

# Michigan Stream Quantification Tool

## Spreadsheet User Manual





**Michigan Stream Quantification Tool**  
**Spreadsheet User Manual**  
**MiSQT v1.0**

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## Acronyms

BEHI/NBS – Bank erosion hazard index / Near-bank stress

BHR – Bank height ratio

BMP – Best management practice

CFR – Code of Federal Register

ECS – Existing condition score

EGLE – Michigan Department of Environment, Great Lakes, and Energy

ER – Entrenchment ratio

FAR – Functioning-at-risk

FF – Functional feet

FFS – Functional foot Score

LWD – Large woody debris

LWDI – Large woody debris index

MI DNRE – Michigan Department of Natural Resources and Environment

MiSQT – Michigan Stream Quantification Tool

NF – Not functioning

NLCD – National Land Cover Dataset

NPDES – National Pollutant Discharge Elimination System

PCS – Proposed condition score

SFPF – Stream Function Pyramid Framework

SQT – Stream Quantification Tool

TMDL – Total Maximum Daily Load

TP – Total phosphorus

## Glossary of Terms

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

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

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

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

Condition score – A value between 1.00 and 0.00 that expresses whether the associated parameter, functional category, or overall restoration reach is functioning, functioning-at-risk, or not functioning compared to a reference condition.

- ECS = Existing Condition Score
- PCS = Proposed Condition Score

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

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

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

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

Functional category – The levels of the stream functions pyramid: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology. Each category is defined by a functional statement.

Functional foot score (FFS) – The product of a condition score and stream length.

- Existing FFS = Existing Functional Foot Score. Calculated by measuring the existing stream length and multiplying it by the ECS.
- Proposed FFS = Proposed Functional Foot Score. Calculated by measuring the proposed stream length and multiplying it by the PCS.

Function-based parameter – A metric that describes and supports the functional statement of each functional category.

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

Index values – Dimensionless values between 0.00 and 1.00 that express the relative condition of a metric field value compared with reference standards.

Metric – Specific tools, equations, assessment methods, etc. that are used to quantify a function-based parameter. (Also called measurement method in *A Function-Based Framework for Stream Assessment and Restoration Projects* [Harman et al., 2012]).

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 (33 CFR 332.2).

Reference curves – A relationship between observable or measurable metric field values and dimensionless index values. These curves are fitted to threshold values that represent the degree of departure from a reference standard for a given field value. These curves are used to calculate the index value for a given metric at a project site.

Reference standard – The subset of reference aquatic resources that are least disturbed and exhibit the highest level of functions. In the SQT, this condition is considered functioning for the metric being assessed, and ranges from least disturbed to pristine condition.

Stream Functions Pyramid Framework (SFPF) – The Stream Functions Pyramid (Pyramid) is comprised of five functional categories stratified based on the premise that lower-level functions (hydrology, hydraulics, geomorphology) support higher-level functions (physicochemical and biology) and that they are all influenced by local geology and climate. The SFPF includes the organization of function-based parameters, metrics (or measurement methods), and reference standards (performance standards) to assess the functional categories of the 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 more broadly in this document to represent stream compensatory mitigation methods including establishment, re-habilitation, re-establishment, and enhancement as defined in the 2008 Compensatory Mitigation for Losses to Aquatic Resources: Final Rule (2008 Rule).

## 1. Purpose and Use

The purpose of this document is to provide instruction on how to use the Michigan Stream Quantification Tool (MiSQT or SQT) Microsoft Excel workbook. This user manual does not provide guidance on data collection techniques; the Data Collection and Analysis Manual is available as a separate document. This manual also **does not provide a methodology for calculating stream credits or debits or outline when the MiSQT will be required**; refer to the EGLE web page for permitting information.

This version of the SQT and user manual has been specifically developed for Michigan. Many of the parameters, metrics, and reference standards are therefore unique to this state. Other stream quantification tools and user manuals have been developed for use in other states, including North Carolina (Harman and Jones, 2017a,b), Tennessee (TDEC, 2018), Wyoming (USACE, 2018a), Georgia (USACE, 2018b), Colorado (USACE, 2020), and Minnesota (MNSQT SC, 2019).

### SQT Manual Guide

1. Spreadsheet User Manual (this document) – *Rules and procedures for entering data into the Microsoft Excel Workbook.*
2. Data Collection and Analysis Manual – *Provides instruction on how to collect and analyze data needed to run the SQT.*

### 1.1. Downloading and Revising the MiSQT

The MiSQT and supporting documents can be downloaded from the EGLE web page.<sup>1</sup>

The following spreadsheets and documents are available:

- MiSQT workbook – Microsoft Excel workbook described in this User Manual.
- Debit Calculator workbook – Microsoft Excel workbook.
- MiSQT Spreadsheet User Manual – This manual describes the MiSQT workbook, all calculations performed by the workbook, and how to use the workbook
- MiSQT Data Collection and Analysis Manual – Manual that describes how to collect data and calculate input for the MiSQT and Debit Calculator.

The MiSQT will be updated and revised periodically as additional data are gathered and reference standards and metrics are refined. Additional Michigan specific data is needed to improve and expand the applicability of the MiSQT. Michigan Department of Environment Great Lakes and Energy (EGLE) will continue to seek opportunities to expand data collection efforts, including development of a coldwater fish metric. Proposals and data related to reference curves, metrics, and parameters may be submitted at any time to the Inland Lakes and Streams Program Coordinator at EGLE, Water Resources Division. Field data from reference quality reaches can support refinement of reference curves and evaluation of metrics. Refer to Section 7 of this manual for more detail on reference curves. The SQT architecture is flexible and future versions of the tool can accommodate additional parameters and metrics. 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 identify reference curves,

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<sup>1</sup> [www.mi.gov/lakesandstreams](http://www.mi.gov/lakesandstreams)

threshold values and should include a justification and rationale (e.g., data sources and/or literature references). General feedback may also be submitted at any time to the Inland Lakes and Streams Program Coordinator at the Michigan Department of Environment Great Lakes and Energy, Water Resources Division, P.O. Box 30458, Lansing, Michigan, 48909-7958, or by contacting the WRD office at 517-284-5567. An email address can be provided on request.

The MiSQT and supporting documents can also be downloaded from the Stream Mechanics web page.<sup>2</sup> Select the Stream Functions Pyramid Framework tab and look for the information below. Other SQTs are also available from this web page, along with the Debit Tool White Paper and an SQT FAQ. This page includes other resources like the Stream Functions Pyramid diagram, *A Function-Based Framework for Stream Assessment and Restoration Projects* (Harman et al., 2012), a rapid assessment method, and new function-based parameters with metrics and reference standards (not included in the Framework book). In addition, the Workshops tab provides a list of courses providing further education on the Stream Functions Pyramid Framework, the SQT, and other courses related to stream assessment and restoration.

## 1.2. Purpose and Uses of the SQT and Debit Calculator

The SQT was developed primarily to show the functional lift associated with stream restoration and mitigation projects. Therefore, a main goal of the SQT is to produce objective, verifiable, and repeatable results by consolidating well-defined procedures for quantitative measures of stream condition and underlying processes.

Specific reasons for developing the SQT include the following:

1. Develop a calculator to determine the numerical differences between an existing (degraded) stream condition and the proposed (restored or enhanced) stream condition. This numerical difference is known as functional lift or uplift. It is related to a stream credit determination method as defined by the 2008 Federal Mitigation Rule (USACE, 2008).
2. Link restoration activities to changes in stream functions by primarily selecting function-based parameters and metrics that can be manipulated by stream restoration practitioners.
3. Link restoration goals to restoration potential. Encourage assessments and monitoring that matches the restoration potential.
4. Incentivize high-quality stream restoration and mitigation by calculating functional lift associated with physicochemical and biological improvements.

These purposes translate into at least six different uses for the SQT and include the following.

Note: This is a universal list that applies beyond potential uses in Michigan.

1. Site Selection – The tool can help determine if a proposed project has enough lift and quality to be considered for a stream restoration or mitigation project (refer to Section 2.3.1).
2. Functional Lift or Loss – The tool can quantify functional lift or loss from a proposed or active stream restoration project. This first happens during the design or mitigation plan phase and progress is then documented for each post-construction monitoring event.

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<sup>2</sup> [stream-mechanics.com](http://stream-mechanics.com)

Refer to Sections 6 and 8. There is a subroutine in the MiSQT that applies to stream restoration projects using BMPs to treat adjacent runoff (Section 6.3).

3. Credit/Debit Determination Method – Credit and debit determination methods can be developed to incorporate the difference in the proposed functional foot score minus the existing functional foot score. Scoring is described in Section 6.4.
4. Permittee Responsible Mitigation – The tool can be applied to on-site, permittee-responsible mitigation to help determine if the proposed mitigation activities will offset the proposed impacts.

For permitted stream impacts, a debit calculator can be used to estimate the functional loss. The debit calculator uses the same parameters, metrics, reference standards, and scoring methodology as the SQT to ensure parity between the debit and credit. The primary difference between the Debit Calculator and the SQT is that the proposed condition score is estimated using impact severity tiers and modeled equations.

### 1.3. Key Considerations

The MiSQT and supporting documentation have been developed, in part, for use in the state's administration of the Part 301 Inland Lakes and Stream program to meet the function-based approaches set forth in the 2008 Federal Mitigation Rule (USACE, 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 used in stream restoration and permitted impacts. These parameters do not comprehensively characterize all structural measures or processes that occur within a stream.
- The SQT is designed to assess the same metrics at a site pre- and post-activity to provide information on the degree to which the condition of the stream system changes following impacts or restoration activities. Unless the same parameters and metrics are used, it is not appropriate to compare scores across sites. To ensure that the flexibility in selecting parameters and metrics during the stream restoration/mitigation process does not create a disparity with debit calculations, the debit tool always calculates a condition and functional-foot score through all five functional categories.
- The overall existing and proposed condition scores range from 0.00 to 1.00. If all five functional categories are assessed, the output score represents a percent of pristine condition. For example, 0.50 represents 50% of pristine. This score is then related to stream size (Strahler stream order) and flow type (perennial, intermittent, and ephemeral), to help match impacted stream types to mitigation stream types and thus avoid out-of-kind mitigation. Further matches can be made by comparing the input and stratification tables between two sites.
- The SQT 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 the restoration potential of a site (see Chapter 3).

- The SQT includes assessments of the stream channel, adjacent floodplain/riparian area, and the lateral drainage area. A rolled-up assessment output score is multiplied by stream length (the unit of measure) to calculate the functional-foot score. Therefore, even though the units are in feet, the SQT assesses more than just the stream channel length.
- The SQT is not a design tool. There may be additional function-based parameters and analyses which are critical to a successful restoration design but sit outside of the scope of the SQT assessment. The SQT instead measures the hydrology, hydraulic, geomorphological, physicochemical, and biological responses or outcomes related to a reach-scale project.

## 2. Introduction

The SQT is an application of the Stream Functions Pyramid Framework (SFPP; Harman et al., 2012) and uses function-based parameters and metrics to assess five functional categories: hydrology, hydraulics, geomorphology, physicochemical, and biology. These terms are described in the next section, followed by an introduction to the SQT.

Section 2.2 provides an overview of the MiSQT workbook. The MiSQT includes 24 metrics within 12 parameters that can be evaluated at a project reach. A basic suite of metrics within 6 parameters are required at all project sites evaluated as part of the state's administration of the Part 301 Inland Lakes and Stream program to provide consistency between impacts and compensatory mitigation and to allow for more consistent accounting of functional change.

Finally, Section 2.3 will provide details on how to use the SQT for a stream restoration project. Chapter 3 will address the critical concept of restoration potential, including how to use the Catchment Assessment worksheet. The remaining chapters will describe each worksheet in the SQT workbook and how to enter data.

### 2.1. Stream Functions Pyramid Framework

The Stream Functions Pyramid (Figure 1) includes five functional categories: Level 1: Hydrology, Level 2: Hydraulics, Level 3: Geomorphology, Level 4: Physicochemical, and Level 5: Biology. The Pyramid is based on the premise that lower-level functions support higher-level functions and that they are all influenced by local geology and climate. Each functional category is defined by a functional statement. For example, the functional statement for Level 1, Hydrology, is "the transport of water from the watershed to the channel," which supports all higher-level functions.

The Stream Functions Pyramid *alone* shows a hierarchy of stream functions but does not provide a specific mechanism for addressing functional capacity, establishing reference standards, or communicating functional lift. The diagram in Figure 2 expands the Pyramid concept into a more detailed framework to quantify functional capacity, establish reference standards, show functional lift, and establish function-based goals and objectives.

