stressor is present.

Riparian Vegetation – This category considers the percent natural land cover in the stream corridor. Using the EnviroAtlas 'Land Cover: Near-Water' layer, users should determine the percent natural land cover in the stream buffer within the HUC-12 sub watershed. If the sub watershed percent natural land cover in the stream buffer is less than or equal to 60%, the stressor is present.

Flow Alteration – This category considers the presence and location of high capacity wells and surface water withdrawals. Using the WDNR Wisconsin Water Quantity Data Viewer 'High Capacity Withdrawal Locations' layer, users should determine whether there are any high capacity withdrawals within the same Public Land Survey System (PLSS) Section as the project. If so, the stressor is present.

Flashiness – This category considers the upstream watershed average runoff curve number. Using the WDNR SWDV 'Watershed Boundaries -> WHD-Plus Catchments' layer, users should determine the average curve number for the entire contributing watershed. If the upstream watershed average curve number is greater than or equal to 75, the stressor is present.

Forested Cover – This category considers the percent of the upstream watershed that is forested. Using the WDNR SWDV 'Watershed Boundaries -> WHD-Plus Catchments' layer, users should determine the percent of the entire contributing watershed that is forested. If 20% or less of the upstream watershed is forested, the stressor is present.

Cropland Cover – This category considers the percent of the upstream watershed that is cropland. Using the WDNR SWDV 'Watershed Boundaries -> WHD-Plus Catchments' layer, users should

[3] https://enviroatlas.epa.gov/enviroatlas/interactivemap/
[4] https://dnrmaps.wi.gov/H5/?Viewer=SWDV
[5] https://dnrmaps.wi.gov/H5/?viewer=Water_Use_Viewer

determine the percent of the entire contributing watershed that is agricultural. If 70% or more of the upstream watershed is agricultural, the stressor is present.

Upstream Impairments – This category considers the presence of impairments and high sediment supply upstream of the project. Using the WDNR SWDV 'Assessments and Impairments' layer, users should determine whether there are any 303(d) listed impaired waters upstream. Indicators of high sediment supply may include, but are not limited to, significant upstream bank erosion/in-stream sediment supply, unbuffered connections of areas of rill/gully erosion, or soils with a high erodibility (K) factor (e.g., >0.45) lacking erosion control or sediment capture practices. Users can obtain a soils K factor via Web Soil Survey or through ESRI shapefiles sourced from the NRCS SSURGO database. If any waters upstream are 303(d) listed for temperature, phosphorous or total suspended solids OR if there is a high sediment supply to the reach, the stressor is present.

Presence of Livestock – This category considers the presence of livestock upstream or within the project area. Aerial imagery or a site visit can be used to ascertain the presence of livestock. If livestock have access to the project reach or immediately upstream, the stressor is present.

Organism Recruitment – This category considers the suitability of habitat in adjacent reaches to facilitate organism recruitment within the project area. Aerial imagery or a site visit can be used to ascertain the suitability of habitat in adjacent reaches. If the channel immediately upstream or downstream of the project is concrete, piped or hardened, the stressor is present.

Aquatic Connectivity – This category considers the presence of structures upstream or downstream that could affect aquatic life movement. Using the WDNR SWDV 'Dams and Floodplains' layer, users should determine whether structures are present upstream or downstream of the project area. The assessment distance will vary based on the species class present. See Table 3 and the procedure below for determining the appropriate assessment distance for this category. If a structure or structures occur within the assessment distance upstream or downstream of the project, the stressor is present.

Table 3: Distances for assessing aquatic organism barriers.

Species Class	Assessment Distance (km)
Inland Cold Water	2
Inland Warm Water	5
Coastal Tributaries	10

To determine the appropriate assessment distance for evaluating aquatic connectivity, follow the steps outlined below:

1) Determine the fishery designation on the WDNR SWDV 'Fisheries Management' layer. Select the species class in Table 3 based on the following criteria:

    a) Inland Cold Water: Project reach is mapped as or within two kilometers of a designated trout stream.

    b) Inland Warm Water: Project reach is mapped as or within 5 kilometers of a designated smallmouth bass stream or does not have a fishery designation.

    c) Coastal Tributaries: Project reach is within 20 stream kilometers of Lake Michigan, Lake Superior, or the Mississippi River.

2) If multiple species class criteria are met conduct the assessment for the species class with the longest assessment distance.

3) Identify authorized dams using the WDNR SWDV 'Dams & Floodplains' layer prior to barrier assessment in the field.
4) Identify barriers for the listed distance upstream and downstream, or to the nearest dam, lake, or impoundment. For example, a total of four stream kilometers is the total assessment distance for inland cold waters.
5) When encountering the confluence of two streams during the upstream assessment continue on the higher order stream. If the confluence is two streams of the same order divide the remaining assessment distance equally between the two tributaries.

<u>Other</u> – This category allows users to identify other stressors present in the contributing watershed that are not characterized above. Space is provided to briefly describe the stressor.

Step 2

Review the stressors identified in the Catchment Assessment. Are there any stressors that are so severe they would prevent even partial restoration potential? A stressor that prohibits partial restoration may constitute a "deal breaker" that could affect site selection until such stressors can be improved. For Step 2, list any stressors that would prevent the project from achieving even partial restoration.

Step 3

For each stressor identified in the Catchment Assessment, determine whether the stressor could be overcome by watershed management activities that are planned or actively occurring in the watershed but not directly associated with the proposed restoration project. 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.

Step 4

Consider the project limits (see reach delineation in Chapter 4.1) and the drainage area (Section 2.3.a). Compare the project size (length and/or area) to the catchment size. Can the scale and type of restoration overcome the stressors or perturbations identified in the Catchment Assessment? Can the stressors be overcome by the size of the project or by doing additional work in the catchment? 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. If many of the stressors could be addressed, then full restoration is likely. If not, then partial restoration is more likely.

Step 5

For each reach within the project area, 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.

Step 6

For each reach within the project area, determine the baseline, existing condition of the reach. Where possible, users should rely on field data entered in the QT worksheet to determine the baseline, existing condition of the reach. In early planning stages, where data are not available to inform an existing condition assessment in the WISQT workbook, estimates of baseline condition can be made from available site information. The QT worksheet will characterize functional capacity by parameter and functional category. List the function-based parameters that are not-functioning or functioning-at-risk. Consider whether these parameters could be addressed as part of the project.

Step 7

Based on the results from Steps 1-6, determine whether the restoration potential is Full or Partial for each reach within the project area[6]. Explain the reasons for your selection. Consider whether the parameters identified in Step 6 could be addressed as part of the project. Identify which parameters/functions could be restored to a functioning condition (reference standard) and which may not. The restoration potential for each project reach is displayed in the Site Information and Reference Selection section of the QT worksheet and the explanation is auto-populated in a text box at the top of the QT worksheet.

2.2.b. Using the WISQT to Assist in Site Selection

The WISQT can be used to assist with selecting or ranking the priority of potential stream restoration or mitigation sites. While there are many other elements to include in a thorough site-selection process (ELI et al. 2016; Starr and Harman 2016); this section highlights how the WISQT can inform that process. The Restoration Potential analysis combines information on the condition of the upstream watershed with reach-scale assessment and constraints to gain an understanding of each reach's restoration potential, and the results can be used to compare the restoration potential, condition and level of restoration effort across multiple sites.

In the WISQT, 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 WISQT 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 4 and Appendix A).

At the site selection 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 and how that lift relates to the programmatic goals, and reach-scale function-based goals. For example, a grant program with a programmatic goal of restoring populations of a native fish species of concern might look for stream reaches that are marginally

[6] Information from Steps 1-4 will likely apply to the entire project area (unless multiple Catchment Assessments are needed), but Steps 5-7 will relate to conditions within each project reach.

degraded and with minimal stressors in the upstream watersheds. The condition of the upstream watershed along with the reach-scale assessment and constraints are considered in the restoration potential analysis. If a site has full restoration potential, the reach-scale problems can be addressed through restoration activities and the fish community could rebound to a reference condition.

The programmatic goals of a project will also influence site selection. Programmatic goals related to providing mitigation credit may prioritize different sites than the example above since they may look to maximize lift, and thus credit, at a project site. Modest reach-scale problems yield a smaller amount of lift even though the final condition score may be high. Mitigation project site selection may prioritize highly degraded sites with the potential to improve as many function-based parameters as possible. The most uplift will occur on a site that has low existing functional capacity with full restoration potential. However, substantial uplift can also occur in highly degraded reaches with partial restoration potential. If the purpose of the project is to provide mitigation under CWA § 404 or RHA § 10, the user should also refer to the St. Paul District Stream Mitigation Procedures (USACE 2023) or consult with USACE for further guidance on site selection.

2.3. Quantification Tool Worksheet

The Quantification_Tool (QT) worksheet calculates condition scores and change in condition for a project reach. There are three areas for data entry:

- Site Information and Reference Selection,
- Existing and Proposed Condition Assessment field values,
- Monitoring Condition Assessment field values.

The QT worksheet also includes several summary tables discussed in Section 2.3.D. below, as well as text boxes describing the reach's restoration potential and goals and objectives. Information in the summary tables is automatically calculated once field values have been entered into the QT worksheet. Text boxes are auto-populated from the narrative entered on the Restoration Potential and Project Summary worksheets, respectively.

Use one QT worksheet for each project reach. The user can duplicate this worksheet when the project area contains multiple reaches. Rename the worksheet to identify the project reach ID. **The QT worksheet title cannot contain spaces and must exactly match the title entered in the Worksheet Title (first column) of the Project_Summary worksheet** (**Figure 4).**

2.3.A. Site Information and Reference Selection

The Site Information and Reference Selection section consists of general site information and input to determine which reference curve(s) to apply in calculating index values for relevant metrics (Figure 5). For some metrics, these curves are stratified by physical stream characteristics like stream type and vegetation attributes. Information on each input field and guidance on how to select values are provided below. It may not be necessary to complete all fields in this section depending on parameter selection.

Figure 5: Example Site Information and Reference Selection input fields from the WISQT.

Site Information and Reference Selection	
Project Name:	Fox Creek
Reach ID:	1
Restoration Potential:	Partial
Ecological Landscape:	Central Lake Michigan Coastal
River Basin:	Wolf River
Existing Stream Length (ft):	1000
Proposed Stream Length (ft):	1200
Existing Stream Type:	F
Design Stream Type:	Bc
Proposed Stream Type:	Bc
Reference Stream Type:	E
Valley Type:	Unconfined Alluvial
Drainage Area (sq. mi.):	4
Stream Slope (%):	0.2
Strahler Stream Order:	Second
Flow Type:	Perennial
Reference Vegetation Cover:	Woody
Stream Temperature:	Warmwater
Fish IBI:	Warmwater
Target Fish Community:	Lake Michigan Trout Young of Year

Users should ensure entries in this section are accurate. Metrics will not be scored or may be scored incorrectly if necessary and/or accurate data are not provided in this section. Additional information on how reference curves are developed and stratified is included in the Scientific Support for the WISQT (WISQT SC, *in draft*).

Project Name – This information will auto-populate from the Project Summary worksheet.

Reach ID – Each project reach within a project area should be assigned a unique identifier (see Section 4.1 for guidance on delineating project reaches). This information will auto-populate from the Project Summary worksheet.

Restoration Potential – This cell is auto-populated by the restoration potential selected by the user on the Restoration Potential worksheet. Restoration potential is determined using the stepwise process described in Section 2.2.a.

Ecological Landscape – This cell is auto-populated from the Project Summary worksheet (Section 2.1). Ecological landscape is not used for reference curve stratification; it is used for communication purposes and to help inform parameter and metric selection.

River Basin – This cell is auto-populated from the Project Summary worksheet (Section 2.1). River basin is not used for reference curve stratification, but is used for communication purposes.

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.

Proposed Stream Length (ft) –The proposed stream length can be estimated from project design documents, and later verified using as-built conditions using the approaches described in Existing Stream Length. Where stream length does not change post-project, the same value can be entered for the Existing and Proposed Stream Length. Stream length is used to calculate the functional feet, so both existing and proposed stream length must be recorded.

Existing Stream Type – This is the Rosgen stream type (Rosgen 1996) before impact or restoration activity. It is determined using existing condition data, as described in Section 4.2. Existing stream type is not used for reference curve stratification, but is used for communication purposes.

Design Stream Type – This is the Rosgen stream type (Rosgen 1996) that will be constructed as part of the project design (i.e., the as-built stream type). It is determined from the design process and other factors described in Section 4.2. Design stream type is not used for reference curve stratification, but is used for communication purposes.

Proposed Stream Type – This is the Rosgen stream type (Rosgen 1996) that is expected to form (evolve to) by the end of the monitoring period (i.e., the restoration target stream type **at project closeout).** It is informed by factors described in Section 4.2 and should be consistent with the estimated conditions identified in the proposed condition assessment. The proposed stream type is not used for reference curve stratification, but is used for communication purposes.

Reference Stream Type – This reflects the Rosgen stream type (Rosgen 1996) that would naturally occur given the valley morphology and absent from anthropogenic influences. The WISQT relies on the reference stream type to stratify reference curves for the entrenchment ratio, pool spacing ratio, and percent riffle metrics. See Section 4.2 for information on characterizing reference stream type.

Valley Type – Valley type is used to stratify reference curves for effective vegetated riparian area. The valley type options are colluvial, confined alluvial, and unconfined alluvial. These terms are defined in the Glossary of Terms.

Drainage Area (mi^2) – The drainage area is the catchment 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 and is used in the Restoration Potential process (Section 2.2).

Stream Slope (%) – The slope is the measured change in elevation across a known stream length. The stream slope is a reach average and not the slope of an individual bed feature (e.g., a riffle). Stream slope is not used for reference curve stratification but is used to determine stream type.

Strahler Stream Order – Stream order as defined by Strahler (1957) is a classification based on stream/tributary relationships. Headwater streams are first order; the stream becomes second order downstream of the confluence of two first order streams; the stream becomes third order downstream of the confluence of two second order streams; and so on. Stream order is not used for reference curve stratification, but is used for communication purposes.

Flow Type – Select the flow permanence of the project reach as the jurisdictional determination of whether a stream resource is perennial, intermittent, or ephemeral. Flow type is not used for reference curve stratification, but is used for communication purposes.

Reference Vegetation Cover – Reference vegetation cover is used to determine the reference curve for the canopy cover metric and to inform metric selection for riparian vegetation. In Wisconsin, vegetation communities include grasslands, oak openings and oak savannahs, oak and pine barrens, northern forests, southern forests, and wetlands, with variation in community patterns across 16 distinct ecological landscapes (WDNR 2015). The user should select the reference vegetation cover as herbaceous or woody based on the natural presence and prevalence of woody species in the riparian zone. The reference vegetation cover is the community that would occur naturally at the site if the reach were free of anthropogenic alteration and impacts. For example, woody species would be naturally present and prevalent in forested communities, while prairie and meadow communities would have an herbaceous reference condition because woody species are not prevalent in these systems. In savannah and barren systems, where wood is a natural component but with a low tree density and a high herbaceous vegetation density, users should coordinate with USACE for advice on which reference curve is appropriate for that specific project. The appropriate reference community type can be determined by locating a similar pristine or minimally altered reference site within the catchment area or watershed, researching historical and ecological descriptions of mature and undisturbed vegetation communities in the vicinity (see *Ecological Landscapes of Wisconsin* [WDNR 2015]), and deduced through understanding the effects of land use practices and management on vegetation communities. All WISQT users should consult with USACE for clarity and confirmation of reference vegetation cover.

<u>Stream Temperature</u> – A water body's temperature class, or modeled natural community classification, can be determined using the WDNR SWDV 'Surface Waters-> Streams Natural Communities' layer and Table 4. Select the WISQT Temperature Class from the following:

- Coldwater
- Cold Transition
- Warm Transition
- Warmwater

The temperature class is used to stratify the reference curves for the Temperature parameter. WISQT users who are uncertain which temperature stratification they should select should consult WDNR's Aquatic Communities website for more information[7].

<u>Fish IBI</u> – This field is used to stratify the reference curves for the Fish Index of Biotic Integrity (fIBI) metric. This metric is stratified by stream temperature with different stream temperatures having different reference curves. Users should coordinate with WDNR to ensure that they select the correct thermal classification (Table 4), and review the metrics and criteria outlined in Lyons (1992), Lyons et al. (1996) and Lyons (2012).

[7] https://dnr.wisconsin.gov/topic/Rivers/AquaticCommunities.html

Table 4: Crosswalk between WDNR Natural Community classes, class and subclass from Lyons et al. (2009) and the WISQT.

WDNR Natural Community	Class and Subclass (Lyons et al. 2009)	WISQT Stream Temperature Class	WISQT fIBI Classification
Cold Headwater	Coldwater	Coldwater	Coldwater
Cold Mainstem			
Cool (Cold-Transition) Headwater	Coolwater and Cold Transition	Cold Transition	Coolwater
Cool (Cold-Transition) Mainstem			
Cool (Warm-Transition) Headwater	Warm Transition	Warm Transition	
Cool (Warm-Transition) Mainstem			
Warm Headwater	Warmwater	Warmwater	Warmwater
Warm Mainstem			
Warm Rivers (non-wadeable)			
*Classifications available at: https://dnr.wisconsin.gov/topic/Rivers/NaturalCommunities.html			

Target Fish Community – The target fish community is used to select the appropriate reference curve for the fish abundance metric. This selection should be informed by the project location and the function-based goals and objectives for the reach.

The target fish communities include:

- Inland streams:
  - Adult Smallmouth Bass (Native)
  - Adult and Yearling Brown Trout
  - Adult and Yearling Brook Trout (Native)
- Coastal streams:
  - Lake Superior Trout Young of Year
  - Lake Michigan Trout Young of Year

Note that the first impassable barrier serves as the delineation between inland streams and coastal streams. If a site is located upstream of an impassable barrier then users should select one of the inland stream options. Properly identifying inland versus coastal systems can be challenging given watershed changes (e.g., dam removal), and users should consult with WDNR field staff.

Within inland streams, there are multiple tools available to identify target species. Users can rely on the following maps to identify whether their project is located in a smallmouth bass or trout mapped waterway: WDR SWDV ‘Fisheries Management’ layer, Trout Regulations and Opportunities User

Tool (T.R.O.U.T.)[8], or classified trout waters by county[9]. If a project reach is not mapped using the above resources, consult with WDNR field staff. Additionally, smallmouth bass waters are described in *A Sampling Framework for Smallmouth Bass in Wisconsin's Streams and Rivers* (Smallmouth Bass Rivers Assessment Team 2006).

Users should consult with their local WDNR field staff or central office point of contact for guidance and approval to use the fish abundance metric for adult and yearling brown trout. Brown trout are not native and compete with the native brook trout population. Where possible, and particularly for projects performed for CWA § 404 mitigation, brook trout should be targeted for restoration instead of brown trout to better support the natural assemblage. Brown trout have similar habitat and water quality requirements as brook trout, so altered in-stream conditions may show lift or loss for brown trout populations where brook trout are scarce or not present.

2.3.B. Condition Assessment Data Entry

Once the Site Information and Reference Selection section is completed, the user can input data into the field value column of the Existing and Proposed Condition Assessment tables (Figure 6). Users reporting monitoring data will enter their data in the Monitoring Condition Assessment table (starting at Row 97 in the WISQT) that includes year, time since as-built (a.k.a. monitoring year), and field values for each metric (Figure 7).

A user will input field values for all selected metrics; a user will rarely input data for all metrics or parameters within the tool (see Section 4.3). The function-based parameters and metrics are listed by functional category, starting with hydrology. Multiple tables 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.

Note: If a field value is entered for a metric in the Existing Condition Assessment, a value must also be entered for the same metric in the Proposed Condition Assessment and all subsequent condition assessments (i.e., as-built, and every monitoring event).

[8] https://dnr.wisconsin.gov/topic/Fishing/trout/TROUT.html
[9] https://dnr.wisconsin.gov/topic/Fishing/trout/streammaps.html

Figure 6: Example input fields from the WISQT for the Existing Condition Assessment (this table is duplicated for the Proposed Condition Assessment).

Functional Category	Function-based Parameters	EXISTING CONDITION ASSESSMENT Metric	Field Value
Hydrology	Catchment Hydrology	Land Use Coefficient	
	Reach Runoff	Land Use Coefficient Concentrated Flow Point Index	
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft) Entrenchment Ratio (ft/ft)	
	Bankfull Dynamics	Width/Depth Ratio State (O/E)	
Geomorphology	Large Woody Debris	LWD Index LWD Frequency (#/100m)	
	Lateral Migration	Dominant BEHI/NBS Percent Streambank Erosion (%) Percent Streambank Armoring (%)	
	Riparian Vegetation	Effective Vegetated Riparian Area (%) Canopy Cover (%) Herbaceous Cover (%) Woody Stem Basal Area (m^2/ha)	
	Bed Form Diversity	Pool Spacing Ratio (ft/ft) Pool Depth Ratio (ft/ft) Percent Riffle (%)	
	Bed Material Characterization	Percent Fines (% < 2mm) Percent Fines (% < 6.35mm) Median Particle Size (d50) (mm)	
Physicochemical	Temperature	Summer Mean Temperature (°C)	
	Nutrients	Benthic Algal Biomass Diatom Phosphorus Index (DPI) (µg/L)	
	Organics	Hilsenhoff Biotic Index (HBI)	
Biological	Macroinvertebrates	mIBI	
	Fish	fIBI Fish Abundance (#/mile)	

Existing Condition Assessment – Existing condition field values are derived from data collection and analysis methods outlined in Chapter 4 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.

Multiple sampling events to inform baseline condition may improve the accuracy of the field value used to calculate lift by quantifying inter- or intra-annual variability (e.g., macroinvertebrates and physicochemical metrics).

Proposed Condition Assessment – Proposed condition field values represent reasonable values for either the restored condition or impacted condition. For mitigation projects, proposed conditions are based on the expected condition at the end of the project monitoring period or at mitigation closeout (e.g., year 5, 7 or 10). Proposed condition field values are estimated/predicted using available project data. Users should rely on available data to estimate the proposed condition field values, including project design studies and calculations, drawings, field investigations, and best available science. Proposed condition field values should be appropriate for the setting, stream type, and watershed conditions within the project area; and, for mitigation projects, consistent with the restoration potential of the site. Bankfull verification and proposed condition field values should be outlined in the restoration or mitigation plan and documented using the Field Value Documentation forms in Appendix B. (Note: field value, as used here, refers to the value entered in the condition assessment table and not the actual collection of field data to yield a field value). More detail on how to determine reasonable values for proposed condition scores are described in relevant metric sections in Chapter 4.

Monitoring Condition Assessment – Monitoring condition field values are derived from post-project data collection and analysis methods outlined in Chapter 4 and Appendix A. Immediately below the Function-Based Categories Summary and Function-Based Categories Summary (FFS) tables (detailed in Section 2.3.d.) is another Condition Assessment table used for monitoring. In this table, the user can input the year (e.g., 2023), time since as-built (a.k.a. monitoring year), and field values for each metric (Figure 7). This table contains space to input field values for 11 post-project condition assessments. The first column is identified as the As-Built Condition followed by 10 condition assessment columns for monitoring.

- The year is the calendar date of the assessment.
- The time since as-built is the number of years after the as-built survey (as-built is considered year 0).

Figure 7: Monitoring Condition Assessment table.

MONITORING CONDITION ASSESSMENT		**Year**	2023	2024	2025
Functional Category	**Function-based Parameters**	**Time since as-built (yr)**	As-Built	1	2
		Metric	**Field Values**		
Hydrology	Catchment Hydrology	Land Use Coefficient			
	Reach Runoff	Land Use Coefficient	55	55	55
		Concentrated Flow Point Index	0	0	0
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft)	1	1	1
		Entrenchment Ratio (ft/ft)	2.2	2.2	2.2
	Bankfull Dynamics	Width/Depth Ratio State (O/E)	1	1	1
Geomorphology	Large Woody Debris	LWD Index	800	808	810
		LWD Frequency (#/100m)			
	Lateral Migration	Dominant BEHI/NBS	L/M	L/M	L/M
		Percent Streambank Erosion (%)	2	2	2
		Percent Streambank Armoring (%)			
	Riparian Vegetation	Effective Vegetated Riparian Area (%)	95	95	95
		Canopy Cover (%)	35	35	40
		Herbaceous Cover (%)	80	80	77
		Woody Stem Basal Area (m^2/ha)	4	4	5
	Bed Form Diversity	Pool Spacing Ratio (ft/ft)	2	2	2
		Pool Depth Ratio (ft/ft)	3	3	3
		Percent Riffle (%)	45	45	45
	Bed Material Characterization	Percent Fines (% < 2mm)	5	5	4
		Percent Fines (% < 6.35mm)	7	7	6
		Median Particle Size (d50) (mm)	45	45	48
Physicochemical	Temperature	Summer Mean Temperature (°C)	25	25	25
	Nutrients	Benthic Algal Biomass			
		Diatom Phosphorus Index (DPI) (µg/L)			
	Organics	Hilsenhoff Biotic Index (HBI)			
Biology	Macroinvertebrates	mIBI			
	Fish	fIBI			
		Fish Abundance (#/mile)			

The methods for calculating index values, color coding and scoring are identical to the existing and proposed condition assessments (described in Section 2.3.d). The same parameters and metrics must be used in the existing condition assessment and all subsequent condition assessments (i.e., proposed, as-built condition and all monitoring events).

2.3.c. Monitoring Schedule Considerations

Functional change is predicted using the existing and proposed condition assessments and then verified through monitoring. Post-construction monitoring ensures that a project has met, or is on track to achieve, the proposed conditions. Once post-project and monitoring data have been collected, those data and WISQT outputs can be used to review regulatory decisions related to performance standards, credit releases, adaptive management, special permit conditions, or project closeout. Monitoring requirements may vary between projects, and thus the monitoring period length, performance standards, and number of monitoring events will be specified by the USACE on a project-specific basis. Below are general guidelines for applying the WISQT.

As-built – As-built condition should verify proposed field values following construction for some metrics (listed below). The as-built field values should highlight any changes from the proposed condition.

- The concentrated flow point index, large woody debris index or LWD frequency, and percent armoring metrics should be measured post-construction or documented in record drawings.
- Floodplain grading should verify flood-prone width for the entrenchment ratio and effective vegetated riparian area metrics.
- Channel dimensions should verify bankfull elevations and metric field values for bank height ratio, entrenchment ratio and bankfull dynamics metrics.
- Channel profile should verify bankfull elevations and pool spacing ratio, pool depth ratio, and percent riffle metric field values.
- The proposed condition field values for the remaining metrics (land use coefficient, other lateral migration metrics, riparian vegetation metrics, and all metrics in the physicochemical and biology functional categories) may not be achieved immediately post-construction.
- For metrics that are not assessed during the as-built monitoring event, existing condition field values should be entered for the as-built condition and subsequent monitoring events until post-project data are collected for a particular metric.

Monitoring Events – Monitoring field values are measured at any given point after restoration activities have been completed and data collection should be sufficient to document potential problems in achieving the proposed condition during the monitoring period. For any field value entered into the WISQT workbook, completed Field Value Documentation forms (Appendix B) must be provided to document values and references for field value entries.

The frequency of monitoring different metrics may vary based on the level of effort and expense of the data collection. Not all metrics will be assessed in every monitoring year. For any metrics not measured in a particular monitoring year, the previously measured value (e.g., existing condition or as-built condition, etc.) should be entered for that monitoring event in the QT worksheet. A new field value is entered in the year it is measured. Field Value Documentation forms should be used to indicate which values have been measured in the current monitoring year and which have been held constant.

Inclusion of physicochemical and biology metrics may require additional upfront planning for data collection and processing. For example, samples may not be collected within every project reach and sampling may not occur annually. Users should consider the season, timing, location and sampling frequency requirements when developing the study design and monitoring schedule for these metrics.

Generally, only one season of data is required to calculate field values for the WISQT. However, meteorological conditions may contribute to interannual variability (e.g., heat, drought, heavy rainfall events), and it may be useful to use multiple years of data to inform condition field values. Additional post-project monitoring may be beneficial if climatic conditions were outside a ‘normal’ condition during the monitoring period, and this should be discussed with USACE as needed.

Project Closeout – All metrics should be measured at project closeout. Note that the user should consult with USACE for guidance if stressors and changes to catchment scale processes are suspected to affect the measured condition at project closeout.

2.3.D. Scoring Reach Condition And Functional Change (Lift or Loss)

Scoring occurs automatically as field values are entered into the condition assessment tables. A field value is a measurement or calculated assessment output for each specific metric. Therefore, the units can vary by metric, e.g., feet, centimeters, or even unitless ratios. As field values are entered, the worksheet calculates 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. Overall condition scores are then multiplied by reach length to generate Functional Feet values.

Elements of the roll-up scoring process are detailed below:

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 QT worksheet, these reference curves are used to calculate an index value.

As a field value is entered in the QT worksheet, the neighboring index value cell will auto-populate with an index value (Example 1a). If the index value cell returns FALSE instead of a numeric index value (Example 1b), the Site Information and Reference Selection section may be missing data.

Example 1: Populating Index Values in the WISQT

(a) *Index values auto-populate when field values are entered.*

Metric	Field Value	Index Value
Pool Spacing Ratio (ft/ft)	5	1.00
Pool Depth Ratio (ft/ft)	0.12	0.12
Percent Riffle (%)	30	0.54

(b) *If FALSE, check that the needed information has been entered in the Site Information and Reference Selection section of the worksheet.*

Metric	Field Value	Index Value
Pool Spacing Ratio (ft/ft)	5	FALSE
Pool Depth Ratio (ft/ft)	0.12	0.12
Percent Riffle (%)	30	FALSE

In Example 1b, the reference stream type was not selected in the Site Information and Reference Selection causing the Index Value to return FALSE because the tool could not determine which reference curve to use.

If the QT 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 Curves worksheet. Note that incorrect information in the Site Information and Reference Selection section may result in applying reference curves that are not ecologically suitable for the project.

However, simply because a numeric index value populates does not guarantee data integrity. Index value calculations will be compromised if incorrect information is input into the Site Information and Reference Selection section, or if incorrect field values are entered.

Roll-up Scoring – Metric index values are averaged to calculate parameter scores; parameter scores are averaged to calculate category scores (Figure 8). The category scores are then weighted and summed to calculate overall scores; overall score weighting by category is shown in Table 5.

- For metrics that are not assessed (i.e., a field value is not entered), the metric is removed from the scoring and no index value is provided. It is NOT counted as a zero for the parameter score calculation. As such, users should not enter anything for metrics that are not assessed.
- In the Existing and Proposed Condition Assessments, roll-up scoring is shown to the right of the field value inputs (Figure 8).
- In the post-project monitoring area of the QT worksheet, field values are entered into a single table (starting at row 100 in the worksheet), index values are calculated in a separate table (starting at row 130 in the worksheet), and parameter and functional category scores are calculated in separate tables above those (starting at rows 64 and 81 in the worksheet, respectively).

Figure 8: Roll-up scoring example.

