South Carolina Stream Quantification Tool

Version 1.1

User Manual

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December 2022

Acknowledgements

The South Carolina Stream Quantification Tool (SC SQT) is the collaborative result of federal and state agency representatives, collectively referred to as the South Carolina Stream Quantification Tool (SC SQT) Steering Committee. The SC SQT and supporting materials are adapted from the North Carolina SQT (NC SQT), which was developed by Stream Mechanics and Ecosystem Planning and Restoration (EPR) with funding and technical support by Environmental Defense Fund. The regionalization of the SC SQT was funded by the SC Department of Natural Resources (DNR) through a Wetland Program Development Grant provided by the US Environmental Protection Agency (USEPA). DNR contracted Stream Mechanics, and its subcontractor EPR, to facilitate and complete the SC SQT and Debit Calculator as well as subsequent updates that account for physicochemical and biology parameters, metrics, and reference curves.

SC SQT Steering Committee

SC Department of Natural Resources (Lead Agency)

US Army Corps of Engineers, Charleston District

US Environmental Protection Agency

SC Department of Health and Environmental Control

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Version

SC SQT Version	Date finalized	Description
Version 1.0	June 2021	Original version
Version 1.1	December 2022	Revised with parameters, metrics, reference curves, and methods for physicochemical and biology functional categories.

Acronyms

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

BHR – Bank height ratio

CWA – Clean Water Act

DNR – South Carolina Department of Natural Resources

ECS – Existing condition score

ER – Entrenchment ratio

FAR – Functioning-at-risk

F – Functioning

FF – Functional feet/foot

FFS – Functional foot score

LWD – Large woody debris

LWDI – Large woody debris index

NF – Not functioning

NLCD – National Land Cover Database

NPDES – National Pollutant Discharge Elimination System

PCS – Proposed condition score

SC – South Carolina

SFPF – Stream Function Pyramid Framework

SQT –Stream Quantification Tool

TMDL – Total Maximum Daily Load

TSS – Total Suspended Solids

USACE – United States Army Corps of Engineers

USEPA – United States Environmental Protection Agency

Glossary of Terms

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

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

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. Colluvium is material that originates on the hillslopes and moves down slope through mass wasting processes to the valley bottom.

Concentrated flow points – Storm drains or erosional features, such as swales, gullies, or other channels, that are created by anthropogenic impacts. Natural ephemeral tributaries and outlets of stormwater control measures (also known as best management practices) are not considered concentrated flow points.

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 (USACE & USEPA, 2008).

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 (USACE & USEPA, 2008).

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 (USACE & USEPA, 2008).

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

Functional capacity – The degree to which an area of aquatic resource performs a specific function (USACE & USEPA, 2008).

Functional category – The levels of the stream functions pyramid: Hydrology, Hydraulics, Geomorphology, Physicochemical, and Biology. Each category is defined by a functional statement (Harman et. al., 2012).

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.

Functions – The physical, chemical, and biological processes that occur in ecosystems (USACE & USEPA, 2008).

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

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

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]).

Mitigation Rule – The 2008 Federal Compensatory Mitigation Rule administered by the US Corps of Engineers and the US Environmental Protection Agency (33 CFR Parts 325 and 332; 40 CFR Part 230).

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 (USACE & USEPA, 2008).

Project area – The geographic extent of a project. A project area may include multiple project reaches, where there are variations in stream physical characteristics and/or differences in design approach.

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

Reference condition – A stream condition that is considered fully functioning for the parameter assessed, where functioning ranges from an unaltered/pristine to minimally or least disturbed condition. Reference condition is not the best available condition that can be achieved at a site. (Also known as reference standard). Note that this definition differs from USACE & USEPA (2008) definition.

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 condition for a given field value. These curves are used to calculate the index value for a given metric at a project reach.

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

Restoration potential – Restoration potential is the highest level of restoration that can be achieved based on an assessment of the contributing catchment, reach-scale constraints, and the results of the reach-scale function-based assessment (Harman et al., 2012).

Stream Functions Pyramid Framework (SFPF) – The Stream Functions Pyramid (Pyramid) is comprised of five functional categories 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 curves (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 fluvial functions and processes to a degraded aquatic resource. 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 Rule. (USACE & USEPA, 2008)

Chapter 1. Overview

The Spreadsheet User Manual (user manual) introduces key concepts and provides instruction on how to use the South Carolina Stream Quantification Tool (SC SQT) workbook. Information on data collection for the SC SQT is provided in the *South Carolina Stream Quantification Tool Data Collection and Analysis Manual* (Data Collection and Analysis Manual).

Version 1.0 of the SC SQT was informed by SQT development in states across the US, including North Carolina (Harman and Jones, 2017), Tennessee (TDEC, 2018), Wyoming (USACE, 2018a), Georgia (USACE, 2018b), Colorado (USACE, 2020), Minnesota (MNSQT SC, 2019), and Michigan (EGLE, 2020). Data collected in South Carolina[1] and in the southeast region were used to develop reference curves. Version 1.1 of the SC SQT and Debit Calculator includes new or revised parameters, metrics, and reference curves for the physicochemical and biology functional categories.

SQT Manual Directory

1. **SQT Spreadsheet User Manual** – *Describes rules and procedures for using the SQT Microsoft Excel workbook.* (This document)
2. **Debit Calculator Manual** – *Describes data collection method options and rules and procedures for using the Debit Calculator Excel workbook.*
3. **Data Collection and Analysis Manual** – *Describes instructions to collect and analyze data for SQT and/or Debit Calculator input*.

1.1. Manual Overview

This manual is organized as follows:

Chapter 1: Describes the purposes, uses, and key concepts of the SQT and where to download the SC SQT components and supporting information.

Chapter 2: Introduces the SC SQT and the Stream Functions Pyramid Framework, the premise of the SQT. Section 2.3 describes how to use the SC SQT for a typical stream restoration project.

Chapter 3: Provides instruction for data entry into the Project Summary spreadsheet in the SQT.

Chapter 4: Provides instruction on how to determine restoration potential and develop function-based goals and objectives as informed by the Catchment Assessment spreadsheet in the SQT.

Chapter 5: Describes how to select parameters and metrics for assessment based on restoration potential and function-based goals and objectives.

[1] https://www.dnr.sc.gov/environmental/streamrestoration.html

Chapter 6: Provides instruction and troubleshooting tips for data entry into the Quantification_Tool spreadsheet. Section 6.2 describes how SQT scoring works. Section 6.3 describes data entry for existing and proposed condition assessments. Section 6.4 describes data entry for monitoring condition assessments.

Chapter 7: Describes the Reference Curves spreadsheet in the SQT and the reference curve development process for South Carolina.

1.2. Purposes and Uses of the SQT

The SQT has been developed to assess and quantify functional lift and loss. The SQT can be used to determine credits or debits resulting from reach-scale activities typically encountered in the Clean Water Act (CWA) §404 program.

A main goal of the SQT is to produce objective, verifiable, and repeatable results by consolidating well-defined data collection procedures for quantitative measures of stream condition and underlying processes. Specific reasons for developing the SQT include the following:

1. Quantify 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 the function-based approaches and can be related to a stream credit determination method as defined by the Mitigation Rule (USACE & USEPA, 2008).
2. Relate restoration activities to changes in stream functions by primarily selecting function-based parameters and metrics that can be altered by reach-scale practices.
3. Connect restoration goals to restoration potential. Encourage assessments and monitoring that match the site's restoration potential.
4. Incentivize high-quality stream restoration and mitigation by calculating functional lift associated with physicochemical and biological improvements.
5. Create parity between functional lift (credits) and loss (debits).