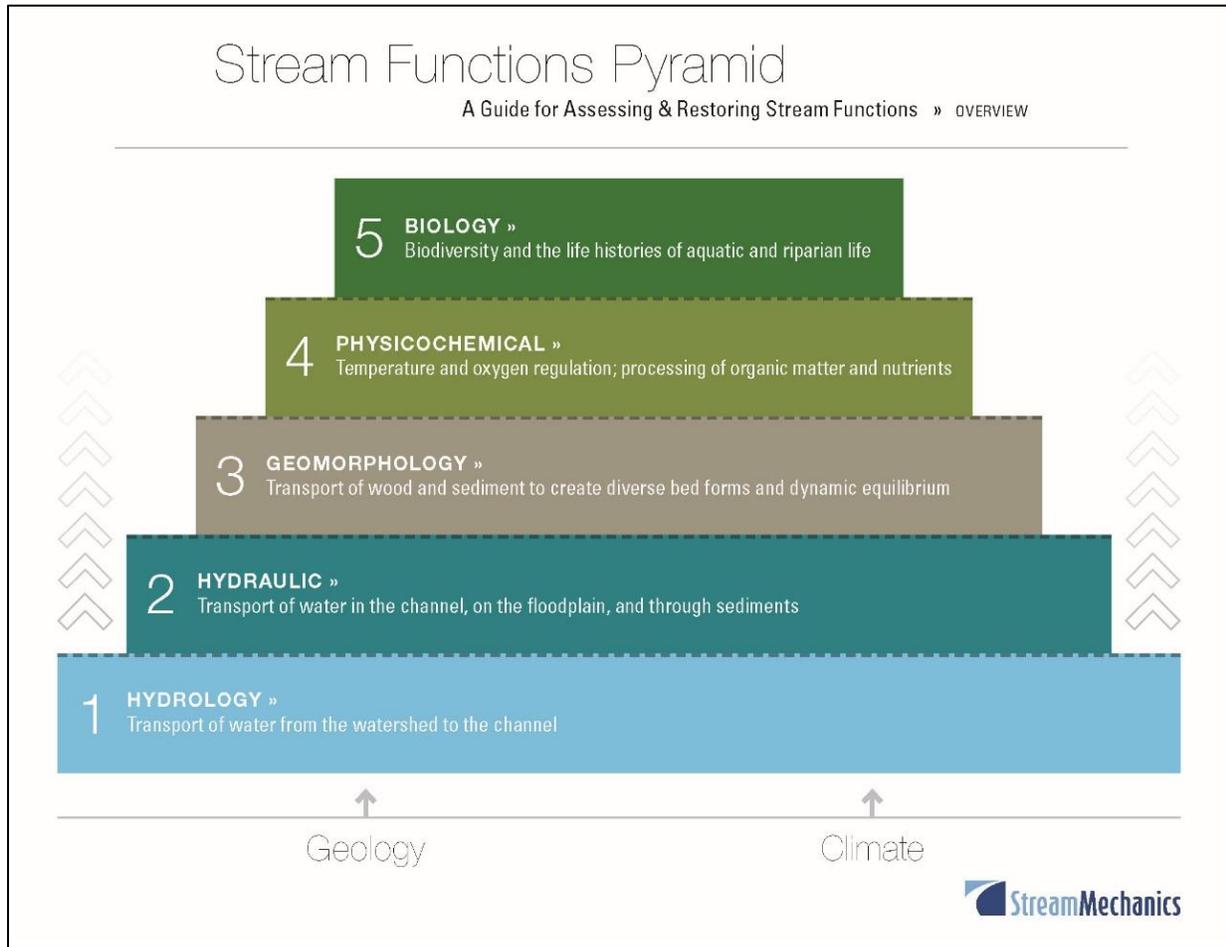


Figure 1. Stream Functions Pyramid.

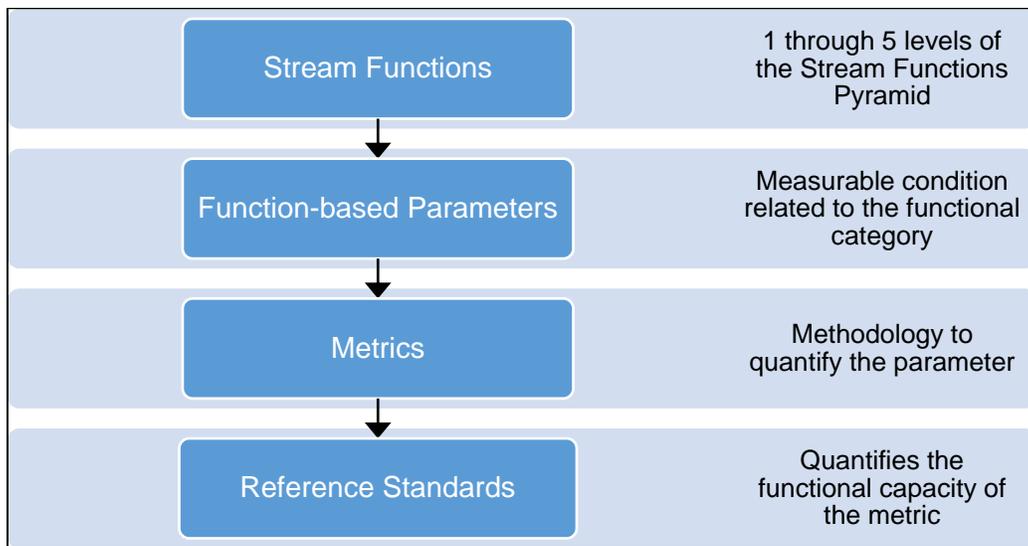


Figure 2. Stream Functions Pyramid Framework.

The Stream Functions block shown at the top of Figure 2 represents the five levels of the Stream Functions Pyramid shown in Figure 1. The remainder of the framework is a “drilling down” approach that provides more detailed forms of analysis to quantify stream functions. The function-based parameters describe and support the functional statements of each functional category. The metrics (referred to in the source material as metrics) are specific tools, equations, assessment methods, etc. that are used to quantify the function-based parameter; there can be more than one metric for a single function-based parameter. Reference standards are measurable or observable end points of stream restoration.

## 2.2. Michigan Stream Quantification Tool (MiSQT)

The MiSQT is a Microsoft Excel Workbook with 7 visible worksheets and one hidden worksheet. There are no macros in the spreadsheet and all formulas are visible but some worksheets are locked to prevent editing. The worksheets include:

1. Project Assessment
2. Catchment Assessment
3. Parameter Selection Guide
4. Quantification Tool (locked)
5. Monitoring Data (locked)
6. Data Summary (locked)
7. Reference Standards (locked)
8. Pull Down Notes – This worksheet is hidden and contains all the inputs for drop-down menus throughout the workbook.

The Quantification Tool, Reference Standards, Monitoring Data, and Data Summary worksheets are locked to protect the formulas that provide scores and calculate functional lift and loss. This chapter will describe each of the visible worksheets in detail.

The SFPF has informed the development of the SQT, a tool that consolidates the components of the SFPF into an Excel workbook to characterize reach-scale stream ecosystem condition. The SQT includes a sub-set of function-based parameters and metrics listed in Harman et al. (2012) along with new parameters and metrics identified as part of the SQT development and regionalization process which are relevant to the stream systems found within the state of Michigan.

### What is the SQT?

The **SQT** is a tool that consolidates the components of the SFPF (Figure 2) into an Excel workbook to characterize reach-scale stream ecosystem condition.

Metrics selected for the SQT are structural or compositional attributes that indicate condition at a given point-in-time. Metrics serve as surrogates for stream functions (33 CFR 332.2) related to the function-based parameters selected for a given functional category. For example, bed form diversity is a partial surrogate for sediment transport processes, which is a geomorphology function. Bed form diversity is NOT a surrogate for macroinvertebrates or fish which are assessed in the biology functional category.

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 is standardized across metrics

by determining how field values relate to functional capacity, i.e., functioning, functioning-at-risk, and not functioning conditions (Table 1).

The reference curves in the SQT 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. However, a single functioning metric, out of several metrics, may not mean that the function-based parameter for a particular stream process is functioning. For example, bed form diversity is a function-based parameter and pool spacing, pool depth compared to riffle depth, and percent riffle are three of its four metrics. Understanding how each metric result contributes to the overall bed form condition is more important than a single metric result and functioning bed form diversity would have an appropriate number of pools (pool spacing), good variability in depth, and an appropriate split of riffles and pools.

#### **Calculating Change in Condition**

It is important to remember that the SQT is intended to compare pre- and post-project conditions at a site. As such, the difference between existing and future site conditions is the most important element.

Reference curves are used to relate point-in-time condition measurements to functional capacity and standardize all metrics to an ecologically relevant scale.

Table 1. Functional Capacity Definitions Used to Define Reference Standards.

Functional Capacity	Definition	Index Score Range
Functioning	A functioning value means that the metric is quantifying the functional capacity of one aspect of a function-based parameter in a way that <b>fully supports aquatic ecosystem structure and function</b> . The reference standard concept aligns with the definition for a reference condition for biological integrity (Stoddard et al., 2006). A score of 1.00 represents an unaltered or pristine condition (native or natural condition). The range of values (0.70-1.00) accounts for natural variability in reference datasets and the potential for reference datasets to include minimally disturbed sites.	0.70 to 1.00
Functioning-at-risk	A functioning-at-risk value means that the metric is quantifying one aspect of a function-based parameter in a way that <b>may support aquatic ecosystem structure and function</b> , but not at a reference standard. In many cases, this indicates the parameter is adjusting in response to changes in the reach or the catchment towards lower or higher function.	0.30 to <0.70
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 <b>does not support aquatic ecosystem structure and function</b> . An index value of 0.29 or less 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 <0.30

### 2.3. MiSQT Stream Restoration Process

This manual provides instruction on how to use the MiSQT workbook for stream restoration/mitigation projects as shown in Table 2. Programmatic goals, site selection, and reach segmentation are briefly discussed below (Sections 2.3.1 and 2.3.2), and the remainder of this manual details the remaining steps.

Table 2. Typical Restoration Process Using the MiSQT.

Task	Associated Worksheets in the MiSQT
<b>Site Selection based on Programmatic Goals</b>	
Identify programmatic goals. Perform site search for sites that could meet these goals (Section 2.3.1).	Project Assessment
Delineate the project area(s) and determine project reaches (Section 2.3.2).	Project Assessment
Assess catchment(s) to understand watershed context and potential constraints (Chapter 3).	Catchment Assessment
Collect reach-specific information to determine reach-scale constraints, current condition, and the likely trajectory of stream condition. Determine proposed/reference stream type. Estimate potential lift and proposed condition score (Chapter 3).	Quantification Tool
<b>Project Initiation</b>	
Verify reach breaks (refer to Data Collection and Analysis Manual). Set function-based goals and quantifiable objectives for each reach.	Project Assessment
Refine responses for Catchment Assessment. Record overall catchment condition and restoration potential.	Catchment Assessment
Select parameters and metrics based on your reach-specific setting and objectives.	Parameter Selection Guide
Collect additional data to characterize the existing condition.	Quantification Tool
<b>Design</b>	
As noted in the introduction, the SQT is not a design tool. However, design alternatives can be compared in the SQT to determine potential functional lift outcomes. (Practitioners should not assume that a 1.00 can be achieved for each metric. This would mean that a pristine stream is being restored, which is generally not possible.)	Quantification Tool
Evaluate the proposed condition based on the proposed design.	
<b>Monitoring</b>	
Collect as-built and monitoring data to characterize post-project condition.	Monitoring Data Data Summary
The proposed field values predicted during the design phase can be 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.	Monitoring Data Data Summary

### 2.3.1. Programmatic Goals and Site Selection

Programmatic goals are bigger-picture goals that are often independent of the project site and stream ecosystem. Programmatic goals generally relate to the project's basis or motivation, such as compensating for unavoidable impacts or restoring fish populations. Where the programmatic goals include biological and physicochemical uplift, identifying sites that are able to meet these goals is instrumental to project success. Programmatic goals are recorded and explained on the Project Assessment worksheet within the SQT (Section 4).

The SQT can be used to assist with selecting a potential stream restoration or mitigation site. During the site selection process, the user may want to estimate the field values required as input using the rapid method (Data Collection and Analysis Manual Appendix A) and best professional judgement—the difference between rapid-based assessments and detailed assessments for various metrics is described in the Data Collection and Analysis Manual Section 3.3.

#### **Compensatory Mitigation as a Programmatic Goal**

Many compensatory mitigation projects in Michigan are permittee-responsible mitigation, where restoration opportunities occur in or near the same channel as impact activities. The restoration performed is to generate compensatory mitigation to offset resource losses incurred by the activity.