Functional Category	Function-based Parameters	Metric	EXISTING CONDITION ASSESSMENT			
			Field Value	Index Value	Parameter	Category
Hydrology	Catchment Hydrology	Land Use Coefficient				0.36
	Reach Runoff	Land Use Coefficient	75	0.30	0.36	
		Concentrated Flow Point Index	0.5	0.42		
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft)	2	0.00	0.06	0.22
		Entrenchment Ratio (ft/ft)	1.2	0.12		
	Bankfull Dynamics	Width/Depth Ratio State (O/E)	1.5	0.38	0.38	
Geomorphology	Large Woody Debris	LWD Index	200	0.10	0.10	0.48
		LWD Frequency (#/100m)				
	Lateral Migration	Dominant BEHI/NBS	M/M	0.50	0.57	
		Percent Streambank Erosion (%)	15	0.63		
		Percent Streambank Armoring (%)				
	Riparian Vegetation	Effective Vegetated Riparian Area (%)	75	0.75	0.54	
		Canopy Cover (%)	70	0.86		
		Herbaceous Cover (%)	10	0.13		
		Woody Stem Basal Area (m^2/ha)	10	0.42		
	Bed Form Diversity	Pool Spacing Ratio (ft/ft)	5.3	1.00	0.67	
		Pool Depth Ratio (ft/ft)	1.8	0.56		
		Percent Riffle (%)	20	0.44		
	Bed Material Characterization	Percent Fines (% < 2mm)	20	0.49	0.50	
		Percent Fines (% < 6.35mm)	20	0.58		
		Median Particle Size (d50) (mm)	25	0.44		
Physicochemical	Temperature	Summer Mean Temperature (°C)				
	Nutrients	Benthic Algal Biomass				
		Diatom Phosphorus Index (DPI) (µg/L)				
	Organics	Hilsenhoff Biotic Index (HBI)				
Biological	Macroinvertebrates	mIBI				
	Fish	fIBI				
		Fish Abundance (#/mile)				

Table 5: Functional Category weights.

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

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.

- For the existing and proposed condition assessments, these overall reach scores are shown in the Functional Change Summary table at the top of the worksheet, next to the Site Information and Reference Stratification section.
- For the post-project monitoring condition assessments, the overall reach scores are calculated in the functional category summary table (row 86 in the worksheet).

Color Coded Scoring – When index values are populated in the condition assessment tables, cell colors automatically change color to identify where on the reference curve the field value lies (Figure 8). 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 when reviewing the summary tables and monitoring data included in the WISQT 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 can only be 0.60.

Scoring Changes by Rule –The percent streambank armoring metric has a default scoring rule. The percent streambank armoring metric captures problems associated with hardened, streambank armoring techniques. If present or proposed armoring techniques exceed 75% of the project reach, then the lateral migration parameter will score a 0.00 and the other lateral migration metrics (BEHI/NBS and percent streambank erosion) do not need to be assessed. At this magnitude, the armoring is so pervasive that lateral migration processes would likely have no functional value.

Calculating Functional Change – The change at an impact or mitigation site is the difference between the existing (pre-project construction) and proposed (post-project construction and all monitoring) scores. Existing, proposed and monitoring condition scores are multiplied by stream length to calculate the change in the functional feet score (ΔFFS). Since the condition score must be 1.00 or less, the functional feet score is always less than or equal to the actual stream length. The functional feet score will only equal 1.00 in a pristine stream where all condition scores equal 1.00.

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

$$Existing\ FFS\ = ECS * Existing\ Stream\ Length$$

$$Proposed\ FFS = PCS * Proposed\ Stream\ Length$$

$$Change\ in\ FFS\ (\Delta FFS) = Proposed\ FFS - Existing\ FFS$$

Functional lift is generated when the existing condition is more functionally impaired than the proposed condition and the change in functional feet yields a positive value. A negative value represents a functional loss.

Functional feet scores are summarized for the reach in the Functional Change Summary table and at the functional category level starting at row 90 in the worksheet.

Functional Lift and Loss Summary Tables

The QT worksheet contains five summaries to present scoring results:

- Functional Change Summary,
- Functional Category Report Card,
- Function-based Parameters Summary,
- Function-based Categories Summary (scores), and
- Function-based Categories Summary (FFS).

All cells within these summary tables are locked; each is discussed below.

Functional Change Summary – The QT worksheet summarizes the scoring at the top of the sheet, next to the Site Information and Reference Selection section. This summary (Figure 9) provides the overall scores from the Existing Condition Assessment and Proposed Condition Assessment sections, calculates the change in condition (PCS-ECS), the total number of functional categories assessed (out of five), presents the percent condition change (%) and incorporates the length of the project to calculate the existing Functional Feet Score (FFS), proposed FFS, the overall change in functional feet (ΔFFS), the percent change in FFS (%) and the functional yield (ΔFFS/LF).

The change in 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 the existing and proposed condition irrespective of stream length.

The percent condition change is the change in condition divided by the ECS:

$$Percent\ Condition\ Change\ (\%)\ = \frac{PCS - ECS}{ECS} * 100$$

Figure 9: Example Functional Change Summary Table.

FUNCTIONAL CHANGE SUMMARY	
Existing Condition Score (ECS)	0.29
Proposed Condition Score (PCS)	0.59
Change in Condition (PCS - ECS)	0.30
Categories Assessed	4
Percent Condition Change (%)	103%
Existing Stream Length (ft)	1000.0
Proposed Stream Length (ft)	1450.0
Additional Stream Length (ft)	450.0
Existing Functional Feet Score (EFFS)	290.0
Proposed Functional Feet Score (PFFS)	855.5
Proposed FFS - Existing FFS (ΔFFS)	565.5 P1
Percent Change in FFS (%)	195%
Functional Yield (ΔFFS/LF)	0.39

The summary includes the existing and proposed stream lengths to calculate and communicate the functional feet score (FFS). A functional foot is the product of a condition score and the stream length. 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 FFS – Existing FFS) 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 to inform credits.

A scoring qualifier is attached to the change in functional feet (ΔFFS) entry in the table. The qualifier relates flow type (perennial, intermittent, and ephemeral) and stream size (Strahler stream order; Strahler 1957) to the overall score to provide context for the ΔFFS value generated (Figure 9 shows a perennial, first order stream indicated by the P1 following the ΔFFS). This qualifier helps match impacted stream types to mitigation stream types, and thus avoid out-of-kind mitigation. Additional matches can be made by comparing the input and stratification tables between two sites.

The change in functional feet is also presented as a percentage, where the change in functional feet is divided by the existing FFS:

$$Percent\ Change\ in\ Functional\ Feet\ Score\ (\%)\ = \frac{Proposed\ FFS - Existing\ FFS}{Existing\ FFS} * 100$$

The change in functional feet is also displayed as yield (Functional Yield). This value is calculated as:

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

This value shows how many functional feet have been generated for every foot of channel being restored. For example, a value of 0.39 means that 0.39 functional feet are being created for every linear foot of restoration work. When the proposed stream length equals the existing stream length, the Functional Yield equals the Proposed Condition Score minus the Existing Condition Score.

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 10). This table provides a general overview of the functional changes pre- and post-project to illustrate where the change in condition is anticipated. In the following figures (10-12b), the applicant collected data through Physicochemical, which is why no summary data is provided in the Biology functional category.

Figure 10: Example Functional Category Report Card.

FUNCTIONAL CATEGORY REPORT CARD				
Functional Category	ECS	PCS	Change in Condition Scores	ΔFFS
Hydrology	0.30	1.00	0.70	180
Hydraulics	0.28	1.00	0.72	184
Geomorphology	0.43	0.79	0.36	103.6
Physicochemical	0.46	0.46	0.00	18.4
Biology				

Function-Based Parameters Summary – This summary starts at row 62 of the QT worksheet and provides a side-by-side comparison of the individual parameter scores for existing, proposed and all monitoring assessments (Figure 11). 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.

Figure 11: Example Function-Based Parameters Summary table.

FUNCTION-BASED PARAMETERS SUMMARY					
Functional Category	Function-Based Parameters	Existing Parameter	Proposed Parameter	As-Built	1
Hydrology	Catchment Hydrology				
	Reach Runoff	0.30	1.00	1.00	1.00
Hydraulics	Floodplain Connectivity	0.18	1.00	1.00	1.00
	Bankfull Dynamics	0.38	1.00	1.00	1.00
Geomorphology	Large Woody Debris	0.10	0.41	0.41	0.42
	Lateral Migration	0.57	1.00	1.00	1.00
	Riparian Vegetation	0.49	0.64	0.63	0.63
	Bed Form Diversity	0.51	0.97	0.97	0.97
	Bed Material Characterization	0.50	0.91	0.91	0.91
Physicochemical	Temperature	0.46	0.46	0.46	0.46
	Nutrients				
	Organics				
Biology	Macroinvertebrates				
	Fish				

Function-Based Categories Summary – This summary starts at row 79 in the QT worksheet and provides a side-by-side comparison of the functional category scores for existing, proposed, and all monitoring condition assessments (Figure 12a). Values are pulled from the Condition Assessment sections of the worksheet. This table can be used to better understand how each functional category score influences the overall scores.

Function-Based Categories Summary (FFS) – This summary starts immediately below the Function-based Categories Summary table and provides a side-by-side comparison of the functional feet score calculated for existing, proposed and all monitoring condition assessments (Figure 12b). This table can be used to better understand how each functional category contributes to the overall functional feet value for the reach.

Figure 12(a-b): Example (a) Function-Based Categories Summary table and (b) Function-Based Categories Summary (FFS) table.

a)

Functional Category	ECS	PCS	Change in Condition
Hydrology	0.30	1.00	0.70
Hydraulics	0.28	1.00	0.72
Geomorphology	0.43	0.79	0.36
Physicochemical	0.46	0.46	0.00
Biology			
Reach Condition Score	0.29	0.65	0.36

b)

Functional Category	EFFS	PFFS	Change in Condition (ΔFFS)
Hydrology	60.0	240.0	180.0
Hydraulics	56.0	240.0	184.0
Geomorphology	86.0	189.6	103.6
Physicochemical	92.0	110.4	18.4
Biology			
Reach FFS	294.0	780.0	486.0

2.4. Reference Curves Worksheet

The Reference Curves worksheet contains the reference curves used to convert metric field values into index values. For information on reference curves, see the Scientific Support for the WISQT (WISQT SC, *in draft*). 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) is standardized across metrics using definitions of functional capacity, i.e., functioning, functioning-at-risk and not-functioning conditions (Table 2). 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 2.

On this worksheet, reference curves are organized into columns based on functional category and appear in the order they are listed in the QT worksheet. One metric can have multiple curves depending on whether reference curves were stratified. For example, the effective riparian area metric is stratified by valley type. Above each reference curve is a table that displays the threshold values used to generate each reference curve. The minimum and maximum values for some reference curves are calculated from the regression equation instead of being defined threshold values (i.e., BHR, summer mean temperature, benthic algal biomass, DPI). For these metrics, these minimum and maximum values are displayed separately on the Reference Curves worksheet to calculate index values on the QT worksheet. All reference curves and their stratifications are described in the Scientific Support for the WISQT (WISQT SC, *in draft*).

There may be instances where better data to inform reference standard and index values are available for a project. USACE can approve an exception to using the reference curves and index values for a metric within the WISQT where sufficient data are available to identify reference standards. Examples of factors that may indicate the need for alternative reference curves include geographic or ecoregion differences, local reference reach data, or better modeling, depending on the parameter and metric.

Chapter 3. Wisconsin Debit Calculator Workbook

The Debit Calculator workbook (WISQT Debit Calculator vBETA.xlsx) is a Microsoft Excel Workbook comprised of 6 worksheets. There are no macros in the workbook and all formulas are visible, though worksheets are locked to prevent editing. The Debit Calculator workbook is a project- or stream-based workbook that includes input for up to 10 reaches within a project area. If a project includes more than 10 reaches, additional Debit Calculator workbooks will be needed.

In all worksheets, users input values into the gray cells and select inputs from the drop-down menus in the blue cells; white cells are locked and will auto-populate with input provided on another worksheet.

The Debit Calculator worksheets include:

- Project Summary
- Functional Loss
- Existing Conditions
- Proposed Conditions
- Reference Curves
- Pull Down Notes – This worksheet is hidden and contains all the inputs for drop down menus throughout the workbook.

3.1. Project Summary Worksheet

The Project Summary worksheet allows for a description of the proposed project and a summary of project reaches within the project area. This worksheet should be completed for all projects.

Project Description – Enter the following information, where applicable:

- Project name
- Applicant
- Project ID/Permit number(s)
- Date
- Project Description – space is provided to include a narrative description of the project.
- Total Functional Loss (Debits in FF) – the total change in functional feet across project reaches (calculated automatically)

Reach Summary – The following information is included for each project reach in the workbook:

- Stream ID by Reach – Each project reach within a project area should be assigned a unique identifier (see Section 4.1 for guidance on delineating project reaches).

- Flow Type – Select the flow permanence of the project reach as the jurisdictional determination of whether a stream resource is perennial, intermittent, or ephemeral.

- Strahler Stream Order – Stream order as defined by Strahler (1957) is a classification based on stream/tributary relationships. Headwater streams are first order; the stream becomes second order downstream of the confluence of two first order streams; the stream becomes third order downstream of the confluence of two second order streams; and so on.

- Impact Description – Briefly describe proposed impact for each reach. Activities can range from culvert installations to bank armoring, or full channel fill and replacement.

- High Quality Waters – High quality waters are determined using the WDNR Surface Water Data Viewer (SWDV)[10]. This input is used to select the default parameter score for the existing condition. Within the WDNR SWDV – 'Priority Navigable Waterways (PNW, ASNRI, PRF), Areas of Special Natural Resources Interest (ASNRI)' layer, users should select the 'PNW-ASNRI Wild and Scenic Rivers' layer and the 'PNW-ASNRI Outstanding and Exceptional Streams' layer. If the project area falls within one of these stream types, select "Yes"; otherwise select "No".
- Downstream Latitude and Longitude – Enter the latitude and longitude of the downstream extent of the reach. This information will auto-populate in the existing and proposed condition worksheets.

Aerial Photograph – There is space in the worksheet to insert an aerial photo of the project area. The imagery should label the upstream and downstream extent of each of the reaches (if there are multiple reaches).

3.2. Functional Loss Worksheet

The Functional Loss worksheet is where users enter data describing the impacts to each reach by selecting an impact severity tier and estimate functional loss. The worksheet consists of user notes, an input table, explanatory information on the impact severity tiers and debit options, and a summary of the results from the Existing and Proposed Conditions worksheets.

The Project Name, Date, and Project ID/Permit Number will auto-populate from the Project Summary worksheet. Each subsequent section of the Debit Calculator worksheet is discussed below.

3.2.A. Functional Loss Summary Table

The Functional Loss Summary Table (Figure 13) is the calculator which summarizes information for all reaches. For each reach, users should select the debit option, existing stream length, proposed stream length and impact severity tier; each is described below. Stream ID and Impact Description will auto-populate from the Project Summary worksheet; existing and proposed condition scores will auto-populate from their respective worksheets. The table will calculate change in functional feet for each reach and total functional loss across all reaches.

Figure 13: Functional Loss Summary Table example.

Functional Loss Summary Table								
Stream ID by Reach	Impact Description	Debit Option	Existing Stream Length	Existing Condition Score	Proposed Stream Length	Impact Severity Tier	Proposed Condition Score	Change in Functional Feet
1	Minor channelization from bridge construction	Partial Assessment	155	0.56	96.5	Tier 3	0.30	-57.9
Total Functional Loss (Debits in FF):								**-57.9**

[10] https://dnrmaps.wi.gov/H5/?Viewer=SWDV

Debit Option – There are three options to determine the existing and proposed site conditions. Users should select Full Assessment, Partial Assessment or No Assessment from the dropdown menu. These options are described below and summarized in Table 6; additional detail is provided in the St. Paul District Stream Mitigation Procedures (USACE 2023).

1. Full Assessment requires the permit applicant to use the Existing Conditions and Proposed Conditions worksheets to calculate the existing and proposed condition scores by quantitatively assessing required parameters. Parameter selection should be determined following coordination with the appropriate regulatory agencies. Once data has been entered into the Existing Conditions and Proposed Conditions worksheets, the scores will auto-populate from the ECS and PCS Summary Table.

2. Partial Assessment is for permit applicants that choose to use the Existing Conditions worksheet only. Users can enter field values from data collection for all selected parameters or use a combination of data collection and default scores. The parameter selection and default score selection will be determined based on coordination with the appropriate regulatory agencies. The proposed condition score will be calculated in the Functional Loss worksheet based on the Impact Severity Tier that is selected.

3. No Assessment allows permit applicants to use a default existing condition score for all required parameters. The existing conditions score will default to 0.90 for high quality waters or 0.80 for all other waters. The proposed condition score will be calculated in the Functional Loss worksheet 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, a default score of 0.30 will be used and displayed in the Functional Loss Summary Table. The Existing Conditions worksheet may display an index value lower than 0.30, but that is not the final site score. This default score ensures that all stream impacts, regardless of the starting condition of the stream, will yield functional loss.

Table 6: Summary of Debit Options.

Debit Option	Existing Condition Score (ECS)*	Proposed Condition Score (PCS)
Full Assessment	Assess existing condition using Existing Conditions worksheet for required parameters	Estimate proposed condition using Proposed Conditions worksheet for required parameters
Partial Assessment	Assess existing condition using Existing Conditions worksheet for selected parameters and use default scores for all other parameters	Use Functional Loss worksheet
No Assessment	Use default scores for all parameters (0.90 for high quality waters and 0.80 for other waters as a default value)	Use Functional Loss worksheet
** ECS cannot be below 0.30 for any of the options.*		

Existing Stream Length – 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.

Proposed Stream Length – Estimate the length of stream channel after impact. 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 can only impact 275 linear feet of stream. The debit calculator will highlight the Proposed Stream Length cell in red if the existing stream length is shorter than the proposed stream length.

Existing and Proposed Condition Scores – The existing and proposed conditions scores from the Existing Conditions and Proposed Conditions worksheets are automatically summarized in the ECS and PCS Summary Table (Section 3.2.B) and auto-populated here.

Impact Severity Tier – Determine the impact severity tier to calculate the proposed condition score for Partial and No Assessment debit options. 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 permanent loss of stream functions and therefore would not require compensatory mitigation, while a 5 would result in total loss of stream functions. The Functional Loss worksheet includes a table listing the impact severity tiers, a description of impacts to key function-based parameters, as well as example activities for each tier. Below that table in the Functional Loss worksheet is another table that lists the impact factors and percent functional loss for each tier (Table 7); these values are used to calculate proposed condition scores. A chart to the left of the Impact Severity Tier tables shows the range of loss modeled from each tier and used to inform the final percent functional loss values. Some activities could fall within more than one tier depending on the magnitude of the impact and efforts taken to minimize impacts using bioengineering techniques or other low-impact practices.

Table 7: Impact Severity Tiers and impact factors.

Tier	Description (Impacts to function-based parameters)	Impact Factor	Percent Functional Loss
0	No permanent impact on any of the function-based parameters	1.00	0%
1	Impacts to riparian vegetation and/or lateral migration	0.84	16%
2	Impacts to riparian vegetation, lateral migration, and bed form diversity	0.72	28%
3	Impacts to riparian vegetation, lateral migration, bed form diversity, and floodplain connectivity	0.53	47%
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	0.23	77%
5	Removal of all aquatic functions	0	100%

Calculating Functional Loss – The change at an impact site is the difference between the existing (pre-project condition) and proposed (post-project construction) scores. Proposed conditions scores are generated using project plans (for Full Assessment only), or through selection of impact severity tiers. Each impact severity tier is assigned an impact factor and percent functional loss which is multiplied by the existing condition score to calculate a proposed condition score. Existing and proposed condition scores are multiplied by stream length to calculate the change in functional feet (ΔFF). Since the condition score must be 1.00 or less, the functional feet score is always less than or equal to the actual stream length. The functional feet score will only equal 1.00 in a pristine stream where all condition scores equal 1.00.

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

$$Existing\ FF = ECS * Existing\ Stream\ Length$$

$$Proposed\ FF = PCS * Proposed\ Stream\ Length$$

$$Change\ in\ FF\ (\Delta FF) = Proposed\ FF - Existing\ FF$$

Functional loss is generated when the proposed condition is more functionally impaired than the existing condition and the change in functional feet yields a negative value.

Once the PCS is calculated, the Functional Loss worksheet uses the equations above to calculate the ΔFF in the Functional Loss Summary Table. The table will automatically total the ΔFF when data are entered for multiple project reaches. The absolute value of the total change in functional feet is then used to calculate the debits required to offset the proposed impacts, as outlined in the St. Paul District Stream Mitigation Procedures (USACE 2023).

3.2.B. ECS and PCS Summary Table

This 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 Functional Loss Summary table. If existing condition field values were not determined from studies, field investigations or best available science, or were otherwise not entered into the Existing Conditions worksheet, ECS will default to a score of 0.90 for high quality waters or 0.80 for all other waters. For No Assessment and Partial Assessment debit options, no data are entered in the Proposed Conditions worksheets and the PCS score is calculated using the impact severity tier. All scores in this table will auto-populate; no data entry is required.

Reminder: 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. This default score ensures that all stream impacts, regardless of the starting condition of the stream, will yield functional loss.

3.3. Existing Conditions and Proposed Conditions Worksheets

The Existing Conditions and Proposed Conditions worksheets are used to input existing and proposed field values for a project reach, with changes in condition calculated in the Functional Loss worksheet. There are two areas for data entry:

- Site Information and Reference Selection
- Condition Assessment field values

Users can score the existing and proposed conditions for 10 reaches in the Existing Conditions and Proposed Conditions worksheets, respectively. Reach IDs will auto-populate from the Project Summary worksheet. When entering data in the Existing and Proposed Condition worksheets, it is important to **ensure data are being entered in the condition assessment associated with the matching reach ID from the Project Summary worksheet.**

3.3.A. Site Information and Reference Selection

The Site Information and Reference Selection section consists of general site information to determine which reference curve(s) to apply in calculating index values for relevant metrics (Figure 14). For some metrics, these curves are stratified by physical stream characteristics like stream type and reference vegetation cover. Information on each input field and guidance on how to select values are provided below. It may not be necessary to complete all fields in this section, depending on parameter selection.

Users should ensure entries in this section are accurate. Metrics will not be scored or may be scored incorrectly if necessary and/or accurate data are not provided in this section.

The Site Information and Reference Selection section (Figure 14) is located above each reach condition assessment in the Existing Conditions and Proposed Conditions worksheets. 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 Wisconsin. Additional information on how reference curves are stratified is included in the Scientific Support for the WISQT (WISQT SC, *in draft*).

Figure 14: Example Site Information and Reference Selection fields from the Debit Calculator.

Site Information and Reference Selection							
Reach ID:	Mainstem Reach 1	Strahler Stream Order:	Second	Fish IBI:	Warmwater	Downstream Latitude:	44.2227
Existing Stream Type:	F	Flow Type:	Perennial	Target Fish Community:	Adult Smallmouth Bass (Native)		
Reference Stream Type:	E	Reference Vegetation Cover:	Woody	High Quality Waters:	Yes	Downstream Longitude:	-88.8041
Valley Type:	Unconfined Alluvial	Stream Temperature:	Warmwater	Drainage Area (sq. mi.):	4		

<u>Reach ID</u> – Each project reach within a project area is assigned a unique identifier in the Project Summary worksheet and each Reach ID is auto-populated in the Existing Conditions and Proposed Conditions worksheets.

<u>Existing Stream Type</u> – This is the Rosgen stream type (Rosgen 1996) before an impact activity. It is determined using existing condition data, as described in Section 4.2.

<u>Reference Stream Type</u> – This reflects the Rosgen stream type that would naturally occur given the valley morphology and absent from anthropogenic influences. The Debit Calculator relies on the reference stream type to stratify reference curves for the entrenchment ratio, pool spacing ratio, and percent riffle metrics. See Section 4.2 for information on characterizing reference stream type.

<u>Valley Type</u> – Valley type is used to stratify reference curves for effective vegetated riparian area. The valley type options are colluvial, confined alluvial, and unconfined alluvial. These terms are defined in the Glossary of Terms.

<u>Strahler Stream Order</u> – This information will auto-populate from the Project Summary worksheet.

<u>Flow Type</u> – This information will auto-populate from the Project Summary worksheet.

Reference Vegetation Cover – Reference vegetation cover is used to determine the reference curve for the canopy cover metric and to inform metric selection for riparian vegetation. In Wisconsin, vegetation communities include grasslands, oak openings and oak savannahs, oak and pine barrens, northern forests, southern forests and wetlands, with variation in community patterns across 16 distinct ecological landscapes (WDNR 2015). The user should select the reference vegetation cover as herbaceous or woody based on the natural presence and prevalence of woody species in the riparian zone. The reference vegetation cover is the community that would occur naturally at the site if the reach were free of anthropogenic alteration and impacts. For example, woody species would be naturally present and prevalent in forested communities, while prairie and meadow communities would have an herbaceous reference condition because woody species are not prevalent in these systems. In savannah and barren systems, where wood is a natural component but at a low tree density and a high herbaceous vegetation density, users should coordinate with USACE for advice on which reference curve is appropriate for that specific project. The appropriate reference community type can be determined by locating a similar pristine or minimally altered reference site within the catchment area or watershed, researching historical and ecological descriptions of mature and undisturbed vegetation communities in the vicinity (see *Ecological Landscapes of Wisconsin* [WDNR 2015]), and deduced through understanding the effects of land use practices and management on vegetation communities. All Debit Calculator users should consult with USACE for clarity and confirmation of reference vegetation cover.

Stream Temperature – A water body's temperature class, or modeled natural community classification, can be determined using the WDNR SWDV[11] 'Surface Waters->Stream Natural Communities' layer and Table 4 (Section 2.3). Select from the following:

- Coldwater
- Cold Transition
- Warm Transition
- Warmwater

The temperature class is used to stratify the reference curves for the Temperature parameter. WISQT users who are uncertain which temperature stratification they should select should consult WDNR's Aquatic Communities website for more information[12].

Fish IBI – This field is used to stratify the reference curves for the Fish Index of Biotic Integrity (fIBI) metric. This metric is stratified by stream temperature with different stream temperatures having different reference curves. Users should coordinate with WDNR to ensure that they select the correct thermal classification in Table 4 (Section 2.3) and review the metrics and criteria outlined in Lyons (1992), Lyons et al. (1996) and Lyons (2012).

Target Fish Community – The target fish community is used to select the appropriate reference curve for the fish abundance metric. This selection should be informed by the project location.

The target fish communities include:

- Inland streams:
  - Adult Smallmouth Bass (Native)
  - Adult and Yearling Brown Trout
  - Adult and Yearling Brook Trout (Native)

[11] https://dnrmaps.wi.gov/H5/?Viewer=SWDV
[12] https://dnr.wisconsin.gov/topic/Rivers/AquaticCommunities.html

- Coastal streams:
  - Lake Superior Trout Young of Year
  - Lake Michigan Trout Young of Year

Note that the first impassable barrier serves as the delineation between inland streams and coastal streams. If a site is located upstream of an impassable barrier then users should select one of the inland stream fish community options. Properly identifying inland versus coastal systems can be challenging given watershed changes (e.g., dam removal), and users should consult with WDNR field staff.

Within inland streams, there are multiple tools available to identify target species. Users can rely on the following maps to identify whether their project is located in a smallmouth bass or trout mapped waterway: WDR SWDV 'Fisheries Management' layer, Trout Regulations and Opportunities User Tool (T.R.O.U.T.)[13], or classified trout waters by county[14]. If a project reach is not mapped using the above resources, consult with WDNR field staff. Additionally, Smallmouth bass waters are described in *A Sampling Framework for Smallmouth Bass in Wisconsin's Streams and Rivers* (Smallmouth Bass Rivers Assessment Team 2006).

Users should consult with their local WDNR field staff or central office point of contact for guidance and approval to use the fish abundance metric for adult and yearling brown trout. Brown trout are not native and compete with the native brook trout population. Where possible, and particularly for projects performed for CWA § 404 mitigation, brook trout should be targeted for restoration instead of brown trout to better support the natural assemblage. Brown trout have similar habitat and water quality requirements as brook trout, so altered in-stream conditions may show lift or loss for brown trout populations where brook trout are scarce or not present.

High Quality Waters – High quality waters is used to select the default parameter score for the existing condition. This information is entered in the Project Summary worksheet and auto-populates in the Existing Condition and Proposed Conditions worksheets.

Drainage Area (mi^2) – The drainage area is the catchment 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.

Latitude/Longitude –This information will auto-populate from the Project Summary worksheet.

3.3.B. Existing and Proposed Condition Assessment Data Entry

Once the Site Information and Reference Selection section is completed, the user can input data into the field value column of the Existing and Proposed Condition Assessment tables (Figure 15).

A user will input field values for all selected metrics; a user will rarely input data for all metrics or parameters within the tool (see Section 4.3 for parameter and metric selection). The function-based parameters and metrics are listed by functional category, starting with hydrology. Multiple tables 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.

[13] https://dnr.wisconsin.gov/topic/Fishing/trout/TROUT.html
[14] https://dnr.wisconsin.gov/topic/Fishing/trout/streammaps.html

Existing Condition – Applicable for the Partial Assessment and Full Assessment debit options. Existing condition field values are derived from data collection and analysis methods outlined in Chapter 4 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 a more comprehensive site assessment. For any field value entered into the Debit Calculator workbook a completed Field Value Documentation form (Appendix B) should be provided to document values and references for field value entries.

Multiple sampling events will improve the accuracy of the field value used to calculate lift by quantifying inter- or intra-annual variability (e.g., macroinvertebrates and physicochemical metrics).

Note: For the Full Assessment option, if a field value is entered for a metric in the Existing Condition worksheet, a value must also be entered for the same metric in the Proposed Condition worksheet.

Proposed Condition – Only applicable for the Full Assessment debit option. Proposed condition field values represent the expected condition post-impact for each selected metric. More detail on how to determine reasonable values for proposed condition scores are described in relevant metric sections in Chapter 4.

3.3.c. Scoring Reach Condition

Scoring occurs automatically as field values are entered into the condition assessment tables. A field value is a measurement or calculated assessment output for each specific metric. Therefore, the units can vary by metric, e.g., feet, centimeters, or even unitless ratios. As field values are entered, the worksheet calculates 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. Overall condition scores are then multiplied by reach length to generate Functional Feet values. Elements of the roll-up scoring process are detailed below.

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, these reference curves are used to calculate an index value.

As a field value is entered in the condition assessment, the neighboring index value cell will auto-populate with an index value (Example 1a in Section 2.3). If the index value cell returns FALSE instead of a numeric index value (Example 1b in Section 2.3), the Site Information and Reference Selection section may be missing data. In Example 1b, the reference stream type was not selected in the Site Information and Reference Selection causing the Index Value to return FALSE because the tool could not determine which reference curve to use.

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 Curves 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. However, simply because a numeric index value populates does not guarantee data integrity. Index value calculations will be compromised if incorrect information is input into the Site Information and Reference Selection section, as well as incorrect field values.

Roll-up Scoring – 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 15). The category scores are then weighted and summed to calculate overall scores; overall score weighting by category is shown in Table 5 (Section 2.3).

- For metrics that are not assessed (i.e., a field value is not entered), the metric is removed from the scoring and no index value is provided. It is NOT counted as a zero for the parameter score calculation. As such, users should not enter anything for metrics that are not assessed.
- In the existing and proposed condition assessments, roll-up scoring is shown to the right of the field value inputs (Figure 15).

Figure 15: Scoring example of a permitted impact using the Partial Assessment debit option. Default scores are applied where parameters were not assessed.