To achieve parity, i.e., no net loss objective laid out by the CWA, the same function-based parameters and metrics used to assess the difference between a degraded and restored condition must also be used to quantify the functional loss experienced in an impacted reach. The Debit Calculator is an application of the SQT that assigns functional loss using the same parameters/metrics assessed with the SQT to generate credits. This user manual focuses on the SQT; information and instruction for the Debit Calculator are provided in the SC Debit Calculator Manual for the US Army Corps of Engineers (USACE) Charleston District (South Carolina Steering Committee, 2022). The primary difference between the tools is that the Debit Calculator includes assessment method options to determine the proposed (impacted) condition.

The purposes of the SQT translate into different uses for the SQT in South Carolina and generally, including:

1. Site Selection – The tool can help determine if a proposed project has enough functional lift to be considered for a stream restoration or mitigation project (Section 2.3.1). The tool can also help with avoidance and minimization by determining which site will yield the least functional loss for a proposed impact activity. The tool can also identify whether a stream may qualify for preservation.
2. Functional Lift or Loss – The tool can quantify functional lift or loss for a proposed or active project. Assessment occurs during the design or mitigation plan phase. Then, progress is assessed and documented for each monitoring event (post-construction). Refer to Chapter 6.
3. Third Party Mitigation (Credit and Debit Determination Method) – Credit and debit determination methods can be developed to incorporate the difference of the proposed functional foot score minus the existing functional foot score. Scoring is described in Chapter 6.
4. Permittee Responsible Mitigation – The tool can be applied to permittee-responsible mitigation to help determine if the proposed mitigation activities will offset the proposed impacts.

1.3. Key Concepts

The following concepts are critical in understanding the applicability and limitations of the SQT:

- 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 **are not intended to** 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.
- The overall existing and proposed condition scores range from 0.00 to 1.00, where each of the five functional categories contributes a maximum of 20% to the overall score. If all five functional categories are assessed, the maximum possible condition score is a 1.00 and the output score represents a percent of an unaltered condition. For example, 0.50 represents 50% of an unaltered condition. However, if only hydrology, hydraulics, and geomorphology functional categories are assessed, the maximum possible output score is a 0.60.
- The overall score output by the SQT is related to stream size (Strahler stream order) and flow type (perennial, intermittent, and ephemeral) to potentially match impacted stream types to mitigation stream types. Additional matches can be made by comparing the input and stratification tables between two sites.

- The SQT does not quantitatively score 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 (Chapter 4). The SQT assesses watershed condition qualitatively.
- The SQT is a reach corridor assessment tool that assesses the stream channel, adjacent floodplain, riparian buffer extent, and the lateral drainage area. The SQT is not solely an in-channel assessment method even though the unit of measure is stream feet (linear feet).
- Functional feet are calculated by multiplying the unit of measure (stream feet) by the overall condition score. The unit of measure provides scale to the overall condition score, an otherwise unit-less measure. A scale is necessary for debit and credit determination.
- The SQT is not a design tool, but design alternatives can be modeled in the SQT to determine and compare potential functional lift *outcomes*. The SQT assesses the *outcome of a design* by measuring the hydrology, hydraulic, geomorphological, physicochemical, and biological responses related to reach-scale practices. However, function-based parameters and analyses critical to a successful restoration design may or may not be included in the SQT assessment.
- Reference curves in the SQT are distinct from performance standards. Reference curves describe functional capacity relative to pristine, unaltered resources. Performance standards are observable or measurable physical, chemical, and/or biological attributes used to determine if a compensatory mitigation project meets its objectives (USACE & USEPA, 2008). Reference curves in the SQT can serve as performance standards, but not vice versa, because performance standards may not necessarily relate to reference condition. Furthermore, regulatory agencies may require additional performance standards beyond standards used in the SQT.

1.4. Downloading and Revising the SQT

The SC SQT can be downloaded from the SC Department of Natural Resources (https://www.dnr.sc.gov/environmental/streamrestoration.html).

The following spreadsheets and documents are available:

- SC SQT workbook – Microsoft Excel workbook described in this User Manual.
- SC SQT Spreadsheet User Manual – This manual. Describes the calculations performed by the SC SQT workbook and how to use the workbook for stream restoration projects.
- SC SQT Data Collection and Analysis Manual – Describes how to collect and process data and calculate input for the SC SQT.
- SC Debit Calculator workbook – Microsoft Excel workbook used to calculate debits.
- SC Debit Calculator Manual – Describes method options for data collection and data entry into the Debit Calculator.

Supporting information can be found at the Stream Mechanics webpage (https://stream-mechanics.com/), including other state SQTs, the Debit Tool White Paper, the Stream Functions Pyramid diagram, *A Function-Based Framework for Stream Assessment and Restoration Projects* (Harman et al., 2012), and new function-based parameters with metrics and reference curves (not included in Harman et al. [2012]). 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.

The SC SQT will be updated and revised periodically as additional data are gathered and reference curves and metrics are refined. Field data supporting refinement of reference curves and evaluation of metrics are appreciated. The 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 to DNR. The written proposal should include a justification and rationale (e.g., data sources and/or literature references) and should follow the Streams Functions Pyramid Framework for identifying reference curves, threshold values, and index scores.

Chapter 2. Introduction

The SQT is a Microsoft Excel workbook used to quantify functional lift and loss. The SQT builds on the Stream Functions Pyramid Framework (Harman et al., 2012), which uses function-based parameters and metrics to assess five functional categories: hydrology, hydraulics, geomorphology, physicochemical, and biology. These terms are described in Section 2.1, followed by an introduction to the SQT (Section 2.2).

The SC SQT includes 28 total metrics[2] within 14 parameters that can be evaluated at a project reach. A basic suite of metrics within 7 parameters are required at all project sites to allow for more consistent accounting of functional change.

2.1. Stream Functions Pyramid Framework (SFPF)

The Stream Functions Pyramid includes five functional categories: Level 1: Hydrology, Level 2: Hydraulics, Level 3: Geomorphology, Level 4: Physicochemical, and Level 5: Biology (Figure 1). The Pyramid is based on the premise that lower-level functions support higher-level functions and that they are all influenced by local geology, climate, and land uses. 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* depicts a hierarchy of stream functions but does not provide a specific mechanism for addressing functional capacity, establishing reference curves, or communicating functional change. The diagram in Figure 2 expands the Pyramid concept into a more detailed framework to quantify functional capacity, establish reference curves, show functional change, and establish function-based goals and objectives.

[2] An additional metric is provided in the monitoring section that is not used for scoring. Refer to Section 6.4.