If the user is deciding between multiple sites, the SQT can be used to rank sites based on the amount of functional lift available and overall condition quality. The functional lift is calculated from the difference in condition scores and/or the functional foot scores. The overall quality is the overall proposed condition score for the restoration reach. Another way to assess overall quality is to evaluate the functional lift of the individual parameters. At a minimum, a proposed site should produce functioning conditions for floodplain connectivity, bed form diversity, and lateral migration. Riparian vegetation should be well within the functioning-at-risk category, e.g., a 0.60 condition score, by the end of monitoring.

Once a site has been selected for a project, a detailed assessment should be completed. This will include taking quantitative measurements of the function-based parameters selected for the project. Guidance on how to select function-based parameters is included in Section 5. Parameter Selection Guide Worksheet.

### 2.3.2. Reach Segmentation

The SQT is a reach-based assessment methodology, and each reach is evaluated separately. Since stream condition or character can vary widely from the upstream end of a project to the downstream end, a large project may be subdivided into multiple reaches. Each project reach will require its own SQT workbook.

The user should determine whether their project area encompasses a single homogeneous reach, or multiple potential reaches. A reach is defined as a stream segment with similar processes and morphology, including characteristics such as such 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, the National Hydrography Dataset (NHD)<sup>3</sup>, and other desktop tools to preliminarily determine reach breaks; these delineations should be verified in the field. Further information on segmenting reaches is provided in the Data Collection and Analysis Manual. **Practitioners should provide justification for the final reach breaks in the Reach Description section of the Project Assessment worksheet.**

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<sup>3</sup> <https://www.usgs.gov/core-science-systems/ngp/national-hydrography>

### 3. Restoration Potential

Restoration potential is the highest level of restoration that can be achieved based on contributing catchment stressors and condition, reach-scale constraints, the results of the reach-scale function-based assessment (existing condition), and an assessment of previous and future responses to disturbances (channel evolution; Harman et al., 2012). Restoration potential is determined using a stepwise process (see Section 3.1). Components important to determining restoration potential are described in detail in the following sections in this Chapter. Restoration potential definitions adapted from Beechie et al. (2010) and provided below:

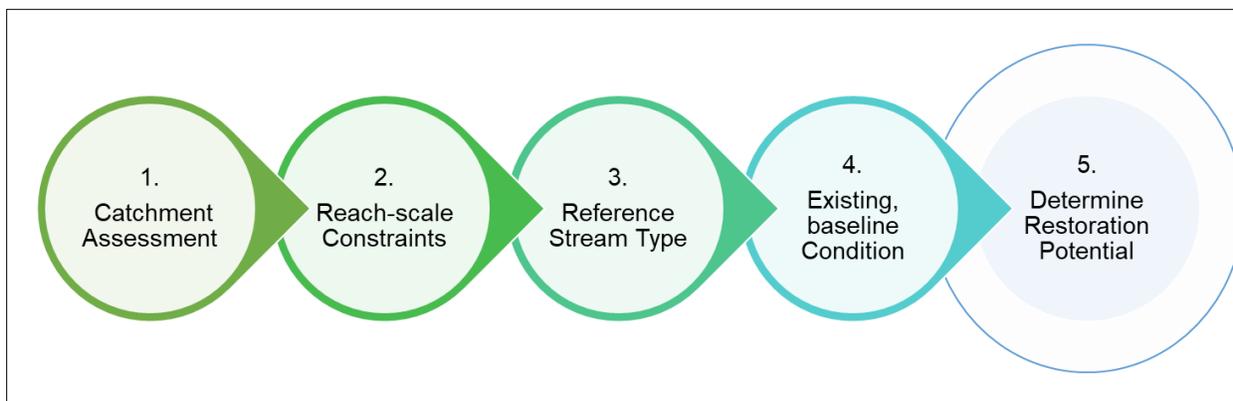
- **Full Restoration Potential** – The project reach has the potential to *restore functions within all five Pyramid levels back to a reference standard condition*. Reference standard condition reflects the least disturbed aquatic resources in a given class of resource and exhibits the highest levels of functions exhibited by that class (Federal Register 73:70 (April 10, 2008) p. 19624). Refer to Table 1 in Section 2.2.
- **Partial Restoration Potential** – The project reach has the potential to *restore some functions to a condition better than pre-project or baseline conditions*. **However**, the project reach does not have the potential to restore to functions within all five pyramid levels back to reference standard condition.

Partial restoration is the most common potential for restoration projects. Typically, some catchment stressors or reach-scale constraints prevent the site from reaching full restoration potential. However, channel stability and in-stream habitat can often be restored to a reference condition through Level 3: Geomorphology. Watershed stressors and perturbations, however, may prevent the site from restoring physicochemical and biology functions to a reference condition. This does not mean that partial restoration cannot lead to improvements in physicochemical and biology functions, but it does mean that they will not be restored to a reference condition.

There are likely situations where even partial restoration is not possible due to the severity of the catchment stressors and project constraints. For example, flow alteration (stressor) may modify the hydrologic and sediment transport processes within a catchment, and in most cases may be outside of the control of the practitioner. Land use constraints like sewer lines and roads may artificially constrain the project limits. Some stressors and constraints limit restoration potential to such a degree that the site is not appropriate for restoration activities. If the underlying processes do not have the potential to support at least partial restoration, the site may not be an appropriate site for restoration/mitigation.

### 3.1. Stepwise Approach to Determining Restoration Potential

Restoration potential is determined through a five-step process (Figure 3), detailed below.



*Figure 3. Stepwise Approach for Determining Restoration Potential.*

1. Complete the Catchment Assessment worksheet following the instructions in the Data Collection and Analysis Manual. Review the scores for each category to determine if an identified stressor can be overcome by proposed activities or whether it will limit restoration potential in the project reach. A stressor that prohibits even partial restoration may constitute a “deal breaker”, meaning the reach is not a good candidate for stream restoration activities unless catchment-scale stressors can be improved. This information is entered into the Catchment Assessment Worksheet.
  - a. Compare the reach size to the catchment size (length and/or area). Can the scale and type of restoration overcome the catchment stressors? At the reach scale, users should consider several factors, including the scale of the restoration project in relation to the watershed. For small catchments where the length or area of the restoration project is large compared to the total stream length or catchment area, reach-scale activities may be able to overcome the stressors and perturbations.
2. 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 the user’s control. A constraint is different than a stressor, which occurs at the catchment-scale outside of the project reach. In some cases, a stressor can be considered a constraint if it is located within the reach and will not be removed as part of the restoration plan. Constraints can negatively affect processes needed to support full restoration potential (and in extreme cases can even limit partial restoration).

Note that natural conditions are not constraints. For example, while hillslopes constrain the lateral extent of meandering streams, 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.

3. Determine reference stream type. Reference stream type is the restoration target at project closeout. Reference stream type represents the stream type that should occur in a specific landscape setting given the current hydrogeomorphic watershed- and reach-scale processes.

Selecting the reference stream type is a qualitative process and therefore requires considerable experience in fluvial geomorphology by the user.

- a. Characterize the current condition of the stream and select the appropriate reference Rosgen stream type.
  - b. Determine the potential Rosgen Channel Succession Scenario (Rosgen, 2006).<sup>4</sup> Is the stream trending towards greater or lesser functionality? What is the realistic final Rosgen stream type as compared to the previously undisturbed stream type?
  - c. Users should then consider whether the proposed project has the potential to restore the reach to the reference stream type identified. The final result is a Rosgen stream type that will be used in the SQT as a reference stream type. The most common results are an E, C, B, or Bc (refer to Example 1). In the Project Assessment worksheet, provide a narrative to justify selection of the reference stream type.
4. Use the Quantification Tool worksheet to determine the baseline condition of the reach. The Quantification Tool worksheet will characterize existing functional capacity by parameter and functional category. Refer to parameter selection guidance in Section 5 of this manual.
  5. Based on Steps 1-4, describe the restoration potential as Full or Partial. Explain the reasons for your selection. Identify which parameters/functions could be restored to a reference standard and which may not. This information is entered in the Project Assessment worksheet.

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<sup>4</sup> The Rosgen Channel Succession Stages (Rosgen, 2006) are not described in detail in this manual and users should consult the source material in applying these methods. Rosgen Channel Succession Stages figure referenced in this text is provided on page 22.

### Example 1: Reference Stream Type

Pre-restoration (existing) stream type: Gc

Historic aerial imagery depict that the stream was channelized prior to 1950. Historical accounts verify beavers were present in the area and the historic condition may have been a beaver meadow. There is no evidence of beaver today.

A Gc stream type in a low gradient, unconfined alluvial valley will often evolve into an F and then a C stream type (Rosgen Channel Succession 1, 3, or 5 shown in Figure 4 on page 22). Since the reach is in a wide alluvial valley, the reference stream type would likely be a C or E. A D<sub>A</sub> stream type may be an appropriate evolutionary end point for the restored stream, but it often takes time to re-establish vegetative communities necessary for anastomosing stream types to be stable (i.e., beyond the timeframe for monitoring and project closeout).

However, it may sometimes evolve into a Bc stream type if the erosion resistance is greater than the driving forces of stream power and sediment discharge or if the stream is located within a steep and narrow valley (e.g., urban land uses confine the natural valley).

The SQT requires the user to determine the restoration potential for each project reach. Restoration potential can be used for a variety of applications. A few are listed below:

- Clear communication of project expectations – Clearly communicating the goals of a stream restoration project, and the expectations in terms of what is being restored, is vital for the practice of stream restoration. Text can be included in a restoration/mitigation plan to clearly communicate project expectations. This will assist funding and regulatory agencies, as well as future readers and researchers, who want to evaluate the project's success in restoring stream functions.
- Development of function-based goals – Restoration potential can be used to inform realistic project goals, which are qualified by catchment- and reach-scale conditions. The development of function-based goals and objectives is described in more detail in Section 3.3.
- Assisting with parameter and metric selection – Function-based goals and objectives can be reflected in parameter and metric selection in the SQT. For example, a reach with full restoration potential should monitor physicochemical and biology parameters (if not for documenting lift, then to avoid loss). When a reach has partial restoration potential, physicochemical and biology parameters may be monitored if lift is expected, however users and regulatory agencies may not want to monitor these functions if there is potential for further watershed impairment.
- Assessing design alternatives – The process of evaluating restoration potential can help in site selection and evaluating design alternatives by raising questions about the size and scope of the project and the removal of reach-scale constraints and catchment stressors. For example, if the project size is increased and constraints are eliminated,

the restoration potential may increase. Section 2.3.1 provides some guidance in using the SQT for site selection.

- Assisting with final site selection – Stream restoration project sites are selected for a wide variety of reasons, primarily depending on the funding or program driver. However, knowing the restoration potential and comparing it to project goals (including funding goals) can assist in site-selection. Section 2.3.1 provides some guidance in using the SQT in alternatives analysis and site selection.

### 3.2. Catchment Assessment Worksheet

The purpose of the Catchment Assessment is to assist in determining the restoration potential of the project reach. The Catchment Assessment includes descriptions of catchment processes and stressors that exist outside of the project reach and may limit functional lift. Most of the categories describe potential problems upstream of the project reach since the contributing catchment has the most influence on water quality and biological health of the project reach. However, there are a few categories, like location of impoundments, that look upstream and downstream of the project reach. Further detail on completing the catchment assessment is provided in the Data Collection and Analysis Manual.

Categories of catchment conditions and stressors are listed by functional category. The categories considered are provided in Table 3.

A catchment condition of good, fair, or poor is assessed for each category in Table 3. There is no requirement to provide an answer for all categories listed and users can add their own category under “Other”. At the top of the form, users can enter the Overall Catchment Condition and Restoration Potential. The overall catchment condition is based on best professional judgement and not an automatic scoring methodology.

The overall catchment condition is left as a subjective determination so that the user can assess and interpret the information gathered. It is possible that one or more of the categories is a “deal breaker,” meaning that the result of that category overrides all other answers. For example, a high specific conductivity in a stream impacted by mining operations could indicate there is little potential for biological lift even if the other categories showed a good condition.

Table 4 shows how the catchment assessment can be used to help determine restoration potential.

Table 3. Catchment Assessment Categories.