EXISTING CONDITION ASSESSMENT					Roll Up Scoring			
Functional Category	**Function-Based Parameters**	**Metric**	**Field Value**	**Index Value**	**Parameter**	**Category**	**Category**	**ECS**
Hydrology	Catchment Hydrology	Land Use Coefficient				0.36	Functioning At Risk	0.53
	Reach Runoff	Land Use Coefficient	75	0.30	0.36			
		Concentrated Flow Point Index	0.5	0.42				
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft)	2	0.00	0.06	0.22	Not Functioning	
		Entrenchment Ratio (ft/ft)	1.2	0.12				
	Bankfull Dynamics	Width/Depth Ratio State (O/E)	1.5	0.38	0.38			
Geomorphology	Large Woody Debris	LWD Index	200	0.10	0.10	0.46	Functioning At Risk	
		LWD Frequency (#/100m)						
	Lateral Migration	Dominant BEHI/NBS	M/M	0.50	0.57			
		Percent Streambank Erosion (%)	15	0.63				
		Percent Streambank Armoring (%)						
	Riparian Vegetation	Effective Vegetated Riparian Area (%)	75	0.75	0.48			
		Canopy Cover (%)	45	0.63				
		Herbaceous Cover (%)	10	0.13				
		Woody Stem Basal Area (m^2/ha)	10	0.42				
	Bed Form Diversity	Pool Spacing Ratio (ft/ft)	5.3	1.00	0.67			
		Pool Depth Ratio (ft/ft)	1.8	0.56				
		Percent Riffle (%)	20	0.44				
	Bed Material Characterization	Percent Fines (% < 2mm)	20	0.49	0.50			
		Percent Fines (% < 6.35mm)	20	0.58				
		Median Particle Size (d50) (mm)	25	0.44				
Physicochemical	Temperature	Summer Mean Temperature (°C)			0.80	0.80	Functioning	
	Nutrients	Benthic Algal Biomass			0.80			
		Diatom Phosphorus Index (DPI) (µg/L)						
	Organics	Hilsenhoff Biotic Index (HBI)			0.80			
Biology	Macroinvertebrates	mIBI			0.80	0.80	Functioning	
	Fish	fIBI			0.80			
		Fish Abundance (#/mile)						

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. Overall reach scores are presented to the right of the category scores for each assessment.

Color Coded Scoring – When index values are populated in the condition assessment tables, cell colors automatically change color to identify where on the reference curve the field value lies (Figure 15). Green coloring indicates index scores that represent a functioning (reference standard) range of condition; yellow indicates index scores that represent a functioning-at-risk range of condition; and red indicates 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. 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.

Default Scores – In the Existing Conditions worksheet, scores for parameters that are not determined from studies, field investigations, or best available science will default to a score of 0.90 for high quality waters or 0.80 for all other waters (Note Physicochemical and Biology scores in Figure 15). 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.

Scoring Changes by Rule –The percent streambank armoring metric has a default scoring rule. The percent streambank armoring metric captures problems associated with hardened, streambank armoring techniques. If present or proposed armoring techniques exceed 75% of the project reach, then the lateral migration parameter will score a 0.00 and the other lateral migration metrics (BEHI/NBS and percent streambank erosion) do not need to be assessed. At this magnitude, the armoring is so pervasive that lateral migration processes would likely have no functional value.

3.4. Reference Curves Worksheet

The Reference Curves worksheet contains the reference curves used to convert metric field values into index values. For information on reference curves, see the Scientific Support for the WISQT (WISQT SC, *in draft*). 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) is standardized across metrics using definitions of functional capacity, i.e., functioning, functioning-at-risk, and not-functioning conditions (Table 2). 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 2.

On this worksheet, reference curves are organized into columns based on functional category and appear in the order they are listed in the Existing Conditions and Proposed Conditions worksheets. One metric can have multiple curves depending on whether the reference curves were stratified. For example, the effective riparian area metric is stratified by valley type. Above each reference curve is a table that displays the threshold values used to generate each reference curve. The minimum and maximum values for some reference curves are calculated from the regression equation instead of being defined threshold values (i.e., BHR, summer mean temperature, benthic algal biomass, DPI). For these metrics, these minimum and maximum values are displayed separately on the Reference Curves worksheet to calculate index values. All reference curves and their stratification are described in the Scientific Support for the WISQT (WISQT SC, *in draft*).

There may be instances where better data to inform reference standard and index values are available for a project. USACE can approve an exception to using the reference curves and index values for a metric in the Debit Calculator where sufficient data are available to identify reference standards. Examples of factors that may indicate the need for alternative reference curves include geographic or ecoregion differences, local reference reach data, or better modeling, depending on the parameter and metric.

Chapter 4. Data Collection and Analysis

This chapter provides instructions on how to collect and analyze data used in the WISQT and Debit Calculator workbooks. Individuals collecting and analyzing these data should have experience and expertise in the selected assessment method, e.g., riparian vegetation, bank erosion hazard index, large woody debris index, etc. Typically, the skills needed include 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.

This chapter includes desktop-based methods, steps for calculating metric field values, and a summary of field methods. For some metrics, multiple field methods are available that will allow for either rapid or more detailed forms of measurement. Rapid field procedures for certain parameters including floodplain connectivity, bankfull dynamics, bed form diversity, and riparian vegetation are provided in Appendix A. Data collection forms and Field Value Documentation forms are available in Appendix B and are described in the Documentation and Field Forms section for each metric below.

Few metrics are unique to the WISQT, 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 and highlight differences in data collection or calculation methods needed for the WISQT. Users should be familiar with these methods prior to data collection.

4.1. Reach Delineation and Representative Sub-Reach Selection

The WISQT 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, as stream condition or character can vary widely from the upstream end of a project to the downstream end, and each WISQT or Debit Calculator workbook includes data entry for up to 10 reaches within a project area.

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.

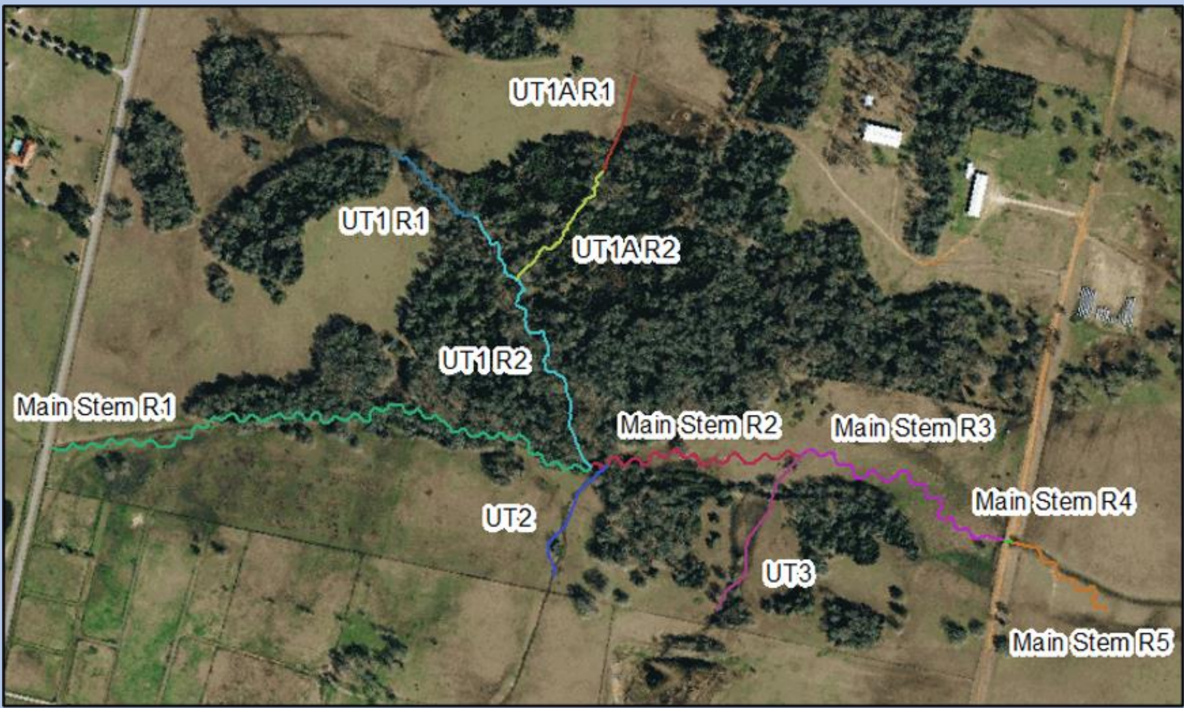
4.1.A. Delineation of Project Reach(es)

The user should determine whether their project area encompasses a single homogeneous reach, or multiple 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 include aerial imagery identifying the locations of all project reaches and provide justification for the final reach breaks in the Project Summary worksheet. Example 2 provides an example of project reach delineation and reach descriptions.

Example 2*:* Project Reach Delineation

The following is an example showing how project reaches are identified based on physical observations. Restoration work (WISQT workbook) 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, requiring two WISQT workbooks.



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.

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 that influences downstream channel size 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.

4.1.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 16). 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 et al. 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.

Hydrology Functional Category:

- Catchment hydrology is evaluated for the portion of the catchment draining to the upstream end of the project reach.
- Reach runoff metrics are evaluated for the entire project reach.

Hydraulics Functional Category:

- Floodplain connectivity and bankfull dynamics are assessed in the representative sub-reach.

Geomorphology Functional Category:

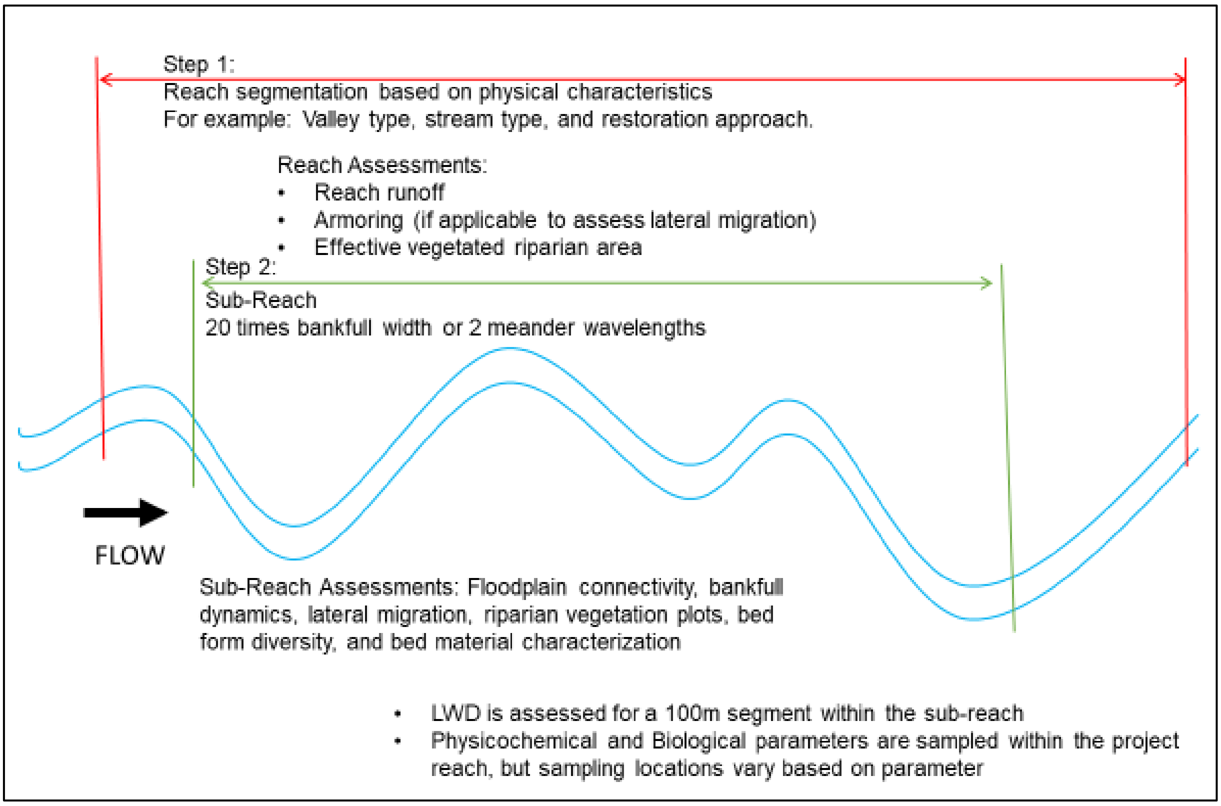
- Large woody debris (LWD) is assessed within a 328-foot (100 meter) segment located, whenever possible, within the representative sub-reach. If the project reach is less than 328 feet, assess the entire project length and normalize the field value to a 328-foot length.

- Bed material characterization and bed form diversity are assessed within the representative sub-reach. All lateral migration metrics are also assessed within the representative sub-reach, except for armoring, which is assessed along the entire project reach.
- Riparian vegetation plots are assessed within the representative sub-reach. Effective vegetated riparian area 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; users should refer to the sampling methods cited in this chapter and in Appendix A to determine the location of sampling.
- For some projects, users may be able to combine multiple reaches into a single sampling effort for physicochemical and biological metrics. An example is a series of reaches along one stream that does not have tributaries and where the team is confident that the existing and proposed (post-project) condition scores will represent all reaches. As reach condition changes and tributary influence increases, the decision about combining reaches can become complicated. Therefore, a monitoring plan should be developed on a case-by-case basis with input from USACE, the practitioner, and project sponsor.

Figure 16: Reach and sub-reach segmentation.



4.2. Determining Stream Type

In the QT worksheet of the WISQT workbook there is space to identify the existing, design, proposed and reference stream types for each project reach using the Rosgen (1996) method. Each of these stream type characterizations provides information on the project reach and could inform the restoration potential determination, project goals and objectives, and reach-specific performance standards. Similarly, in the Existing Conditions and Proposed Conditions worksheets in the Debit

Calculator workbook, there is space to identify the existing and reference stream type. Reference stream type is used to stratify reference curves for the entrenchment ratio, pool spacing ratio, and percent riffle metrics.

Stream types are based on the Rosgen stream type classification system and the basic fluvial landscapes where they typically occur, which are described in detail in *Applied River Morphology* (Rosgen 1996) and in *Part 654 Stream Restoration Design National Engineering Handbook* (NRCS 2007). The broad-level stream type is determined using entrenchment ratio, width depth ratio, sinuosity, and slope (Figure 17). While existing stream type is calculated from field data, determining design, proposed, and reference stream types will require additional sources of information. The Rosgen channel succession scenarios (Rosgen 2006) or other channel or stream evolution models (e.g., Schumm 1984, Cluer and Thorne 2013, Castro and Thorne 2019) can be used as a guide for determining potential trajectories. Where available this information can be further supported with information from the design process (e.g., fluvial landscape, historic channel conditions, watershed hydrology, sediment transport, and/or anthropogenic constraints); historic, geomorphic, and stratigraphic evidence; and an evaluation of process drivers.

Figure 17: 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			

<u>Existing Stream Type</u> – Existing stream type reflects the Rosgen stream type before impact or restoration activities. The existing stream type is not used to select the appropriate reference curve or determine index values but is provided for communication and can be used to inform restoration potential. The existing stream type is determined through a field survey of the project reach.

<u>Design Stream Type</u> – The design stream type reflects the channel dimension, pattern, and profile that will be constructed as part of the project design. Therefore, it is also the as-built stream type. Users should select this stream type after considering the existing stream type, project design, channel succession/evolution, and process drivers (Figure 17 and Example 3). This stream type may or may not be the same as the proposed or reference stream types.

<u>Proposed Stream Type</u> – The proposed stream type reflects the dimension, pattern, and profile that is expected to form (evolve) by the end of the monitoring period. The proposed stream type is the restoration target **at project closeout** informed by the design and an understanding of channel/stream evolution processes (Example 3) and should be consistent with the expected conditions within the Proposed Condition Assessment. This stream type may or may not be the same as design or reference stream type. For example, in alluvial valleys, it is common for practitioners to design a C, with the expectation it will evolve into an E over the course of the monitoring period. The proposed stream type is provided for communication and to inform the development of performance standards, for example, to account for any anticipated changes between as-built conditions and conditions at the end of the monitoring period.

Reference Stream Type – The reference stream type reflects the channel dimension, pattern, and profile that would naturally occur in a given valley in the absence of human influences. The reference stream type is used to stratify reference curves for the entrenchment ratio, pool spacing ratio, and percent riffle metrics, and can also inform restoration potential. This stream type may or may not be the same as existing, design and proposed stream types.

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 (Example 3). To determine reference stream type, users should have experience and knowledge about channel evolution, process drivers and the Rosgen stream classification system. For the WISQT, the reference stream type would be a C or E in unconfined alluvial valleys and a B for colluvial valleys. In confined alluvial valleys, the reference stream type would be a C or Bc depending on historic evidence of a meandering stream or step-pool stream. Reference curve stratification for entrenchment ratio, pool spacing ratio, and percent riffle are not available for some other reference stream types, such as DA reference stream type. This should be considered during Parameter and Metric Selection (Section 4.3).

Example 3: Determining Stream Types

Scenario A:


(a)


(b)


(c)


(d)

Existing Stream Type = G5c (Figure a). The stream is incised and entrenched with a low bankfull width/depth ratio, slope less than 2%, and a sand bed.

Reference Stream Type = C5 (Figure b). The reference reach is immediately upstream of the project reach. It is a single-thread, stream/wetland complex in a forested watershed that has not been disturbed in many decades. There was no evidence that the stream had ever been channelized or altered.

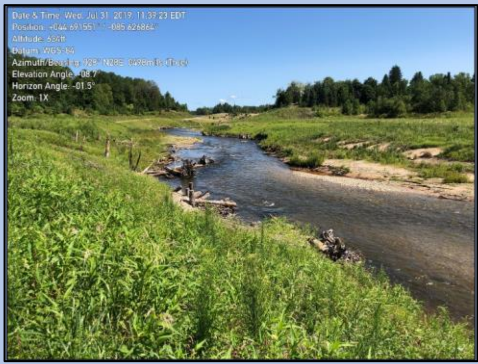
Design Stream Type = C5 (Figure c). The design (and as-built) stream type is a C. The entrenchment ratio is very large (>10), the bankfull width/depth ratio is >12 to encourage wetland development on the floodplain similar to the reference reach (a higher width/depth ratio can yield a shallower depth to the water table in this landscape and produce a stream/wetland complex). The upstream watershed is forested with low sediment supply. Stream power is low, erosion resistance is low, and the biotic interaction with riparian vegetation is high. These factors contribute to the decision to design a higher width/depth ratio than an E stream type, which would be more effective at transporting sediment in a low slope valley.

Proposed Stream Type (Figure d) = C5. Based on the design and an understanding of channel evolution in an unconfined alluvial valley in this landscape, it is anticipated that the proposed stream type at the end of five years of monitoring will remain a C5. This decision was also informed by the reference reach immediately upstream of the project reach.

Example 3: Determining Stream Types (cont'd)

Scenario B:

(a)

(b)


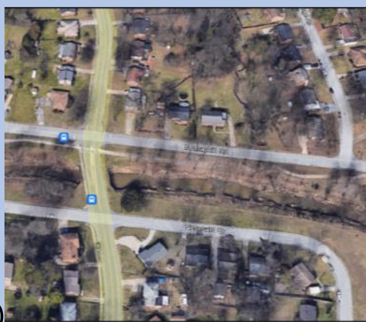
Existing Stream Type = Does not apply. Existing condition is a lake.

Reference Stream Type = C4 (Figure a). This river is in an unconfined alluvial valley with slopes <1%, and a gravel bed. Many reaches in undisturbed portions of the watershed classify as a C4.

Design/Proposed Stream Type = B4c (Figure b). The design goal is to remove the downstream dam and restore the stream channel in its former location. However, there is not enough funding to excavate the floodplain and remove the accumulated sediment in the lake bottom. Instead, floodplain (bankfull) benches will be constructed to provide a moderate entrenchment ratio (1.4 - 2.2). A Bc was selected as the design stream type due to reach-scale constraints. For the stream to evolve into a C stream type, significant floodplain erosion would have to occur. The stream type is expected to remain stable over the duration of the monitoring period, thus the proposed stream type is also a Bc.

Senario C:

(a)

(b)

(c)


Existing Stream Type = F4 (Figure a). This stream is in an urban setting, and is incised and entrenched but with a higher bankfull width/depth ratio than the Gc from Scenario A. This stream has a gravel bed.

Reference Stream Type = E4 (Figure b). The reach is in an unconfined alluvial valley that is currently developed with homes and roads. The stream has been confined and channelized, however, it is still classified as an unconfined alluvial valley for reference stream type purposes. Therefore, the reference stream type is a C or an E. Other reference reach streams in this region are E's due to the dense, woody vegetation along the streambanks and lack of cobble in the streambeds.

Design/Proposed Stream Type = B4c (Figure c). The design stream type is a Bc due to reach-scale constraints, including a sewer line along one bank and a road near the other. A bankfull bench will be constructed and the banks sloped to provide a moderate entrenchment ratio. In-stream structures will be used to create a step-pool sequence. Because no change in stream type is expected between the as-built condition and year five monitoring, proposed stream type is also a Bc. Maintaining channel stability is important due to the urban landscape.

4.3. Parameter and Metric Selection

The WISQT workbook and Debit Calculator workbook include 28 metrics used to quantify 14 parameters. Not all metrics and parameters will need to be evaluated at each site. The user should refer to this section, consider landscape setting, function-based goals/objectives, and restoration potential when selecting parameters.

IMPORTANT CONSIDERATIONS:

- For CWA § 404 and RHA § 10 projects, USACE has discretion over which field methods, metrics, and parameters are used for a project; therefore, users should consult with USACE prior to data collection on a project. In addition, USACE strongly encourages applicants or bank sponsors to consult with the St. Paul 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 throughout all condition assessments (i.e., existing, proposed, as-built, and monitoring) within a project reach once selected, otherwise the relative weighting between metrics and parameters changes and the overall scores are not comparable over time.

- For metrics that are not selected in the WISQT workbook (i.e., a field value is not entered), the metric is not included in the scoring. It is NOT counted as a zero. No value should be entered if a metric is not selected.

- In the Debit Calculator workbook, default scores are provided for all parameters except catchment hydrology and bed material characterization to ensure that authorized stream impacts are adequately mitigated. If metrics are selected for assessment and field values are entered, then the default score is replaced with the calculated values for that parameter and metric. Refer to Section 3.2 for more information on how functional loss is calculated using impact severity tiers.

- 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. A basic set of metrics within 7 parameters is recommended at all project sites evaluated for CWA § 404 or RHA § 10 purposes to provide consistency between impacts and compensatory mitigation and allow for more consistent accounting of functional change.

- Field methods are generally focused on single-thread wadeable streams. Some metrics may be difficult to sample in non-wadeable streams or anastomosed stream/wetland complexes and may require alternate field methodologies. For CWA § 404 or RHA § 10 projects, sampling plans in these systems should be discussed with USACE 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 anastomosed or ephemeral channels, the user should note this and select only applicable parameters (Table 8). While a parameter and associated metrics may be applicable to ephemeral and/or anastomosed channels, unique reference curves were not developed specifically for these systems. Where reference expectations for a particular metric may vary based on stream type or flow permanence, more focus should be placed on the difference in pre- and post-project scores rather than the absolute value.

- In beaver-influenced systems, application of the SQT should be evaluated on a case-specific basis, as there are several potential geomorphic responses to beaver activity. The first is where a beaver dam slows the flow of water in the channel but does not impound water to such a degree that it inundates the adjacent floodplain. In this case, the SQT can be applied, and users may need to wade the impounded reach to evaluate bedforms, even though the bedforms are flooded. The second scenario is where a beaver dam spans the full width of the floodplain, including the channel, creating a pond or series of ponds. In this case, the SQT is not easily applicable, and a wetland or lentic assessment may be more appropriate. A third scenario may be where a beaver dam is located on the floodplain or side channel, but not in the main channel (e.g., oxbows, sloughs, or small tributaries within the project area). In this case, the SQT can be used, but a wetland assessment or lentic assessment may be more appropriate in areas of beaver activity on the floodplain.

Table 8: Applicability of metrics across flow type and in stream/wetland complexes. An 'x' denotes that one or more metrics within a parameter are applicable.

Applicable Parameters	Perennial	Intermittent	Ephemeral	Stream/ Wetland Complexes (Anastomosed, DA)	Stream/ Wetland Complexes (Single thread, E/Cc-)
Catchment Hydrology	x	x	x	x	x
Reach Runoff	x	x	x	x	x
Floodplain Connectivity	x	x		x[1]	x
Bankfull Dynamics	x	x			x
Large Woody Debris	x	x	x	x	x
Lateral Migration	x	x	x		x
Bed Material Characterization	x	x	x	x	x
Bed Form Diversity	x	x			x
Riparian Vegetation	x	x	x	x	x
Temperature	x	Where baseflows extend through sampling period		x	x
Nutrients	x			x	x
Organics	x			x	x
Macroinvertebrates	x			x	x
Fish	x			x	x

[1] Entrenchment ratio is not applicable for stream/wetland complexes within DA stream types.

SPECIFIC GUIDANCE ON PARAMETER AND METRIC SELECTION

Catchment Hydrology: This parameter is recommended where the project area includes a significant portion of the catchment and uplift or loss from land use change is possible. There is only one metric to assess this parameter (land use coefficient). Consult with USACE for guidance on whether to use this parameter when using the WISQT workbook or Debit Calculator workbook.

Reach Runoff: This parameter should be evaluated at all project sites and is represented by two metrics. Users should evaluate the land use coefficient metric and the concentrated flow point index metric together. The two metrics are complimentary, as each contribute differently to an overall understanding of anthropogenic alteration of hydrologic processes in the lateral drainage; therefore, they should be applied together.

Floodplain Connectivity: This parameter should be evaluated at all project sites and is represented by two metrics: bank height ratio (BHR) and entrenchment ratio (ER). 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 anastomosed systems, where the BHR should be applied but not the ER.

Bankfull Dynamics: This parameter should be evaluated in all single-thread, wadeable streams. There is only one metric (width/depth ratio state) to assess this parameter.

Large Woody Debris (LWD): This parameter should be evaluated at all project sites and is represented by two metrics. Users can evaluate either the LWD Index (LWDI) or LWD Frequency metric, but not both. The LWDI metric better characterizes the complexity of large wood in streams but takes more time to assess.

Lateral Migration: This parameter should be evaluated at all single-thread reaches and is represented by three metrics. Additional guidance on metric selection follows:

1. The dominant BEHI/NBS and percent streambank 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 streambank 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 bank would be assessed for BEHI/NBS in the existing condition assessment but would be counted as an armored bank and NOT included in the BEHI/NBS assessment in the proposed condition. The same applies for a bank that is currently armored where armoring would be removed (i.e., the bank would be assessed for armoring but not BEHI/NBS under existing condition, but potentially included in the BEHI/NBS assessment for proposed and post-project monitoring assessments). A bank cannot count as both armored (preventing natural lateral migration processes) and as having the potential to erode.

Riparian Vegetation: This parameter should be evaluated at all project reaches and is represented by four metrics. effective vegetated riparian area, canopy cover, and herbaceous cover should always be evaluated. For reaches with woody reference vegetation cover, the woody stem basal area metric should also be evaluated.

Bed Form Diversity Parameter: This parameter should be evaluated at all single-thread perennial and intermittent project sites and is represented by three metrics: pool spacing ratio, pool depth ratio, and percent riffle. The three metrics are complimentary, as each contribute differently to an overall understanding of bed form diversity within the reach; therefore, users should evaluate all three metrics together. Additional guidance on metric selection follows:

1. The pool spacing ratio metric is not applicable to natural bedrock systems, ephemeral streams, naturally straight sand bed channels, or anastomosed channels. The pool depth ratio and percent riffle metrics should be evaluated together at these reaches.

Bed Material Characterization: This parameter is only applicable in gravel and cobble bed streams that naturally have a d50 greater than 34mm and is not applicable in natural small-gravel or sand bed streams. This parameter is represented by three metrics: two types of percent fines and median particle size. Therefore, this parameter is recommended for alluvial or colluvial stream reaches where altered sediment transport processes have shifted or have the potential to shift the grain-size distribution away from the reference condition. For example, this parameter could be applied in instances where legacy silt/sand is present, but the underlying bed material is gravel or cobble. These metrics may not be applicable in ecological landscapes where surficial geology would likely result in finer grained natural bed composition (e.g., Central Sand Hills, Central Sand Plains, Northeast Sands, or Northwest Sands).

Temperature, Nutrients and Organics[15]: These parameters are recommended for assessment where measurable changes are anticipated. There is one metric for temperature (summer mean temperature), two metrics for nutrients (benthic algal biomass and diatom phosphorus index), and one metric for organics (Hilsenhoff biotic index). For restoration projects (WISQT workbook), they are recommended for projects with goals and objectives related to water quality improvements when supported by the restoration potential result. One or more parameters can be applied at a project site.

Where nutrients will be measured, the benthic algal biomass metric should always be used. When benthic algal biomass scores between 1 and 2, the DPI metric will also be **required** and field values for both metrics should be entered into the condition assessments.

Macroinvertebrates[15]: This parameter is recommended for assessment in wadeable perennial and intermittent reaches where measurable changes are anticipated and is represented by one metric: mIBI. For restoration projects (WISQT workbook), it is recommended for projects with goals and objectives related to biological improvements and when supported by the restoration potential result. It is recommended that macroinvertebrate and fish parameters be evaluated together.

Fish[15]: This parameter is recommended for assessment in wadeable and non-wadeable perennial project reaches where measurable changes are anticipated and is represented by two metrics: fIBI and fish abundance. For restoration projects (WISQT workbook), it is recommended for projects with goals and objectives related to biological improvements and when supported by the restoration potential result. It is recommended that macroinvertebrate and fish parameters be evaluated together.

When selecting the fish parameter, the fIBI metric should always be evaluated. The fish abundance metric can also be selected in perennial and intermittent reaches where measurable change is anticipated. Prior to using the fish abundance metric, users should coordinate with the local field staff from WDNR to discuss their project and use of the metric. Please follow this link to locate your local fisheries biologist: https://dnr.wisconsin.gov/topic/Fishing/people/fisheriesbiologists.html. See Section 2.3.a or 3.3.a for additional instruction for selecting the target fish community for the fish abundance metric.

4.4. Bankfull Identification and Verification

Bankfull feature identification and verification should be completed by geomorphologists, hydrologists, engineers, or biologists who have the academic training and practical experience to find field indicators that separate channel forming processes from depositional processes associated with the floodplain or flood prone area. This is not an activity for untrained or inexperienced staff.

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[15] Without evaluating the physicochemical and biological parameters, the maximum overall score in the WISQT 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 WISQT workbook.

Before going to the field, calculate the drainage area to the downstream end of the reach. StreamStats[16] is a simple tool that can be used to delineate the watershed and obtain discharge data for flow events that are larger than bankfull, e.g., 2, 5, 10, 25, 50, and 100-year events. In addition, a bankfull regional curve that shows the bankfull area versus drainage area should be obtained and taken to the field. To the knowledge of the authors, there are no published regional curves for Wisconsin. For stream mitigation projects, it is recommended that bankfull regional curves be developed by competent stream assessment professionals before starting a project. Where a regional curve is not available or cannot be developed, users should consider other available regional curves, e.g., draft curves or curves from adjacent states. Regional curves can be tested whether they are applicable to the project area by surveying a reference reach within the project area watershed or nearby watershed. If the bankfull area from the reference reach falls within the range of scatter (refer to Step 3 instructions below), there is reasonable confidence the curves are applicable.