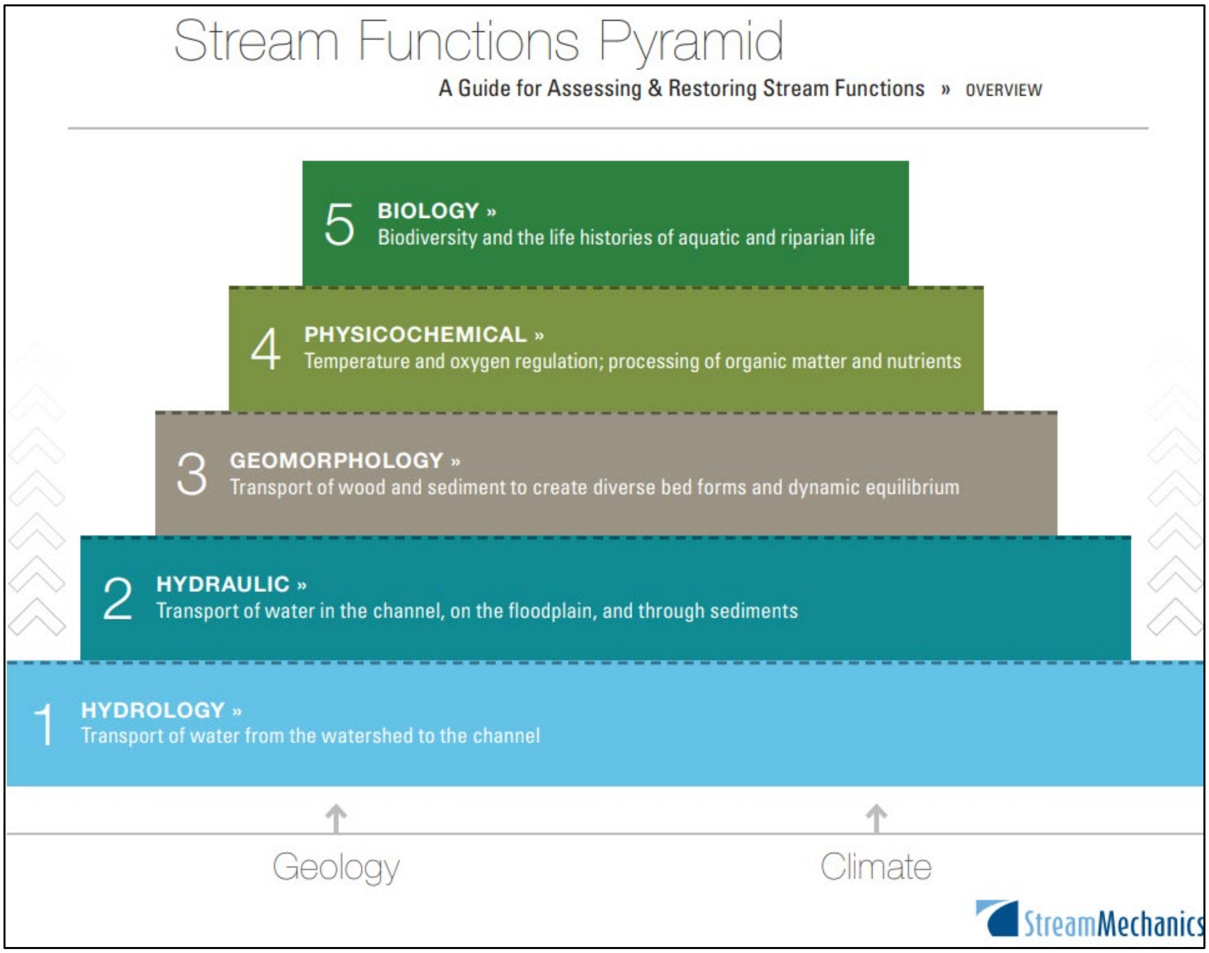


Figure 1. Stream Functions Pyramid

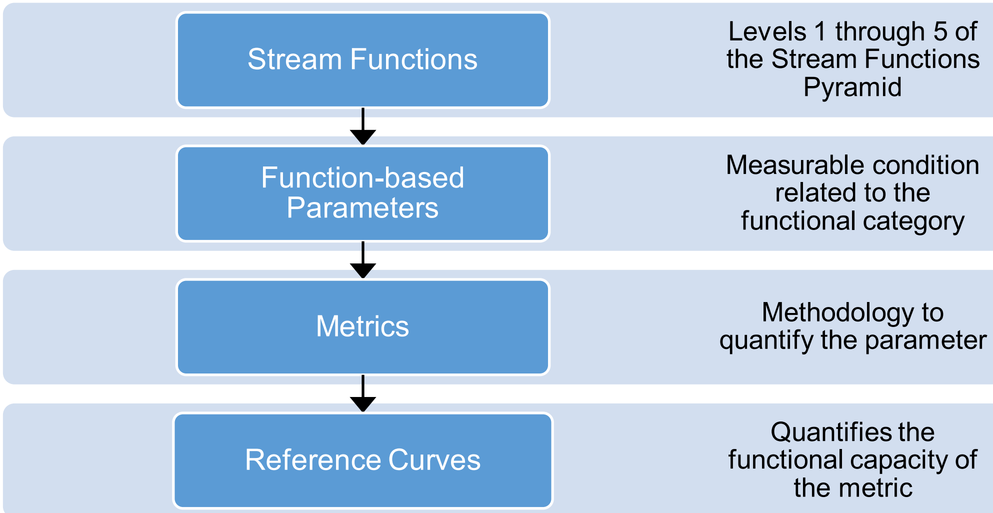


Figure 2. Stream Functions Pyramid Framework

The Stream Functions block shown at the top of Figure 2 represents the five levels of the Stream Functions Pyramid. 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 (known as measurement methods in Harman et al., 2012) 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 curves (known as performance standards in Harman et al., 2012) relate measurable or observable end points of stream restoration to functional capacity compared to a reference condition.

2.2. South Carolina Stream Quantification Tool (SC SQT)

The SQT includes a sub-set of function-based parameters and metrics listed in Harman et al. (2012). Additionally, the SC SQT includes new parameters and metrics identified during the development and regionalization process which are relevant to the stream systems found within the state of South Carolina. The SC SQT workbook includes five visible spreadsheets and one hidden spreadsheet. There are no macros in the spreadsheet and all formulas are visible, but spreadsheets are locked to prevent editing.

The spreadsheets include:

1. Project Summary
2. Catchment Assessment
3. Parameter and Metric Selection
4. Quantification_Tool
5. Reference Curves
6. Pull Down Notes – This spreadsheet is hidden and contains all the inputs for drop-down menus throughout the workbook.

> The user can make copies of the Catchment Assessment and Quantification_Tool spreadsheets to capture multiple streams and reaches within a project area.

This chapter describes each of the visible spreadsheets in detail. The user can make copies of the Catchment Assessment and Quantification_Tool spreadsheets to capture multiple streams and reaches within a project area.

Metrics selected for the SQT are structural or compositional attributes that indicate condition at a given point-in-time. Thus, metrics are surrogates for stream functions (USACE & USEPA, 2008). Parameters are "function-based" because they are described by metrics that are indicators, rather than direct measures, of function. Function-based parameters are assigned to the singular functional category which they describe to help understand the overall function. For example, bed form diversity is a partial surrogate for sediment transport processes, so it contributes to the overall understanding of geomorphic function. Bed form diversity is NOT a surrogate for the biology functional category.

Each metric is linked to reference curves that relate measured field values to a regional reference condition. A field value for a metric is assigned an index value (0.00 – 1.00) using the applicable reference curve. 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 or thresholds that represent the degree to which the aquatic resources are functioning and/or the degree to which stream condition departs from reference condition. However, a single functioning metric, out of several metrics, may not mean that the function-based parameter or a particular stream process is functioning. For example, bed form diversity is a function-based parameter described by pool spacing, pool depth, and percent riffle metrics. Understanding how each metric result contributes to the overall bed form condition is more important than a single metric result. A functioning bed form diversity score describes a reach with an appropriate pool spacing, good variability in pool depth, and an appropriate split of riffles and pools.