Categories (Functional Category Affected)		Descriptions
1	Concentrated Flow (Hydrology)	Potential for concentrated flow/impairments to reach restoration site.
2	Impervious cover (Hydrology)	Percent of catchment that is impervious surface upstream of the restoration site.
3	Land Use Change (Hydrology)	Rapidly urbanizing versus rural and primarily forested.
4	Distance to Roads (Hydrology)	Proximity of existing and planned roads to the restoration site.
5	Percent Forested (Hydrology)	Percent of catchment that is forested upstream of the restoration site.
6	Flashiness Index (Hydrology)	Variability of the stream hydrograph in response to storms.
7	Riparian Vegetation (Geomorphology)	Presence of riparian corridors on streams contributing to the restoration site.
8	Sediment Supply (Geomorphology)	Potential sediment supply from upstream bank erosion and surface runoff.
9	Located on or downstream of a 303(d) listed stream; TMDL presence/absence (Physicochemical)	Proximity of site to 303(d) listed streams and whether the listed streams have a TMDL/Watershed management plan.
10	Agricultural Land Use (Physicochemical)	Livestock access to stream and/or intensive cropland in the catchment likely to impact restoration site conditions.
11	Inline Watershed Impoundments (Biology)	Proximity of impoundments and impact on project area and fish passage.
12	Organism Recruitment (Biology)	Condition of channel bed and bank immediately upstream and downstream of the restoration site.
13	Other	Choose your own.

Table 4. Connecting Catchment Condition and Restoration Potential.

Restoration Potential	Catchment Assessment Results	
	Overall Score	Description
Full	Good	The catchment has very few stressors and would support water quality and biology at a reference condition if the reach-scale problems are corrected. Note: It is possible to achieve a full restoration potential with a Poor to Fair catchment score if the percent of the catchment being treated is very high. However, it may take a long period of time to achieve.
Partial – Goals include physicochemical improvements	Fair to Good	The catchment has hydrology impairments from adjacent sources, e.g., parking lots or heavy use areas. Stormwater and agricultural BMPs can be used to reduce runoff and nutrient levels to reference condition at a sub-catchment scale (catchment draining to the BMP).
Partial – Goals focus on geomorphology improvements	Poor to Fair	Catchment health will not support water quality and biology to a reference condition. For catchments that score near the higher end of fair, reach-scale restoration may improve water quality and biology, just not to a reference condition. The chances of water quality and biological improvement will increase with project length and percent of catchment being treated.
None	Poor	It is possible to have a catchment health score so low that reach-scale restoration is unattainable. In addition to the catchment score, however, this is dependent on the reach length, reach condition, and constraints.

### 3.3. Function-Based Design Goals and Objectives

Function-based design goals and objectives can be developed once the restoration potential is determined. Design goals are different than programmatic goals. Programmatic goals are big-picture goals that are the basis or motivation for a project and are often independent of the project site. For example, a programmatic goal might be to offset on-site unavoidable impacts by generating mitigation credits or a grant that funds projects to increase the biomass of sport fish populations. Design goals are statements about *why* the project is needed *at the specific project site*. They are general intentions and often cannot be validated. Objectives are more specific. They help explain *how* the project will be completed. Objectives are tangible and can be validated, typically by performance standards. (Harman et al., 2012)

Function-based design goals can be developed for partial and full restoration potentials. A goal that is tied to **partial restoration potential means that there is not an expectation of**

**returning biology to a reference condition.** However, minor to moderate improvements in biology are possible if the watershed perturbations and stressors are not too bad.

Examples of function-based design goals with a partial restoration potential include:

- Restore native brook trout habitat. This is a partial restoration potential goal because habitat (a level 3: geomorphology function) is being restored. There is no promise that native brook trout will occupy the habitat. However, the goal does communicate why the project is being undertaken.
- Reduce sediment supply from eroding streambanks. Sediment supply is a function that is part of the geomorphology category and is therefore a level 3 or partial restoration potential.
- Reduce nutrient loading from land uses within the lateral drainage area. This is a goal related to partial restoration potential because it does not include a goal of returning biology to a reference condition.

Function-based objectives list the parameters that will be manipulated in order to achieve the goal. Ideally, the objectives will be written in a way that communicates functional lift at the parameter and metric level. Examples include:

- Improve floodplain connectivity from not functioning to functioning. This is a parameter level objective showing categorical lift.
- Improve floodplain connectivity by decreasing the bank height ratio from 2.0 to 1.0 and increasing the entrenchment ratio from 1.2 to 5.0. This is a more quantitative objective that shows lift at the metric level.

This same process can be followed for other function-based parameters and metrics that must be addressed to achieve the design goals. The values used in quantifying metrics are the performance standards used in monitoring.

**The design goals and objectives are communicated in a narrative form and entered into the Project Assessment worksheet.** The design goals are then compared to the restoration potential to ensure that the goals do not exceed the restoration potential. For example, it is not possible to have a design goal of restoring native brook trout biomass if the reach has only partial restoration potential, meaning that the catchment stressors and reach constraints will not support brook trout, e.g., because the catchment is developed and water temperature entering the project reach is too high for brook trout. However, the goal could be revised to restore the physical habitat for native brook trout, e.g., provide riffle-pool sequences, cover from a riparian buffer, and appropriate channel substrate. This is a geomorphology goal that matches the partial restoration potential. If native brook trout populations in the project reach are to be monitored, increasing native brook trout biomass could be possible even with a partial restoration potential but restoring native brook trout populations to reference conditions would not be expected or possible. If catchment-level improvements are implemented, over time, the restoration potential could shift from partial to full. Notice, however, that this requires reach-scale *and* catchment-scale restoration.

## 4. Project Assessment Worksheet

The purpose of the Project Assessment worksheet is to identify and describe the reach and communicate the purpose of the project. This worksheet communicates the goals of the project related to the funding drivers and the restoration potential of the specific site.

Programmatic Goals – The programmatic goals relate to the project’s basis or motivation. These are bigger-picture goals that are often independent of the project site. Select Mitigation – Credits, Restoration, Grant, Violations/ Damage Settlements, TMDL, or Other from the drop-down menu.

Reach Description – The SQT is a reach-based assessment and one Excel workbook should be assigned to each reach in a project site.

Enter the following information, if applicable:

- Project name,
- Reference number (MiWaters Submission or Violation Number),
- Unique reach ID,
- Township, range, section, and
- The latitude and longitude of the downstream extent of the reach.

Space is provided to describe the reach and the characteristics that separate it from the other reaches in the project. Delineation criteria are provided in the Data Collection and Analysis Manual.

There is a drop-down menu for the user to select the Rosgen Channel Succession Stages (Figure 4; Rosgen, 2006), which was determined as part of the restoration potential process described in the previous chapter. For further information and when applying these methods, the user should refer to the source material (Rosgen, 2006) or freely available Part 654 Stream Restoration Design National Engineering Handbook (USDA NRCS, 2007). There is a text box for the user to provide rationale for the selection.

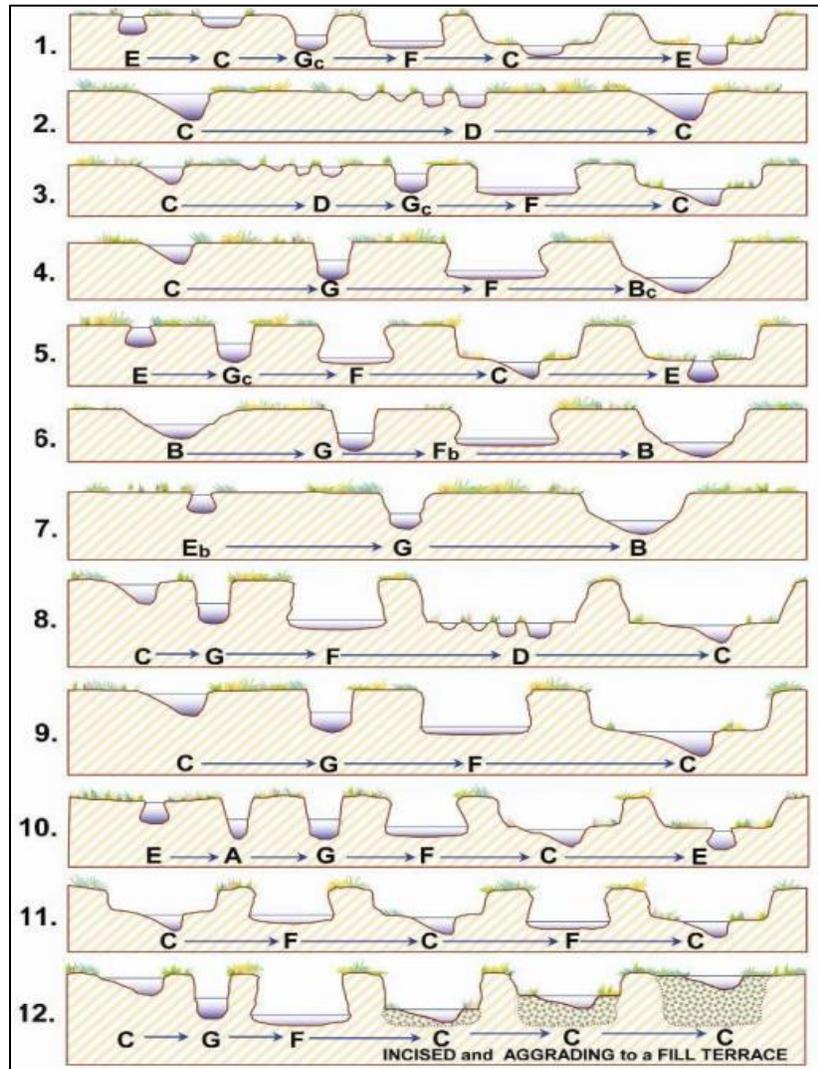


Figure 4. Rosgen Channel Succession Stages. Image from Rosgen (2006).

Restoration – There are three text boxes under the restoration heading. The first provides space to expand on the programmatic goals for restoration projects. For example, if the programmatic goal is to offset on-site project impacts by generating mitigation credits, then the text box under restoration could be used to provide more information about the type and number of credits needed.

The connection between the restoration potential and the programmatic goals should be explained in the second text box under restoration. The restoration potential is described as full or partial. The restoration potential is also entered on the Quantification Tool worksheet. For example, if the programmatic goal is to offset on-site project impacts by generating mitigation credits and the reach had partial a restoration potential, then the text box could explain how bringing geomorphology to a functioning level would create the necessary credits. It would also communicate that the project is unlikely to return biology to a reference condition.

The third text box under restoration provides space to describe the function-based goals and objectives of the project. These goals should match the restoration potential. More information on developing goals and objectives is provided in the previous chapter.

Aerial Photograph of Project Reach – Provide an aerial photograph of the project reach. The photo should include labels indicating where work is proposed, the project easement, reach IDs, any BMPs, and any important features within the project site or catchment.

## 5. Parameter Selection Guide Worksheet

The MiSQT workbook includes 24 metrics used to quantify 12 parameters. It also includes a BMP Routine that adds functional feet to the reach score based on changes in runoff and treatment of nutrients. Not all metrics and parameters will need to be evaluated at each site. The user should consider landscape setting, function-based goals/objectives and restoration potential when selecting parameters. The Parameter Selection Guide worksheet and this section provide guidance on which parameters in the MiSQT to assess for a project. It is recommended that practitioners and regulators/funders work together to determine a list of parameters suitable for each project that will determine whether project goals and objectives are being met.

A basic suite of metrics within 6 parameters are recommended for all sites and required at all project sites evaluated as part of the state's administration of the Part 301 Inland Lakes and Stream program to allow for more consistent accounting of functional change between impacts and compensatory mitigation. The basic suite of metrics includes:

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

In order to provide a minimum condition achieved by restoration, it is recommended that all projects bring floodplain connectivity, lateral migration, and bed form diversity to a functioning condition at the end of the project. Since the riparian vegetation parameter is based on a functioning forest, restoration sites with newly planted trees will not achieve a functioning score within the typical five- to ten-year monitoring period.

The SQT can be applied to stream restoration projects installed in combination with BMPs but should not be applied to stand-alone BMPs or BMPs installed independently of/not adjacent to a stream restoration reach. Add **both** the parameters within the BMP Routine:

- Reach Runoff
- Nutrients

EPA's Region 5 model<sup>5</sup> should be used to model the impact of BMPs on runoff volume and nutrients and the **modeled values** can be entered into the BMP Routine for these parameters.

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<sup>5</sup> STEPL can be used instead of Region 5 where multiple BMPs are proposed in series.

**Important Considerations:**

- The same parameters and metrics must be used in the existing condition and all subsequent condition assessments (i.e., proposed, as-built, and monitoring) within a project reach, otherwise the relative weighting between metrics and parameters changes and the overall scores are not comparable over time.
- For metrics that are not selected (i.e., a field value is not entered), the metric is not included in the scoring. It is NOT counted as a zero.
- The overall scores should not be compared or contrasted between sites when parameters and metric selection varies between project sites. To evaluate multiple sites, the same suite of parameters and metrics would need to be collected at all sites.