Bankfull identification and verification should be completed prior to collecting hydraulic or geomorphic data. Steps 1 and 2 below are used to identify the bankfull feature; Steps 3 and 4 are used to verify the bankfull feature.

Documentation and Field Forms: Bankfull verification is performed as part of the existing condition assessment and not part of the proposed condition assessment. Monitoring assessments should follow a similar process to verify that the top of bank is the bankfull indicator. Users should describe the bankfull verification process on the Field Value Documentation form in Appendix B.

BANKFULL IDENTIFICATION PROCESS:

Step 1: Look for Geomorphic Features

Look for geomorphic features that correspond to bankfull elevation, recognizing that there may be more than one feature in a reach. Common geomorphic features include the inner berm, bankfull, and terrace(s). In incised channels, bankfull is often the back of a depositional bench within the channel. The inner berm is a depositional feature that is below the bankfull feature, with a depth that is approximately one-half of the bankfull depth. The inner berm is often misidentified as bankfull by practitioners who are inexperienced with making bankfull calls. The inner berm may be the front of a sloping bench in incised channels, a smaller bench below the floodplain, or a lower break-in-slope on a point bar. The terrace is the easiest feature to identify. It is an abandoned floodplain adjacent to an incised channel. Figure 18 shows an example of the inner berm and terrace in relation to the bankfull elevation.

[16] https://streamstats.usgs.gov/ss/

Figure 18: Example of inner berm, bankfull, and terrace features.

Common bankfull features include the following in priority order:

- Top of the streambank (non-incised, reference condition).
- Top of point bar. Be aware that a point bar might have two breaks in slope. The lower is often the inner berm and the top is typically bankfull.
- Top or back of depositional bench inside channel (incised channels, top of bank is terrace).

There are other bankfull indicators, such as vegetation and stain lines; however, the indicators above are more reliable.

Step 2: Measure Difference in Water Surface and Bankfull Indicator

Measure the difference in water surface and the presumed bankfull feature at multiple locations where indicators exist. The differences should not vary by more than about 0.2 feet for the bankfull feature, unless there is a major change in the bed elevation, e.g., a headcut or waterfall. Note, the difference between water surface and other geomorphic features, such as the inner berm or terrace, might differ from that of the bankfull feature. For example, it is common for the difference between water surface and the inner berm to be half of the difference between water surface and bankfull. The difference between water surface and a terrace will be greater than the difference between water surface and bankfull. Differences between water surface and both inner berm and terrace elevations can also be recorded in case they are needed in Step 4. Figure 19 shows two practitioners measuring the difference between water surface and the bankfull feature, which, at this restored site, is also the top of the streambank. The results from Step 2 are used in Step 3.

Where detailed survey methods were implemented, the difference between water surface and bankfull should be consistent between the surveyed cross-sections and the longitudinal profile. This can be visually observed by comparing the slope of the best-fit-line through bankfull indicators in the longitudinal profile and compare that slope to the water surface slope for the reach. These two lines should be parallel, as shown in the longitudinal profile.

Figure 19: Example of measuring the difference in water surface and bankfull features.

BANKFULL VERIFICATION PROCESS:

Step 3: Stable Riffle Cross Section

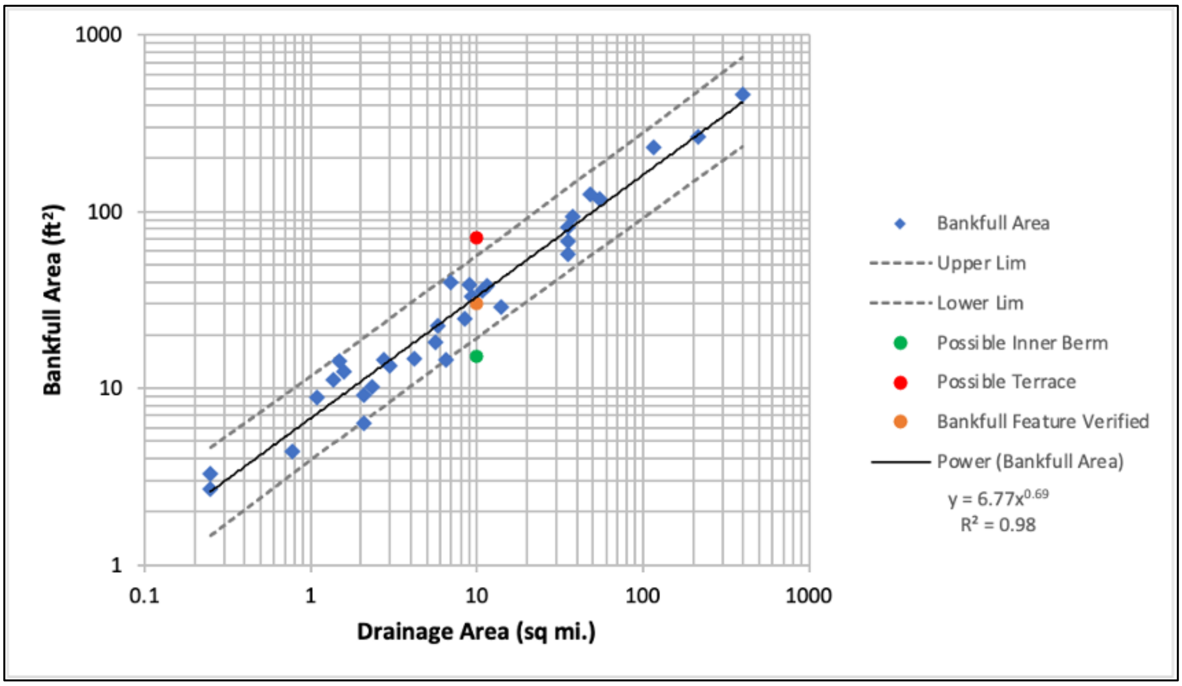
Find a stable riffle within or just upstream or downstream of the reach where the bed and banks are free to adjust from the natural sequence of flows. Survey a cross section at the bankfull indicator and calculate the bankfull cross-sectional area. If a bankfull indicator is not present, use the difference in water surface and bankfull features from Step 2 to “pin” the bankfull indicator before surveying the cross section.

Step 4: Plot the Bankfull Area onto a Regional Curve

Plot the calculated bankfull area from Step 3 onto the most applicable regional curve. If the plotted point falls within the prediction interval limits, the regional curve can be considered as representative of the project reach. If the plotted point is above the prediction interval limit, a terrace might have been surveyed rather than the active floodplain. If the plotted point is below the prediction interval limit, an inner berm may have been surveyed. More assessment will be needed to determine if the correct geomorphic feature was identified or if the regional curve is not representative of the project reach.

Figure 20 shows an example of the scenarios described above (note this regional curve is an example only and is not applicable to Wisconsin). The solid black line is the best-fit line through the bankfull area data points (blue diamonds). These points represent reference condition or at least stable streams free to adjust from the natural sequence of flows with obvious bankfull features. The dashed lines represent the upper and lower 95% prediction interval limits. The orange dot plots within the prediction limits of the regional curve; this verifies that the field determination of bankfull from Step 1 is correct. The red dot plots above the prediction limits, indicating the cross-sectional area is larger than expected. This could mean that a terrace was surveyed rather than a bankfull feature. The green dot represents a feature that is below the prediction limits, which could indicate that an inner berm was surveyed rather than bankfull.

Figure 20: Example of regional curve showing bankfull verification.



If the cross-sectional area does not plot within the range of scatter but there is certainty that the bankfull feature was properly identified (e.g., there are no other indicators present), then the regional curve may not be representative of the precipitation/runoff processes in the project watershed and the regional curve cannot be used. Additional fieldwork would be needed to confirm that the identified feature is bankfull.

IF NO REGIONAL CURVES ARE AVAILABLE AND REGIONAL CURVES ARE NOT BEING DEVELOPED:

Users can survey slope and sample bed material at the stable riffle to calculate the bankfull discharge associated with the geomorphic feature(s) identified in Step 2. The bankfull discharge can be verified using a flood frequency analysis. Flood frequency analysis is based on discharge rather than area and it is important to remember that unless velocity is measured in the field (average velocity for a cross-section using a flow meter) then the calculated discharge value for a cross-section is a coarse estimate. StreamStats is the most likely source of flood frequency data. Use USGS regional regression equations for the 2-, 5-, and 10-year discharges. StreamStats calculates higher return intervals, but these are not needed (or preferred) for this analysis. Relationships are not linear and thus, including higher return interval events will affect the results. Plot the calculated discharge on the x axis and the return interval on the y-axis. Fit a regression line through the data and use the equation to calculate the return interval of the reach based on the estimated bankfull discharge. If the result is less than 2 years, this supports that the feature is bankfull. Bankfull discharge modeling and return interval calculations should be performed by engineers, hydrologists, or biologists with experience working with hydrology data.

If no indicators are present in the reach, or upstream/downstream, and no regional curves are available, then a watershed-specific set of regional curves will be required, or the practitioner will need to develop hydrology and hydraulic models and assume that bankfull is the 1.5-year discharge.

4.5. Hydrology Functional Category

The SFPF functional statement for this category is the transport of water from the watershed to the channel. There are two function-based parameters used to inform the functional statement within the hydrology functional category. The two function-based parameters are: catchment hydrology and reach runoff. Refer to Section 4.3 of this manual for recommendations on when to apply each parameter and metric.

4.5.A. Catchment Hydrology and Reach Runoff

The overall catchment for a project reach is defined as the land area draining to the downstream end of the project reach. The overall catchment is split into two portions (Figure 21):

1) the land area that drains to the upstream extent of the project reach, and

2) the land that drains laterally into the stream reach.

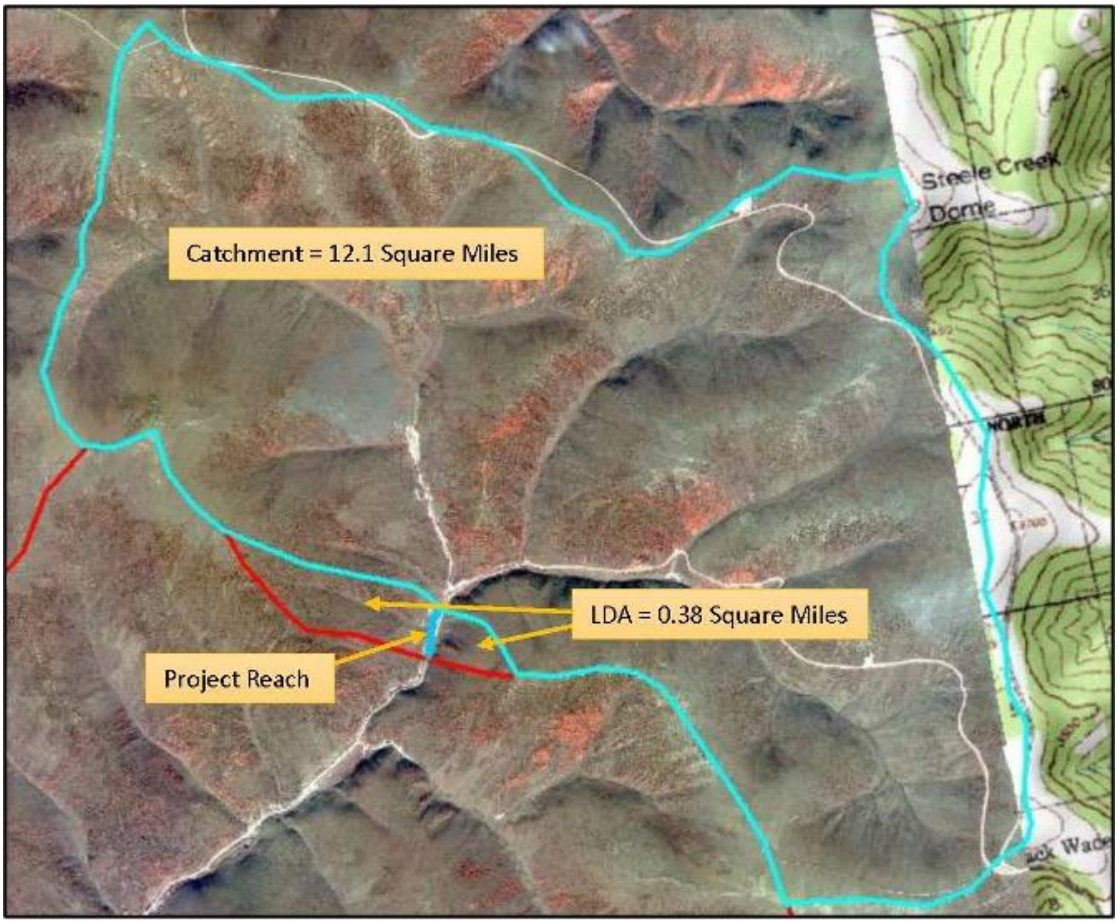
The land that drains to the upstream extent of the project reach is used within the catchment hydrology parameter. The catchment hydrology parameter considers the land uses (e.g., forested versus urban) within the upstream catchment. If an impact, restoration, or mitigation project encompasses a large portion of the contributing catchment, then functional change may be captured with this parameter. If the project is small compared to the catchment, functional change will likely be negligible. There is one metric to assess the catchment hydrology parameter: land use coefficient.

The reach runoff parameter is assessed within the lateral drainage area (LDA) for the project reach, which is the portion of the drainage area that is adjacent and drains laterally into the project reach. More specifically, the reach runoff parameter characterizes water that is being delivered to the stream channel via overland flow. In the example provided in Figure 21, the blue line delineates the land area that drains to the upstream extent of the project reach (12.1 mi^2) while the LDA represents the portion adjacent to the project reach (0.38 mi^2).

There are two metrics to assess the reach runoff parameter: land use coefficient and concentrated flow point index.

Experience Requirements: Data collection for catchment hydrology and reach runoff parameters should be performed by professionals with experience in GIS or other spatial analysis software.

Figure 21: Example showing the upstream catchment area and lateral drainage area (LDA).



Land Use Coefficient

Land use data serves as a surrogate for the infiltration and runoff processes within the upstream catchment and lateral drainage area. The same metric is used in catchment hydrology and reach runoff parameters.

An area-weighted land use coefficient quantifies the influence of land use on runoff potential within the upstream catchment (for the catchment hydrology parameter) and the lateral drainage area (LDA; for the reach runoff parameter). As the land use coefficient increases, the runoff generated from that land increases. Higher values, nearer 100, indicate more runoff potential while lower values, nearer 0, indicate less runoff. Land use coefficients are shown in Table 9.

Table 9: Land use descriptions and associated land use coefficients (adapted from NRCS 1986).

Land Use Description (adapted from TR-55)	Land Use Coefficient
Urban Areas Land Uses	
Open Space (lawns/turf, parks, golf courses, cemeteries, etc.)	69
Impervious areas	98
Unpaved Roads (e.g., dirt/gravel)	85
Commercial, business and industrial districts	92
Residential districts by average lot size:	
<1/4 acre	75
~1 acre	68
>2 acres	65
Agricultural Lands/Natural Land Cover	
Open Water – refers to impounded water behind dams only	100
Cropland	74
Pasture, grassland, or range – continuous forage for grazing	69
Meadow – continuous grass, protected from grazing and generally mowed for hay	58
Brush – brush-weed-grass mixture with brush major element	56
Woods – grass combination (orchard or tree farm)	65
Woods – disturbed by heavy grazing	66
Woods – forested areas protected from grazing and w/adequate litter and brush covering the soil	55
Native Prairie	55

Method:

1. The drainage area for the project reach should be delineated to complete the Site Information and Reference Selection (Section 2.3.a. or Section 3.3.a) using available topographic data (e.g., StreamStats, USGS maps, LiDAR or other digital terrain data). Using this drainage area, delineate the upstream catchment area from the LDA (Figure 21) and then calculate one or both, as needed, in acres.

2. Using recent aerial imagery[17] or the USGS National Land Cover Database (NLCD), delineate the different land use types within the upstream catchment area and/or LDA and calculate the area occupied by each land use type listed in Table 9. **Note: open water that is not impounded (e.g., oxbow lakes) is excluded from the lateral drainage area.** Sum the area of natural open water and subtract from the total catchment area and/or LDA to get $Area_{total}$.

3. Using Table 9, assign each land use type a land use coefficient value and document any assumptions.

4. Calculate an area-weighted land use coefficient for the upstream catchment area and/or the LDA. 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 $Area_{total}$ (see following equation).

[17] Google Earth or high-resolution digital imagery is available from DigitalGlobe. DigitalGlobe imagery is available for purchase but is available at no cost for federal employees.

$$Field\ Value = \frac{\sum [\![(Area]\!]_i * \ Land\ Use\ Coefficient_i)}{Area_{total}}$$

Estimating proposed condition field values: Proposed field values for the land use coefficient can be calculated based on anticipated areas of land use change in the upstream catchment area and/or LDA that are associated with the proposed project. Stream restoration projects may convert land uses within the project area to natural land cover, particularly in the riparian area adjacent to the channel. Keep in mind that newly planted vegetation is considered an immature vegetation community. The area-weighted land use coefficient will change over time as vegetation matures. For a given compensatory mitigation project, performance standards outside the SQT assessment should define when the site can be considered mature (e.g., vegetation density, diversity, diameter at breast height).

Documentation and Field Forms: Record the upstream catchment area and/or LDA and the area within each land use type on the Field Value Documentation Form in Appendix B; in the notes column, describe the source of the land cover data. Include a map depicting topography, upstream catchment and/or LDA boundaries and land uses, with data layers clearly labeled. The Field Value Documentation form will automatically calculate the field value from the information entered.

Concentrated Flow Point Index (CFPI)

The Concentrated Flow Point Index (CFPI) characterizes the effects of concentrated flows within the LDA by accounting for the contributing drainage area and channel type of each concentrated flow point (CFP).

A CFP is an ephemeral, erosional feature, such as a swale, gully, or other constructed channel or drainage feature that alters or concentrates runoff directly into a stream. Examples include ditches, storm drains, and drain tiles. Additionally, CFPs include channels that have formed where a pipe or other drainage feature discharges to open ground that has subsequently eroded to form a channelized feature.

Example 4*: Concentrated Flow Points*

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

Natural ephemeral channels, spring outlets, outlets from properly functioning best management practices (BMPs), and “natural” streams impacted by channelization or other man-made activities are not considered CFPs. Best management practices are defined as structural measures that mitigate the hydrologic and physicochemical impacts of anthropogenic land covers (EPA 1999). BMPs are often engineered or constructed facilities, such as a stormwater wetland or infiltration basin, that reduce pollutant loading and modify volumes and flow. An undisturbed stream channel flowing into a project reach is also not a CFP, but instead would be considered a tributary and separate project reach.

This metric assesses the contributing drainage area and type of CFP that enters the project reach. The CFPI is calculated using the following equation:

$$CFPI = \sum \left(\frac{CFP\ drainage\ area}{Lateral\ drainage\ area} \times \ Channel\ Type\ Ranking \right)$$

Method: The CFPI should be evaluated throughout the project reach.

1. Review terrain and aerial imagery of the lateral drainage area to identify natural drainages and potential concentrated flow points before going in the field.
2. Delineate the LDA adjacent to the project reach (see land use coefficient metric).
3. Walk the entire project reach, including both sides of the stream channel, and record the location (i.e., latitude and longitude, left or right bank) and type of any observed concentrated flow points. See Table 10 for CFP channel types and their rankings. Vegetation cover should be estimated within the channel bed (e.g., within the ordinary high-water mark). Where CFPs are composed of multiple CFP channel types, ranking should be based on the feature at its outlet to the stream.
4. Delineate the contributing drainage areas of each concentrated flow point identified in the field. The drainage area for CFPs can be determined using topography data and storm drain networks[18].
5. Calculate the CFPI using the equation above.

Table 10: Rankings for each CFP channel type. Note that higher ranking reflects lower functional capacity.

CFP Type	Ranking
Pipe or open concrete channel	1.0
Open channel with >4% slope or impermeable soils	0.9
Open channel with <4% slope and <50% vegetation cover	0.8
Open channel with <4% slope and 50-90% vegetation cover	0.7
Open channel with <4% slope and >90% vegetation cover	0.6

Estimating proposed condition field values: Proposed field values for this metric can be calculated based on anticipated changes to CFPs in the project area associated with the proposed project. Stream restoration projects may reduce concentrated flow entering the channel by dispersing flow in the floodplain, increasing ground cover in the channel, or by installing stormwater best management practices within the project area. *Combining multiple CFPs into a single CFP is not considered an improvement.* The restoration activity should diffuse or capture the runoff. Example activities include filling ditches, removing pipes, routing concentrated flow into created or constructed wetlands, and other stormwater control measures.

Documentation and Field Forms: For each CFP, field and desktop data should be entered in the Project Reach form in Appendix B. CFPs and channel type ratings should be identified in the field; desktop area calculations should also be recorded on the Project Reach form. For each CFP, the form will automatically calculate the percent of the LDA flowing into each concentrated flow point and report a CFPI score. The form will sum individual CFPI scores to yield the CFPI field value that is entered into the WISQT workbooks. This information is then automatically populated on the Field Value Documentation form.

[18] Note that drain tiles may drain areas that do not necessarily follow the surface topography. For consistency in applying the methods, where the mapped drain tile location extends beyond the lateral drainage area for the reach (e.g., crosses a watershed divide), the surface area draining to the physical location of the drain tile will be mapped but not included in the contributing drainage area or the LDA.

4.6. Hydraulics Functional Category

The functional statement for hydraulics is the transport of water in the channel, on the floodplain, and through sediments. There are two function-based parameters for hydraulics: floodplain connectivity and bankfull dynamics. Refer to Section 4.3 of this manual for recommendations on when to apply each parameter and metric.

4.6.A. Floodplain Connectivity

The floodplain is the area adjacent to the channel that is inundated during overbank flow events. This parameter includes metrics that evaluate whether flows larger than bankfull can access, and the extent to which they access the floodplain.

There are two metrics to assess floodplain connectivity: bank height ratio (BHR) and entrenchment ratio (ER).

Experience Requirements: Data collection for floodplain connectivity metrics should be performed by professionals that have experience with standard survey techniques and experience with identification and verification of bankfull.

Bank Height Ratio (BHR)

The bank height ratio (BHR) is a measure of channel incision and an indicator of whether flood flows can access and inundate the floodplain (Rosgen 2014). BHR is measured in a riffle and calculated as the low bank height divided by the maximum bankfull riffle depth (D_{max}). 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.

$$BHR = \frac{Low\ bank\ height}{Maximum\ bankfull\ riffle\ depth}$$

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4).

At every riffle within the representative sub-reach:

1. Measure the length of the riffle (see Glossary of Terms for riffle definition).
2. Identify the bankfull and top of low bank features. Use the bankfull verification process to help identify bankfull features. If a physical indicator that has been verified is present, use that feature. For low bank height, identify the break between the channel and a floodplain or terrace on both sides of the stream and identify the bank with the lower elevation. Further instruction for incised channels is provided in Appendix A.
3. At the approximate mid-point of the riffle, record the low bank elevation, bankfull elevation and the thalweg elevation. Users should consider whether the approximate mid-point is representative of the entire riffle length. If not, for example due to a CFP or other feature, the measurement location can be shifted. This should be documented on the field forms, with appropriate rationale for shifting the data point.
4. Calculate the low bank height by subtracting the thalweg elevation from the low bank elevation.
5. Calculate the difference between the bankfull elevation and the thalweg elevation (bankfull maximum depth).

6. Calculate the BHR for each riffle by dividing the low bank height (Step 4) by the bankfull maximum depth (Step 5). Note, when the top of low bank and the bankfull feature are the same, the BHR equals 1.0.
7. Using the BHR and riffle length for every riffle feature within the representative sub-reach, calculate the weighted BHR using the equation below. Example 5 demonstrates the weighted BHR calculation. The weighted BHR should then be entered as the field value in the WISQT.

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

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

Standard survey protocols are required to collect accurate elevation data for Step 3 above. Appendix A provides instructions for rapid survey methods which use a tape, survey rods, and hand levels.

Estimating proposed condition field values: The proposed condition field value for BHR should be based on the proposed riffle length and proposed channel cross-section for every riffle in a representative sub-reach of the proposed channel. Calculations should consider any proposed activities that may alter the cross-section or longitudinal profile, including floodplain excavation and construction of berms or levees.

Documentation and field forms: On the Field Value Documentation form in Appendix B, note the file location of survey data and profile/cross-section figures, the survey method and any post-processing tools used. If users record the length of each riffle and the BHR at each riffle on the form, it will calculate the metric field value from the data entered. If using the Rapid Geomorphic Survey method outlined in Appendix A, users should enter field data on the Rapid Survey form in Appendix B. For other surveying protocols, an optional longitudinal survey form and cross section form are provided in Appendix B.

Example 5: 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			

Entrenchment Ratio (ER)

The entrenchment ratio (ER) is a ratio of the flood-prone area width divided by the bankfull width, where the flood-prone area width is the width of the floodplain at a depth that is twice the bankfull maximum riffle depth (Rosgen 1996).

$$ER = \frac{Flood - prone\ Width}{Bankfull\ Width}$$

Method: Prior to calculating this metric, users need to complete the bankfull verification process (see Section 4.4).

The ER should be measured for each riffle within the representative sub-reach to calculate the weighted ER (see equation below and Example 6). Note: If the flood-prone width is uniform (as verified by using topographic data), it is unnecessary to measure at every riffle and the ER can be measured at a single representative riffle (follow steps 2 through 4 below).

1. Measure the length of the riffle (see Glossary of Terms for riffle definition).
2. Identify the bankfull elevation. Use the bankfull verification process to help identify bankfull features. If a physical indicator that has been verified is present, use that feature.
3. At the approximate mid-point of the riffle, record the bankfull channel width and flood-prone width. Users should consider whether the approximate mid-point is representative of the entire riffle length. If not, for example due to a CFP or other feature, the measurement location can be shifted. This should be documented on the field forms, with appropriate rationale for shifting the data point.
4. Calculate the ER by dividing the flood-prone width by the bankfull channel width. Record the ER for each riffle.
5. Using the ER and riffle lengths for every riffle feature within the representative sub-reach, calculate the weighted ER using the equation below and Example 6. The weighted ER should then be entered in the WISQT.

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

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

Standard survey protocols are required to collect accurate dimensions and elevation data for Steps 2 and 3 above. Alternatively, Appendix A provides rapid survey instructions using a tape, survey rod, and a range finder.

Estimating proposed condition field values: The proposed condition field value for ER will be based on the proposed riffle length, flood-prone area width, and channel width for every riffle in a representative sub-reach of the proposed channel. Calculations should consider any proposed activities that may alter the flood-prone area, cross-section, or longitudinal profile, including floodplain excavation and construction of berms or levees.

Documentation and field forms: On the Field Value Documentation Form in Appendix B, note the file location of survey data and profile/cross-section figures, the survey method and any post-processing tools used. If users record the length of each riffle and ER at each riffle on the form, it will calculate the metric field value from the data entered. If using the Rapid Geomorphic Survey method outlined in Appendix A, users should enter field data on the Rapid Survey form in Appendix B. For other surveying protocols, an optional longitudinal survey form and cross section form are provided in Appendix B.

Example 6: 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 = 584/305 = 1.9			

4.6.B. Bankfull Dynamics

This parameter characterizes the dynamic flow conditions created by the interaction of flowing water against the streambed and banks by comparing existing channel shape to reference condition (Harman et al. 2012).

There is one metric to assess bankfull dynamics: width/depth ratio state (WDRS; % of expected).

Experience Requirements: Data collection for bankfull dynamics should be performed by professionals that have experience with standard survey techniques and experience with identification and verification of bankfull.

Width/Depth Ratio State (WDRS)

The width/depth ratio (W/D) is measured at a riffle and is the bankfull width divided by the bankfull mean depth. The bankfull mean depth is calculated as the cross-sectional area divided by the bankfull width. This ratio is then divided by a reference W/D to calculate the width/depth ratio state (WDRS; Rosgen 2014).

$$Width\ Depth\ Ratio\ State = \left. \frac{W_{bankfull}}{D_{bankfull\ mean}} \middle/ Reference\ W/D \right.$$

An increase in WDRS is generally associated with accelerated streambank erosion, excess aggradation or deposition processes, and over-widening of the stream channel. This metric can serve as an indicator of aggradation (W/D is larger than reference value) and incision (W/D is less than reference value). However, a W/D that is smaller than reference W/D should be considered in combination with the BHR (i.e., a decrease in W/D with a corresponding increase in BHR indicates degradation, but a decrease in W/D with a BHR near 1.0 does not).

Method: Prior to calculating this metric, users need to complete the bankfull verification process (see Section 4.4). Scoring for this metric is influenced by the bank height ratio metric and users should refer to the Scientific Support for the Wisconsin Stream Quantification Tool for more information (WISQT SC, *in draft*).

At every riffle within the representative sub-reach:

1. Measure the length of the riffle (see Glossary of Terms for riffle definition).
2. At the approximate mid-point of the riffle, identify the bankfull elevation and survey the bankfull cross-section with sufficient detail to calculate bankfull area. Users should consider whether the approximate mid-point is representative of the entire riffle length. If not, for example due to a

CFP or other feature, the measurement location can be shifted. This should be documented on the field forms, with appropriate rationale for shifting the data point. Use the bankfull verification process to help identify bankfull features. If a physical indicator that has been verified is present, use that feature.

3. Calculate the bankfull width, cross-sectional area, mean depth, and W/D for each riffle. Note, for the rapid method, the mean depth can be estimated by measuring the depth from edge-of-channel to bankfull. In this case, the cross-sectional area does not need to be calculated.
4. Using the W/D and riffle length for every riffle feature within the representative sub-reach, calculate the weighted W/D using the equation below.

$$W/D_{weighted} = \frac{\sum_{i=1}^{n}\left(\frac{W}{D}_i * RL_i\right)}{\sum_{i=1}^{n} RL_i}$$

Where, RL_i is the length of the riffle where $\frac{W}{D}_i$ was measured.

5. Determine the reference W/D. Since the W/D can play a large role in the design process and is often linked to slope and sediment transport assessments, the reference W/D is selected by the user. The reference W/D can come from the stable riffle cross-section or a riffle cross-section at a reference reach adjacent to the project reach. If these options do not work, the bankfull width and mean depth regional curves can be used. However, the stream types used to create the regional curves should be the same as the reference stream type.
6. Calculate the WDRS field value by dividing the results of Step 4 by the reference W/D (Step 5).

Estimating proposed condition field values: The reference W/D value will remain the same for the existing and proposed calculations, and all monitoring events. The observed W/D for the proposed condition field value should be based on the proposed riffle length and proposed channel cross-section for every riffle in a representative sub-reach of the proposed channel. Calculations should consider any proposed activities that may alter the cross-section, including bank angle and stabilization.

Documentation and Field Forms: On the Field Value Documentation Form in Appendix B, note the file location of survey data and profile/cross-section figures, the survey method and any post-processing tools used. Users should also record the reference W/D, describe how it was calculated (e.g., from the stable riffle cross-section, a riffle cross-section at a reference reach, or through the design process), and provide any needed justification for the selected reference W/D. If users record the length of each riffle and W/D at each riffle on the form, it will calculate the WDRS metric field value from the data entered. If using the Rapid Geomorphic Survey method outlined in Appendix A, users should enter field data on the Rapid Survey form in Appendix B. For other surveying protocols, an optional longitudinal survey form and cross section form are provided in Appendix B.