Calculating Change in Condition

It is important to remember the SQT compares 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 Curves

Functional Capacity	Definition	Index Score Range
Functioning (F)	A functioning value means that the metric is quantifying the functional capacity of one aspect of a function-based parameter in a way that **fully supports aquatic ecosystem structure and function**. The reference condition 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 high-quality reference datasets and the potential for these datasets to include minimally and least disturbed sites.	0.70 to 1.00
Functioning-at-risk (FAR)	A functioning-at-risk value means that the metric is quantifying one aspect of a function-based parameter in a way that **may support aquatic ecosystem structure and function**, but not at a reference condition. 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 (NF)	A not functioning value means that the metric is quantifying or describing one aspect of a function-based parameter in a way that **does not support aquatic ecosystem structure and function**. An index value less than 0.30 represents an impaired or severely altered condition relative to reference condition; an index value of 0.00 represents a condition that provides no functional capacity for that metric.	0.00 to <0.30

2.3. SC SQT Stream Restoration Process

The typical process for stream restoration projects is outlined in Table 2. Site selection is briefly discussed in this section and the remainder of this manual describes the rest of the process in detail.

Table 2. Typical Restoration Process Using the SQT

Phase and Task(s)	Associated Spreadsheets in the SC SQT
Site Selection based on Programmatic Goals	
Identify programmatic goals. Perform search for sites that could meet these goals (Section 2.3.1).	Project Summary
Delineate the project area(s) and determine project reaches (Section 2.3.2).	Project Summary
Assess catchment(s) to understand watershed context and potential constraints.	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 (final) quality.	Quantification_Tool
Project Initiation	
Verify reach breaks (refer to Data Collection and Analysis Manual). Set function-based goals and quantifiable objectives for each reach.	Project Summary
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. Coordinate with any regulating agencies for final parameter and metric selection.	Parameter and Metric Selection
Collect additional data to characterize the existing condition.	Quantification_Tool
Design	
Evaluate the proposed condition based on the proposed design or compare design alternatives. The SQT is not a design tool. However, design alternatives can be modeled in the SQT to identify and select the restoration design that will result in the greatest functional lift while meeting project constraints. (Practitioners should not assume that a 1.00 can be achieved for each metric. This would mean that an unaltered or pristine stream is being restored, which is generally not possible.)	Quantification_Tool
Monitoring	
Collect as-built and monitoring data to characterize post-project condition.	Quantification_Tool

Phase and Task(s)	Associated Spreadsheets in the SC SQT
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.	Quantification_Tool

2.3.1. PROGRAMMATIC GOALS AND SITE SELECTION

Programmatic goals are bigger-picture goals that are often independent of the project site, and generally relate to the project's funding source. For example, a programmatic goal might be to create mitigation credits. Where the programmatic goals include biological and physicochemical lift, identifying site(s) that can meet these goals are instrumental to project success. Programmatic goals are recorded and explained on the Project Summary spreadsheet within the SQT (Chapter 3).

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 based on rapid methods 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.

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. 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, flow dynamics, 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. Guidance on how to select function-based parameters is included in Chapter 5.

2.3.2. REACH SEGMENTATION

The SQT is a reach corridor assessment method where each reach is evaluated separately. Since stream condition or character can vary widely from the upstream end of a project area to the downstream end, a large project may be subdivided into multiple reaches. **Each project reach will require its own Quantification_Tool spreadsheet** (Chapter 6). The Quantification_Tool spreadsheet can be copied, renamed, and results summarized in the Project Summary spreadsheet (Chapter 3).

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), process drivers, 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, National Hydrography Dataset (NHD)[3] and other desktop tools to preliminarily determine reach breaks; these delineations will 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 Summary section of the Project Summary spreadsheet.**

[3] https://www.usgs.gov/core-science-systems/ngp/national-hydrography

Chapter 3. Project Summary Spreadsheet

The purpose of the Project Summary spreadsheet is to identify and describe the reaches within a project area and communicate the purpose of the project. Cells that allow input are shaded and all other cells are locked.

Programmatic Goals – The programmatic goals relate to the funding source of the project. These are broader, overarching goals that are often independent of the project site. Select Mitigation – Credits, Mitigation – Debits, TMDL, Grant, or Other from the drop-down menu. Space is provided for the user to expand on the programmatic goals of the project.

Project Description – Enter the following information, if applicable:

- Project name,
- Project ID (e.g., SAC),
- Ecoregion,
- River Basin, and
- 12-digit U.S. Geological Survey Hydrologic Unit Code (HUC).

Reach Summary – This table automatically populates the Reach ID, existing condition score (ECS), proposed condition score (PCS), and ∆FF from the Quantification_Tool spreadsheet(s) in the workbook.

Space is provided to describe each reach and the characteristics that separate it from the other reaches in the project.

The SC SQT v1.1 is a project- or stream-based workbook and copies of the Quantification_Tool spreadsheet can be made for every reach on a stream or within a project area. The Quantification_Tool spreadsheet can be renamed. **The spreadsheet title must not include spaces and must be entered as an exact match into column A.** Row 19 is hidden because it contains pointers to cells on the other spreadsheets.

Aerial Photograph of Project Area – Provide an aerial photograph of the project area. The photo could include labels indicating where work is proposed, the project easement, project reaches and any important features within the project site or catchment.

Chapter 4. Catchment Assessment Spreadsheet

The purpose of the Catchment Assessment in the SQT workbook is to assist in determining the restoration potential of the project reach. 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). Restoration potential is determined using a stepwise process described in Section 4.1. Components important to determining restoration potential are described in detail in the following sections.

Restoration potential definitions are provided below:

- Full Restoration Potential – The project reach has the potential to *restore functions within all five Pyramid levels back to a reference condition.*[4] Reference condition reflects the least disturbed aquatic resources, in a given class of resource, and the highest levels of functions exhibited by that class (USACE & USEPA, 2008). 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 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.

For example, watershed processes and reach-scale constraints influencing a project site are often functioning at a level where some functions/conditions, such as floodplain connectivity, channel stability (dynamic equilibrium) and in-stream habitat can be restored, but watershed and reach-scale processes may be limiting the ability to restore some or all ecological functions, i.e., restoration of physicochemical or biological functions to a reference condition. Improvements in all five Pyramid levels may be observed during monitoring, but these improvements may not reflect a reference condition for biological integrity (Stoddard et al., 2006).

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 these factors 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 appropriate for restoration.

[4] Intermittent streams will only be assessed through the Geomorphology Functional Category.

4.1. Stepwise Approach to Determining Restoration Potential

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

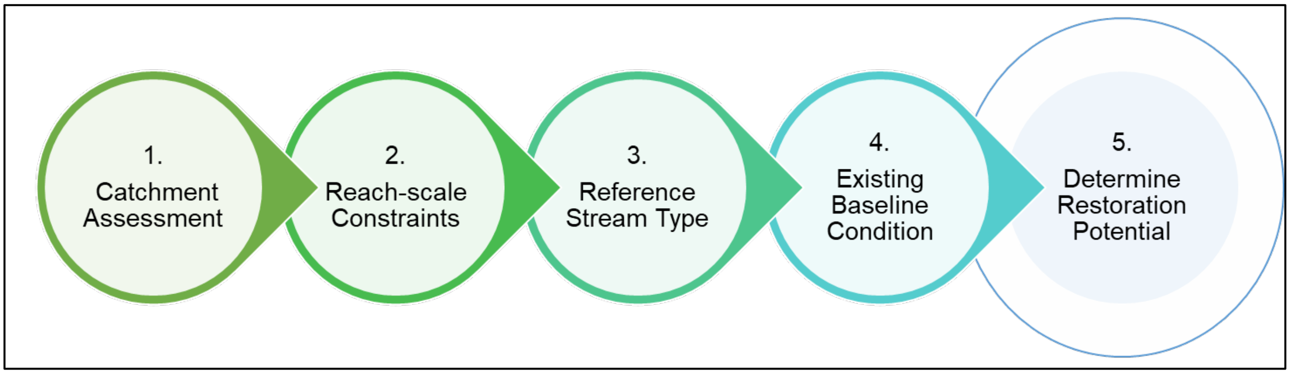


Figure 3. Stepwise approach for determining restoration potential.