**Specific guidance on parameter selection:**

Reach Runoff Parameter: This parameter should be evaluated at all project sites. Both metrics, land use change coefficient and concentrated flow points, should be evaluated together.

Floodplain Connectivity Parameter: This parameter should be evaluated at all project sites. Users must evaluate both the bank height ratio (BHR) and entrenchment ratio (ER) metrics. ER characterizes the horizontal extent of the floodplain while BHR characterize the frequency of floodplain inundation. The only exception is in multi-thread systems, where the BHR should be applied, but the ER is not applicable.

Large Woody Debris (LWD) Parameter: This parameter should be evaluated at all project sites. The parameter is quantified by the Large Woody Debris Index (LWDI) metric. The LWDI metric characterizes the complexity of large wood in streams.

Lateral Migration Parameter: This parameter should be evaluated at all project sites. Users must evaluate the dominant Bank Erosion Hazard Index/Near-Bank Stress (BEHI/NBS) and percent erosion metrics together. The dominant BEHI/NBS characterizes the magnitude of bank erosion and the percent of erosion characterizes the extent of bank erosion within a reach. The percent armoring metric should be used in addition to the other metrics when armoring techniques are present or proposed in the project reach.

Riparian Vegetation Parameter: This parameter should be evaluated at all project sites. The buffer width metric is evaluated at all sites. The rest of the metric selection is performed based on the reference (pre-settlement) vegetation community (Table 5). Guidance on selecting the reference vegetation community is provided in the Data Collection and Analysis Manual.

*Table 5. Riparian Vegetation Metric Selection*

Forested	Scrub-shrub	Herbaceous
Buffer Width	Buffer Width	Buffer Width
Average DBH	Native Shrub/Sapling Density	Native Herbaceous Cover
Tree Density		
Native Shrub/Sapling Density		

Bed Form Diversity Parameter: This parameter is typically evaluated at all single-thread perennial and intermittent project sites. This parameter should not be assessed in multi-thread channels or naturally straight sand-bed channels where the bedforms are created by large wood. Users must evaluate pool spacing ratio, pool depth ratio, and percent riffle metrics together. The aggradation ratio metric is optional and would be used in addition to the other three metrics. Aggradation ratio is recommended for meandering single-thread stream types in transport settings where the riffles are exhibiting signs of aggradation.

Temperature, Bacteria, Dissolved Oxygen, and Nutrients Parameters: These parameters are recommended for projects with goals and objectives related to water quality improvements or projects where improvements to these parameters are anticipated based on restoration potential. One or more parameters can be applied at a project site.

- Note: Without evaluating the physicochemical and biological parameters, the maximum overall score in the SQT will be 0.60. Selecting and assessing parameters in both physicochemical and biological functional categories will increase the maximum overall score to 1.0 in the SQT. (See section 6.4 for more detail).

Macroinvertebrates Parameter: This parameter is recommended for stream projects with goals and objectives related to biological improvements or projects where improvements in biological condition are anticipated based on restoration potential. The P51 procedure is only applicable to wadeable sites while the P22 procedure is only applicable to non-wadeable sites.

Fish Parameter: This parameter is recommended for stream projects with goals and objectives related to biological improvements or projects where improvements in biological condition are anticipated based on restoration potential. The metric for this parameter is only applicable to warmwater or warm transitional, wadeable streams. Note: A Michigan Department of Natural Resources Fisheries Division Cultural & Scientific Collectors Permit<sup>6</sup> is required for sample collection.

BMP Routine: The MiSQT includes a BMP Routine to capture the benefits of treating non-point source runoff. **Where BMPs are required as part of an NPDES permit, the BMP Routine cannot be used to generate lift.** There are two parameters, each with one metric to quantify the parameter: Effective impervious cover assesses reach runoff and total phosphorus assesses the nutrients parameter. When using the BMP Routine, both metrics should be used in combination.

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<sup>6</sup> Michigan Department of Natural Resources Fisheries Division Cultural & Scientific Collectors Permit: [https://www.michigan.gov/dnr/0,4570,7-350-79134\\_82777-452717--,00.html](https://www.michigan.gov/dnr/0,4570,7-350-79134_82777-452717--,00.html)

### Example 2: Parameter Selection

Consider a typical restoration project in a pastureland setting. Two new roadways and associated culverts are proposed along a stream. The catchment is small and consists mostly of rural and agricultural land uses with some urban land uses (roadway footprint). The overall catchment assessment is fair, but stressors would not preclude some biological lift.

The programmatic goal of this project is to offset on-site impacts from the culverts by generating functional lift. The applicant plans to place a conservation easement on the stretch of stream that runs through the pasture, upstream of the proposed culverts, and improve function as compensatory mitigation to offset functional losses from the culverts. The project goals are to improve habitat for native fish and reduce sediment supply from eroding banks. Restoration actions include: 1) fencing to keep cattle out of the channel; 2) grading to provide floodplain connectivity and greater bed form diversity; 3) adding woody debris to the channel to provide channel complexity and fish habitat; and 4) planting woody riparian vegetation along the streambank and across the floodplain. The parameter list would likely consist of:

- Reach runoff
- Floodplain connectivity (Will be brought to a functioning condition.)
- Lateral migration (Will be brought to a functioning condition.)
- Riparian vegetation
- Bed form diversity (Will be brought to a functioning condition.)
- Large woody debris
- Bacteria
- Macroinvertebrates
- Fish

Even though the project only has partial restoration potential, there is monitoring of physicochemical and biology functions. The bacteria parameter is included because cows currently have access to the stream channel and keeping the cattle out of this reach is likely to provide physicochemical lift. The benthic macroinvertebrates and fish are monitored because the applicant expects that macroinvertebrates will improve and that the culverts will remain passable by native fish species. This would contribute more functional lift to the restoration project; however, the project is not expected to return macroinvertebrates and fish biomass back to a reference condition.

## 6. Quantification Tool Worksheet

The Quantification Tool worksheet is the main sheet in the SQT Excel workbook. It is the calculator where users enter data describing the existing and proposed conditions of the project reach and functional lift, or loss, is quantified.

The Quantification Tool worksheet requires data entry in three areas: site information and reference standard stratification, existing condition assessment field values, and proposed condition assessment field values. For projects with adjacent or upstream BMPs, there are three BMP Routines, each requires data entry in three sections: site information, existing condition assessment field values, and proposed condition assessment field values. Cells that allow input are shaded grey and all other cells are locked. Each section of the worksheet is discussed below.

### 6.1. Site Information and Reference Standard Stratification

The Site Information and Reference Standard Stratification section is shown in Figure 5 and each item is briefly described in this section.

<b>Site Information and Reference Standard Stratification</b>	
Project Name:	Example
Reach ID:	Main Stem Reach 1
Restoration Potential:	Partial Restoration
Existing Stream Length (ft):	1800
Proposed Stream Length (ft):	1800
Existing Stream Type:	
Proposed/ Reference Stream Type:	C
Valley Type:	Confined Alluvial
Drainage Area (sq. mi.):	270
Strahler Stream Order:	Fourth or greater
Flow Type:	Perennial
Ecoregion:	Northern Lakes and Forests
Bed Material:	Gravel
Stream Slope (%):	0.5
Stream Temperature:	Coldwater
Wadeable/Non-wadeable:	Non-wadeable
Reference Vegetation Community:	Forested

Figure 5. Site Information and Reference Standard Stratification Input Fields.

Many of the fields in this section are linked to the selection of parameters, metrics, and reference curves. The reference standard stratification for each metric is summarized in Appendix A, the list of metrics. Where reference curves for a metric are stratified, the index value calculations cells will refer to this section. An index value of FALSE may occur in a condition assessment (existing, proposed, or monitoring) if:

- There are data missing from the Site Information and Reference Standard Stratification section.
- There are not reference standards for the selected input. For example, there are not reference standards for the P51 fish metric for coldwater streams.

Note that incorrect information in the Site Information and Reference Standard Stratification section may result in applying reference standards that are not suitable for the project, which may result in over- or under-estimation of functional lift (or loss). **Accurate estimates increase the chances that mitigation obligations can be met at the end of the monitoring period.**

The user should input values into the gray cells and select an input from the drop-down menus in the blue cells. Any cells within this section that are white are locked from editing and the input is provided by the user on another worksheet. Instructions for collecting data to populate this section are provided in the Data Collection and Analysis Manual.

## 6.2. Condition Assessments

The Quantification Tool worksheet contains two condition assessments: existing and proposed. Metrics are listed by functional category and then parameter (Figure 6). Each metric has a neighboring field value cell that is gray (value input) or blue (select input from a drop-down). All metric field values are input values except for the dominant BEHI/NBS input, which is selected from a drop-down.

A project would never enter field values for all metrics included in the SQT. The Parameter Selection Guide worksheet and Section 5 of this manual provide guidance on parameter and metric selection.

Table 6 provides the expected range of values for each metric. **Guidance on collecting and analyzing data to calculate field values for the condition assessments are provided in the Data Collection and Analysis Manual.** Additionally, Appendix A includes a list of all function-based parameters, metrics, and reference standards.

### Proposed Condition Field Values

Proposed field values that describe the physical post-project condition of the stream reach should be based on project design studies and calculations, drawings, field investigations, and best available science. Accurate estimates increase the chances that mitigation obligations can be met at the end of the monitoring period.

- Field values that describe the existing condition are determined using the methods described in the Data Collection and Analysis Manual. An existing condition score (ECS) relies on baseline data collected from the project reach before any work is completed.
- Field values that describe the proposed condition should consist of reasonable values for restored conditions. 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 should be appropriate for the setting, stream type, and watershed conditions within the project area; consistent with the restoration potential of the site; and representative of the site conditions likely to occur at the end of an established monitoring period.
- Field values entered for monitoring condition assessments are measured post-restoration (more detail provided in Section 8).

Function-Based Parameters	Metric	Field Value
Reach Runoff	Land Use Change Coefficient	71
	Concentrated Flow Points (#/1000 LF)	1
Floodplain Connectivity	Bank Height Ratio	3.1
	Entrenchment Ratio	1.1
Large Woody Debris	LWD Index	800
Lateral Migration	Dominant BEHI/NBS	H/M
	Percent Streambank Erosion (%)	60
	Percent Streambank Armoring (%)	20
Riparian Vegetation	Buffer Width (ft)	20
	Average DBH (Inches)	8
	Tree Density (#/Ac)	77
	Native Shrub/Sapling Density (#/Ac)	40
	Native Herbaceous Cover (%)	
Bed Form Diversity	Pool Spacing Ratio	8.2
	Pool Depth Ratio	3
	Percent Riffle (%)	75
	Aggradation Ratio	
Temperature	July Mean Temperature (°F)	68
Bacteria	E. Coli (cfu/100 ml)	
Nutrients	Total Phosphorus (mcg/L)	
Dissolved Oxygen	DO Concentration (mg/L)	
Macroinvertebrates	Macroinvertebrate P51 Index Score	55
	Macroinvertebrate P22 Index Score	
Fish	Fish P51 Index Score	

Figure 6. Example Field Value Data Entry in the Condition Assessment.

Table 6. Expected Range of Values for Metric Field Values.

Metric	Field Value Range	Metric	Field Value Range
Land Use Change Coefficient	0.0 – 100.0	Pool Spacing Ratio	≥ 0.0
Concentrated Flow Points (#/1000 LF)	≥ 0.00	Pool Depth Ratio	≥ 1.00
Bank Height Ratio	≥ 1.00	Percent Riffle (%)	≥ 0.0
Entrenchment Ratio	≥ 1.00	Aggradation Ratio	≥ 1.00
LWD Index	≥ 0	July Mean Temperature (°F)	≥ 60.0
# Pieces (#/328 ft)	≥ 0	Fecal Coliform (E. Coli/100 ml)	0 – 10,000
Percent Streambank Erosion (%)	0 – 100	Measured Total Phosphorus (mcg/L)	> 0.0
Percent Streambank Armoring (%)	0 – 100	10 <sup>th</sup> Percentile Summer DO Concentration (mg/L)	≥ 0.0
Buffer Width (ft)	≥ 0	P51 – Macroinvertebrates	-9 – 9
Average DBH (in)	≥ 0.0	P22	0 – 100
Tree Density (#/Ac)	≥ 0	P51 - Fish	-9 – 9
Native Shrub/Sapling Density (#/Ac)	≥ 0	Effective Impervious Cover (%)	0 – 100
Native Herbaceous Cover (%)	0 – 100	STEPL or Region 5 model (mcg/L)	> 0.0

### 6.3. BMP Routine

The MiSQT includes a BMP Routine to capture the benefits of BMPs on treating non-point source runoff. For the MiSQT, BMPs are structural or vegetative measures that treat stormwater runoff that drains to the project reach. **Where BMPs are required as part of an NPDES permit, the BMP Routine cannot be used to generate lift.**

There is space to include the modeled effects of up to three BMPs in the BMP Routines within the Quantification Tool worksheet below the Proposed Condition Assessment. Stormwater BMPs that are installed adjacent or upstream of the stream restoration project can provide additional lift using the Quantification Tool worksheet. The SQT should not be applied to stand-alone BMP projects that do not include stream restoration activities.