4.7. Geomorphology Functional Category

The functional statement for the geomorphology category is the transport (and storage) of sediment and wood to create diverse bedforms and dynamic equilibrium. The WISQT contains five function-based parameters to characterize the functional statement: large woody debris, lateral migration, riparian vegetation, bed form diversity, and bed material characterization. Not all geomorphic parameters will be evaluated for all projects. Refer to Section 4.3 of this manual for guidance on parameter and metric selection.

4.7.A. Large Woody Debris

Large woody debris (LWD) is defined as dead wood, standing or fallen, over 3.28 feet (1m) in length and at least 3.94 inches (10 cm) in diameter at the largest end[19]. The wood must be within the bankfull channel or spanning the bankfull channel. LWD that lies in the floodplain but is not at least partially in the active channel is not counted[20].

There are two metrics to assess LWD: Large Woody Debris Index (LWDI) and LWD Frequency.

Experience Requirements: Data collection for LWD metrics should be performed by individuals with experience in large wood assessments.

Large woody Debris Index (LWDI)

The LWDI is a dimensionless value based on rating the geomorphic significance of LWD pieces and dams within a 328-foot (100 meter) section of stream. This index was developed by the USDA Forest Service Rocky Mountain Research Station (Davis et al. 2001).

Method:

1. Identify the 328 feet (100 m) length within the project reach that contains the most LWD. Preferably this 328-foot reach is within the representative sub-reach. If the project reach is less than 328 feet, the LWDI should be determined using the entire reach length and the index value normalized to represent a value per 328 feet.
2. Follow the guidance within Davis et al. (2001) and the *Application of the Large Woody Debris Index: A Field User Manual Version 1* (Harman et al. 2017) to score LWD pieces and dams and to calculate the reach LWDI (Example 7). The LWDI value is entered as the field value in the WISQT.

Estimating proposed condition field values: The proposed condition field value is based on the proposed amount and anticipated recruitment of LWD throughout the project reach. See Harman et al. (2017) for examples of structures using LWD and how they score. The proposed value should consider the removal of any existing LWD or installation of new LWD that would occur during project construction.

Documentation and Field Forms: Field forms from Harman et al. (2017) are provided for convenience in Appendix B. Record the field value on the Field Value Documentation form in Appendix B.

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[19] 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.
[20] See Zone 4 description in Harman et al. (2017) for additional detail.

Example 7: Calculation of the Large Woody Debris Index

This table includes hypothetical data from a stream assessment using the LWDI. See Davis et al. (2001) and Harman et al. (2017) for additional detail.

Category: Pieces of LWD						
Scoring Criteria	**1**	**2**	**3**	**4**	**5**	**Total**
Length/BKF Width	1	5	1	4	19	30
Diameter (cm)	20	6	1	2	1	30
Location	8		10	7	5	30
Type	16		7	6	1	30
Structure	19		8	1	2	30
Stability	3		6	1	20	30
Orientation (deg)	6	4	2	6	12	30
Total	73	30	105	108	300	**616**
Category: Debris Dams						
Scoring Criteria	**1**	**2**	**3**	**4**	**5**	**Total**
Length (% of BKF Width)					1	1
Height (% of BKF Depth)					1	1
Structure	1					1
Location					1	1
Stability			1			1
Total	1	0	3	0	15	**19 * 5 = 95**
Notes:				**Total LWDI Score**		**711**

Calculating pieces of large wood:

1) Each piece of large wood is ranked 1-5 for each scoring criteria. The “Total” column is used to verify that each piece of LWD is accounted for (e.g., every row totals 30).
2) The number of pieces for each scoring criteria are summed, and then multiplied by the rank score for each column (1-5 at the top of the table) to calculate the total for each column (e.g., 27 pieces in Column 4 multiplied by 4 equals 108). This weighted value is displayed in the “Total” row.
3) The totals for each column are then added together for the Pieces of Large Wood category score (e.g., 73 + 30 + 105 + 108 + 300 = 616)

Calculating debris dams

1) Use the same procedure as described in 1-3 above to score debris dams.
2) After the total for each column is added together, that value is then multiplied by 5 to account for the greater influence of debris dams on the stream (e.g., 19 * 5 = 95)

Calculating Total LWDI score

The Pieces of Large Wood and Debris Dams category scores are added together to calculate the Total LWDI Score (e.g., 616 + 95 = 711). **This is the field value entered into the WISQT.**

Large Woody Debris Frequency (LWD Frequency)

The LWD Frequency metric is a count of the number of LWD pieces within a 328- foot (100 meter) section of stream.

Method:

1. Identify the 328 feet (100 m) length within the project reach that contains the most LWD. Preferably this 328-foot reach is within the representative sub-reach. If the project reach is less than 328 feet, count the number of pieces within the entire reach length and then normalize the value to represent a value per 328 feet.
2. Count all pieces of dead and fallen wood wholly or partially within the active channel that are over 3.28 feet (1 m) in length and at least 3.94 inches (10 cm) in diameter at the largest end within the 328-foot reach. For debris dams, to the extent possible, count each piece within the dam that qualifies as LWD. The number of pieces observed is the field value input for the WISQT. No additional calculation is required unless the sampled reach length is less than 328 ft.

Estimating proposed condition field values: The proposed condition field value is based on the proposed amount and anticipated recruitment of LWD throughout the project reach. The proposed value should consider the removal of any existing LWD or installation of new LWD that would occur during project construction. See Harman et al. (2017) for examples of structures using LWD.

Documentation and Field Forms: Data are recorded on the Project Reach form. Once entered on the Project Reach form, the field value will auto-populate in the Field Value Documentation form in Appendix B.

4.7.b. Lateral Migration

Lateral migration is the movement of a stream laterally across its floodplain and is largely driven by processes influencing bank erosion and deposition.

There are three metrics for this parameter: dominant bank erosion hazard index (BEHI)/near bank stress (NBS), percent streambank erosion, and percent streambank armoring.

Experience Requirements: Data collection for lateral migration metrics should be performed by professionals with training and experience in applying BEHI/NBS methods.

Dominant Bank Height Erosion Index/Near Bank Stress (Dominant BEHI/NBS)

The BEHI is a method used to estimate the tendency of a given stream bank to erode based on bank angle, riparian vegetation, rooting depth and density, surface protection, and bank height relative to bankfull height. NBS is an estimate of shear stress exerted by flowing water on the stream banks (Rosgen 2014).

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4). Dominant BEHI/NBS should be evaluated throughout the representative sub-reach.

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

1. Measure the bank length of **every** outside meander bend and determine its BEHI/NBS category. The outside of the meander bend is always assessed, even when it is not eroding. Partition the

banks based on different BEHI and NBS conditions. For example, a study bank that is a consistent BEHI condition but two NBS conditions should be assessed as two study banks.

2. Measure the bank length of **any other bank that is actively contributing sediment** and determine its BEHI/NBS category. The following areas should not be included in the assessment:
    a) Depositional zones (e.g., point bars) or other areas that are not actively eroding (Rosgen 2014).
    b) Riffle sections that are not eroding and have low potential to erode. Note, an undercut bank does not automatically count as an eroding bank. Do not include undercut banks in riffles that are not migrating, widening, or downcutting.
    c) Banks that are armored (see percent streambank armoring metric for armored banks).
3. Add the length of all assessed banks (left banks plus right banks) in the representative sub-reach to calculate the Total Assessed Length (see Example 8).
4. Divide the length of each assessed bank by the Total Assessed Length (Result from Step 3).
5. Sum the percent of assessed bank length for each category (Example 8). 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. If there are two or more BEHI/NBS categories with the same total percent, the category representing the highest level of bank erosion should be selected as the Dominant BEHI/NBS. To enter the field value in the WISQT, a drop-down list of BEHI/NBS categories is provided.

Estimating proposed condition field values: The proposed condition field value should be based on anticipated changes to channel bank conditions or hydraulic conditions associated with the proposed project reach within the representative sub-reach of the proposed channel. Note that aspects of BEHI that pertain, or could pertain, to riparian vegetation (rooting depth, rooting density, and surface protection) should be estimated for conditions at the end of the monitoring period.

Documentation and field forms: Record the total assessed length and all observed BEHI/NBS categories and respective bank lengths on the Field Value Documentation form in Appendix B or provide the field value and the file location of assessment data. Field data should be provided with the submittal, along with a map of ratings along the representative sub-reach. An optional lateral migration field form is provided in Appendix B.

Example 8: Calculation of Dominant BEHI/NBS

In this example, data were collected within a 550-foot-long representative sub-reach. Actively eroding banks and the outside of meander bends were assessed using the BEHI/NBS methods. Note: Total assessed bank length, including left and right banks, within the representative sub-reach was 155 feet.

Bank ID (Left and Right)	BEHI/NBS	Length (Feet)	Percent of Total (%)
L1	Low/Low	50	(50 / 155) *100 = 32
L2	High/High	12	8
R1	Mod/High	22	14
R2	High/High	31	20
L3	Low/Mod	9	6
R3	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.

PERCENT STREAMBANK EROSION

The percent streambank erosion metric provides a quantitative measure of the extent of active bank erosion (length of reach experiencing erosion). The percent streambank erosion metric field value is measured as the length of stream bank that is actively eroding divided by the total bank length in the representative sub-reach (e.g., reach length times two). This metric compliments the dominant BEHI/NBS metric which is an indicator of the magnitude of active bank erosion. Actively eroding banks are defined by the BEHI/NBS category as shown in Table 11.

Method:

1. Perform the dominant BEHI/NBS assessment methods as described in the previous section.
2. Sum the lengths of all banks within the BEHI/NBS categories that are considered actively eroding (Table 11).

Table 11: BEHI/NBS stability ratings that represent actively eroding and non-eroding banks.

Non-eroding Banks	*Actively Eroding Banks*
BEHI ratings of VL or L, M/VL, M/L	M/M, M/H, M/VH, M/Ex, BEHI ratings of H, VH, or Ex
Key: VL = Very Low, L = Low, M = Moderate, H = High, VH = Very High, Ex = Extreme.	

3. Calculate the total length of streambank in the representative sub-reach. This is two times the channel (sub-reach) length. Note, this value is different from the assessed bank length used to calculate the dominant BEHI/NBS metric.

4. Divide the total length of actively eroding bank (Step 2) by the total length of streambank within the representative sub-reach (Step 3). Refer to Example 9.

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

Estimating proposed condition field values: The proposed condition field value should be based on any anticipated changes to channel bank or hydraulic conditions associated with the proposed project within the representative sub-reach. For mitigation projects, this may include an estimate of the expected extent of bank erosion at the end of monitoring, keeping in mind that monitoring events will document whether the proposed condition is achieved. For impact sites, the user must estimate the extent of bank erosion that is likely, considering hydraulic expansion/contraction effects associated with stream crossings. Removing vegetation along the bank is also likely to lead to bank erosion.

Documentation and Field Forms: Record the total length of actively eroding banks and the field value on the Field Value Documentation form in Appendix B. Field data should be provided with the submittal, along with a map of ratings along the representative sub-reach. An optional lateral migration field form is provided in Appendix B.

Example 9: Calculation of Percent Streambank 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 within the representative sub-reach (1,100 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
R3	**High/High**	**31**

Percent Streambank 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.

Method:

1. Walk the **entire project reach**, including both sides of the stream channel, and measure the lengths of armored banks.

2. Calculate the total length of streambank in the project reach. The total length of streambank is the sum of the left and right bank lengths within the project reach and can be calculated by multiplying the project reach length by two.

3. The percent streambank armoring field value is calculated by summing lengths of all armored banks within the project reach (Step 1) and dividing by the total length of streambank (Step 2). Multiply by 100 to report as a percentage.

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

Estimating proposed condition field values: The proposed condition field value is based on any additional armoring or armoring proposed to be removed as part of the project. This additional or reduced length should be added to or subtracted from the length of bank armoring measured in the existing condition and divided by the proposed total length of streambank in the reach (proposed reach length multiplied by two).

Documentation and field forms: Armored reach lengths should be recorded on the Project Reach form in Appendix B; the field value will automatically calculate once data has been entered. The field value will be automatically populated on the Field Value Documentation form in Appendix B.

4.7.c. Riparian Vegetation

Riparian vegetation is defined as the plant communities contiguous to, and affected by, surface and subsurface hydrology and fluvial disturbance within the stream corridor.

There are four metrics for riparian vegetation: effective vegetated riparian area, canopy cover, herbaceous cover, and woody stem basal area. Riparian vegetation metrics should be sampled between July 1 and August 31.

Experience Requirements: Data collection for riparian vegetation metrics should be performed by professionals who have experience with vegetation sampling protocols and estimating cover.

Effective Vegetated Riparian Area

The effective vegetated riparian area metric is the proportion of the effective riparian area that consists of natural vegetation. Areas that have anthropogenic induced structures or features (roads, buildings, utility lines, etc.); or agricultural vegetation that is harvested, removed, or otherwise managed (crops, sod, tree farms, etc.); or low relative areal vegetation cover (≤ 50% for the WISQT) are not considered vegetated for purposes of this metric. The effective riparian area is calculated using bankfull width and meander width ratio estimates that vary by valley type.

Method:

1. Conduct the desktop determination method (Steps 1-8 outlined below, Figure 22a-f) to estimate the effective riparian area and effective vegetated riparian area within the entire project reach prior to going out in the field.

2. During riparian data collection, effective riparian area indicators and currently vegetated area extent should be verified in the field using the procedure outlined in Appendix A. Effective riparian area and effective vegetated riparian areas should be recalculated based on adjustments made in the field (Figure 22f).

3. Divide the field-verified effective vegetated riparian area by the field-verified effective riparian area and multiply by 100 to calculate the percentage of the effective riparian area that is vegetated. This is the metric field value.

Desktop Determination:

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

1. Obtain aerial imagery and topographic information (preferably at least 2-foot contour intervals) of the stream reach and associated valley.

2. Determine valley type as alluvial, confined alluvial or colluvial (See Section 2.3.a. or Section 3.3.a).

3. Estimate bankfull width (feet). Note that width estimates made prior to a field visit may need to be revised after completing the bankfull verification process (Section 4.4) to determine the bankfull channel width of the stable riffle (Appendix A).

4. Multiply bankfull width by the typical Meander Width Ratio (MWR) based on the valley type (Table 12). Add additional width to account for additional area outside of meander bends per the equation below.

$$Effective\ Riparian\ Area\ Width = W_{Bankfull} * MWR + 2 * W_{additional}$$

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	7	25
Confined Alluvial	3	15
Colluvial	2	10

5. Apply the effective riparian area width to the stream reach by centering it on the stream channel and, as necessary, adjusting it to lie within the stream valley.

   - 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 22a). Long meander bends will require two points to capture stream sinuosity.

   - At each point, draw a line equivalent to the calculated expected riparian area width (calculated in Step 4) perpendicular to the direction of flow within the channel centered on the point (Figure 22b).

   - Connect the endpoints of the lines on each side (Figure 22c).

   - Using aerial imagery and other spatial data, such as topographic layers or digital elevation models, identify substrate and hydrologic indicators of the valley or floodplain edge. Hydrologic and substrate indicators may include a fluvially formed break in slope between bank edge and valley edge, a change in sediment from fluvial sediments (rounded) to hillslope sediment (angular), or evidence of flood events (e.g., bar deposition, staining, water marks, or floodplain mapping). Review the mapped extent (Figure 22d) and identify any areas where the mapped extent and substrate or hydrologic indicators do not align (indicated with arrows in Figure 22d).

- Adjust the mapped extent so the effective riparian area aligns with appropriate indicators (Figure 22e). For example, the extent should be narrowed in any areas that overlap a hillslope which is clearly above the expected stage of the 100-year recurrence interval flow; indicators may include topographic data and floodplain mapping. Conversely, the extent should be widened to fully encompass the stream valley bottom; indicators may include floodplain mapping and/or observable indicators of floodplain and the influence of fluvial processes (e.g., fluvial sediments, bar deposition, water staining and water marks).

6. Calculate the area (square meters) of the polygon. This is the **effective riparian area** for the stream reach. This area should include the stream channel itself. The effective riparian area and indicators should be noted on the Effective Riparian Area form prior to going out in the field.

7. Within the effective riparian area, use aerial imagery to identify and delineate the extent of natural vegetation extending from the stream landward on the left and right banks. This area should include the stream channel itself, including exposed point bars. Use desktop tools to map the extent of riparian vegetation. The following are considered not vegetated for this metric:

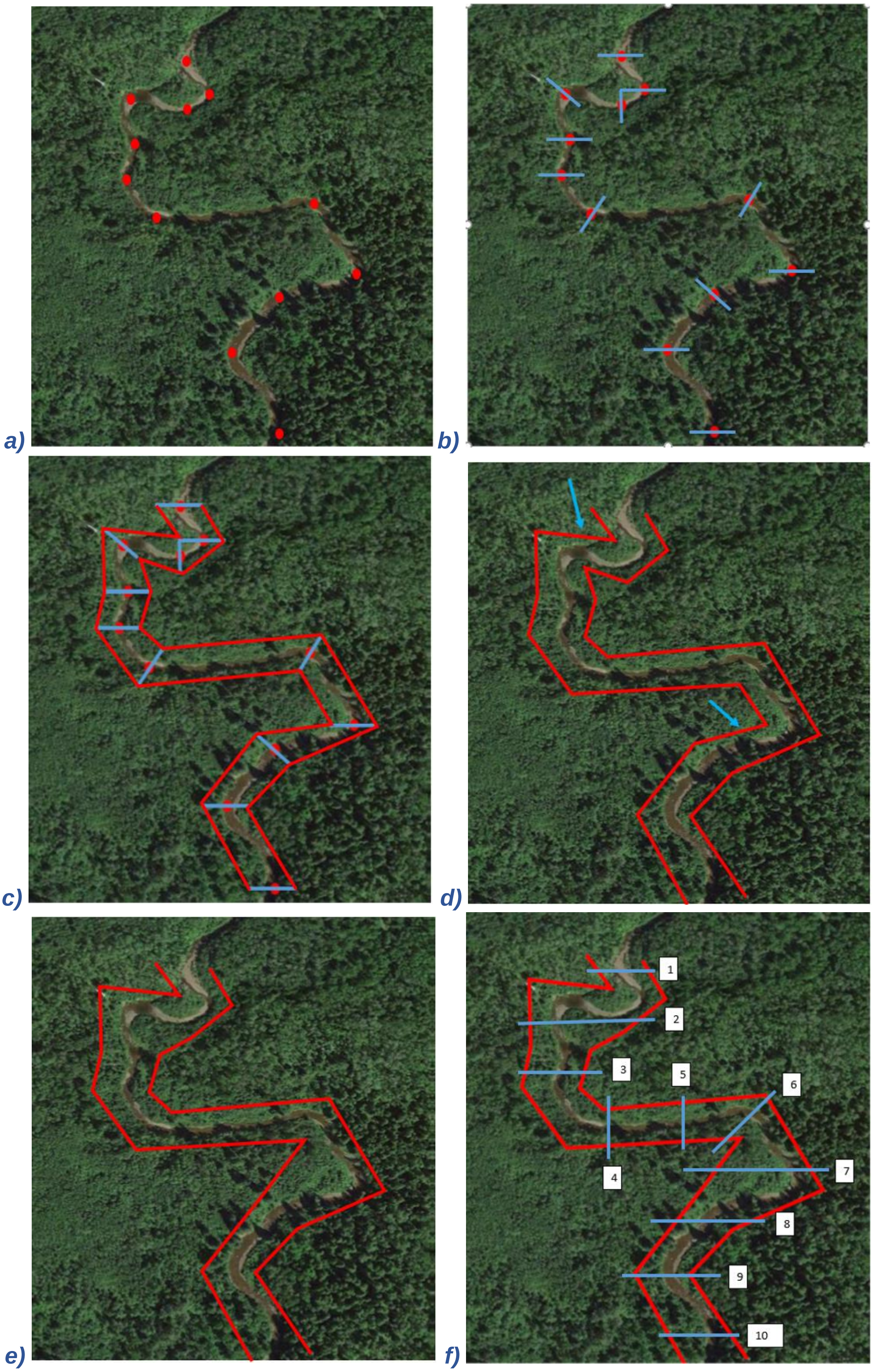
   - Contiguous areas of less than 50% vegetative cover (all strata combined).
   - Areas with non-natural vegetation that is periodically harvested, removed, or otherwise managed such as crops, sod, tree farms, etc.
   - Areas with human-induced structures or features (roads, buildings, utility lines, driveways, etc.) even if vegetation is growing within their footprint.

8. Calculate the area (square meters) of the vegetated polygon. This is the **effective vegetated riparian area** for the stream reach. The effective vegetated riparian area and indicators should be noted on the Effective Riparian Area form prior to going out in the field.

Estimating proposed condition field values: The field value for this metric is the percent of the effective riparian area that is currently vegetated; the effective riparian area calculated for existing condition should be held constant and used for proposed and monitoring calculations. The effective vegetated riparian area for the proposed condition can be calculated based on anticipated areas of riparian vegetation planting or riparian vegetation removal/disturbance associated with the proposed project within the effective riparian area. Note: proposed field values for riparian vegetation metrics will vary based upon planting schedule, channel work (e.g., reducing incision can increase the effective vegetated riparian extent percentage), and the monitoring period. For example, a site with a 10-year monitoring period may be expected to achieve a higher proposed condition score compared to that same site with only a 5-year monitoring period.

Documentation and Field Forms: Complete the Effective Riparian Area form in Appendix B. The field value will automatically populate on the Field Value Documentation form in Appendix B.

Figure 22(a-f): Example of desktop delineation (a-e) and field verification (f) of the effective riparian area.



Canopy Cover

The canopy cover metric characterizes the absolute areal cover of woody vegetation > 1m (3.28 ft) tall within the riparian area. This metric is determined by estimating the cover of trees and shrubs over 1m tall within each riparian vegetation plot. (Note: this includes the entirety of trees and shrubs over 1m tall, rather than just the part of the individual that is above 1m).

Method: This metric is assessed within each riparian plot in the representative sub-reach. Riparian vegetation should be assessed during the growing season within nested sampling plots in the representative sub-reach (Figure 23). Instructions for riparian vegetation plot locations, layout, and data collection methods are outlined in Appendix A.

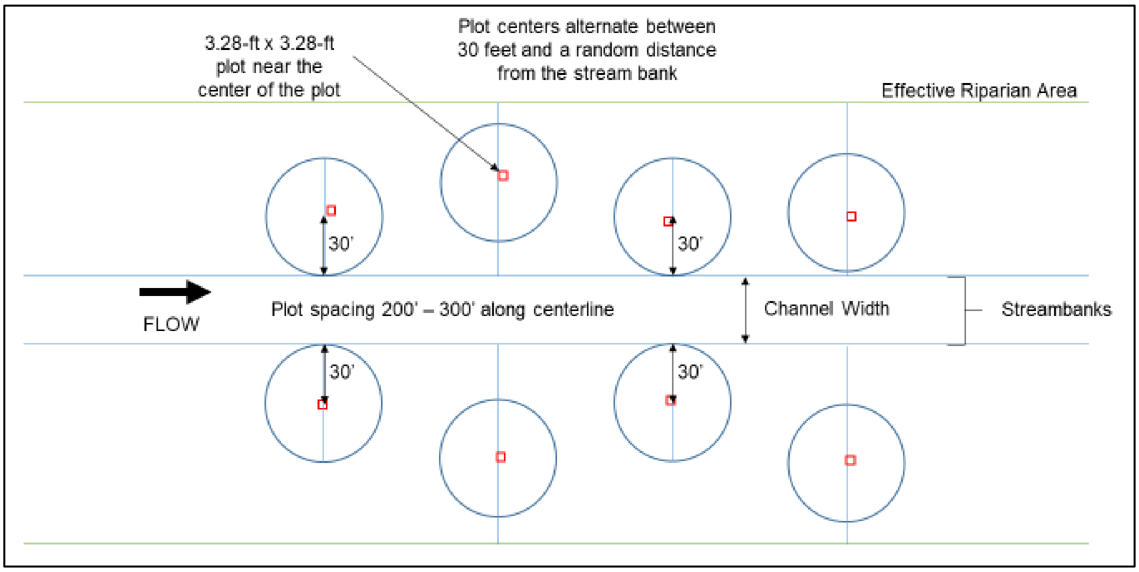
1. Visually estimate the total, or absolute, areal cover of woody vegetation > 1m tall within each 30-foot radius plot.

2. Average values across all plots to calculate the field value for the WISQT.

Estimating proposed condition field values: The proposed condition field value should be an estimate of canopy cover for conditions at project closeout. Users should consider the extent of preserved vegetation, vegetation removal, and the growth rates and expected cover for planted vegetation over the monitoring period. For example, a site with a 10-year monitoring period would be expected to achieve a higher proposed condition score compared to that same site with only a 5-year monitoring period.

Documentation and Field Forms: All data from riparian vegetation plots should be recorded on the Riparian Vegetation form in Appendix B. Record the number of plots and the field value on the Field Value Documentation form in Appendix B.

Figure 23: Riparian vegetation plot layout.



Herbaceous Cover

This metric characterizes the relative cover of vegetation in the herbaceous strata. The herbaceous strata is defined as all herbaceous vegetation and all woody vegetation < 1m (3.28 ft) tall.

Method: This metric is assessed within each riparian plot in the representative sub-reach. Riparian vegetation should be assessed during the growing season within nested sampling plots in the representative sub-reach (Figure 23). Instructions for riparian vegetation plot locations, layout, and data collection methods are outlined in Appendix A.

1. Visually estimate the relative cover of herbaceous vegetation, woody vegetation < 1m tall, and bare soil within each nested 3.28-ft x 3.28-ft (1m^2) plot.
2. Sum the herbaceous and woody vegetation (< 1m) relative cover estimates. Average values across all plots to calculate the field value for the WISQT.

Estimating proposed condition field values: The proposed condition field value should be an estimate of herbaceous cover for conditions at project closeout. Users should consider the extent of preserved existing vegetation, vegetation removal, the expected cover for planted seeds given shading and seral expectations over the monitoring period.

Documentation and Field Forms: All data from riparian vegetation plots should be recorded on the Riparian Vegetation form in Appendix B. Record the number of plots and the field value on the Field Value Documentation form in Appendix B.

Woody Stem Basal Area

Woody stem basal area is an estimate of the effective riparian area occupied by woody stems that are greater than 1.37m high. The metric characterizes the basal area per hectare (m^2/hectare) and is assessed by stem counts and diameter measurements of stems at breast height (1.37m) in plots.

Method: This metric is assessed within each riparian plot in the representative sub-reach. The method provided below is based on the CVS-EEP Protocol for Recoding Vegetation (Lee et al. 2008) and is modified for use in Wisconsin. Instructions for riparian vegetation plot locations, layout, and data collection methods are outlined in Appendix A.

1. Count and record DBH of all woody stems within the plot. Stems must be from woody, perennial species and at least 1.37 meters high[21]. 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 DBH classes provided on the Riparian Vegetation field form to determine the midpoint value. Users may need to calibrate themselves by measuring several stems before visual grouping stems into DBH classes. Measure and record the DBH of all woody stems exceeding 30.5 cm DBH.
2. Calculate basal area for each DBH midpoint or measured DBH in m^2, using the formula below to convert from cm to m^2.

$$Stem\ Basal\ Area = (DBH^2) * 0.00007854$$

3. Multiply the number of stems by the individual stem basal area to determine the total stem basal area for each DBH class. Sum all the stem basal area values to determine the total basal area for each sampling plot.
4. Divide the total basal area for each plot (m^2) by the sampling plot size in hectares (ha) to adjust the plot values to a hectare basis. Use the formula shown below to calculate basal area (m^2/hectare).

[21] 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.

$$Basal\ Area\ (\mathrm{m^2/ha}) = \frac{Total\ Plot\ Basal\ Area\ (\mathrm{m^2})}{Plot\ size\ (\mathrm{hectares})}$$

5. Average the basal area measurements from each riparian plot. This value will be your woody stem basal area (m^2/ha) metric.

Estimating proposed condition field values: The proposed condition field value should be an estimate of the woody stem basal area at the site for conditions at project closeout. Users should consider the extent of preserved vegetation, vegetation removal, and the growth rates for planted and volunteer species over the monitoring period.

Documentation and Field Forms: All data from riparian vegetation plots should be recorded on the Riparian Vegetation form in Appendix B. Record the number of stems in each size class less than 30.5 cm DBH and the DBH for each stem > 30.5cm DBH on the Riparian Vegetation form; this form will calculate the total basal area for each plot. Record the number of plots and the field value on the Field Value Documentation form in Appendix B.

4.7.D. Bed Form Diversity

Bed forms include the various channel features that maintain heterogeneity and stability in the channel form, including riffles, runs, pools, and glides (Rosgen 2014). Together, these bed features create important channel patterns and habitats for aquatic life. Riffles and pool types are defined below (and in the Glossary of Terms) and more detail on bed feature identification is provided in Appendix A.

There are three metrics for this parameter: pool spacing ratio, pool depth ratio, and percent riffle.

Experience Requirements: Data collection for bed form diversity metrics should be performed by professionals that have experience with standard survey techniques, prior field experience identifying fluvial bed forms, and experience with identification and verification of bankfull. Users should have prior field experience in identifying bedform features sequences in different stream types, including experience differentiating between geomorphic pools and significant pools as defined by the WISQT.

Pool Spacing Ratio

The pool spacing ratio is a measure of the distance between geomorphic pools and can be indicative of the channel stability and geomorphic function. This metric compares the stream length distance between sequential geomorphic pools to the bankfull width of the stable riffle cross-section (Rosgen 2014).

Geomorphic pools are associated with planform features and remain intact over time and across a range of flow conditions. Examples include pools associated with the outside of a meander bend (streams in alluvial valleys) and downstream of a large cascade or step (streams in colluvial valleys). Note that significant pools are not included in this metric (see Glossary of Terms). More detail on bed feature identification is provided in Appendix A.

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 4.4) and determine the bankfull channel width of the stable riffle (Appendix A).

1. Record the location along the longitudinal profile of the maximum pool depth of every geomorphic pool in the representative sub-reach. Measure and record the distance between the maximum depths of the sequential pools.

Standard survey protocols are required to collect accurate location data of the stream centerline[22]. Appendix A provides rapid survey instructions using a tape and survey rod.

2. The pool spacing ratio is calculated for each pair of sequential geomorphic pools in the representative sub-reach using the equation below. Note that the bankfull channel width to calculate this metric is from a stable riffle (see Appendix A).

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

3. The median pool spacing ratio, calculated from all the pool spacing ratios from the representative sub-reach, should be entered as the field value. NOTE: a field value should not be calculated with less than three pool spacing ratio measurements. Users may need to extend beyond the representative sub-reach to collect three pool spacing ratio measurements.

When working in streams that have been straightened (channelized), a bed form sequence may not be present. This typically occurs because pool forming processes (meandering and scour processes) have been removed. In this case, the reach will likely be mostly riffle habitat and the user should enter a field value of 0.0 for this metric. This result indicates that a bed form sequence should be present based on the reference stream type, but it is absent due to channelization. This situation is most common in channelized C and E stream types where the meander width ratio (belt width/bankfull width) is less than 3.5 and the sinuosity is less than 1.2.