1. Complete the Catchment Assessment spreadsheet 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 viable candidate for stream restoration activities unless catchment-scale stressors can be improved. This information is entered into the Catchment Assessment spreadsheet.

   At the reach scale, users should consider several factors, including the scale of the restoration project in relation to the watershed. Compare the reach size to the catchment size (length and/or area). Can the scale and type of restoration overcome the catchment stressors? 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, hillslopes are a natural condition of the catchment and not a constraint, as defined here. Additionally, 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. For stream restoration projects, each stream reach will have four stream types to consider: existing, design, proposed, and reference. Each of these stream type characterizations provides information on the project reach and could inform the restoration potential determination, project goals and objectives, and reach-specific performance standards. Existing stream type reflects the Rosgen stream type before impact or restoration activities. The design stream type reflects the channel dimension, pattern, and profile that will be constructed as part of the project design. Therefore, it is also the as-built stream type. Proposed stream type is the restoration target at the end of monitoring/project closeout. (Note, there are times where the design stream type and proposed stream type may be the same.) Reference stream type represents the dimension, pattern, and profile that would naturally occur in a specific landscape setting given the hydrogeomorphic watershed- and reach-scale processes. Reference stream type is used to stratify reference curves for the entrenchment ratio, pool spacing ratio, pool depth ratio, and percent riffle metrics. This stream type may or may not be the same as design and proposed stream types.

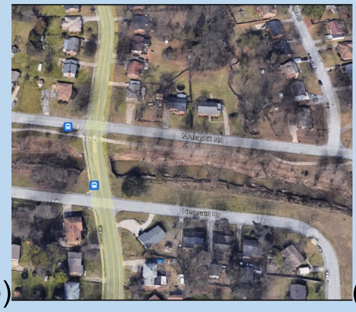
   Selecting the reference stream type requires users have experience and knowledge about channel evolution, process drivers and the Rosgen stream classification system.

   a. Characterize the current condition of the stream and evaluate the process drivers (Castro and Thorne, 2019).
   b. Determine the current and future potential Stream Evolution Model (SEM) (Cluer and Thorne, 2013), if applicable, and the Rosgen Channel Succession Scenario (Rosgen, 2006). Is the stream trending towards greater or lesser functionality? What is the realistic final SEM stage and Rosgen stream type as compared to the previously undisturbed SEM stage or stream type?
   c. Users should then consider whether the proposed project has the potential to restore the reach to the reference stream type identified. This process results in 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 (Example 1).

4. Use the Quantification_Tool spreadsheet to determine the baseline condition of the reach. The Quantification_Tool spreadsheet will characterize existing functional capacity by parameter and functional category. Refer to the parameter and metric selection guidance in Chapter 5 of this manual and the Data Collection and Analysis 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 condition and which may not. This information is entered in the Quantification_Tool spreadsheet.

The process drivers (Castro and Thorne, 2019), SEM (Cluer and Thorne, 2013), and 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.

Example 1: Determining Stream Types

(a)  (b)  (c) 

Existing Stream Type = F4 (Figure a). This stream is in an urban setting, and is incised and entrenched but with a high bankfull width/depth ratio.

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

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

The SQT requires the user to determine the restoration potential for each project reach. Restoration potential can be used for a variety of applications, including:

- Clear communication of project goals and 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 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 4.3.
- 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 must monitor physicochemical and biology parameters. 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 monitor physicochemical and biology functions due to the potential for further watershed impairment external to the project.

- Assisting with alternatives analysis – The process of evaluating restoration potential can help develop 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.
- 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.

4.2. Catchment Assessment

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 (Table 3). 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 integrity. 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 spreadsheet is provided in the Data Collection and Analysis Manual.

The data collected in the Catchment Assessment will be similar or identical for separate reaches along the same stream. There is space at the top of the spreadsheet to record the reach IDs for all reaches for which the completed form is applicable. Copies can be made of the Catchment Assessment spreadsheet if the project area consists of multiple streams. Cells that allow input are shaded and all other cells are locked.

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. The Overall Catchment Condition is determined by interpreting the results using best professional judgement. The Overall Catchment Condition is not automatically scored.

Table 3. Catchment Assessment Categories

Categories (Functional Category Affected)		Descriptions
1	Concentrated Flow	Potential for concentrated flow/impairments to project area.
2	Impervious Cover	Percent of catchment that is impervious surface upstream of the project area.
3	Urbanization	Potential for land use change based on proximity to urban centers.
4	Development Activities	Proximity of existing or planned development activities near the project site (e.g., utility rights-of-way, pipeline, mining, silviculture, roads, etc.).
5	Percent Forested	Percent of catchment that is forested upstream of the project area.
6	Riparian Vegetation	Presence of riparian corridors on streams contributing to the project area.
7	Sediment Supply	Potential sediment supply from upstream bank erosion and surface runoff.
8	Proximity to 303(d) or TMDL listed waters	Proximity of site to 303(d) listed streams and whether the listed streams have a TMDL or Watershed management plan.
9	Agricultural Land Use	Livestock access to stream and/or intensive cropland in the catchment likely to impact conditions in the project area.
10	NPDES Permits	Proximity of NPDES permits to the project area and quantity within the upstream catchment.
11	Inline Watershed Impoundments	Proximity of impoundments and impact on project area and fish passage.
12	Organism Recruitment	Condition of channel bed and bank immediately upstream and downstream of the project area.
13	Other	Choose your own.

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 sediment supply in a stream impacted by upstream silviculture operations could indicate there is little potential for biological lift even if the other categories exhibited a good condition. Table 4 shows how the catchment assessment can be used to help determine restoration potential.

Table 4. Connecting Catchment Condition and Restoration Potential

Restoration Potential	Results from Catchment Assessment
Full	Overall Score = 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]	Overall Score = Poor to Fair. The catchment will have hydrology impairments from runoff entering the project reach from adjacent sources, e.g., parking lots or heavy use areas. Stormwater control measures (SCMs) and agricultural best management practices (BMPs) can be used to reduce runoff and nutrient levels to reference condition at a sub-catchment scale (catchment draining to the SCM or BMP).
Partial [Goals focus on geomorphology improvements]	Overall Score = Poor to Fair. Catchment integrity 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, but 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	It is possible to have a catchment integrity score so low that reach-scale restoration is unattainable. This scenario is dependent on the catchment score as well as the reach length, reach condition, and constraints.

4.3. Function-Based Design Goals and Objectives

Function-based design goals and objectives can be developed once the restoration potential is determined. Design goals are statements about *why* the project is needed at the specific project site. Goals are general intentions and often cannot be validated. (Note: design goals are different than programmatic goals, which generally relate to the project's purpose or funding source [Section 2.3.1]). Design objectives are more specific; they help explain *how* the project will be completed. Objectives are tangible and can be validated, typically by performance standards.

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 no expectation to return biology to a reference condition**. However, minor to moderate improvements in biology are possible if the watershed perturbations and stressors are not egregious.

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 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 addressing functional lift at the parameter level.)
- 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 quantitative objective that addresses functional lift at the metric level. Values used to quantify metric improvement are derived from the performance standard and/or reference condition used in monitoring.)