Within each BMP Routine (Figure 7) there are four sections: Site Information, Existing Condition Assessment, Proposed Condition Assessment, and Results.

Site Information		BMP 1	
BMP ID:	<b>Example</b>	Values are calculated using EPA's Region 5 model unless multiple BMPs are proposed in series, then the applicant should use STEPL.	
Basin Area treated by BMP (Ac):	120		
Effective Stream Length (ft):	2286.31		
Existing Condition Assessment			
Function-Based Parameters	Metric	Field Value	Index Value
Reach Runoff	Effective Impervious Cover (%)	10	0.50
Nutrients	Total Phosphorus (mcg/L)	140	0.03
Proposed Condition Assessment			
Function-Based Parameters	Metric	Field Value	Index Value
Reach Runoff	Effective Impervious Cover (%)	10	0.50
Nutrients	Total Phosphorus (mcg/L)	110	0.12
Results			
BMP Existing Score		0.27	
BMP Proposed Score		0.31	
Existing BMP Functional Foot Score		617.3	
Proposed BMP Functional Foot Score		708.8	
Proposed FFS - Existing FFS		91.50	

Figure 7. BMP Routine Example

The BMP Routine treats the BMP as a tributary to the project reach.

- The BMP ID field is a unique identifier for the BMP data being entered.
- Instead of identifying a project reach length for a BMP, the BMP Routine calculates an effective stream length from the area treated by the BMP (measured in Acres).

$$Effective\ Stream\ Length\ (ft) = \sqrt{43,560\ ft^2 / Ac * Basin\ Area\ (Ac)}$$

Only a subset of function-based parameters and metrics available in the stream reach condition assessments are available in the BMP Routine: reach runoff and nutrients. The nutrients parameter is assessed as a concentration instead of a load (load equals the pollutant concentration times the flow volume). This is important because the reduction in runoff volume is captured by the reach runoff parameter. Calculating reductions in nutrient load would effectively double count the effects of a BMP on reducing runoff volume.

**Field values in the BMP Routine are modeled and values entered in the stream reach condition assessments are measured.** For most projects, phosphorus will only be modeled when BMPs are included. However, if the practitioner or regulator believes that the BMPs could influence the total phosphorus concentration in the project reach, field values within the reach condition assessments can be measured.

Only two functional categories are represented in the BMP Routine and unlike the reach condition assessments, the functional categories are not weighted in the scoring. Based on the data in the BMP Routine, the BMP Existing Score is an average of the metric index values in the BMP Existing Condition Assessment. The BMP Proposed Score is an average of the index

values in the BMP Proposed Condition Assessment. The functional foot scores (FFS) are calculated by multiplying the BMP scores by the effective stream length.

$$\text{Existing BMP FFS} = \text{BMP Existing Score} * \text{Effective Stream Length}$$

$$\text{Proposed BMP FFS} = \text{BMP Proposed Score} * \text{Effective Stream Length}$$

The sum of the existing and proposed BMP FFS from the three BMP Routine boxes are summed and included in the BMP Functional Change Summary at the top of the Quantification Tool worksheet. These scores are added to the stream functional foot score in the Functional Feet Summary table at the top of the Quantification Tool worksheet.

#### 6.4. Scoring Functional Lift and Loss

Scoring occurs automatically as field values are entered into the condition assessment. A field value will correspond to an index value ranging from 0.00 to 1.00 for that metric (refer to Chapter 9). 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 equally (multiplied by 0.20) and summed to calculate functional change.

Index Values: The reference curves that translate a field value into an index value for each metric are visible in the Reference Standards worksheet and summarized in Appendix A.

**Chapter 9 goes into more detail on how index values are calculated in this worksheet.**

When a field value is entered for a metric on the Quantification Tool worksheet an index value between 0.00 and 1.00 is assigned to the field value (Figure 8).

Metric	Field Value	Index Value
Land Use Change Coefficient	71	0.27
Concentrated Flow Points (#/1000 LF)	1	0.70

Figure 8. Index Values Automatically Populate When Field Values Are Entered.

When a field value is entered on the Quantification Tool worksheet, the neighboring index value cell checks the data in the Site Information and Reference Standard Stratification section and either returns an index value based on the appropriate reference standard or returns FALSE (Figure 9). Some metrics have a limited range of application. For example, the P51 metric for fish only has reference standards for wadeable, warm and warm-transitional streams. If the project reach is non-wadeable or coldwater, then the field value will return FALSE. An index value of FALSE may also occur if the Site Information and Reference Standard Stratification section is missing data, as is the case in Figure 9 where proposed/reference stream type were missing.

Pool Spacing Ratio	5	FALSE
Pool Depth Ratio	3	1.00
Percent Riffle (%)	60	FALSE
Aggradation Ratio		

Figure 9. Index Value Errors due to not Providing Proposed/Reference Stream Type in the Site Information and Reference Standard Stratification Section.

If the worksheet does not return an index value as expected, the user should check the Site Information and Reference Standard Stratification section in the SQT for data entry errors and then check the stratification for the metric in Appendix A to see if there are reference standards applicable to the project. Incorrect information in the Site Information and Reference Standard Stratification section may result in applying reference standards that are not suitable for the project.

**Note that the P51 metrics** for fish and macroinvertebrate parameters require a change in field value of two or more to generate lift. The proposed condition index value calculation will check whether the difference between the existing condition field value and proposed condition field value is less than two. If that difference is less than two, the index value for the proposed condition is set equal to the index value from the proposed condition. If that difference is greater than or equal to two, the proposed condition index value will calculate using the reference curve.

Roll Up Scoring: Metric index values are averaged to calculate parameter scores; parameter scores are averaged to calculate category scores. The category scores are then weighted equally (multiplied by 0.20) and summed to calculate overall condition scores (Figure 10). For metrics that are not assessed, a field value is not entered. The metric is thereby removed from the scoring and no index value is provided. It is NOT counted as a zero in calculating the parameter score.

Recall that the following delineations apply to all index values:

- Index value range of 0.70 – 1.00 = Functioning (F)
- Index value range of 0.30 – 0.69 = Functioning-At-Risk (FAR)
- Index value range of 0.00 – 0.29 = Not Functioning (NF)

Because category scores are additive, a maximum overall score of 1.00 is only possible when parameters within all five categories are evaluated. **This roll-up scoring procedure incentivizes monitoring physicochemical and biology functional categories since the maximum overall condition score achievable without monitoring these functional categories is 0.60.**

This score is then related to stream size (Strahler stream order) and flow type (perennial, intermittent, and ephemeral) to help match impacted stream types to mitigation stream types and thus avoid out-of-kind mitigation. Further matches can be made by comparing the input and stratification tables between two sites.

**The tool's output reflects only the metrics that are measured.** Thus, care must be taken to interpret the results. For example, while the tool may report that a stream is functioning at a

physicochemical level, this may be because only temperature was assessed but there may be indicators in the catchment assessment to suggest that other physicochemical parameters may be a concern in the stream.

Functional Category	Function-Based Parameters	Parameter	Category	Category	Overall
Hydrology	Reach Runoff	0.49	0.49	Functioning At Risk	0.32
Hydraulics	Floodplain Connectivity	0.00	0.00	Not Functioning	
Geomorphology	Large Woody Debris	0.42	0.44	Functioning At Risk	
	Lateral Migration	0.23			
	Riparian Vegetation	0.53			
	Bed Form Diversity	0.59			
Physicochemical	Temperature	0.13	0.13	Not Functioning	
	Bacteria				
	Nutrients				
	Dissolved Oxygen				
Biology	Macroinvertebrates	0.55	0.55	Functioning At Risk	
	Fish				

*Figure 10. Roll Up Scoring Example—the functional category scores are an average of the category parameter scores and the overall score is the result of the category scores multiplied by 0.2 and summed.*

**Functional Change:** The Quantification Tool worksheet summarizes the scoring at the top of the sheet, next to and under the Site Information and Reference Standard Stratification section. There are five summary tables: Functional Change Summary, BMP Functional Change Summary, Functional Feet Summary, Functional Category Report Card, and Function-based Parameter Summary. The Functional Change Summary (Figure 11) provides the overall scores from the Existing Condition Assessment and Proposed Condition Assessment sections.

<b>FUNCTIONAL CHANGE SUMMARY</b>	
Existing Condition Score (ECS)	0.32
Proposed Condition Score (PCS)	0.57
Change in Functional Condition (PCS - ECS)	0.25
Percent Condition Change	78%
Existing Stream Length (ft)	1800
Proposed Stream Length (ft)	1800
Additional Stream Length (ft)	0
Existing Functional Foot Score (FFS)	576
Proposed Functional Foot Score (FFS)	1026
Proposed FFS - Existing FFS ( $\Delta FF$ )	<b>450 P4+</b>
Yield ( $\Delta FF$ /Proposed LF)	0.25

Figure 11. Functional Change Summary Example.

The percent condition change is the change in functional condition divided by the ECS.

$$\text{Percent Condition Change} = \frac{PCS - ECS}{ECS} * 100$$

The rest of the table calculates and communicates Functional Foot Scores (FFS). An FFS is produced by multiplying a condition score by the stream length. 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.

$$\text{Existing FFS} = ECS * \text{Existing Stream Length}$$

$$\text{Proposed FFS} = PCS * \text{Proposed Stream Length}$$

A positive Proposed FFS – Existing FFS is the amount of functional lift generated by the restoration activities and could be considered a credit as part of a stream mitigation credit determination method. A negative value is the amount of functional loss generated by impact activities and could be considered a debit as part of a stream mitigation debit determination method. The flow permanence (perennial, intermittent, or ephemeral) and the Strahler stream order (Strahler, 1957) provide context for the  $\Delta FF$  value generated (Figure 11 shows a perennial, fifth order stream indicated by the P4+ following the  $\Delta FF$ ).

#### Functional Lift

A positive delta (Proposed FFS – Existing FFS) is the amount of functional lift generated by the restoration activities and could be considered a credit as part of a stream mitigation credit determination method.

The functional change is also shown as yield, calculated as the change in functional feet divided by the proposed stream length for the project reach.

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

The functional feet score for BMPs is tabulated separately in the BMP Functional Change Summary (Figure 12). The results in this table are the sum of the Existing and Proposed FFS from the three BMP Routine boxes located under the Proposed Condition Assessment. The difference between the proposed and existing FFS is calculated. The BMP Routine is discussed in detail in the next section.

<b>BMP FUNCTIONAL CHANGE SUMMARY</b>	
Existing BMP Functional Feet Score (FFS)	592
Proposed BMP Functional Feet Score (FFS)	818
Proposed BMP FFS - Existing BMP FFS	226

Figure 12. BMP Functional Change Example.

There is a final Functional Feet Summary table that sums the  $\Delta$ FFS from stream reach and BMP Routines (Figure 13). The Existing Stream FFS and the existing BMP FFS are added. Similarly, the proposed stream FFS and proposed BMP FFS are added. The Total Proposed FFS is then subtracted from the Total Existing FFS to calculate the uplift achieved, and the yield for the project is calculated using the proposed stream reach length.

<b>FUNCTIONAL FEET (FF) SUMMARY</b>	
Existing Stream FFS + Existing BMP FFS	700
Proposed Stream FFS + Proposed BMP FFS	1313
Total Proposed FFS - Total Existing FFS	613
Yield ( $\Delta$ FF/Proposed LF)	0.41

Figure 13. Functional Feet Summary Example.

The Functional Category Report Card (Figure 14) pulls the existing condition score (ECS) and proposed condition score (PCS) for each of the five functional categories from the Condition Assessment sections of the worksheet for a side-by-side comparison.

<b>FUNCTIONAL CATEGORY REPORT CARD</b>			
<b>Functional Category</b>	<b>ECS</b>	<b>PCS</b>	<b>Functional Change</b>
Hydrology	0.49	0.72	0.23
Hydraulics	0.00	0.86	0.86
Geomorphology	0.44	0.82	0.38
Physicochemical	0.13	0.32	0.19
Biology	0.55	0.66	0.11

*Figure 14. Functional Category Report Card Example.*

The Function-based Parameters Summary also provides a side-by-side comparison, but for individual parameter scores (Figure 15). Values are pulled from the condition assessment sections of the worksheet.