Estimating proposed condition field values: The proposed condition field value should be based on the proposed channel profile in colluvial valleys and based on the proposed channel profile and meander geometry in alluvial valleys. In colluvial valleys, the pool spacing ratio defines the distance between pools that are downstream of a step or riffle/cascade. Small pools within the riffle/cascade (significant pools) are not counted. In meandering streams, pool spacing can be easily estimated from the plan form geometry as the spacing between the apex of successive meander bends. If a profile has been developed, the spacing can be measured from the deepest location within the bend downstream to the next bend. Significant pools within the riffle that are created by large wood or in-stream structures are not counted. For both colluvial and meandering streams, the median pool spacing ratio is used for the proposed condition field value.

Documentation and Field Forms: On the Field Value Documentation form in Appendix B, note the file location of survey data and profile/cross-section figures, the survey method and any post-processing tools used. If users record the number of geomorphic pools, the bankfull width, and all calculated pool spacing ratios on the Field Value Documentation form, it will calculate the field value from the information entered. If using the Rapid Geomorphic Survey method outlined in Appendix A, users should enter field data on the Rapid Survey form. For other surveying protocols, an optional longitudinal survey form and cross section form are provided in Appendix B.

Pool Depth Ratio

Pool depth ratio is a measure of pool quality, with deeper pools scored higher than shallow pools. The metric compares the bankfull pool maximum depth at every geomorphic and significant pool to the bankfull riffle mean depth.

[22] Appendix A field methods instruct users to stretch the tape along the streambank. Channel centerline and streambank are considered equivalent.

Significant pools are pools other than geomorphic pools that meet the following criteria: the pool must be deeper than the riffle, have a concave shaped bed surface, sometimes have a water surface slope that is flatter than the riffle, and a width that is at least half the width of the channel. More detail on bed feature identification is provided in Appendix A.

Method: Prior to calculating this metric, users need to complete bankfull verification (Section 4.4), evaluate the stable riffle, and calculate the bankfull mean depth (Appendix A).

At every geomorphic and significant pool within the representative sub-reach:

1. Identify the bankfull elevation and pool maximum depth. The bankfull verification process (Section 4.4) should be used to identify the bankfull elevation.

2. Measure and record the difference between the bankfull elevation and the thalweg elevation (bankfull pool maximum depth).

   Standard survey protocols are required to collect accurate location data of the stream centerline and elevation data. Appendix A provides rapid survey instructions using a tape survey rod, and hand level.

   If a longitudinal profile is generated, the best-fit-line through the bankfull points should be used to calculate the bankfull elevation associated with each pool maximum depth.

   For the rapid survey, the difference in bankfull and water surface (established during the bankfull verification process) should be used at each bankfull pool maximum depth location.

3. Pool depth ratio is calculated for each pool in the representative sub-reach by dividing the bankfull pool maximum depth by the bankfull riffle mean depth from the stable riffle survey.

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

4. Average the pool depth ratio values from all geomorphic and significant pools in the representative sub-reach and enter it as the field value.

Estimating proposed condition field values: The proposed condition field value should be based on the proposed channel profile. See pool spacing ratio above but note that both significant and geomorphic pools are included in this metric. For example, in a meandering channel, pools associated with meander bends (geomorphic) are included along with significant pools that are created by in-stream structures, e.g., wood and rock vanes.

Documentation and Field Forms: On the Field Value Documentation form in Appendix B, note the file location of survey data and profile/cross-section figures, the survey method and any post-processing tools used. If users record all pool depths, number of pools measured, mean riffle depth on the Field Value Documentation Form in Appendix B, it will calculate the field value from the information entered. If using the Rapid Geomorphic Survey method outlined in Appendix A, users should enter field data on the Rapid Survey form in Appendix B. For other surveying protocols, an optional longitudinal survey form and cross section form are provided in Appendix B.

Percent Riffle

The percent riffle is the proportion of the representative sub-reach containing riffle features, as distinct from pool features. Riffles are shallow, steep-gradient channel segments typically located between pools. Riffles are the river's natural grade control feature (Knighton 1998) and are sometimes referred to as fast-water channel units (Hawkins et al. 1993; Bisson et al. 2017). For purposes of the SQT, riffles broadly represent the section between lateral-scour pools known as a crossover, regardless of bed material size. Therefore, the term riffle also refers to the crossover in sand bed streams and the cascade section of higher gradient streams. For the percent riffle metric, riffles are measured from head of riffle to head of significant or geomorphic pool. The SQT does not distinguish run features from riffles; runs are considered riffles and similarly glides are considered pools. More detail on bed feature identification is provided in Appendix A.

Method:

1. Measure the length of each riffle in the representative sub-reach. Riffle length is measured from the head (beginning) of a riffle downstream to the head of a geomorphic or significant pool. Riffle length may include riffles with small pools that do not meet the criteria to be considered a significant pool as defined in this manual.

   Standard survey protocols are required to collect accurate location data of the thalweg and bed form features. Alternately Appendix A provides rapid survey instructions using a tape, survey rod, and hand level.

2. Add the length of all riffles within the representative sub-reach. Percent riffle is calculated by dividing the total length of riffles within the representative sub-reach by the total representative sub-reach length.

$$\% \, Riffle = \frac{\sum(Riffle \; length_{sub-reach})}{Total \; length_{sub-reach}} * 100$$

Estimating proposed condition field values: The proposed condition field value should be based on the proposed channel plan form and profile. In meandering streams, the riffle can be estimated as the cross over between bends (e.g., from the point of tangency/head of riffle to the downstream bend's point of curvature/head of pool). In step-pool streams in colluvial valleys, the estimate can also be made from the plan form or profile based on the location of structures; riffles/cascades and steps will count as the riffle estimate.

Documentation and Field Forms: On the Field Value Documentation form in Appendix B, note the file location of survey data and profile/cross-section figures, the survey method and any post-processing tools used. Record the total riffle length within the sub-reach on the Field Value Documentation form to calculate the field value. If using the Rapid Geomorphic Survey method outlined in Appendix A, users should enter field data on the Rapid Survey form in Appendix B. For other surveying protocols, an optional longitudinal survey form and cross section form are provided in Appendix B.

4.7.E. Bed Material Characterization

Bed material (substrate) characterization considers the grain size composition of the streambed and is an important parameter in function-based assessments and stream restoration designs in cobble and gravel bed streams that are receiving excess fine sediments from bank erosion.

The bed material characterization parameter includes three metrics: percent fines (< 2mm), percent fines (< 6.35mm), and median particle size (d50). These metrics are only applicable in coarse gravel and cobble bed streams that naturally have a d50 greater than 34mm. These metrics are not applicable in sand bed or small-gravel streams (see Section 4.3 for additional information).

Experience Requirements: Data collection should be performed by qualified field teams with training in bed form assessment protocols or similar data collection procedures focused on sediment in streambeds.

Percent Fines (< 2mm and < 6.35mm)

Fine sediments are the particles within a project reach within the smaller size fractions (< 2mm and < 6.35mm) and are measured as a percentage of the total number of particles within a sample.

Median Particle Size (d50)

The median particle size (d50) is the diameter of the particle within a sample where 50% of the sampled population is equal to or finer than that particle.

Method for percent fines and median particle size:

1. Collect bed material data using a 200-particle random-walk pebble count within the representative sub-reach. Users interested in additional information related to these metrics can also refer to Benoy et al. (2012) under *"Physical Deposited Sediment Thresholds: Geomorphic Criteria"* and Sutherland et al. (2010).

2. Identify the median particle size (d50 mm) and calculate the percent fines (< 2mm and < 6.35mm) and from the completed 200-particle pebble count. The field values for < 2mm and < 6.35mm percent fines are the number of particles sampled with an intermediate axis less than 2mm or 6.35mm, respectively, divided by the total number of particles counted and multiplied by 100.

$$\% \, Fines = \frac{\# \, Particles < 2mm \; or < 6.35mm}{Total \, \# \, Particles \; sampled} * \; 100$$

Estimating proposed condition field values: Bed material is a parameter recommended for projects where fining of the bed material is occurring due to bank erosion or where activities are proposed that could lead to decreased fine sediment deposition over coarse bed material (e.g., gravel). 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.

Documentation and Field Forms: The number of particles < 2mm and < 6.35mm, the median particle size (d50) and the total number of particles should be recorded on the Field Value Documentation form in Appendix B. The form will calculate the field value from the information entered. An optional Pebble Count form is provided in Appendix B.

4.8. Physicochemical Functional Category

The functional statement for the physicochemical functional category is temperature and oxygen regulation, processing of organic matter and nutrients. The WISQT contains three function-based parameters to assess the physicochemical functional category: temperature, nutrients, and organics. Refer to Section 4.3 of this manual for recommendations on when to apply each parameter and metric.

4.8.a. Temperature

Temperature is used to calculate a change in condition resulting from reach-scale impact and restoration activities. The primary goal of the metric's field value and associated score is to calculate functional loss or functional lift. Consequently, temperature parameter scores used for the WISQT assessment are not suitable for use as 303d Impaired Waters attainment and listing values. Please visit Wisconsin DNR's WISCALM webpage, which can be accessed by typing WISCALM into your web browser, for additional information about Wisconsin's Impaired Waters standards and classifications. Please contact USACE for additional information about use of the WISQT's temperature parameter.

There is one metric for this parameter: summer mean temperature.

Experience Requirements: Data collection for temperature metrics should be performed by personnel with experience installing stream temperature data loggers and processing data in accordance with the *Guidelines and Standard Procedures for Continuous Temperature Monitoring* (WDNR 2004).

Summer Mean Temperature

The summer mean temperature is the average of continuously recorded temperatures measured during the summer months of June, July, and August.

Method:

1. Install continuous temperature data loggers upstream of the project area and at the downstream extent of each project reach[23] from June 1 to August 31 following the *Guidelines and Standard Procedures for Continuous Temperature Monitoring* (WDNR 2004). Note: A logger upstream of the project area may not be needed for some projects, e.g., an isolated road crossing. Consult with USACE for guidance.

Loggers should be in comparable habitats for pre- and post-project data collection. Additional information can be found in *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams* (US EPA 2014).

2. For each data logger, calculate the summer mean as the average of all the recorded values within the sampling window. Note whether the ambient temperature is considered normal for that location and time.
3. The field value for the existing condition assessment is the summer mean temperature at the downstream extent of the reach calculated from pre-project data.
4. **To calculate the monitored condition field values characterizing post-project condition**, follow Steps 1-3 above and then adjust the value based on the change in summer mean temperature from the upstream sample site using the following steps:
    a. Determine the difference in summer mean temperature upstream of the project area from before to after the project.
    b. Adjust the downstream, monitored summer mean temperature by subtracting the difference in summer mean temperature from upstream calculated in Step 4a. An example is provided in Example 10.

Note: Only one season of data are required to calculate a field value for the WISQT. However, as water temperature is strongly influenced by meteorological conditions, it is recommended that multiple years of data are collected and averaged to inform the existing condition field value. Additional post-project monitoring events may be beneficial if air temperatures were outside 'normal' during the monitoring period, and this should be discussed with USACE as needed.

[23] Where multiple project reaches are on the same stream and can reasonably be considered similar, a logger within every reach may not be required. At a minimum, the first and last reach on a single stream should contain a logger. Multiple factors influence local instream temperature and should be considered when determining the number and placement of loggers (EPA 2014, Dunham et al. 2005). Factors include but are not limited to: groundwater input, vegetation shading, sheet flow, slope, and flow.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in the summer mean temperature field value resulting from the project. Practices that could impact in-stream summer temperatures include, but are not limited to, altering streamside vegetation and channel shading, groundwater connections, or summer baseflows. Temperature modeling, such as the CE-QUAL-W2 or HEC-RAS, could be used to estimate thermal changes resulting from differences in shading and groundwater inputs.

Documentation and Field Forms: Users should complete a temperature logger data form (see Appendix C. Example Field Sheets for Continuous Temperature Thermistors in WDNR 2004) and develop a time-series plot of the data. Record the field value and the sample collection date on the Field Value Documentation form in Appendix B and note the file path or location of the data form and time-series plot. On this form, users should also note any data gaps or whether the ambient temperatures for the sampling period are considered normal for that location and time.

Example 10: Calculation of Summer Mean Temperature

Year	Summer Mean Temperature (ºC)			
	Upstream of Project Area	Difference from baseline	Project Reach	Field Value
2022 Pre-project/ Existing	15.9 (Baseline)	-	17.3	17.3
2023 Construction	-	-	-	-
2024 Monitoring Year 1	16.2	16.2 – 15.9 = 0.3	16.8	16.8 - 0.3 = 16.5
2025 Monitoring Year 2	15.8	15.7 – 15.9 = -0.1	16.7	16.7 + 0.1 = 16.8

4.8.B. Nutrients

Excessive nitrogen and/or phosphorus can lead to excess plant and algal growth, which in turn can degrade stream microhabitats, cause diel cycling of dissolved oxygen concentrations, and blooms of toxin producing algae.

There are two metrics included in the WISQT for this parameter, benthic algal biomass and the diatom phosphorous index. Nutrients should be sampled between July 1 and September 15, during baseflow condition. Users should avoid sampling within 14-21 days following a storm event or if water levels are substantially above normal (e.g., > 0.15m).

Experience Requirements: Field values for the nutrient metrics should be calculated by professionals with experience with the field methods outlined in *Viewing Bucket Method for Estimating Algal Abundance in Wadeable Streams v3.6.* (WDNR 2020a) and/or *Diatom Collections for Calculation of the Diatom Phosphorus Index (DPI) 3.0* (WDNR 2020b).

Benthic Algal Biomass

The Benthic algal biomass metric is a visual assessment of whether a reach is, or is not, exhibiting a nutrient response. The method uses a viewing bucket to efficiently quantify biomass and coverage of filamentous benthic algae in the reach.

Method:

1. Lay out 12 equally spaced transects within the representative sub-reach[24] according to the WDNR quantitative habitat protocols (WDNR 2002) with four equidistant points on each transect (i.e., left, left-center, right-center and right).

   Algal benthic biomass should be assessed along a minimum length of 100m. If the representative sub-reach is less than 100m, transects should extend beyond the representative sub-reach but not beyond the project reach. If the project reach is less than 100m, use of this metric should be discussed with USACE prior to sampling.

2. Starting from the downstream end of the representative sub-reach, assess benthic algal biomass using the viewing bucket method outlined in *Viewing Bucket Method for Estimating Algal Abundance in Wadeable Streams v3.6* (WDNR 2020a), with one sample from each transect staggered across the stream from left to right in a zig-zag pattern.

   Benthic algal biomass should be observed and characterized on a grid with a minimum of 25 points within a viewing bucket.

3. The final algal score is calculated as the weighted mean of all scores (excluding N/A values). This value can be calculated using the Algal Biomass Field Data sheet in WDNR (2020a).

Note: Only one season of data are required to calculate a field value for the WISQT. However, as nutrient levels are influenced by meteorological conditions, such as rainfall amounts, it is **recommended** that multiple years of data are collected and averaged to inform the baseline/existing condition field value. Additional post-project monitoring may be beneficial if weather conditions were outside ‘normal’ during the monitoring period, and this should be discussed with USACE as needed.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in filamentous benthic algal biomass resulting from the project. Practices that could impact filamentous benthic algal biomass include, but are not limited to, altering nutrient loads entering the stream channel from the lateral drainage area (through management agreements or buffer planting).

Documentation and Field Forms: Users should complete an Algal Biomass Field Data sheet (see *Viewing Bucket Method for Estimating Algal Abundance in Wadeable Streams v3.6* (WDNR 2020a)). Record the field value, the sample collection date, and file path or location of the field form on the Field Value Documentation form in Appendix B. On this form, users should also note whether the ambient conditions for the sampling period are considered normal for that location and time.

Diatom Phosphorus Index (DPI)

The diatom phosphorus index (DPI) is a response indicator for total phosphorus and is designed to assess for the impacts of eutrophication and is reported as µg/L.

[24] Where multiple project reaches are on the same stream and can reasonably be expected to have similar nutrient levels, a single representative-sub reach assessment can be used to inform field values for multiple project reaches. The following factors influence nutrients and should be considered when determining the number and location of samples: shading, runoff sources and inputs, including tributaries, local hydraulics that affect velocity and frequency of scouring events, substrate characteristics, and differing ability to grow benthic algae.

Method:

1. Collect and preserve samples in accordance with the methods outlined in *Diatom Collections for Calculation of the Diatom Phosphorus Index (DPI) 3.0* (WDNR 2020b). Methods will vary depending on the type of substrate; one method should be selected for the reach based on the following priority: rock, gravel, sand, silt.

   Samples should be collected from three riffles within the representative sub-reach; however, if there aren't an adequate number of riffles, collect from three riffles within the project reach. If there are less than three riffles within the project reach, sample the nearest riffles (upstream or downstream), ensuring there are no ephemeral/intermittent/perennial tributaries or concentrated flow points between sampled riffles. If three suitable riffles are not present in or outside the project reach, samples can be collected from areas with the coarsest substrate within the project reach. Note that where extensive tile drains or CFPs are present, it may be difficult to locate three riffles between these features. As such users should discuss the sampling plan with USACE prior to data collection.

2. Submit samples to the Wisconsin State Laboratory of Hygiene (WSLH) for processing. At this time, WSLH will provide the DPI result. Results are reported in µg/L and entered into the WISQT.

Only one season of data are required to calculate a field value for the WISQT. However, as nutrient levels are influenced by meteorological conditions, including rainfall, it is **recommended** that multiple years of data are collected and averaged to inform the baseline/existing condition field value. Additional post-project monitoring may be beneficial if weather conditions were outside 'normal' during the monitoring period, and this should be discussed with USACE as needed.

Where reaches are on the same stream and can reasonably be expected to have similar nutrient levels, a single assessment reach can be used to inform multiple project reaches. At a minimum the first and last reaches on a single stream should be sampled.

The following factors influence nutrients and should be considered when determining the number and location of samples: shading, runoff sources and inputs, including tributaries, local hydraulics that affect velocity and frequency of scouring events, substrate characteristics, and differing ability to grow benthic algae.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in total phosphorous resulting from the project. Practices that could impact total phosphorus include, but are not limited to, altering nutrient loads entering the stream channel from the lateral drainage area (through management agreements or buffer planting). Altering flow volumes could also lead to changes in phosphorous concentration.

Documentation and Field Forms: Users should complete a Diatom Analysis form (4800-028), which is available at WDNR's Surface Water Integrated Monitoring System (SWIMS) website. Record the field value and the sample collection date on the Field Value Documentation form in Appendix B, as well as the file path or location of the Diatom Analysis form and any laboratory results. Users should also note whether the ambient conditions for the sampling period are considered normal for that location and time.

4.8.c. Organics

This parameter characterizes changes in water quality associated with organic pollution.

There is one metric in the WISQT for this parameter: the Hilsenhoff biotic index (HBI). Sampling can occur in the Spring (April – May) or Fall (September – October). Users should ensure that annual monitoring occurs during the same season to ensure that data is comparable between years.

Experience Requirements: Field values for macroinvertebrate metrics should be collected by professionals with training and experience sampling and preserving samples in accordance with the *Guidelines for the Standard Collection of Macroinvertebrate Samples from Wadeable Streams v2.0* (WDNR 2017).

Samples require identification and enumeration at a professional taxonomic laboratory. WDNR is responsible for approving the taxonomic laboratory used to process macroinvertebrate samples and recommends the following lab: University of Wisconsin Stevens Point Aquatic Bio-Monitoring Lab (weal@uwsp.edu / 715-346-3209). Should this lab be unavailable, please contact WDNR to request or suggest a suitable replacement taxonomic laboratory.

Hilsenhoff Biotic Index (HBI)

The HBI is a macroinvertebrate multimetric assessment that uses tolerance values of various taxa to characterize changes in water quality associated with organic enrichment and changes in dissolved oxygen concentrations (Hilsenhoff 1987).

Method:

1. Within each project reach[25], collect and preserve samples in accordance with the methods outlined in the *Guidelines for the Standard Collection of Macroinvertebrate Samples from Wadeable Streams v2.0* (WDNR 2017).
2. Samples will need to be processed and enumerated in a lab (see experience requirements above). These results will then be used to calculate the HBI score as outlined in Hilsenhoff (1987) and entered into the WISQT.

Note: Only one season of data are required to calculate a field value for the WISQT. However, it is recommended that multiple years of data be collected and averaged to inform the baseline/existing condition field value. This is particularly important if the site experienced greater than normal rainfall or drought conditions. Additional post-project monitoring may be beneficial if site conditions were outside ‘normal’ during the monitoring period, and this should be discussed with USACE as needed.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in the HBI score resulting from the project. Practices that could impact the HBI score include, but are not limited to, altering effluent loads entering the stream channel from the lateral drainage area (e.g., through management agreements, upgraded infrastructure or buffer planting), reducing sedimentation to improve habitat conditions, or other restoration techniques.

Documentation and Field Forms: Users should complete the Wadeable Macroinvertebrate Field Data Report (WDNR Form 3200-081). Record the field value and the sample date(s) on the Field Value Documentation form in Appendix B, as well as the file path or location of WDNR form 3200-081 and any laboratory results. Users should also note whether the ambient conditions for the sampling period are considered normal for that location and time.

[25] Where project reaches are on the same stream and can reasonably be expected to have similar macroinvertebrate communities, a single assessment reach can be used to inform multiple project reaches. At a minimum, the first and last reaches on a single stream should be sampled.

4.9. Biology Functional Category

The biology functional statement is the biodiversity and life histories of aquatic and riparian [animal] life. The WISQT contains two function-based parameters to assess the biology functional category: macroinvertebrates and fish. Refer to Section 4.3 of this manual for recommendations on when to apply each parameter and metric.

4.9.A. Macroinvertebrates

Benthic macroinvertebrates, also called aquatic macroinvertebrates, are an integral part of the food web and are commonly used as indicators of stream ecosystem condition.

There is one metric for this parameter, a macroinvertebrate index of biotic integrity (mIBI). Sampling for the mIBI sampling can occur in the Spring (April – May) or Fall (September – October). WISQT users should ensure that annual monitoring occurs during the same season to ensure that multi-year data is comparable.

Experience Requirements: Field values for macroinvertebrate metrics should be collected by professionals with training and experience sampling and preserving samples in accordance with the *Guidelines for the Standard Collection of Macroinvertebrate Samples from Wadeable Streams v2.0* (WDNR 2017).

Samples require identification and enumeration at a professional taxonomic laboratory. WDNR is responsible for approving the taxonomic laboratory used to process macroinvertebrate samples and recommends the following lab: University of Wisconsin Stevens Point Aquatic Bio-Monitoring Lab (weal@uwsp.edu / 715-346-3209). Should this lab be unavailable, please contact WDNR to request or suggest a suitable replacement taxonomic laboratory.

Macroinvertebrate Index of Biotic Integrity (mIBI)

The mIBI is a regionally developed and validated macroinvertebrate multimetric assessment for coldwater and warmwater wadable streams in Wisconsin.

Method:

1. Within each project reach[26], collect and preserve samples in accordance with the methods outlined in the *Guidelines for the Standard Collection of Macroinvertebrate Samples from Wadeable Streams v2.0* (WDNR 2017).

2. Samples will need to be processed and enumerated in a lab (see experience requirements above). These results should be used to calculate the mIBI in accordance with the metrics and ecoregion criteria outlined in Weigel (2003).

3. mIBI scores are entered as the field value in the WISQT. Note that samples that collect fewer than 50 individuals should be assigned a very poor rating and a field value of 0.

Note: Only one season of data is required to calculate a field value for the WISQT. However, it is recommended that multiple years of data are collected and averaged to inform the baseline and existing condition field value. Macroinvertebrate communities could be stressed by increased rainfall

[26] Where project reaches are on the same stream and can reasonably be expected to have similar macroinvertebrate communities, a single assessment reach can be used to inform multiple project reaches. At a minimum, the first and last reaches on a single stream should be sampled.

or drought, or warmer than normal weather conditions. Additional post-project monitoring may be beneficial if climatic conditions were outside a 'normal' during the monitoring period, and this should be discussed with USACE as needed.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in mIBI score resulting from the project. Practices that could impact macroinvertebrate communities include, but are not limited to, altering in-stream water quality; presence, extent, and quality of macroinvertebrate habitat; and landscape and aquatic connectivity.

Documentation and Field Forms: Users should complete the Wadeable Macroinvertebrate Field Data Report (WDNR Form 3200-081). Record the field value and the sample date(s) on the Field Value Documentation form in Appendix B, as well as the file path or location of WDNR form 3200-081 and any laboratory results. Users should also note whether the ambient conditions for the sampling period are considered normal for that location and time.

4.9.B. Fish

Fish are an integral part of many functioning stream ecosystems and are an important management priority within Wisconsin.

There are two metrics included in the WISQT to assess this parameter: a fish index of biotic integrity (fIBI) and fish abundance. Fish sampling index periods vary by species and location; users should consult Table 13 or Appendix A to determine the appropriate sampling timeframe for their project.

Note that a scientific collectors permit is required to perform fish sampling. A scientific permit can be found at this link: https://dnr.wi.gov/files/PDF/forms/9400/9400-379.pdf

Experience Requirements: Users should have experience performing standard fish sampling techniques to capture the full array of potential species at a site and should be familiar with the methods outlined in *Guidelines for Assessing Fish Communities of Wadeable Streams in Wisconsin v2.0* (WDNR 2018), and *A Sampling Framework for Smallmouth Bass in Wisconsin's Streams and Rivers* (Smallmouth Bass Rivers Assessment Team 2006). Electrofishing, species identification, and population estimates should be performed by trained fisheries biologists or aquatic ecologists. Fisheries biologists or aquatic ecologists performing species identification should be able to identify 100% of the fish species present, including non-native or invasive species (e.g., silver carp).

Table 13: Sampling timeframes by location and target fish community

Species	Geography	Recommended Sampling Timeline	Length of Stream Assessed
Smallmouth Bass	Southern 2/3 of WI	May 24 – September 15	760 m (2500 ft)
	Northern 1/3 of WI	June 7 – August 31	
Brown Trout, Brook Trout, Lake Michigan Trout Young of Year, and Lake Superior Trout Young of Year	Southern 2/3 of WI	May 15 – September 30	35x mean stream width, with 100m (min.) – 400m (max.)
	Northern 1/3 of WI	May 30 – September 15	

Fish Index of Biotic Integrity (fIBI)

The fIBI reflects the response of fish assemblages to environmental disturbance at multiple scales[27].

Method:

1. Within each project reach[28], fish sampling should be conducted following the methods outlined in *Guidelines for Assessing Fish Communities of Wadeable Streams in Wisconsin v2.0* (WDNR 2018). The fIBI is stratified based on a site's thermal classification – coldwater, coolwater, or warmwater – and users should consult with WDNR to select the proper thermal classification for their site.
2. Following fish sampling, calculate the appropriate fIBI based on the site's thermal classification using the metrics and criteria outlined in Lyons (1992), Lyons et al. (1996) and/or Lyons (2012). Note that if fewer than 25 specimens are collected in a coolwater stream, the fIBI is 0.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in fIBI scores resulting from the project. Practices that could impact fish communities include, but are not limited to, altering in-stream water quality; altering the presence, extent, and quality of habitat through changes to reach hydrology, hydraulics, and geomorphic parameters; and landscape and aquatic connectivity. Stream or watershed management actions that alter summer water temperatures, minimum flows and stream habitat parameters should also be considered.

Documentation and Field Forms: Users should report their data using the Wadeable Stream Fish Assessment Form (WDNR form 3600-230). Users should ensure that specific and correct data are collected to ensure applicable metrics and indexes can be calculated (see WDNR 2018). Record the field value and the sample collection date on the Field Value Documentation form in Appendix B, as well as the file path or location of WDNR form 3600-230.

Fish Abundance

The fish abundance metric evaluates the number, or abundance, of certain size classes of adult and/or juvenile fish species within a reach (Table 14) and focuses on abundance within a selected target fish community (see Section 2.3.a. or Section 3.3.a.).

Prior to using the fish abundance metric, WISQT users should coordinate with the local field staff from WDNR to discuss their project and use of the metric. Please follow this link to locate your local fisheries biologist: https://dnr.wisconsin.gov/topic/Fishing/people/fisheriesbiologists.html

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[27] In 2023, WDNR launched a process to revise the fIBI's used in Wisconsin. Although the data collection methods will not change, the thresholds for the fIBI's may change. The WISQT will be updated once those revised thresholds are finalized and made publicly available.

[28] For some projects, users may be able to combine multiple reaches into a single sampling effort. An example is a series of reaches that do not have tributaries and where the team is confident that the existing and proposed condition scores will represent all reaches. The decision about what reaches to include or not include can become complicated as reach condition changes and tributary influence increases. A monitoring plan should be developed with input from USACE, the practitioner, and project sponsor.

Table 14: Size classifications for target fish communities.

Target Fish Community	Size Class
Inland streams: Adult Smallmouth Bass	≥ 8”
Inland streams: Adult and Yearling Brown Trout	≥ 4”
Inland streams: Adult and Yearling Brook Trout	≥ 4”
Lake Michigan coastal streams: Trout Young of Year	< 4”
Lake Superior coastal streams: Trout Young of Year	< 4”

Method:

1. Fish sampling for smallmouth bass should be conducted following the methods outlined in *A Sampling Framework for Smallmouth Bass in Wisconsin’s Streams and Rivers* (Smallmouth Bass Rivers Assessment Team 2006). For all other fish species, users should refer to the *Guidelines for Assessing Fish Communities of Wadeable Streams in Wisconsin v2.0* (WDNR 2018). The assessment length is based on the fish species of interest (Table 13). Regardless of length assessed, the data collection process should work downstream to upstream and end at a fish movement barrier (e.g., riffle).

   Sampling should occur between May and September of each year with differences in timing based upon geography and species (Table 13). Sampling should occur after the rapid rise in stream temperatures each spring (>~55° F) and before the stream temperatures drop in the fall (<~60° F). Similarly, care should be taken to avoid sampling within a week of high-water events in the summer. Conductivity in Wisconsin streams can vary significantly (50-1500 µS/s), and conductivity that is too high or too low can influence electrofishing effectiveness. Consult with WDNR for guidance when operating in streams suspected to have high or low conductivity. Lastly, WISQT users should avoid sampling streams that have been recently stocked.

2. Calculate the number of fish per mile that meet the size class criteria in Table 14; this value should be normalized based upon the stream length assessed. This is the field value for the WISQT.

Note that for coastal streams, interannual variability of the young of the year (YoY) catch per unit of effort (CPE) can be high and multiple years of sampling data are recommended. When multiple years of data have been collected, users should use the highest value recorded for the field value. Recently collected fish data collected by the state may be available to inform existing conditions at a site, please contact your local WDNR field staff for more information.

Estimating proposed condition field values: Proposed condition field values should estimate/predict the expected change in fish abundance after stream restoration work has been completed. Practices that could improve fish abundance include habitat connectivity, riparian vegetation restoration, improved instream habitat (e.g., large woody debris, pools), restored flows, changes to water quality, or more restrictive angling regulations.

Documentation and Field Forms: Users should report their data using the Wadeable Stream Fish Assessment Form (WDNR form 3600-230). Users should ensure that specific and correct data are collected to ensure applicable metrics can be calculated. Record the sampling dates and results on the Field Value Documentation form in Appendix B, as well as the file path or location of WDNR form 3600-230.