This process can be followed for other function-based parameters and metrics. Document the design goals and objectives in the Quantification_Tool spreadsheet for each project reach. Then, compare the design goals to the restoration potential to ensure that the goals do not exceed the restoration potential. For example, a site with a partial restoration potential that proposes to improve floodplain connectivity, and aquatic and floodplain habitat using several beaver dam analogs. The proposed restoration activities fall under hydraulic and geomorphology goals, which match the site's partial restoration potential. For this project, the beaver dam analogs are expected to promote sediment deposition, provide aquatic habitat in-stream and on the floodplain, and enhance in-stream nutrient processing, helping to improve physicochemical functions. As a result, this restoration project may improve the biomass of fish, birds, and other fauna on-site, but is not expected to restore biological conditions to reference conditions given watershed stressors. If catchment-level improvements are implemented, over time, the restoration potential could shift from partial to full. However, this requires reach-scale *and* catchment-scale restoration.

Chapter 5. Parameter and Metric Selection Spreadsheet

The SC SQT includes 28 metrics[5] used to quantify 14 parameters. Not all metrics and parameters will be evaluated at each site. The user should consider landscape setting, function-based goals/objectives, and restoration potential when selecting parameters. Guidance on parameter selection is summarized in the Parameter and Metric Selection spreadsheet within the SQT workbook.

Practitioners are not allowed to selectively choose parameters to maximize functional lift. For example, a practitioner cannot obtain functional lift in riparian vegetation by planting a riparian buffer when the channel is incised and actively eroding the bed and/or banks. To ensure successful restoration by following the Stream Functions Pyramid Framework, the SQT requires assessment of certain parameters.

The following seven parameters, spanning the hydrology, hydraulics, and geomorphology functional categories, are required for all reaches throughout South Carolina where applicable:

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

To ensure some functional lift from restoration, it is recommended that **ALL** projects bring floodplain connectivity, flow dynamics, lateral migration, and bed form diversity to a functioning condition at the end of the project.[6] These parameters can show improvement during a typical monitoring period of five to seven years. Other parameters, like riparian vegetation or reach runoff, may take more time to improve or can be difficult to improve with reach-scale restoration depending on the size of the project. Restoration sites with newly planted trees will not achieve a functioning score within the typical five- to seven-year monitoring period, but it is possible to achieve a score well within the functioning-at-risk category (e.g., 0.60), by the end of the monitoring period.

Important Considerations:

- For a project reach, the same parameters and metrics must be assessed in the existing condition, proposed condition, as-built, and monitoring assessments to maintain the relative weighting between metrics and parameters. If not, overall scores are not comparable over time.
- The overall scores of project sites assessed with different parameters and metrics cannot be compared between sites. To compare results across multiple sites, the same suite of parameters and metrics must be measured to ensure a sound comparison.
- Metrics not selected (where a field value is not entered) are excluded from scoring. They are NOT counted as zeroes.

[5] An additional metric is provided in the monitoring section that is not used for scoring. Refer to Section 6.4.
[6] Where these parameters are applicable.

5.1. Parameter and Metric Selection

Information on parameter and metric selection is presented below by functional category and function-based parameter. Note that a basic suite of metrics within seven parameters are required at all project sites to allow for more consistent accounting of functional change. The basic suite includes metrics in the following parameters: reach runoff, floodplain connectivity, flow dynamics, large woody debris, lateral migration, bed form diversity, and riparian vegetation.

Hydrology

Reach Runoff Parameter: This parameter should be evaluated at all project reaches and both the land use coefficient and concentrated flow points metrics should be evaluated together. Land use coefficient characterizes the hydrologic processes altered by changing natural vegetated land covers to managed or urban land uses. Concentrated flow point characterizes accelerated drainage of the surrounding landscape to the project reach.

Hydraulics

Floodplain Connectivity Parameter: This parameter should be evaluated at all project reaches. Users must evaluate both the bank height ratio (BHR) and entrenchment ratio (ER) metrics. It is recommended to use ER in combination with BHR. ER characterizes the horizontal extent of the floodplain while BHR characterizes the frequency of floodplain inundation. The only exception to this relationship is in multi-thread systems where the ER is not applicable and only the BHR should be applied.

Flow Dynamics Parameter: Width/depth (W/D) ratio state is required for all single-thread channels. W/D ratio state indicates flow dynamics against the stream bed and banks by characterizing channel shape compared to reference condition. The metric used to characterize this parameter is applicable for all single-thread perennial and intermittent project reaches.

Geomorphology

Large Woody Debris (LWD) Parameter: This parameter should be evaluated at all project reaches. Users can evaluate either the Large Woody Debris Index (LWDI) or large wood piece count metric, but not both. The LWDI metric better characterizes the complexity of large wood in streams but takes more time to assess.

Lateral Migration Parameter: This parameter should be evaluated at all project reaches. However, this parameter should not be assessed for systems naturally in disequilibrium (e.g., some braided streams, ephemeral channels, and alluvial fans or other systems with naturally high rates of bank erosion). Users must evaluate the dominant Bank Erosion Hazard Index/Near-bank Stress (BEHI/NBS) and percent streambank 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. Percent streambank erosion and dominant BEHI/NBS are measured in single-thread channels.

- The erosion rate metric is measured in substitute of dominant BEHI/NBS and percent streambank erosion.

- The percent streambank armoring metric should be used in addition to the other metrics **only** when armoring techniques are present or proposed in the project reach.

Riparian Vegetation Parameter: This parameter should be evaluated at all project reaches. The three metrics measured at each project reach are buffer width, average diameter at breast height (DBH), and tree density. Invasive/non-native cover should be reported for all project reaches during monitoring although this metric is not scored. **In addition** to those metrics, practitioners should also use the following metrics:

- Native shrub density (number/acre) IF the riparian vegetation community consists of pastureland, cropland, or other land uses without existing trees (i.e., canopy cover at project closeout will be < 20%).
- Native herbaceous cover (%) IF the area adjacent to the project reach is or should be a Piedmont prairie vegetation community.
- Monoculture area (%) IF silviculture operations are present within the conservation easement, the mitigation boundary, and/or adjacent to the project reach.

Bed Form Diversity Parameter: This parameter should be evaluated at all single-thread perennial and intermittent project reaches. Bed form diversity should not be assessed in multi-thread channels, bedrock streams, or naturally straight sand-bed channels where the bedforms are created by large wood. Users must evaluate the following metrics together: pool spacing ratio, pool depth ratio, and percent riffle. Together these metrics characterize the relative amount of pool and riffle habitat, relative depth of pools, and spacing of pools for energy dissipation and complexity.

Physicochemical

Temperature, Bacteria, Nitrogen, Phosphorus, and Suspended Sediment Parameters: These parameters are optional for restoration projects, but recommended for **wadeable, perennial** stream projects with goals and objectives related to water quality improvements or where improvements to these parameters are anticipated based on restoration potential. These parameters are also highly recommended for project reaches proposed for preservation credits. Please note that the physicochemical functional category only applies to perennial streams. One or more parameters can be applied at a project reach, and notes regarding the temperature and suspended solids parameters are listed below:

- Temperature is only applicable to **perennial coldwater** streams and is recommended for streams that are designated Trout (Natural; Put, Grow, and Take; and Put and Take) streams under S.C. Code of Regulation 61-69 (DHEC, 2020).
- SC SQT users have the option of selecting either the Turbidity or Total Suspended Solids (TSS) metric for Suspended Sediment, but not both. If measuring through the Biology Functional Category, the suspended sediment parameter must be measured.

Biology

It is recommended that where applicable, the macroinvertebrates and fish parameters be assessed together, and if measuring through biology, the suspended sediment parameter must also be measured. Please note that the biology functional category only applies to perennial streams. As with the parameters for physicochemical, it is recommended that biology be assessed for project reaches proposed for preservation credits.