- This table can be used to better understand how the category scores were determined. For example, while the physicochemical category may be functioning which would suggest the stream could support biology functions, it is possible that only temperature was assessed, and dissolved oxygen is too low to support functioning biology.
- This table also makes it possible to quickly spot if a parameter was not assessed for both the existing and proposed condition assessments. The same parameters and metrics must be used in the existing condition and all subsequent condition assessments (i.e., proposed, as-built, and monitoring) within a project reach, otherwise the relative weighting between metrics and parameters changes and the overall scores are not comparable over time.
- Finally, the table can be reviewed to determine if any required parameters were totally omitted from the assessment.

<b>FUNCTION-BASED PARAMETER SUMMARY</b>			
<b>Functional Category</b>	<b>Function-Based Parameters</b>	<b>Existing Parameter</b>	<b>Proposed Parameter</b>
Hydrology	Reach Runoff	0.49	0.52
Hydraulics	Floodplain Connectivity	0.00	0.91
Geomorphology	Large Woody Debris	0.42	0.42
	Lateral Migration	0.23	0.73
	Riparian Vegetation	0.53	0.56
	Bed Form Diversity	0.59	1.00
Physicochemical	Temperature	0.13	0.15
	Bacteria		
	Nutrients		
	Dissolved Oxygen		
Biology	Macroinvertebrates	0.55	0.57
	Fish		

Figure 15. Function Based Parameters Summary Example.

## 7. Reference Standards Worksheet

The Reference Standards worksheet displays reference curves (graphical relationships) which convert field values for metrics into index values. Field values are a measurement or calculation input into the SQT for a specific metric. Units vary based on the metric or measurement method used. Index values are dimensionless values between 0.00 and 1.00 that express the relative condition of a metric field value compared with reference standards (refer to Section 2.2). Metric index values are categorized into functional capacity categories: functioning (F; 0.70-1.00), functioning-at-risk (FAR; 0.30-0.69), or not functioning (NF; 0.00-0.29).

The Reference Standards worksheet is locked to protect calculations. The user cannot make changes to the reference standards. However, the user can view the reference standards and make suggestions for data-driven changes (e.g., local reference reach data or better modeling). **Refer to Section 1.1 for instructions in submitting data and proposed revisions to the MiSQT.**

On the worksheet, metric reference curves are organized into columns based on the functional category. To account for natural variability among stream systems, reference curves for specific metrics may be stratified by differences in stream type, ecoregion, reference vegetation community, wadeable/non-wadeable, or stream temperature. The full list of reference standards and their stratification is provided in Appendix A.

To develop reference curves, field values were identified for each metric that would serve as thresholds between the categories of functional capacity outlined in Table 1 (Section 1.2). Three approaches were taken to identify threshold values:

1. Where possible, thresholds were derived from field values already identified in the State of Michigan's technical publications or the literature (e.g., based on water quality standards, channel classification, or existing indices).
2. Where literature values were not available, threshold values were developed using data from regional resource surveys and other available regional datasets. In evaluating reference datasets, the team considered the degree of departure from reference standard to identify the threshold values. For example, the interquartile range of reference standard sites within a dataset may be used to identify the 0.70 and 1.00 field values for developing a reference curve. This is similar to other approaches that identify benchmarks or index values (e.g., Bureau of Land Management, 2017). In the use of existing datasets, the advisory team relied on the definitions of reference standard condition provided by the authors.
3. Where existing data or literature were limited, expertise of members of the advisory team were relied on to identify threshold values. In some instances, the decision was made to not identify thresholds between all categories and instead extrapolate index values from a best fit line from available data or literature values.

Following the identification of these threshold values, reference curves were fit using relationships between threshold values (e.g., linear, polynomial). These continuous relationships allow index scores to account for incremental changes in field values, which is important for determining a change in the pre- and post-project condition.

Reference curve development for an example metric, buffer width (Figure 16), is described below (Example 3).

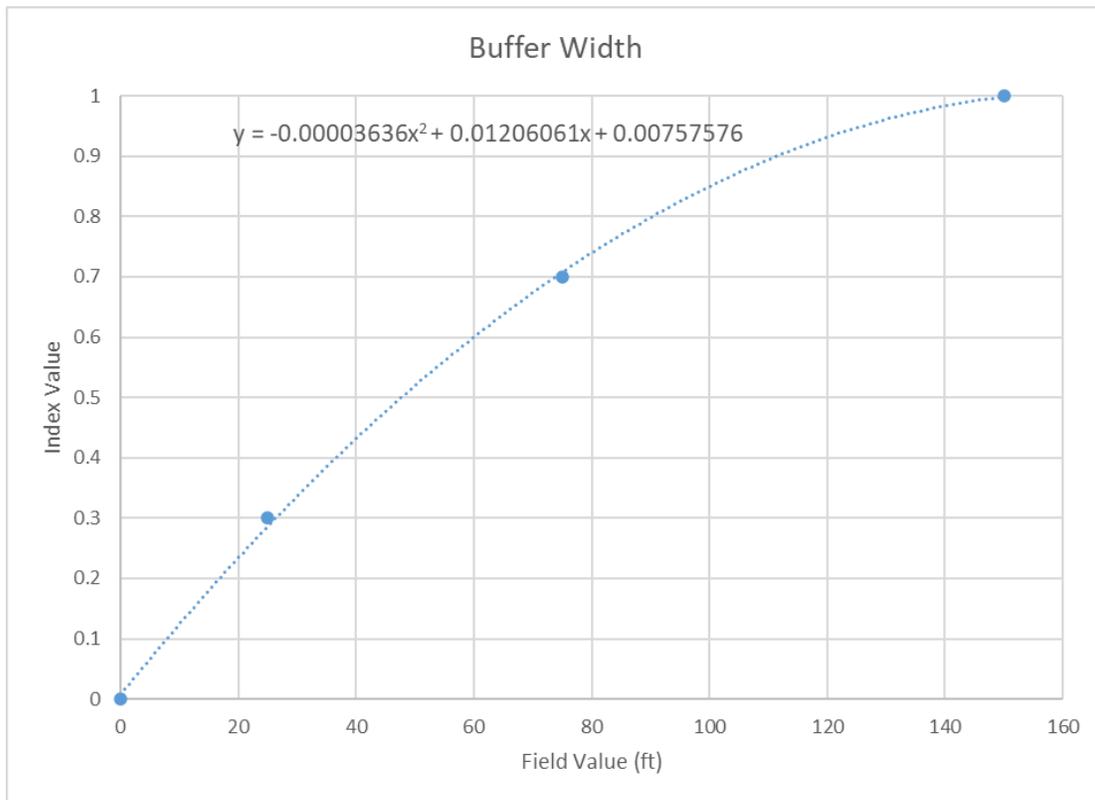


Figure 16. Buffer width reference curve.

### Example 3: Reference Curve Development for Buffer Width

Characterizing the extent of riparian zones is important, as functioning riparian zones influence (and are influenced by) many instream and floodplain processes (Fischer and Fischenich, 2000; Mayer et al., 2005). Reference standard thresholds are from the Michigan Rapid Assessment Method for Wetlands (MiRAM; MI DNRE, 2010) that classifies buffers as follows:

- Wide buffers are greater than or equal to 150 feet wide
- Medium buffers are between 75 and 150 feet wide
- Narrow buffers are between 25 and 75 feet wide
- Very narrow buffers are less than 25 feet wide

These narrative descriptions were matched to the functional capacity thresholds described in Table 1 (Section 2.1). A polynomial curve was used to calculate index values as this matched the literature understanding of trapping efficiency and nutrient removal documented by various studies on buffer efficiency as a management practice (Mayer et al., 2005; Bentrup, 2008).

## 8. Monitoring Data and Data Summary Worksheets

The Monitoring Data worksheet contains 11 condition assessment tables that are identical to the condition assessments in the Quantification Tool worksheet (Figure 6). The first table is identified as the As-Built Condition followed by 10 condition assessment tables for monitoring. The user can enter the monitoring date and year at the top of each condition assessment table, e.g., year 1 for the first growing season post-project.

- The monitoring year is the number of years after the as-built survey (as-built is considered year 0). This input is used on the Data Summary sheet.
- The date is the calendar date of the assessment.

The same parameters and metrics must be used in the existing condition and all subsequent condition assessments (i.e., proposed, as-built, and monitoring) within a project reach, otherwise the relative weighting between metrics and parameters changes and the overall scores are not comparable over time.

The index value calculations in the Monitoring Data worksheet link to the Site Information and Reference Standard Stratification section on the Quantification Tool worksheet and scoring is identical to the process described in Section 8.3.

The Data Summary worksheet provides a summary of project data from the existing condition, proposed condition, as-built condition, and monitoring assessments, as pulled from the Quantification Tool and Monitoring Data worksheets. **This worksheet does not require any data entry.** The Data Summary worksheet features a function-based parameter summary (Figure 17), a functional category report card (Figure 18), and four plots showing this information graphically.

The four plots include an overall condition score, functional feet score (note, this does not include any functional feet generated from the BMP Routines), functional category scores (Figure 19), and what are referred to as the “big four” parameters. As noted in Chapter 7, it is recommended that **ALL** projects monitor and bring floodplain connectivity, lateral migration, and bed form diversity (when applicable<sup>7</sup>) to a functioning condition at the end of the project. Riparian vegetation should be at a 0.60 or greater to show that vegetation growth is on a trajectory towards a mature, native community. The condition of these four parameters is shown graphically in the Big Four Parameters – Condition Score Tracking plot.

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<sup>7</sup> Bed form diversity should not be assessed in multi-thread channels or naturally straight sand-bed channels where the bedforms are created by large wood.

Function-Based Parameters	Existing Parameter	Proposed Parameter	As-Built	Monitoring Year		
				1	4	7
Reach Runoff	0.49	0.52	0.52	0.52	0.52	0.52
Floodplain Connectivity	0.00	0.91	0.91	0.91	0.91	0.91
Large Woody Debris	0.42	0.42	0.42	0.42	0.42	0.42
Lateral Migration	0.23	0.73	0.73	0.60	0.72	0.73
Riparian Vegetation	0.53	0.58	0.56	0.56	0.57	0.58
Bed Form Diversity	0.59	1.00	1.00	1.00	1.00	1.00
Temperature	0.13	0.15	0.15	0.15	0.15	0.15
Bacteria						
Nutrients						
Dissolved Oxygen						
Macroinvertebrates	0.55	0.57	0.21	0.16	0.45	0.57
Fish						

Figure 17. Function-based Parameters Summary displaying three example monitoring events.

Functional Category	ECS	PCS	As-Built	Monitoring Year		
				1	4	7
Hydrology	0.49	0.52	0.52	0.52	0.52	0.52
Hydraulics	0.00	0.91	0.91	0.91	0.91	0.91
Geomorphology	0.44	0.68	0.68	0.64	0.68	0.68
Physicochemical	0.13	0.15	0.15	0.15	0.15	0.15
Biology	0.55	0.57	0.21	0.16	0.45	0.57
<b>Overall Score</b>	<b>0.32</b>	<b>0.57</b>	<b>0.49</b>	<b>0.48</b>	<b>0.54</b>	<b>0.57</b>
<b>Functional Feet</b>	<b>576</b>	<b>1026</b>	<b>882</b>	<b>864</b>	<b>972</b>	<b>1026</b>

Figure 18. Functional Category Report Card.

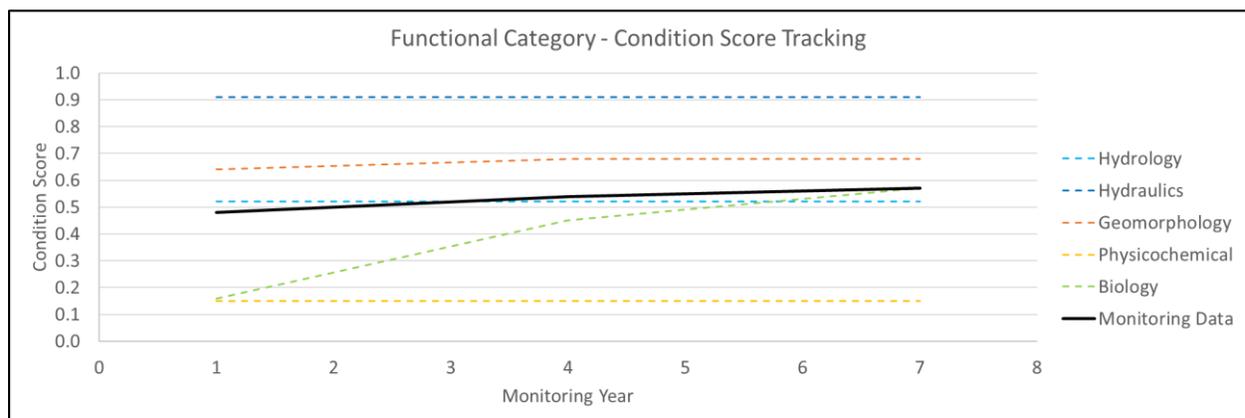


Figure 19. Functional Category Condition Score Tracking.