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APPENDIX A:

Field Data Collection Methods for the

Wisconsin Stream Quantification Tool and Debit Calculator

Table of Contents

A1. Introduction and Purpose

The purpose of this document is to assist the user in preparing for and collecting data to inform metrics within the WISQT workbook and Debit Calculator workbook. This appendix lays out a recommended set of steps for data collection that integrates methods unique to the WISQT along with methods and measurements that are commonly applied and/or detailed in other instruction manuals or literature.

Individuals collecting and analyzing these data should have experience and expertise in the selected assessment method, e.g., riparian vegetation, bank erosion hazard index, large woody debris index, etc. Typically, the skills needed include botany, ecology, hydrology, and geomorphology. **Interdisciplinary teams of at least two people with a combination of these skill sets are necessary to ensure consistent and accurate data collection and analyses**. 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.

This appendix is a compliment to Chapter 4 of the User Manual, which provides experience requirements for each parameter, information on how to select parameters and metrics, and calculate metric field values from field/desktop data.

A2. Field Preparation Information

Parameter selection will dictate the methods and number of visits necessary to accomplish data collection for all metrics. Prior to going into the field, the user should determine which parameters and metrics to assess and complete the Parameter Selection Checklist (see Section 4.3 of the User Manual). Rapid survey options for field data collection are available for floodplain connectivity, bed form diversity, large woody debris, and nutrients. Some methods are not provided in this appendix (Table A.1); therefore, **users should be familiar with the methods and review the references in Table A.1. prior to field sampling.**

Table A.1: Field methods not included in this document.

Metric or Method	References
Pebble count	• For stream type classification, see *River Stability Field Guide, Second Edition* (Rosgen 2014) • For bed material characterization, see Benoy et al. (2012)
Detailed Longitudinal and Cross-sectional Surveys	• *Stream Channel Reference Sites: An Illustrated Guide to Field Technique* (Harrelson et al. 1994), or • *River Stability Field Guide, Second Edition* (Rosgen 2014)
Large Woody Debris Index (LWDI)	• Pages 73 – 77 of *Monitoring Wilderness Stream Ecosystems* (Davis et al. 2001); and • *Application of the Large Woody Debris Index: A Field User Manual Version 1* (Harman et al. 2017)
Bank Erosion Hazard Index/Near Bank Stress (BEHI/NBS)	• Appendix D of *Function-Based Rapid Field Stream Assessment Methodology* (Starr et al. 2015), *or* • *River Stability Field Guide, Second Edition* (Rosgen 2014)
Temperature Parameter	• *Guidelines and Standard Procedures for Continuous Temperature Monitoring* (WDNR 2004).
Nutrients Parameter	• For benthic algal biomass, see *Viewing Bucket Method for Estimating Algal Abundance in Wadeable Streams v3.6* (WDNR 2020a), and the *Guidelines for Evaluating Habitat of Wadeable Streams* (WDNR 2002) for setting up transects. • For diatom sampling, see *Diatom Collections for Calculation of the Diatom Phosphorus Index (DPI) 3.0* (WDNR 2020b).
Organics and Macroinvertebrate Parameters	• Section 1001.3 of the *WDNR Field Procedures Manual* (WDNR 2011). • *Guidelines for the Standard Collection of Macroinvertebrate Samples from Wadeable Streams v2.0* (WDNR 2017).
Fish Parameter	• *Guidelines for Assessing Fish Communities of Wadeable Streams in Wisconsin v2.0* (WDNR 2018). • For fish abundance, also see *A Sampling Framework for Smallmouth Bass in Wisconsin's Streams and Rivers* (Smallmouth Bass Rivers Assessment Team, 2006).

Rapid Versus Detailed Assessment Methods

Before going to the field, the assessment team should determine if a rapid or detailed assessment method will be used for floodplain connectivity, bankfull dynamics, and bed form diversity. This decision will affect the equipment and data processing tools needed to complete the assessment. The rapid method is commonly used for the existing condition assessment applied to the Debit Calculator, early stages of a stream restoration/mitigation project (like for site selection and approval processes), and even monitoring for restoration (not mitigation) projects. The detailed method is used for approved mitigation projects and restoration projects that want profile and cross section plots.

The **rapid method** for floodplain connectivity, bankfull dynamics, and bed form diversity means that a survey tape will be stretched along the channel. Survey rods, hand levels, line levels, a range finder, and tape measures are used to take the measurements. Survey equipment like a laser level or Total Station are not needed. A step-by-step approach to performing a rapid floodplain, bankfull dynamics, and bed form diversity assessment is provided in Section A4.

The **detailed method** refers to standard surveying techniques using equipment like a laser level, total station, or real-time kinetic (RTK) technologies. The equipment is used to survey a longitudinal profile of the thalweg, water surface, inner berm if present, bankfull, and top-of-low-bank features. Cross sections are used for the riffles, and pools if desired. The survey data are then processed in the office and then the floodplain connectivity, bankfull dynamics, and bed form diversity metric field values are calculated.

Data Forms

Forms for data collection and completion of the WISQT are provided in Appendix B and listed below. Several of the data forms are also available as Microsoft Excel workbooks where data can be entered upon returning from the field. There is a shading key on some of the field forms that indicates which cells are 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 versions. These cells can also be filled out on a printed field form. Other data processing tools, such as the Mecklenburg Reference Reach Spreadsheet (Mecklenburg 2004) can be used to process field data and calculate metric values when using the detailed method for floodplain connectivity, bankfull dynamics and bed form diversity. This spreadsheet is available at https://stream-mechanics.com/resources/ under Spreadsheet Tools.

Required Forms (Appendix B):

Parameter Selection Checklist
Project Reach Form
Effective Riparian Area form
Riparian Vegetation form(s)
Field Value Documentation forms (Hydrology & Hydraulics, Geomorphology)
Field Value Documentation forms (Physicochemical and Biology if Restoration Potential is full)

Optional Forms (Appendix B):

Rapid Survey form (*required if rapid method has been selected)*
Longitudinal Profile form (for detailed method)
Cross Section form (for detailed method)
Pebble Count form
Lateral Migration form
LWDI form (also available from Harman et al. 2017)

Forms from external sources:

Field Sheets for Continuous Temperature Thermistors (Appendix C, WDNR 2004)
Benthic Algal Biomass Field Data form found in *Viewing Bucket Method for Estimating Algal Abundance in Wadeable Streams v3.6* (WDNR 2020a)
DPI: Diatom Analysis (Form 4800-028 WDNR. 2020b.)
Wadeable Macroinvertebrate Field Data Report (Form 3200-081, WDNR)
Wadeable Stream Fish Assessment Form 3600-230 from WDNR

Equipment List

This list provides the equipment needed to assess the basic set of metrics within the hydrology, hydraulics, and geomorphology functional categories. Additional equipment will be needed for other metrics. At a minimum, the following field gear will be needed:

- Field forms and maps (Rite in the Rain paper recommended)
- Clipboard, pencils, and sharpies
- Waders or wading boots (no felt bottoms)
- Pin flags (50) and roll of flagging tape
- Camera
- Metric ruler
- Measuring tapes (e.g., 300ft, 100ft and 50 ft). Tapes that have English units on one side and metric on the other are recommended.
- Calipers (helpful for the LWD assessment)
- Clinometer (for bank angle measurements of BEHI)
- GPS unit (helpful with lateral migration and effective riparian area)
- Range finder (helpful for large flood-prone width measurements, effective riparian area, and sinuosity field measurements)
- DBH tape measured in centimeters (used for the woody stem basal area metric)
- Survey equipment – The rapid method described in this appendix allow measurements to be made with a hand or line level and stadia rod. Detailed geomorphic survey methods will require standard survey equipment, such as a stadia rod, laser level, total station, or RTK.

Metric Sampling Periods & Restrictions

Sampling periods for metrics vary. Most metrics in the WISQT can be assessed in a single day or visit, but multiple days or visits may be required, depending on the complexity and size of the site and which metrics were selected for analysis. Table A.2. shows sampling restrictions and considerations by parameter. Parameters that are not listed do not have sampling restrictions.

Table A.2: Sampling periods and restrictions by parameter.

Parameter	Sampling Periods	Sampling Restrictions/Notes
Lateral Migration	None specified; see notes	Samples should be collected in the same season from year to year to account for seasonal differences in riparian vegetation.
Bed Form Diversity	Baseflow periods	Sampling should occur during baseflow periods for safety and efficiency.
Riparian Vegetation	July 1 – August 31	None
Temperature	June 1 – August 31	None
Nutrients	July 1 - September 15	Sampling should occur during baseflow conditions and should be avoided within 14 to 21 days following a storm event. If water levels are substantially above normal (> 0.15m), sampling should not occur.
Organics and Macroinvertebrates	Spring (April - May) or Fall (September – October)	Samples should be collected in the same season from year to year to ensure multi-year data is comparable.
Fish	May 24 – September 15	Smallmouth Bass in the southern 2/3 of WI
	June 7 – August 31	Smallmouth Bass in the northern 1/3 of WI
	May 15 – September 30	Brown Trout, Brook Trout, Lake Michigan Trout Young of Year, and Lake Superior Trout Young of Year in the southern 2/3 of WI
	May 30 – September 15	Brown Trout, Brook Trout, Lake Michigan Trout Young of Year, and Lake Superior Trout Young of Year in the northern 1/3 of WI

A3. Reach and Representative Sub-Reach Assessments

The following sequence of steps is recommended to collect data in the field. Depending on which parameters are selected, not all steps will need to be completed for all projects.

Preparation and Reach Segmentation

1. Prior to field work, the user should determine whether the project area should be delineated into multiple project reaches (see Section 4.1 of the User Manual).
2. Conduct necessary pre-field desktop activities; review Chapter 4 of the User Manual. For each reach users should review available information and prepare a list of action items for the field to:
    a. Complete the Restoration Potential worksheet (WISQT workbook only; not applicable for Debit Calculator workbook),
    b. Complete the Site Information and Reference Selection section of the Quantification Tool (WISQT workbook) or Existing Condition worksheet (Debit Calculator workbook) and the Site Information section of the **Project Reach form**,
    c. Support the proper identification and verification of bankfull in the field (Section 4.4), and
    d. Collect all field data for applicable/selected metrics.
3. At the site, 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 upstream and downstream ends of each reach.

   When multiple project reaches exist on the same stream, data collection typically proceeds from upstream to downstream. However, if biological sampling is being performed, plan to evaluate the most downstream sampling reach first and work upstream or collect biological samples prior to other instream work to avoid muddy waters and impacted samples.

Project Reach Assessment

1. Within each project reach, walk along the stream bank to view locations and character of riffles, the number of concentrated flow points, length of armoring, and bankfull indicators. Definitions and further instruction are provided in Chapter 4 of the User Manual.
    a. Record length of any armored sections of bank on the **Project Reach Form.**
    b. Record number, location, and type of concentrated flow points on the **Project Reach Form.**
    c. Follow the bankfull identification and verification described in Section 4.4 of the User Manual.
    d. Classify the stream using the Rosgen method. The slope and sinuosity can come from the reach-scale assessment. Record data on the **Project Reach Form.**
2. Select the location within the reach for biological sampling (if applicable).

3. If applicable, sample macroinvertebrates in accordance with WDNR procedures (2017). Processed samples should be immediately preserved and stored in a cool, shaded area for the remainder of data collection.
4. If applicable, sample benthic algal biomass and/or diatoms; refer to WDNR (2020a) and WDNR (2020b).
    a. For benthic algal biomass, sampling should occur within 12 equally spaced transects within the representative sub-reach according to WDNR (2002) with four equidistant points on each transect (i.e., left, left-center, right-center and right). The assessment length should no less than 100m; if the representative reach is less than 100m, transects should extend beyond the representative sub-reach but not beyond the project reach. If the project reach is less than 100m, use of this metric should be discussed with USACE prior to sampling.
5. If applicable, sample fish in accordance with WDNR procedures (2018).
6. If the project reach is long, determine the location of the representative sub-reach. Record the GPS location at the upstream and downstream ends of the representative sub-reach.
    a. Measurements from the representative sub-reach will quantify floodplain connectivity, bankfull dynamics, large woody debris, lateral migration (except armoring), bed material characterization, and bed form diversity parameters, as well as riparian vegetation plot-based metrics.
    b. The representative sub-reach should be at least 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. Record the length of the representative sub-reach.
7. Within the representative sub-reach, collect bed form diversity, flow dynamics, and floodplain connectivity data using either rapid methods described in Section A4 or detailed survey methods (e.g., Harrelson et al. 1994, Rosgen 2014).
    a. Sections A6 and A7 provide additional information on identifying low bank height in incised streams and bed form identification. These metrics are part of the floodplain connectivity and bed form diversity parameters, respectively.
8. Perform dominant BEHI/NBS measurements throughout the representative sub-reach per methods outlined in Rosgen (2014) or Starr et al. (2015) and with the following modifications.
    a. Measure the bank length of **every** outside meander bend and determine its BEHI/NBS category. The outside of the meander bend is always assessed, even when it is not eroding.
    b. Measure the bank length of **any other bank that is actively eroding** and determine its BEHI/NBS category. The following areas should not be included in the assessment: depositional zones (e.g., point bars) or other areas that are not actively eroding, riffle sections that are not eroding and have low potential to erode and

banks that are armored. Undercut banks in riffles that are not migrating are not considered eroding and should not be assessed.

9. Conduct a large woody debris assessment, riparian vegetation surveys, and bed material characterization (when applicable based on parameter selection).

    a. For LWD, identify the 328 feet (100 m) length of the project reach that contains the most LWD, preferably within the representative sub-reach. For LWDI index (detailed method), see methods and field forms within Davis et al. (2001) or Harman et al. (2017). For LWD Frequency (rapid), count all pieces of dead and fallen wood wholly or partially within the active channel that are over 3.28 feet (1 m) in length and at least 3.9 inches (10 cm) in diameter at the largest end within the 328-foot reach. For debris dams, to the extent possible, count each piece within the dam that qualifies as LWD. LWD counts are recorded on the Project Reach Form.

    b. For bed material characterization, conduct a 200-particle random-walk Wolman pebble count within the study riffle (see Wolman 1954, Benoy et al. 2012).

    c. For riparian vegetation, see Riparian Vegetation section below. Effective Riparian Area and Riparian Vegetation forms are provided in Appendix B.

10. Install temperature sensors as applicable based on parameter selection (see WDNR 2004).

<u>Riffle Surveys</u>

Riffle cross-sections are used for multiple purposes in the WISQT, including bankfull identification and verification, rapid measurements for the bank height ratio, W/D, and entrenchment ratio, and a stable riffle that is needed for bankfull width and mean depth values that are used to calculate bed form diversity metric ratios. More information is provided below on the use of riffle cross sections.

- Stable Riffle, described in Section 4.4 of the User Manual, is a stable riffle that is used for *bankfull verification*. Dimensions from this riffle also provide the denominator for the pool spacing and pool depth ratios. Stable riffle data from the rapid method can be recorded on the **Project Reach** Form.
- At least one riffle cross-section is needed to determine the *existing stream type* of the project reach. This riffle should be located in the representative sub-reach and provide measurements for the entrenchment ratio metric field value where flood-prone width is uniform (as verified using topographic data).
- Data to calculate the bank height ratio and width/depth ratio should be collected at every riffle in the representative sub-reach to quantify floodplain connectivity and bankfull dynamics. These data can be collected from cross-sections at the center of each riffle or from the riffle data collected for the longitudinal survey (see Section A4 for more information about the rapid method).

Rapid Method for Surveying the Riffle Cross Section

1. Determine the location of the cross-section within the riffle. Make sure that the cross-section is perpendicular to the direction of flow at bankfull.

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 identified during the bankfull identification and verification process.

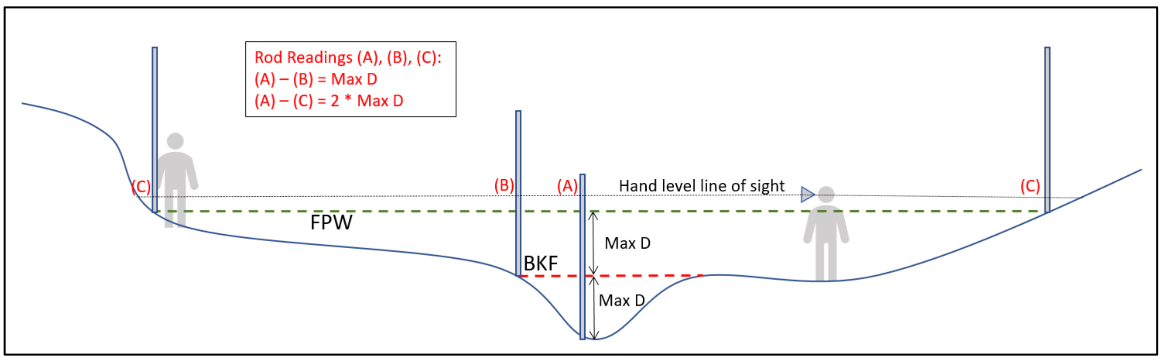
3. Record the bankfull width.

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, edge of channel, water surface, the thalweg, and other points along the channel bottom.

6. Identify the flood-prone elevation (e.g., relative elevation or stadia rod reading) and measure the flood-prone width (FPW) as shown in Figure A.1. The flood-prone width should be measured perpendicular to the fall line of the valley. The FPW can be measured using a tape, range finder, or GPS.

Figure A.1: Surveying Flood-Prone Width.



For the stable riffle, space is provided on the **Project Reach Form** to calculate the bankfull mean depth and cross-sectional 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. Compare the bankfull width, mean depth, and area to the regional curve values on the field form.

A4. Rapid Survey for Floodplain Connectivity, Bankfull Dynamics, and Bed Form Diversity

This section outlines rapid survey methods to collect data to inform floodplain connectivity, bankfull dynamics, and bed form diversity parameters. These rapid survey techniques are considered more rapid than surveying the longitudinal profile and cross-sections using surveying equipment like a laser level, total station, or RTK. They require little post-processing of the field data.

The optional 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, width/depth ratio state, percent riffle, average pool depth ratio, and median pool spacing ratio.

Method

1. Beginning at the upstream end of the representative sub-reach, stretch tape(s) along either the left or right bank as close to the edge of the channel as possible, threading them through riparian vegetation or other obstructions if necessary. Tape(s) can be secured to the ground with chain 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.
2. Record sub-reach length in the **Rapid Survey form**.
3. Working from upstream to downstream, take measurements at every riffle and pool within the sub-reach. NOTE: Review pool identification instructions provided in Section A7.
    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 (if applicable), width/depth ratio state, 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 a **significant or geomorphic pool**.
        ii. Identify the approximate middle of the riffle feature. The sample location doesn’t have to be the exact center. Look for places that have bankfull indicators and a good line of sight to the top of bank and flood-prone width, but that is also representative of the riffle condition.
        iii. From mid-riffle, measure the bankfull width using a bankfull indicator. If an indicator is not present, use the difference in water surface and bankfull to pin the tape. The difference in water surface and bankfull was done during the bankfull identification and verification process. Make sure the tape is level.
        iv. 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. NOTE: see Section A6 for how to identify low bank in incised streams.

v. From mid-riffle, measure the difference in stadia rod readings from the thalweg to the bankfull elevation, or measure down from the tape to the thalweg. Record this value as the bankfull maximum depth on the **Rapid Survey form**. If a bankfull feature is not present, measure the difference in stadia rod readings from the thalweg to the water surface and then add the value recorded for the difference between bankfull stage and water surface.

vi. From mid-riffle, measure the difference in stadia rod readings from the edge of channel, which is the breakpoint between the streambed and streambank, to the bankfull elevation, and record this value as the mean depth on the **Rapid Survey form**.

Note: Using the edge of channel up to the bankfull elevation measurement as an estimate of mean depth works best in streams where the thalweg is close to the middle of the channel. If scour or large sediment deposits are at the edge of the channel, this method should not be used. An alternative approach in this case is to measure multiple bankfull depths across the channel (refer to Rapid Riffle Survey instructions in Section A3), average the depths, and record this value as the mean depth on the **Rapid Survey form**.

vii. Flood-prone width should also be measured at each riffle in sub-reaches with changes in valley width or a bank height ratio near, or greater than, 2.0. 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**.

b. Identify pools within the sub-reach. Refer to pool definitions in Section A7 of this appendix for geomorphic and significant pools.

c. 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. Identify the pool as a geomorphic pool or a significant pool.

ii. Determine the deepest point of the pool and record the station.

iii. Measure the maximum 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.

A5. Effective Riparian Area and Riparian Vegetation

Effective Riparian Area Field Verification Method

1. Within the entire project reach, walk through the effective riparian area along both banks and confirm or adjust the desktop-based riparian vegetation mapping based on field observations. Examine the reach and landscape.

   For effective riparian area: Locate the mapped extent in the field using GPS points and inspect the area landward from the extent for at least 10 meters or 32.8 feet (see example in Figure A.2). Verify this extent using field observations.

   For effective vegetated riparian area: Locate the mapped extent in the field using GPS points. Verify this extent aligns with the current extent of riparian vegetation (excluding all artificial vegetation that is periodically harvested/removed such as crops, sod, tree farms, etc.). Riparian vegetation should be contiguous with the stream channel, extending landward towards the extent of the effective riparian area; areas interrupted by any human-related disturbances or structures (roads, buildings, utility lines, etc.) should be excluded. It may be necessary to locate areas that are not vegetated using GPS units and/or other survey and measurement methods for stream reaches that cannot be readily discerned on aerial imagery.

2. Record any adjustments to riparian area extent using GPS; riparian area measurements and mapping can be revised in the office later. Field verification points should be indicated and labeled on the riparian area figure. Indicators should be noted on the **Effective Riparian Area form**.

Riparian Vegetation Plot Layout

Vegetation metrics are assessed at permanent plots located at equally spaced intervals along the representative sub-reach. Permanent plots are used for all condition assessments (existing, proposed, as-built, and monitoring).

1. Calculate the number of sampling plots by dividing the sub-reach length by the plot spacing in Table A.3. Fewer plots may be evaluated if the representative sub-reach is short or if the riparian vegetation is very uniform in structure and composition throughout the sub-reach. Additional plots may be added at sites with variable riparian vegetation.

   Table A.3: Number of sampling plots per sub-reach.

Sub-reach length (LF)	Number of plots per side
<1000	1 plot every 200 LF
≥1000	1 plot every 300 LF

2. Select a random starting point between 30 and 100 feet from the upstream extent of representative sub-reach.

3. The plots are 30-foot (9.1m) radius circles located on either side of the stream bank (Figure A.2). On each side of the stream bank, plots will alternate between (a) being located tangent to the primary channel (center of the plot 30 feet from the stream bank) and (b) being

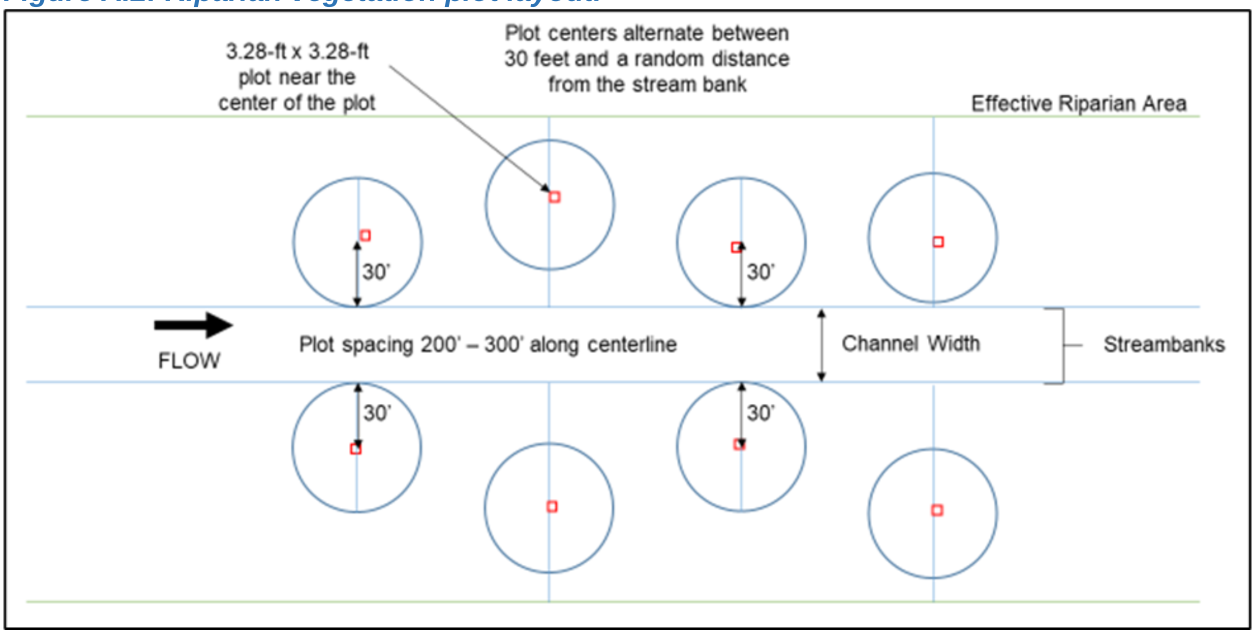
randomly located within the effective riparian area (center of the plot is >30 feet from the stream bank). For plots located within the buffer, i.e., not tangent to the bank, the center of the plot will be a random distance from the stream bank as shown in Figure A.2. Plots must be within the effective riparian area.

4. The herbaceous layer shall be sampled using a 3.28-foot by 3.28-foot (1m^2) sample plot near the plot center (Figure A.2).

5. Subsequent sampling plot locations should be identified using the spacing interval identified in step 1 above. Plot locations on the right side of the stream should use the same station locations as identified on the left. For example, if the reach is 2400' in length and the first plot center point is at 30', then subsequent plots would be centered every 300' at 330', 630', 930' and so on up to 2130'.

If a plot does not fit (e.g., the effective riparian area is not 60' wide) then the plot shape can be altered if the area is equivalent. For example, if the effective riparian area is only 50' wide, then a square plot that is 50' wide and 57' long would be an equivalent area to the circular plots. Plots should not overlap. If necessary, vegetation plots may extend beyond the downstream end of the representative sub-reach but should not extend outside the project reach.

Figure A.2: Riparian vegetation plot layout.



<u>**Riparian Vegetation Plot Data Collection Method**</u>

1. All data should be recorded on the **Riparian Vegetation form**.

2. Take a photo of the riparian plot, ensuring the herbaceous plot is visible. Note the photo number on the data form or include the plot number in the photograph.

3. Note the geomorphic location of the 30-ft radius plot as inside meander, outside meander, or straight/riffle. If this changes over the length of the plot, record the geomorphic location of the majority of the plot. Note the distance of the plot to the stream.

4. Within each 3.28-foot by 3.28-foot riparian plot, visually estimate the relative percent cover for herbaceous species, woody species less than 1m in height, and bare soil or open water areas relative to the total area of the plot. The relative areal cover is the proportional cover provided by each strata as a percentage of the total plot, ranging from 0 – 100%; the total percentage across all strata should not exceed 100%. Use the cover class ranges in Table A.4 for the estimates. Enter the cover midpoint estimate in the **Riparian Vegetation form**.

Table A.4: Cover Class Descriptions.

Cover Class Range	Midpoint
>95 - 100%	97%
>75 - 95%	85%
>50 - 75%	62.5%
>25 - 50%	37.5%
>5 - 25%	15%
>1 - 5%	3%
>0 - 1%	0%

5. Within each 30-foot radius riparian plot, visually estimate the absolute percent areal cover provided by all woody vegetation greater than 1m in height. When estimating, include the entirety of trees and shrubs over 1m tall, rather than just the subset of the individual that is above 1m. Plants overhanging the plot do not need to be rooted in the plot to be included; however, plants rooted outside the effective riparian area should not be included. Use the cover class ranges in Table A.4 for the estimates. Enter the cover midpoint estimate in the **Riparian Vegetation form.**

6. Collect DBH data within the entire 30-foot (9.1m radius) plot. 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.5 to determine the midpoint value. Measure and record the exact DBH of all woody stems exceeding 30.5 cm DBH. Enter the number of stems in each size class less than 30.5 cm DBH and the DBH for each stem >30.5cm DBH on the **Riparian Vegetation** form.

Table A.5: DBH Classification.

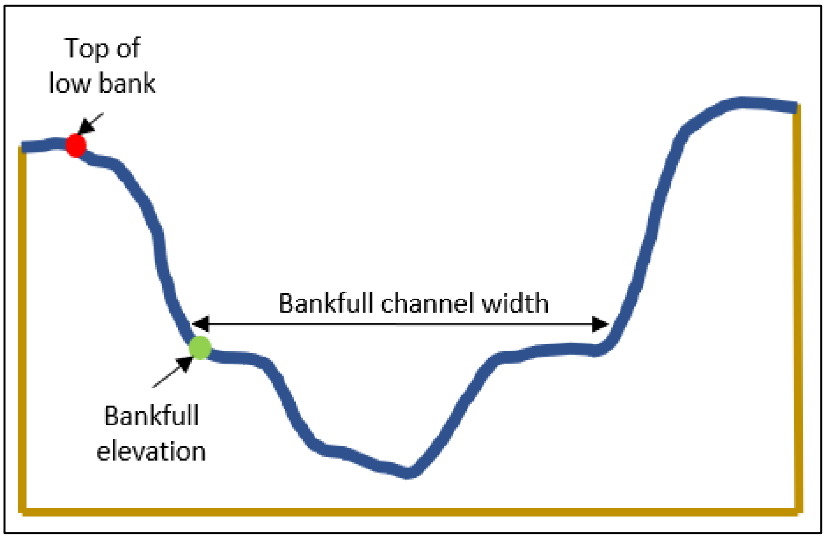
DBH (cm)	DBH Midpoint (cm)
0 – 2.5	1.25
2.5 – 5	3.75
5 – 7.5	6.75
7.5 – 12.5	10
12.5 – 20.5	16.5
20.5 – 30.5	25.5
>30.5	Measure

A6. Identifying Low Bank Height in Incised Streams

In incised channels with a bankfull bench, determining when bankfull and the top of bank are equal can be challenging. Two common scenarios are detailed below to aid users in low bank identification.

Scenario 1 – If the bankfull elevation is identified as the back of the bench as shown in Figure A.3, then the low bank feature is the top of the left bank in the cross-section shown.

Figure A.3: Incised Stream Scenario 1, where bankfull elevation and low bank elevation are not equal.



Scenario 2 – If the bankfull elevation is identified as the front of the bench as shown in Figure A.4, then the width of the bankfull bench(es) must be considered before the low bank feature can be determined.

- For C/E reference stream types, if the floodplain bench width (left bench + bankfull channel + right bench) is greater than 2.2 times the bankfull channel width, then the low bank feature is equal to bankfull (shown as the green dots in Figure A.4).
- For B reference stream types, if the floodplain bench width is greater than 1.4 times the bankfull channel width, then the low bank feature is equal to bankfull (shown as the green dots in Figure A.4).
- If total width is less than or equal to the 2.2 for C/E reference stream types or 1.4 for B reference stream types, then the low bank feature is top of the right bank shown in Figure A.5.

Figure A.4: Incised Stream Scenario 2, where the width of bankfull benches determine low bank elevation.