Macroinvertebrates Parameter: The macroinvertebrate parameter is optional and recommended for wadeable perennial stream projects with goals and objectives related to biological improvements or where improvements in biological condition are anticipated based on restoration potential or the length of stream being restored.

- This metric is only applicable to **perennial streams with drainage areas 3 square miles (approximately 7 square kilometers) or larger.**

Fish Parameter: The Fish parameter is optional and recommended for wadeable perennial stream projects with goals and objectives related to biological improvements or where improvements in biological condition are anticipated based on restoration potential or the length of stream being restored.

- This metric is restricted to **perennial streams with drainage areas between 1.5 square miles and 63 square miles (approximately 4 square kilometers and approximately 165 square kilometers respectively)**.

The parameter selection process for an example project is presented in Example 2.

Example 2: Parameter Selection

Consider a typical partial restoration potential project in a pastureland setting. The catchment is small and consists mostly of rural and agricultural land uses. The overall catchment assessment is fair, but stressors would not preclude some physicochemical and biological lift. The project goals are habitat improvement for native fish and reducing sediment supply from eroding banks. The work will 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 consist of:

- Reach runoff
- Floodplain connectivity (Must be brought to a functioning condition)
- Flow dynamics (Must be brought to functioning condition)
- Large woody debris
- Lateral migration (Must be brought to a functioning condition)
- Riparian vegetation (Must be brought to well within functioning-at-risk category, e.g., near 0.6)
- Bed form diversity (Must be brought to a functioning condition)
- Bacteria*
- Suspended Sediment**
- Macroinvertebrates*
- Fish*

*While the project only has partial restoration potential, there is monitoring of physicochemical and biology functions. The bacteria parameter is included because cows have access to the stream channel. Keeping the cattle out of this reach is likely to provide physicochemical lift via reduced *E. coli*. The macroinvertebrates and fish are being monitored because the practitioner expects that one or both parameters will exhibit some improvement. This would contribute more functional lift to the restoration project; however, the project is not expected to return the integrity of macroinvertebrate and fish communities back to a reference condition.

**Suspended sediment is required for projects that assess through biology

Chapter 6. Quantification_Tool Spreadsheet

The Quantification_Tool spreadsheet is the main sheet in the SC SQT Excel workbook. It is the calculator where functional lift or loss is determined by users entering data quantifying the existing and proposed conditions of the project reach. This spreadsheet also provides an as-built condition assessment and entry for up to 10 monitoring assessments. Cells that allow input are shaded and all other cells are locked.

The SQT is a reach corridor assessment and requires one Quantification_Tool spreadsheet for each reach. The user can duplicate this spreadsheet when the project area contains multiple reaches. This spreadsheet can be renamed to identify the project reach ID. **The spreadsheet title cannot contain spaces and the exact text string must be entered into the Project Summary spreadsheet to populate results in the Reach Summary table.**

The Quantification_Tool spreadsheet requires data entry in four areas:

- Goals and objectives;
- Site information and reference curve stratification;
- Existing and proposed condition assessments; and
- Monitoring condition assessments.

There is also space on the Quantification_Tool spreadsheet to explain the restoration potential of the reach based on programmatic goals and the catchment assessment results. Each section of the spreadsheet is discussed below.

6.1. Site Information and Reference Curve Stratification

The Site Information and Reference Curve Stratification section is shown in Figure 4. Users input values into the gray cells and select inputs from the drop-down menus in the blue cells. White cells within this section are locked from editing and the input is provided by the user on another spreadsheet. Instructions for collecting data to populate this section are provided in the Data Collection and Analysis Manual.

Site Information and Reference Curve Stratification	
Project Name:	Example Project
Reach ID:	UT1
Restoration Potential:	Partial
Preservation (Y/N):	No
Ecoregion:	Blue Ridge Mountains
River Basin:	Savannah
Existing Stream Length (ft):	1400
Proposed Stream Length (ft):	1500
Existing Stream Type:	G
Reference Stream Type:	Bc
Valley Type:	Confined Alluvial
Drainage Area (sq. mi.):	1.5
Stream Slope (%):	0.5
Strahler Stream Order:	Second
Flow Type:	Perennial
Proposed Bed Material:	Gravel
Buffer Valley Slope (%):	5 - 20 %
Dominant Buffer Land Use:	Commercial / Golf Course / Agriculture / Silviculture
Proposed Canopy Cover (%) at project closeout:	> 20 %
Stream Temperature:	Coldwater
Fish Bioassessment Class:	2 - Upland Savannah

Figure 4. Site Information and Reference Curve Stratification Input Fields

Many of the fields in this section are linked to the selection of parameters, metrics, and reference curves. Where reference curves for a metric are stratified, the index value calculation cells will use the input provided in this section to select the appropriate reference curves. The reference curve stratification for each metric is summarized in Appendix A. Note that incorrect information in the Site Information and Reference Curve Stratification section may result in applying reference curves that are not suitable for the project, effecting site scoring.

6.2. Scoring Functional Change (Lift or Loss)

Scoring occurs automatically as field values are entered into the condition assessments (e.g., existing, proposed, and monitoring described in Sections 6.3 and 6.4). A field value in the SQT is a measurement or calculation input for a specific metric and units vary based on the metric used. The SQT uses a roll-up scoring process as follows:

- A field value corresponds to an index value ranging from 0.00 to 1.00 for that metric.
- Where more than one metric is used per parameter, these index values are averaged to calculate parameter scores.
- Similarly, multiple parameter scores within a functional category are averaged to calculate functional category scores.

- Functional category scores are weighted and summed to calculate an overall condition score.
- The change in functional condition is the difference between proposed and existing overall condition scores.

Elements of the roll-up scoring process and tips are detailed below.

Index Values: Reference curves, which translate a field value into an index value for each metric, are visible in the Reference Curves spreadsheet and summarized in Appendix A. When a field value is entered for a metric on the Quantification_Tool spreadsheet an index value between 0.00 and 1.00 is assigned to the field value (Figure 5). **Chapter 7 provides more detail on how index values are calculated in this spreadsheet.**

Metric	Field Value	Index Value
Land Use Coefficient	60	0.78
Concentrated Flow Points (#/1000 LF)	1.8	0.46

Figure 5. Index Values automatically populate when Field Values are entered.

Tip: When a field value is entered, the neighboring index value cell checks the data in the Site Information and Reference Curve Stratification section and either returns an index value based on the appropriate reference curve or returns FALSE. A FALSE is returned when:

- Data are missing from the Site Information and Reference Curve Stratification section (Figure 6).
- Reference curves do not exist for the selected input. For example, the summer daily maximum temperature metric only has reference curves for coldwater streams. If the project reach classifies as warmwater, then the field value will return FALSE.

Metric	Field Value	Index Value
Pool Spacing Ratio	3.4	FALSE
Pool Depth Ratio	1.8	FALSE
Percent Riffle (%)	40	0.00

Figure 6. Index Value Errors

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

Roll-Up Scoring: Metric index values are averaged to calculate parameter scores; parameter scores are averaged to calculate category scores. For metrics that are not assessed (i.e., a field value is not entered), the metric is removed from the scoring and no index value is provided. It is NOT counted as a zero for the parameter score calculation.

- In the existing and proposed condition assessment areas of the spreadsheet, roll-up scoring occurs next to the field value inputs (Figure 7).
- In the post-project monitoring area of the Quantification_Tool spreadsheet, field values are entered into a single table (starting at row 59 in the spreadsheet), index values are calculated in a separate table (starting at row 90 in the spreadsheet), and parameter and functional category scores are calculated in separate tables below those (starting at rows 120 and 136 in the spreadsheet, respectively).

The category scores are then multiplied by 0.20 and summed to calculate overall condition scores.