## 8.1. Monitoring

Monitoring requirements (e.g., monitoring period length, performance standards, and number of monitoring events) may vary between projects. Below are general guidelines for the SQT during monitoring.

Existing Condition – Existing condition field values are measured prior to the implementation of restoration activities (e.g., grading, planting, and installation of wood).

- 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 all subsequent condition assessments (proposed, as-built, and every monitoring event).
- For metrics where only a single sampling event is required (fish, macroinvertebrate, and physicochemical metrics), multiple sampling events will improve the accuracy of the field value used to calculate lift by quantifying inter- or intra-annual variability

Proposed Condition – Proposed condition field values are estimated/predicted using available project data. 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).

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.

- Channel plan form should verify pool spacing ratio in meandering streams and the proposed stream length.
- Concentrated flow points, large woody debris index, percent armoring, and percent side channels metric field values should be measured post-construction or documented in record drawings.
- Floodplain grading should verify flood-prone width for the entrenchment ratio.
- Channel dimensions should verify bankfull elevations and metric field values for bank height, entrenchment ratio, and aggradation ratio.
- 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 and **the existing condition field value 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. The field values that were predicted during the design phase are also the performance standards.<sup>8</sup> If these field values are not obtained during monitoring and the trend is not towards the predicted value, an

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<sup>8</sup> EGLE may require additional performance standards beyond what is used in the SQT

adaptive management plan may be needed. The frequency of monitoring different metrics can vary based on the level of effort and expense of the data collection.

- To complete a condition assessment on the Monitoring Data worksheet, the user should first fill in any measured values and then, **for any metrics not assessed, hold the previously measured field value constant.**

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

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**Appendix A**  
**List of Metrics**



Functional Category	Function-Based Parameters	Metric (Units)	Reference Standard Stratification		Not Functioning		Functioning-At-Risk		Functioning		Notes
			Type	Description	Min (index = 0)	Max (index ≤ 0.29)	Min (index ≥ 0.3)	Max (index ≤ 0.69)	Min (index ≥ 0.7)	Max (index = 1)	
Hydrology	Reach Runoff	Land Use Change Coefficient					70.0		55.0	≤ 30.0	
		Concentrated Flow Points (#/1000 LF)							1.0	0.0	
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft)					1.50			≤ 1.00	
		Entrenchment Ratio (ft/ft)	Proposed Stream Type	C or E			2.00		2.40	≥ 5.00	
			Proposed Stream Type	A, B or Bc			1.20		1.40	≥ 2.20	
Geomorphology	LWD	LWD Index			0				1350	≥ 2825	The threshold values reported here are used to make the reference curves but due to the slope of the line values ±25 may also yield the noted index value.
		Lateral Migration	Dominant BEHI/NBS			Refer to WY Science Document <sup>1</sup>					
	Percent Streambank Erosion (%)				≥ 75				10	≤ 5	These were revised to match WSQT updates.
	Percent Streambank Armoring (%)				≥ 30		21		9	0	
	Riparian Vegetation	Buffer Width (ft)			0		26		74	≥ 150	Note, these values differ from the threshold values used in the SQT due to the linear fit.
		Average DBH (Inches)	Reference Vegetation Community	Forested	0					≥ 12	
		Tree Density (#/Ac)	Reference Vegetation Community	Forested	0		300			95 200	Higher tree densities plateau at a score of 0.50 for values ≥ 300
		Native Shrub/Sapling Density (#/Ac)	Reference Vegetation Community	Forested	0					≥ 100	
			Reference Vegetation Community	Scrub-shrub	0					≥ 470	
	Native Herbaceous Cover (%)	Reference Vegetation Community	Herbaceous	0					≥ 80		
	Bed Form Diversity	Pool Spacing Ratio (ft/ft)	Proposed Stream Type	C or E	≤ 1.0 ≥ 9.0					3.5 6.0	
				A or B	≥ 6.5			5.0	≤ 4.0		
			Bc	≥ 8.0			6.0	≤ 5.0			
		Pool Depth Ratio (ft/ft)			≤ 1.1		1.5		2.0	≥ 3.0	
		Percent Riffle (%)	Proposed Stream Type	C or E	≤ 20 ≥ 85						45 65
A or B				≤ 20 ≥ 90					50 60		
Aggradation Ratio			≥ 1.6		1.4	1.2		≤ 1.0			

**Note:** <sup>1</sup> Wyoming Stream Technical Team. 2018. Scientific Support for the Wyoming Stream Quantification Tool, Version 1.0. U.S. Army Corps of Engineers, Omaha District, Wyoming Regulatory Office. Cheyenne, WY.



Functional Category	Function-Based Parameters	Metric (Units)	Reference Standard Stratification		Not Functioning		Functioning-At-Risk		Functioning		Notes
			Type	Description	Min (index = 0)	Max (index ≤ 0.29)	Min (index ≥ 0.3)	Max (index ≤ 0.69)	Min (index ≥ 0.7)	Max (index = 1)	
Physicochemical	Temperature	July Mean Temperature (°F)	Stream Temperature	Coldwater			66.2			≤ 59.0	
				Cold-transitional			69.8			≤ 66.2	
				Warm-transitional or Warm			78.8			≤ 69.8	
	Bacteria	E. Coli (cfu/100 ml)			≥ 4500		1000		300	≤ 10	The threshold values reported here are used to make the reference curves but due to the slope of the curves values ± 5
	Nutrients	Total Phosphorus (mcg/L)	Ecoregion	Northern Lakes and Forests or North Central Hardwood Forests	≥ 151		50.0		12.0	≤ 3.9	The threshold values reported here are used to make the reference curves but due to the slope of the curves values ± 0.1 (functioning) to ±7 (not functioning) may also yield the noted index value.
			Ecoregion	Southern Michigan or Northern Indiana Drift Plains	≥ 186		90.0		30.0	≤ 12.5	
			Ecoregion	Huron Erie Lake Plains or Eastern Corn Belt Plains	≥ 550		160		70	≤ 29	
Dissolved Oxygen	DO Concentration (mg/L)	Stream Temperature	Warm-transitional or Warmwater	0.00		4.00		5.00			
		Stream Temperature	Cold-transitional or Coldwater	0.00		6.00		7.00			
Biology	Macroinvertebrates	Macroinvertebrate P51 Index Score	Wadeable/Non-Wadeable	Wadeable	-9.0		-3.7	3.6		9.0	Note, these values differ from the threshold values used in the SQT due to the linear fit.
		Macroinvertebrate P22 Index Score	Wadeable/Non-Wadeable	Non-wadeable	0		29	70		100	
	Fish	Fish P51 Index Score	Wadeable/Non-Wadeable & Stream Temperature	Wadeable and Warm or Warm-Transitional	-10.0		-4	4		10.0	
BMP Routine	Reach Runoff	Effective Impervious Cover (%)			≥ 60		21		5	0	Note, these values differ from the threshold values used in the SQT due to the linear fit.
	Nutrients	Total Phosphorus (mcg/L)	Ecoregion	Northern Lakes and Forests or North Central Hardwood Forests	≥ 151		50.0		12.0	≤ 3.9	The threshold values reported here are used to make the reference curves but due to the slope of the curves values ± 0.1 (functioning) to ±7 (not functioning) may also yield the noted index value.
			Ecoregion	Southern Michigan or Northern Indiana Drift Plains	≥ 186		90.0		30.0	≤ 12.5	
			Ecoregion	Huron Erie Lake Plains or Eastern Corn Belt Plains	≥ 550		160		70	≤ 29	



Functional Category	Function-Based Parameter	Metric	Reference Standard Stratification	Reference Standard Threshold Notes and References
Hydrology	Reach Runoff	Land Use Change Coefficient		Best professional judgement and NRCS TR-55 methodology.
		Concentrated Flow Points (#/1000 LF)		Best professional judgement. Full write-up provided in Scientific Support for the Wyoming Stream Quantification Tool,
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft)		Literature values from Rosgen (1996), Harman et al. (2012).
		Entrenchment Ratio (ft/ft)	Proposed Stream Type	Rosgen stream type classification breaks (1996) and best professional judgment.
Geomorphology	LWD	LWD Index		Unpublished Michigan dataset.
	Lateral Migration	Dominant BEHI/NBS		Best professional judgement. Full write-up provided in Scientific Support for the Wyoming Stream Quantification Tool, Version 1.0. (Wyoming Stream Technical Team, 2018).
		Percent Streambank Erosion (%)		
		Percent Streambank Armoring (%)		
	Riparian Vegetation	Buffer Width (ft)		Michigan Department of Natural Resources and Environment (2010)
		Average DBH (Inches)	Reference Vegetation Community	Based on values from Michigan State Forest Management Plan (2008), Natural Community Surveys of Potential Ecological Reference Areas on State Forest Lands (Cohen et al., 2008), and Ohio's Part 6 Standard Wetland Mitigation Protocols (Mack et al., 2004).
		Tree Density (#/Ac)	Reference Vegetation Community	Based on values calculated from Michigan State Forest management Plan (2008) and calculations of ideal basal area from Silviculture Guide for Northern Hardwoods in the Northeast (Leak et al., 2014).
		Native Shrub/Sapling Density (#/Ac)	Reference Vegetation Community	Based on best professional judgement using the references noted above for average DBH and tree density.
		Native Herbaceous Cover (%)	Reference Vegetation Community	E.A. Summers, C.V. Noble, J.F. Berkowitz, and F.J. Spilker. 2017. Operational Draft Regional Guidebook for the Functional Assessment High-Gradient Headwater Streams in and Low-Gradient Perennial Stream in Appalachia. USACE ERDCO, Wetlands Regulatory Assistance Program.
		Bed Form Diversity	Pool Spacing Ratio (ft/ft)	Proposed Stream Type
	Pool Depth Ratio (ft/ft)			Literature values from Rosgen (2014) and several published and unpublished datasets.
	Percent Riffle (%)		Proposed Stream Type	Literature values from several published and unpublished datasets.
Aggradation Ratio			Developed using stability ratings from Width Depth Ratio State described by Rosgen (2014).	
Physicochemical	Temperature	July Mean Temperature (°F)	Stream Temperature	Based on best professional judgement using published data on species typical within each temperature tier. Refer to Michigan Water Withdrawal Assessment Tool (WWAT) for fact sheets on each stream temperature tier and species lists.
	Bacteria	E. Coli (cfu/100 ml)		Published thresholds from state documents.
	Nutrients	Total Phosphorus (mcg/L)	Ecoregion	Multiple reports from UPEPA - Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregions.
	Dissolved Oxygen	DO Concentration (mg/L)	Stream Temperature	Based on state thresholds for water quality. Fact sheet available from: <a href="https://www.michigan.gov/documents/deq/wrd-sw-as-ecoli_527147_7.pdf">https://www.michigan.gov/documents/deq/wrd-sw-as-ecoli_527147_7.pdf</a>
Biology	Macroinvertebrates	Macroinvertebrate P51 Index Score	Wadeable/Non-Wadeable	Creal, W., Hanshue, S., Kosek, S., Oemke, M., & Walterhouse, M. 2018. GLEAS Procedure 51 Metric Scoring and Interpretation. GLEAS Surface Water Quality Division.
		Macroinvertebrate P22 Index Score	Wadeable/Non-Wadeable	MI DEQ, Water Resources Division, Surface Water Assessment Section. 2013. Qualitative Biological and Habitat Survey Protocols for Nonwadeable Rivers. WRD-SWAS-022.
	Fish	Fish P51 Index Score	Wadeable/Non-Wadeable & Stream Temperature	Creal, W., Hanshue, S., Kosek, S., Oemke, M., & Walterhouse, M. 2018. GLEAS Procedure 51 Metric Scoring and Interpretation. GLEAS Surface Water Quality Division.
BMP Routine	Reach Runoff	Effective Impervious Cover (%)		Schueler, T.R, Fraley-McNeal, L., & Capiella, K. 2009. Is impervious cover still important? Review of Recent Research. Journal Hydrologic Engineering, 14
	Nutrients	Total Phosphorus (mcg/L)	Ecoregion	Multiple reports from UPEPA - Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for Rivers and Streams in Nutrient Ecoregions.