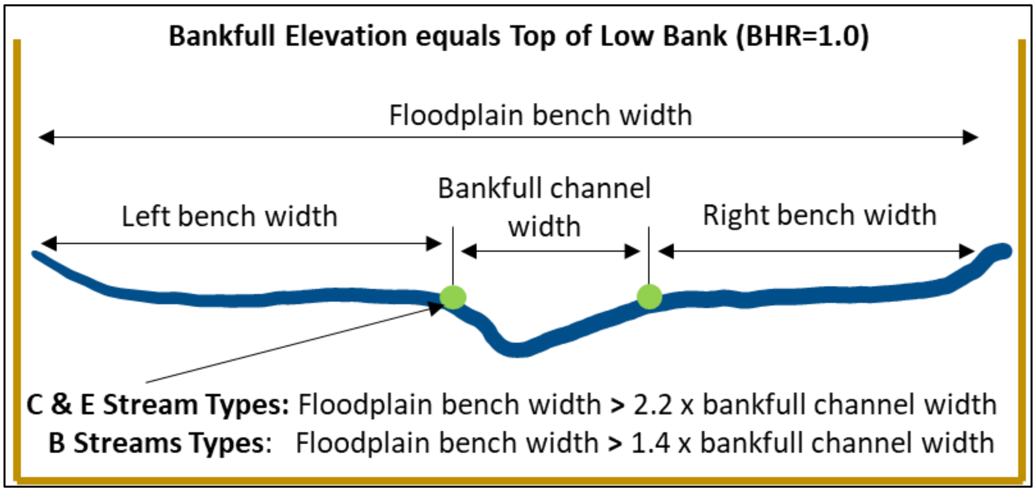
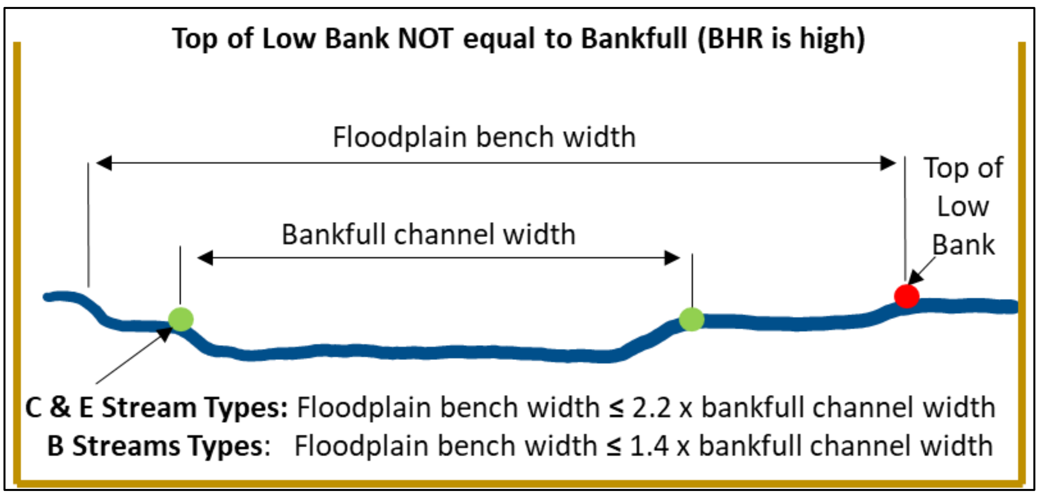


Figure A.5: Bankfull elevation is the front of the bench, and calculations determine location of low bank.



A7. Bed Feature Identification

Bed forms include the various channel features that maintain heterogeneity and stability in the channel form, including riffles, runs, pools, and glides (Rosgen 2014). Together, these bed features create important channel patterns and habitats for aquatic life. Riffles and pool types are defined in this section.

Riffles are shallow, steep-gradient channel segments typically located between pools. Riffles are the river's natural grade control feature (Knighton 1998) and are sometimes referred to as fast-water channel units (Hawkins et al. 1993, Montgomery and Buffington 1998). For purposes of the SQT, in meandering streams riffles broadly represent the section between lateral-scour pools known as a **crossover**, regardless of bed material size. The term riffle also refers to the crossover section in sand bed streams and the cascade section of steep mountain streams. For the percent riffle metric in the WISQT, riffles are measured from head of riffle to head of significant or geomorphic pool. The WISQT does not distinguish run features from riffles, runs are considered riffles and similarly glides are considered pools.

Ripples are small-scale bed forms in sand bed channels. As sand accumulates and the size of the ripple grows, it becomes a dune. Other sand-bed forms include plane beds and anti-dunes (Knighton 1998). Ripples are not identified as part of a SQT assessment.

The SQT requires identification of two pool types: **geomorphic pools** and **significant pools**. Guidance for identifying pools in different valley types is provided below. **Note: Pool identification is slightly different for pool spacing than it is for pool depth and percent riffle metrics.** Guidance on pool identification for each metric is provided under each metric's description.

Geomorphic pools are associated with planform features that create large pools that remain intact over many years and flow conditions. These pools are associated with the outside of a meander bend (streams in alluvial valleys) and downstream of a large cascade or step (streams in colluvial valleys). The pool spacing ratio metric only applies to geomorphic pools.

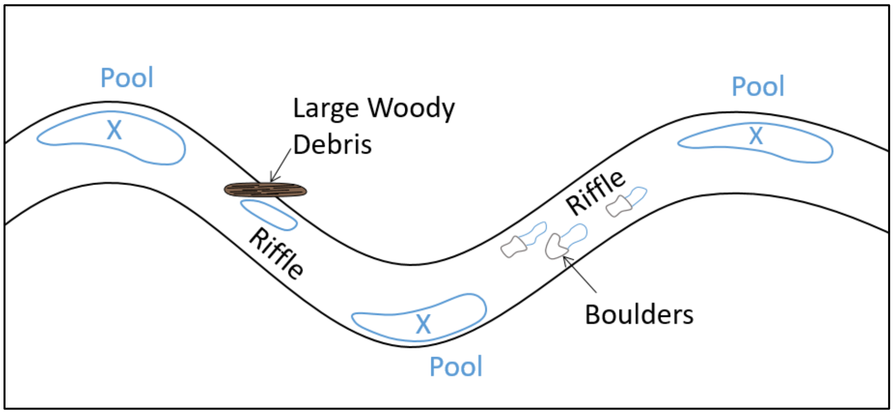
Significant pools are pools not classified as geomorphic pools. They are often associated with wood, boulders, convergence, and backwater in the main channel. Significant pools are contained within the main channel; contain the thalweg; are laterally and longitudinally concave; and span at least 50% of the wetted channel at any location within the pool. Significant pools are used in calculating the pool depth ratio and percent riffle metrics.

Pools that do not meet the criteria for significant pools are sometimes called micro-pools. Micro-pools are small and may not last for a long period of time or after a large flow event. Micro-pools can be found in riffles and cascades. An example is a scour pool downstream of a single piece of large woody debris that is less than 50% of the wetted channel. **Micro-pools are never counted as pools in the SQT.**

<u>Identifying Geomorphic Pools in Alluvial-Valley Streams</u>

Geomorphic pools in alluvial valleys are located along the outside of the meander bend. Figure A.6 provides an illustration of what is and is not counted as a geomorphic pool (pools counted 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 micro-pools. 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.

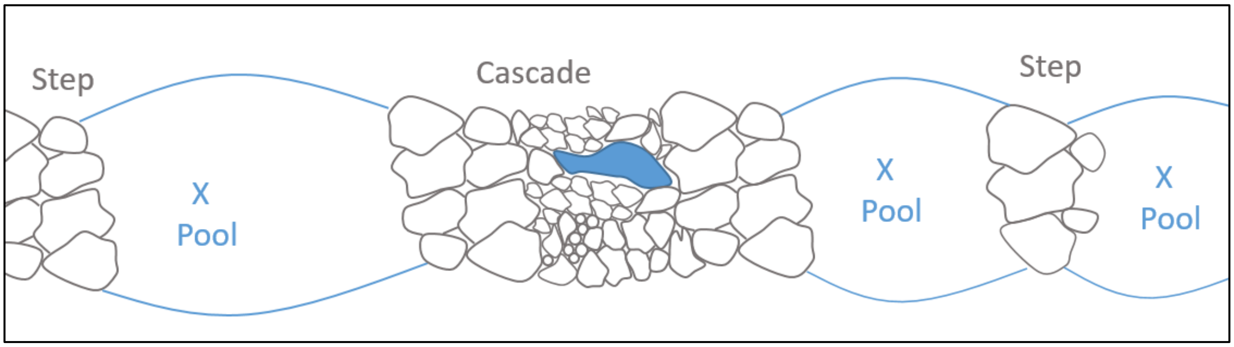
Figure A.6: Pool Spacing in Alluvial Valley Streams



Identifying Geomorphic Pools in Colluvial and V-Shaped Valleys

Pools in colluvial or v-shaped valleys should only be counted as geomorphic pools if they are downstream of a step, riffle, or cascade. Micro-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 A.7. 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 A.7: Pool Spacing in Colluvial and V-Shaped Valleys



APPENDIX B:

Required and Optional Field Forms for Data Collection

	Function-Based Parameter		Metric(s)	Documentation and Field Forms
□	Catchment Hydrology	□	Land Use Coefficient (D)	Field Value Documentation (H&H)
□	Reach Runoff*	□	Land Use Coefficient* (D) **AND** Concentrated Flow Point Index* (D/F)	Project Reach Form Section II(c) **AND** Field Value Documentation (H&H)
□	Floodplain Connectivity*	□	Bank Height Ratio* **AND** Entrenchment Ratio* (F)	Field Value Documentation (G) **AND** Rapid Survey Form** **OR** Cross Section** **AND** Longitudinal Survey Forms**
□	Flow Dynamics*	□	Width/Depth Ratio State* (F)	Field Value Documentation (G) **AND** Rapid Survey Form** **OR** Cross Section** **AND** Longitudinal Survey Forms**
□	Large Woody Debris* (LWD)	□	LWD Index (F)	LWDI Form** **AND** Field Value Documentation (G)
			or	
		□	LWD Frequency (no. of LWD Pieces/ 100 meters) (F)	Project Reach Form Section VI **AND** Field Value Documentation (G)
□	Lateral Migration*	□	Dominant BEHI/NBS* **AND** Percent Streambank Erosion* (F)	Lateral Migration Form** **AND** Field Value Documentation (G)
		□	Percent Armoring (F)	Project Reach Form Section II(B) **AND** Field Value Documentation (G)
□	Bed Material Characterization	□	Percent Fines (<2mm) **AND** Percent Fines (<6.35mm) **AND** Median Particle Size (F)	Pebble Count Form** **AND** Field Value Documentation (G)
□	Bed Form Diversity*	□	Pool Spacing Ratio* **AND** Pool Depth Ratio* **AND** Percent Riffle* (F)	Field Value Documentation (G) **AND** Longitudinal Survey** **OR** Rapid Survey Form**
□	Riparian Vegetation*	□	Effective Riparian Area* (D/F) **AND** Canopy Cover* (F) Herbaceous Vegetation Cover* (F) **AND** Woody Stem Basal Area[1] (F)	Field Value Documentation (G) **AND** Effective Vegetated Riparian Area **AND** Riparian Vegetation forms
		□	Effective Riparian Area* (D/F) **AND** Canopy Cover* (F) **AND** Herbaceous Vegetation Cover* (F)	
□	Temperature	□	Summer Mean (F)	Field Value Documentation (P&B)
□	Nutrients	□	Benthic Algal Biomass **AND** Diatom Phosphorous Index[2] (F)	Field Value Documentation (P&B) **AND** Benthic Algal Biomass Field Data form found in Viewing Bucket Method for Estimating Algal Abundance in Wadeable Streams v3.6 (WDNR 2020a).*** DPI: Diatom Analysis (Form 4800-028 WDNR)***
□	Organics	□	Hilsenhoff Biotic Index(F)	Macroinvertebrate Field Data Report (WDNR Form 3200-081)*** **AND** Field Value Documentation (P&B)

□	Macroinvertebrates	□ Macroinvertebrate IBI (F)	Macroinvertebrate Field Data Report (WDNR Form 3200-081)*** **AND** Field Value Documentation (P&B)

□	Fish	□ Fish IBI (F) □ Fish Abundance (F)	Field Value Documentation (P&B)

* Include in all assessments
** Forms are optional and are included for convenience
*** Forms not included in Appendix B; see original source.
(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.
[2] Include Diatom Phosphorous Index only if average Benthic Algal Biomass values are between 1 and 2

Date:
Investigators:

EXISTING or MONITORING
(Select one)

Wisconsin Stream Quantification Tool
Project Reach Form

I. Site Information

Project Name:	
Reach ID:	
Drainage Area (sq. mi.):	
Lateral Drainage area (acres):	
Valley Type:	
Stream Reach length (ft):	
Latitude:	
Longitude:	

Note: if form is being used for proposed condition scores, do not complete Section IIA or Sections III - V.

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.

Length of Armoring on banks (ft):		0	0	0	0	0	0	0
Total (ft)	0.0							
Percent Armoring (%)								

C.

Concentrated Flow Point Index					
Concentrated Flow Point ID	Stream Side (L/R)	Station ID or Lat/Long	Acres Draining to CFP	CFP Ranking*	CFPI Score
				Total CFPI Score	

*Key to CFP Channel Type and Ranking	
	Pipe or Open Concrete Channel = 1
	Open Channel with >4% Slope or Impermeable Soils = 0.9
	Open Channel With <4% Slope and <50% Vegetation Cover = 0.8
	Open Channel with <4% Slope and 50-90% Vegetation Cover = 0.7
	Open Channel with <4% Slope and >90% Vegetation Cover = 0.6

Date:
Investigators:

EXISTING or MONITORING
(Select one)

Wisconsin Stream Quantification Tool
Project Reach Form

III. Identification of Representative Sub-Reach

Representative Sub-Reach Length At least 20 x the Bankfull Width	
Latitude (downstream extent):	
Longitude (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	
H.	Does the the bankfull area fall within the range of scatter from the regional curve?	

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.

Cross Section Measurements Depth measured from bankfull			
Station	Depth	Station	Depth

Cross Section Calculations					
W	**Average D**	**Area**	**W**	**Average D**	**Area**
-	-	-			

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 (%)		*Average slope from the representative sub-reach will be measured and calculated.*
F.	Channel Material Estimate		*Pebble count forms are available to aid in this determination.*
	Stream Length (ft)		
G.	Valley Length (ft)		
	Sinuosity		
H.	Stream Type		

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
A or G	F	B	E	C

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

Date:	EXISTING or PROPOSED or MONITORING	Wisconsin Stream Quantification Tool
Investigators:	(Select one)	Effective Riparian Area

Project Reach ID:
Stream Reach Length:

Shading Key
Desktop Value
Field Value
Calculation

DESKTOP DETERMINATION

For MWR approach, enter the following information:

Valley Type:		Meander Width Ratio Used:		Additional width (ft):	
		Bankfull width (ft):		Estimated Riparian Area Width (ft):	

Aerial imagery mapped extent:	Effective Riparian Area (acres):	

Check Aerial Imagery indicators used to adjust effective riparian area extent:

	Valley Edge		Slope break/Terrace	Notes:
	Change in Sediment		Other:	
	Evidence of Flooding			
	Change in Vegetation			

Vegetated (acres):	

Check Aerial Imagery indicators used to adjust Vegetated riparian area extent:

Estimated Effective Vegetated Riparian Area %:

	Contiguous areas of less than 50% vegetative cover (all strata combined)	Notes:
	Areas with non-natural vegetation that is periodically harvested, removed or otherwise managed such as crops, sod, tree farms, etc.	
	Areas with human-induced structures or features (roads, buildings, utility lines, driveways, etc.) even if vegetation is growing within their footprint.	
	Other:	

FIELD VERIFICATION

Date of Field visit:

Field verified extent:	Effective Riparian Area (acres):		Vegetated (acres):	

Effective Vegetated Riparian Area %:

Check indicators observed in the field at **effective riparian area** extent:				Check indicators observed in the field at **vegetated area** extent:	
	Valley Edge		Slope break/Terrace		Contiguous areas of less than 50% vegetative cover (all strata combined)
	Change in Sediment		Other:		Areas with non-natural vegetation that is periodically harvested, removed or otherwise managed such as crops, sod, tree farms, etc.
	Evidence of Flooding				Areas with human-induced structures or features (roads, buildings, utility lines, driveways, etc.) even if vegetation is growing within their footprint.
	Change in Vegetation				Other:

Insert Aerial Photo of Project Reach with Effective Riparian Area and Effective Vegetated Riparian Area extents:

Shading Key
Desktop Value
Field Value
Calculation

Date:
Investigators:

EXISTING or MONITORING
(Select one)

Wisconsin Stream Quantification Tool
Riparian Vegetation Form

Reach ID:
Stream length:
Total number of Plots:

Shading Key
Field Value
Calculation

Cover Range	Midpoint
>95-100%	97%
>75-95%	85%
>50-75%	62.5%
>25-50%	37.5%
>5-25%	15%
>1-5%	3%
>0-1%	0%

	Plot Information:					
Plot ID#						
Stream Side (L:/R)						
Geomorphic Location:						
Relative Areal Cover[1] Herbaceous Strata (all veg <1m in height[2])	**Enter 1x1m Plot Cover Midpoints below:**					
Non-woody Herbs, Grasses and Forbs						
Woody Shrubs and Saplings						
Barren, Bare Dirt or Duff						
Herbaceous Cover (sum of woody and non-woody cover midpoints)						
Total Areal Cover[3] Canopy Strata (woody vegetation >1m in height[2])	**Enter Canopy Cover Midpoint (30' radius plot) below:**					
Canopy Cover (cover midpoint)						

Geomorphic Location: I, O, S
Inside meander, Outside meander, Straight/riffle

Date:
Investigators:

EXISTING or MONITORING
(Select one)

Woody Stem Basal Area at dbh[4]		Enter number of stems for each DBH range below:											
DBH Range	**Midpoint**	**Number**	**Total[5]**	**Number**	**Total[5]**	**Number**	**Total[5]**	**Number**	**Total[5]**	**Number**	**Total[5]**	**Number**	**Total[5]**
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	**For >30.5 cm enter DBH to nearest cm below:**											
		DBH	**Area[5]**	**DBH**	**Area[5]**	**DBH**	**Area[5]**	**DBH**	**Area[5]**	**DBH**	**Area[5]**	**DBH**	**Area[5]**
Plot Radius (ft):	30												
Plot Area (ha):	0.02627												
Total Cross-sectional Area (m^2):													
Woody Steam Basal Area (m^2/ha):													

Geomorphic Location: I, O, S
Inside meander, Outside meander, Straight/riffle

[1]Relative areal cover is the proportional cover by vegetation type; the total across all types should not exceed 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]Total areal cover of all woody plants that exceed 1m height, estimate should include cover of entire shrub or tree, not just the portion >1m.

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

[5]Number of stems multiplied by stem cross-sectional area (Area = $\pi(d/2)^2$ with diamater (*d*) equal to midpoint). For stems >30.5cm, cross-sectional area calculated using measured DBH as the diamater (Area = $\pi(d/2)^2$ with diamater (*d*) equal to measured DBH). Units are in square meters (m^2).

Notes:

Geomorphic Location: I, O, S
Inside meander, Outside meander, Straight/riffle

Reach ID: EXISTING or PROPOSED or MONITORING (Select one) Wisconsin Stream Quantification Tool Field Value Documentation

Item		Value	Notes
Reach Hydrology & Hydraulics			
Catchment Hydrology			
Land Use Coefficient			
Provide the filepath or location of aerial image depicting boundary of upstream catchment and land uses:			
Upstream Catchment Drainage Area (Acres)			Source of land cover data:
Natural open water (Acres)			
Revised Total Drainage Area (total; Acres)			
Open Space (acres)			
Impervious area (acres)			
Unpaved Roads (acres)			
Commercial, business and industrial districts (acres)			
Residential <1/4 acre ave. lot size (acres)			
Residential ~1 acre ave. lot size (acres)			
Residential >2 acres ave lot size (acres)			
Open Water - only impounded water behind dams (acres)			
Cropland (acres)			
Pasture, grassland, or range – continuous forage for grazing (acres)			
Meadow – continuous grass, protected from grazing and generally mowed for hay (acres)			
Brush – brush-weed-grass mixture with brush major element (acres)			
Woods – grass combination (orchard or tree farm) (acres)			
Woods--disturbed by heavy grazing (acres)			
Woods—forested areas protected from grazing and w/adequate litter and brush covering the soil (acres)			
Native Prairie (acres)			
FIELD VALUE - Catchment Land Use Coefficient (%)			*Calculated*

Reach Runoff

Land Use Coefficient

Provide the filepath or location of aerial image depicting boundary of LDA and land uses within LDA:

Lateral Drainage Area (Acres)			Source of land cover data:
Natural open water (Acres)			
Revised LDA (total; Acres)			
Open Space (acres)			
Impervious area (acres)			
Unpaved Roads (acres)			
Commercial, business and industrial districts (acres)			
Residential <1/4 acre ave. lot size (acres)			
Residential ~1 acre ave. lot size (acres)			
Residential >2 acres ave lot size (acres)			
Open Water - only impounded water behind dams (acres)			
Cropland (acres)			
Pasture, grassland, or range – continuous forage for grazing (acres)			
Meadow – continuous grass, protected from grazing and generally mowed for hay (acres)			
Brush – brush-weed-grass mixture with brush major element (acres)			
Woods – grass combination (orchard or tree farm) (acres)			
Woods--disturbed by heavy grazing (acres)			
Woods—forested areas protected from grazing and w/adequate litter and brush covering the soil (acres)			
Native Prairie (acres)			
FIELD VALUE - LDA Land Use Coefficient (%)			*Calculated*

Concentrated Flow Point Index (CFPI)

Provide the filepath or location of aerial image depicting CFP locations and contributing areas:

FIELD VALUE - Concentrated Flow Point Index		*Pulls from project reach form.*

Reach ID: EXISTING or PROPOSED or MONITORING (Select one)

Wisconsin Stream Quantification Tool
Field Value Documentation

Reach Hydrology & Hydraulics

Hydraulics

Breifly describe how bankfull was verified:

Representative Sub-Reach Geomorphic Survey Method (Select one):

Longitudinal Profile & Cross Section	OR	Rapid Survey
If selected, provide filepath or location of survey data, longitudinal profile & cross-section figures. Provide measurements from survey below.		If selected, complete Rapid Survey form. There is no need to re-enter data below.

Floodplain Connectivity

Riffle lengths - Riffle 1		List survey methods/post processing tools:
Riffle lengths - Riffle 2		
Riffle lengths - Riffle 3		
Riffle lengths - Riffle 4		

Bank Height Ratio

BHR - Riffle 1		
BHR - Riffle 2		
BHR - Riffle 3		
BHR - Riffle 4		
FIELD VALUE - Weighted Bank Height Ratio (ft/ft)		*Calculated*

Entrenchment Ratio

ER - Riffle 1		If only one ER surveyed, enter the same value for all riffles and note which riffle the ER measurement was taken.
ER - Riffle 2		
ER - Riffle 3		
ER - Riffle 4		
FIELD VALUE - Weighted Entrenchment Ratio (ft/ft)		*Calculated*

Bankfull Dynamics

Width/Depth Ratio State

Describe how reference W/D ratio was determined. If the reference W/D ratio is from a cross section, provide the filepath or location of the cross section figure:

Reference W/D Ratio		
W/D - Riffle 1		
W/D - Riffle 2		
W/D - Riffle 3		
W/D - Riffle 4		
FIELD VALUE - WDRS (% of expected)		*Calculated*

Shading Key
Field Value
Calculation

Reach ID: EXISTING or PROPOSED or MONITORING (Select one)

Wisconsin Stream Quantification Tool
Field Value Documentation

Item	Value(s)	Notes
Geomorphology		
Large Woody Debris		
LWD Index		
FIELD VALUE - LWDI		*Enter from LWDI spreadsheet output*
No. of LWD Pieces/ 100 meters		
FIELD VALUE - LWD Frequency		*Pulls from project reach form.*
Lateral Migration		
Dominant BEHI/NBS		
Total Length of Bank Assessed (ft)		Note here if Lateral Migration form was used. If so, there is no need to re-enter data; only enter field value.
BEHI/NBS Category 1		
Total Bank Length for Category 1 (ft)		
BEHI/NBS Category 2		
Total Bank Length for Category 2 (ft)		
BEHI/NBS Category 3		
Total Bank Length for Category 3 (ft)		Provide file path or location of map of ratings within the representative sub-reach:
BEHI/NBS Category 4		
Total Bank Length for Category 4 (ft)		
BEHI/NBS Category 5		
Total Bank Length for Category 5 (ft)		
BEHI/NBS Category 6		
Total Bank Length for Category 6 (ft)		
FIELD VALUE - Dominant BEHI/NBS		
Percent Streambank Erosion (%)		
Length of Eroding Streambanks		
Representative Sub-reach Length (ft)		*Pulls from project reach form.*
FIELD VALUE - Percent Streambank Erosion (%)		*Calculated*
Percent Streambank Armoring (%)		
FIELD VALUE - Percent armoring (%)		*Pulls from project reach form.*
Riparian Vegetation - Field Forms Required, values calculated from those forms.		
Effective Vegetated Riparian Area (%)		
FIELD VALUE - Effective Vegetated Riparian Area (%)		*Pulls from Effective Riparian Area form*
Canopy Cover (%)		
Number of plots (30 ft radius)		
FIELD VALUE - Canopy Cover (%)		*Calculate average from all plots*
Herbaceous Vegetation Cover (%)		
FIELD VALUE - Relative Herbaceous Cover (%)		*Calculate average from all plots*
Woody Stem Basal Area		
FIELD VALUE - Woody Stem Basal Area		*Calculate average from all plots*

Reach ID: EXISTING or PROPOSED or MONITORING (Select one) Wisconsin Stream Quantification Tool Field Value Documentation

Bed Form Diversity

Representative Sub-Reach Geomorphic Survey Method (Select one):

Longitudinal Profile & Cross Section	**OR**	**Rapid Survey**
If selected, provide filepath or location of survey data, longitudinal profile & cross-section figures. Provide measurements from survey below.		If selected, complete Rapid Survey form. There is no need to re-enter data below.

Pool Spacing Ratio

Number of Geomorphic Pools		
Bankfull Riffle Width (ft)		
Pool Spacing - Pool 1 to Pool 2		
Pool Spacing - Pool 2 to Pool 3		
Pool Spacing - Pool 3 to Pool 4		
FIELD VALUE - Pool Spacing Ratio		*Calculated*

Pool Depth Ratio

Mean Riffle Depth		
Number of pools measured		
Pool Depth - Pool 1		
Pool Depth - Pool 2		
Pool Depth - Pool 3		
Pool Depth - Pool 4		
Pool Depth - Pool 5		
Pool Depth - Pool 6		
FIELD VALUE - Pool Depth Ratio		*Calculated*

Percent Riffle (%)

Representative Sub-Reach Length		*Pulls from project reach form.*
Total Riffle Length in Representative Sub-Reach		
FIELD VALUE - Percent Riffle (%)		*Calculated*

Bed Material Characterization

Percent Fines (%)

Total number of particles sampled		Provide file path or location of data. Note here if Pebble Count form was used.
Number of Particles <2mm		
Number of Particles <6.35mm		
FIELD VALUE - d50		
FIELD VALUE - Percent Fines (<2%)		*Calculated*
FIELD VALUE - Percent Fines (<6.35%)		*Calculated*

Were physicochemical and/or biological data collected during normal conditions? If no, provide additional detail:

Item	Value	Notes
Physicochemical		
Temperature		
Provide file path or location of map showing logger placement:		
Date & Time First Sensor Reading		
Date & Time Last Sensor Reading		
Sampling Interval		
Summer Mean Temperature (^oC)		
Provide file path or location of temperature logger data form and time-series plot of temperature data:		
Baseline (Pre-project) Upstream summer mean temperature (^oC)		
Upstream summer mean temperature (^oC) N/A to Pre-project Field Value		
Project Reach summer mean temperature (^oC) N/A to Pre-project Field Value		
FIELD VALUE - Summer Mean Temperature (^oC)		
Nutrients		
Benthic Algal Biomass		
Provide file path or location of Benthic Algal Biomass Field Data form:		
Sampling date(s)		
FIELD VALUE - Weighted Mean Algal Biomass Score		
Diatom Phosphorous Index		
Provide file path or location of the Diatom Analysis (Form 4800-028 WDNR) and lab results:		
Sampling date(s)		Note substrate method used:
FIELD VALUE - Diatom Phosphorous Index (µg/L)		
Organics		
Hilsenhoff Biotic Index		
Provide file path or location of Macroinvertebrate Field Data Report (WDNR Form 3200-081) and lab		
Sampling date(s)		
FIELD VALUE - Hilsenhoff Biotic Index Score		

Biology

Macroinvertebrates

Provide file path or location of map showing macroinvertebrate sampling location(s):

mIBI

Provide file path or location of Macroinvertebrate Field Data Report (WDNR Form 3200-081) and lab results/taxa list:

Sampling date(s)		Note ecoregion used to calculate mIBI:
FIELD VALUE - mIBI		

Fish

Provide file path or location of map showing fish sampling location(s):

Provide file path or location of fish data:

fIBI

Sampling date(s)		
Thermal Class/Natural community type		
FIELD VALUE - fIBI		

Fish Abundance

Sampling date(s)		
Target Fish Community		
FIELD VALUE - Fish Abundance		*Calculated*

Date:
Investigators:

EXISTING or MONITORING
(Select one)

Wisconsin 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	R9
Begin Station									
End Station									
BKF Width (ft)									
Low Bank Height (ft)									
BKF Max Depth (ft)									
BKF Mean Depth (ft)									
Flood Prone Width (ft)									
Riffle Length (ft) *Including Run*									
Bank Height Ratio (BHR) Low Bank H / BKF Max D									
Entrenchment Ratio (ER)									
W/D BKF Width/BKF Mean Depth									
BHR * Riffle Length (ft)									

C.	Total Riffle Length (ft)	
D.	**Weighted BHR** $\frac{\Sigma(Bank\ Height\ Ratio_i \times \text{Riffle Length}_i)}{\Sigma Riffle\ Length}$	
E.	**Weighted ER**	
	Weighted W/D (Observed; O)	
F.	Reference W/D (Expected; E)	
	Width/Depth Ratio State (O/E)	
G.	**Percent Riffle (%)**	

Shading Key
Field Value
Calculation
Desktop Value

Date:
Investigators:

EXISTING or MONITORING
(Select one)

Wisconsin 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	P9
Geomorphic Pool? Select G or No from pull-down.									
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

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	Middle of Riffle	MR	TBM1	___________
Head of Run	N	Top of Bank	TOB	Pool Max Depth	PMD	TP	___________
Head of Pool	P	Edge of Channel	EC	Temp. Bench Mark	TBM	TP	___________
Head of Glide	G	Inner Berm	IB	Turning point	TP	TP	___________
Thalweg	TW						

All units are in feet

Survey:			**Thalweg**	**Water Surface**	**Bankfull**	**Top of Low Bank**	**Inner Berm**	**Wbkf**	**Wfpa**	**Key Code/Note**
Station	**BS (+)**	**HI**	**FS (-)**	**FS (-)**	**FS (-)**	**FS (-)**	**FS (-)**			

Page________of_________

Survey:			Thalweg	Water Surface	Bankfull	Top of Low Bank	Inner Berm	Wbkf	Wfpa	Key Code/Note
Station	BS (+)	HI	FS (-)	FS (-)	FS (-)	FS (-)	FS (-)			

Page________of_________

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 XSEC # Long Pro Station Feature

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

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

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

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:		

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.