- For the existing and proposed condition assessments, these overall reach scores are shown in the Functional Change Summary table at the top of the spreadsheet, next to the Site Information and Reference Curve Stratification section.
- For the post-project monitoring condition assessments, the overall reach scores are calculated in the functional category summary table (row 141 in the spreadsheet).

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 because the maximum overall condition score without monitoring these functional categories is 0.60.

Functional Category	Function-based Parameters	Metric	EXISTING CONDITION ASSESSMENT			
			Field Value	Index Value	Parameter	Category
Hydrology	Reach Runoff	Land Use Coefficient	60	0.78	0.89	0.89
		Concentrated Flow Points (#/1000 LF)	0	1.00		
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft)	1	1.00	0.85	0.93
		Entrenchment Ratio (ft/ft)	2.2	0.7		
	Flow Dynamics	Width/Depth Ratio State (O/E)	1	1.00	1.00	
Geomorphology	Large Woody Debris	LWD Index	500	0.82	0.82	0.64
		LWD Piece Count (#/100m)				
	Lateral Migration	Erosion Rate (ft/yr)			0.73	
		Dominant BEHI/NBS	M/L	0.60		
		Percent Streambank Erosion (%)	8	0.85		
		Percent Streambank Armoring (%)				
	Riparian Vegetation	Buffer Width (ft)	130	0.61	0.68	
		Average DBH (in)	4	0.43		
		Tree Density (#/acre)	150	1.00		
		Native Shrub Density (#/acre)				
		Native Herbaceous Cover (%)				
		Monoculture Area (%)				
	Bed Form Diversity	Pool Spacing Ratio (ft/ft)	0	0.00	0.35	
		Pool Depth Ratio (ft/ft)	3	1.00		
		Percent Riffle (%)	3	0.05		
Physicochemical	Temperature	Summer Daily Maximum (°F)	55	1.00	1.00	0.94
	Bacteria	E. Coli (MPN/100 ml)	70	0.88	0.88	
	Nitrogen	Total Nitrogen (mg/L)				
	Phosphorus	Total Phosphorus (mg/L)				
	Suspended Sediment	Total Suspended Solids (mg/L)				
		Turbidity (NTU)				
Biology	Macroinvertebrates	EPT Taxa Present				
	Fish	South Carolina Biotic Index				

Figure 7. Roll-up Scoring Example for the Existing Condition Assessment, resulting in functional category scores. This format is the same for the Proposed Condition Assessment.

The SQT's output only reflects the metrics that are measured. Thus, care must be taken to interpret the results. For example, while the SQT may report a functioning physicochemical score, but this may be because only temperature was monitored. There may be indicators in the catchment assessment to suggest that other parameters may be of concern in the stream.

Scoring Exceptions: There are three scoring exceptions in the SQT:

- For preservation reaches, field values should not be entered for the proposed condition assessment. The proposed condition score in the Functional Change Summary is automatically set equal to the existing condition score. Monitoring event field values can still be entered into the SQT and compared to the existing condition score.
- The width/depth ratio state metric captures problems associated with aggradation (width/depth is larger than reference value) and incision (width/depth is less than reference value). A width/depth that is smaller than the reference width/depth is only a problem if the channel is incised (as indicated by the BHR). Thus, when a field value less than 1 is entered into the SQT for the width/depth ratio state metric, the index value calculation will check whether the BHR is greater than 1.2. If BHR is greater than 1.2,

then the reference curve will be used to calculate the index value. If BHR is less than or equal to 1.2, then the reference curve is not used to compute the index value and instead, a 1.00 index value is assigned.

- The percent streambank armoring metric captures problems associated with hardened, streambank armoring techniques.[7] If present or proposed armoring techniques exceed 50% of the project reach, then the lateral migration parameter will score a 0.00 and the other lateral migration metrics (BEHI/NBS and percent streambank erosion) do not need to be assessed. At this magnitude, the armoring is so pervasive that lateral migration processes would likely have no functional value.

Functional Change: The Quantification_Tool spreadsheet summarizes the scoring at the top of the sheet, next to the Site Information and Reference Curve Stratification section. The Functional Change Summary (Figure 8) provides the overall scores from the Existing Condition Assessment and Proposed Condition Assessment sections, also referred to as the existing condition score (ECS) and proposed condition score (PCS).

FUNCTIONAL CHANGE SUMMARY	
Existing Condition Score (ECS)	0.40
Proposed Condition Score (PCS)	0.64
Change in Functional Condition (PCS - ECS)	0.24
Percent Condition Change	60%
Existing Stream Length (ft)	1400
Proposed Stream Length (ft)	1500
Additional Stream Length (ft)	100
Existing Functional Foot Score (FFS)	560.00
Proposed Functional Foot Score (FFS)	960.00
Proposed FFS - Existing FFS (∆FF)	**400 P2**
Functional Yield (∆FF/LF)	0.27

Figure 8. Functional Change Summary Example

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

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

The rest of the table calculates and communicates Functional Foot Scores (FFS). A 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.

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

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

[7] This metric should not be used if armoring is not present or proposed. It will result in inaccurate scoring.

A positive change in functional condition (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. A scoring qualifier is attached to the change in functional condition (ΔFF). The qualifier relates flow type (perennial, intermittent, and ephemeral) and stream size (Strahler stream order; Strahler, 1957) to the overall score to provide context for the ΔFF value generated (Figure 8 shows a perennial, second order stream indicated by the P2 following the ΔFF). This qualifier could be used to help match impacted stream types to mitigation stream types. Additional matches can be made by comparing the input and stratification tables between two sites.

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

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

Functional change is summarized at the parameter and functional category levels located at the bottom of the Quantification_Tool spreadsheet (Figure 9). These tables pull the existing and proposed scores from the relevant area of the spreadsheet and calculate the post-project monitoring parameter and functional category scores for a side-by-side comparison. Even though the SQT calculates an overall condition score for the reach, the SQT was developed primarily to calculate a change in condition resulting from reach-scale activities. As such, the most important output of the SQT is the difference between the existing and proposed conditions.

Tip: The overall condition scores themselves can only be interpreted by reviewing the parameter and functional category scores used to generate the overall condition scores. The parameter and functional category summary tables can be used to:

- Quickly determine if a parameter was not assessed for both the existing and proposed condition assessments;
- Quickly determine if any required parameters were omitted from the assessment; and to
- Analyze monitoring trends.

Functional Category	Function-Based Parameters	Existing Parameter	Proposed Parameter	As-Built	1
Hydrology	Reach Runoff	0.62	0.89	0.89	0.89
Hydraulics	Floodplain Connectivity	0.12	0.85	0.85	0.85
	Flow Dynamics	0.75	1.00	1.00	1.00
Geomorphology	Large Woody Debris	0.20	0.82	0.82	0.82
	Lateral Migration	0.29	0.95	0.95	0.95
	Riparian Vegetation	0.63	0.81	0.76	0.72
	Bed Form Diversity	0.83	0.93	0.93	0.95
Physicochemical	Temperature	0.37	0.43	0.37	0.40
	Bacteria				
	Nitrogen				
	Phosphorus				
	Suspended Sediment				
Biology	Macroinvertebrates				
	Fish				

Functional Category	ECS	PCS	As-Built	1
Hydrology	0.62	0.89	0.89	0.89
Hydraulics	0.43	0.93	0.93	0.93
Geomorphology	0.49	0.88	0.87	0.86
Physicochemical	0.37	0.43	0.37	0.40
Biology				
Reach Condition Score	0.38	0.63	0.61	0.62

Figure 9. Parameter and Functional Category Summary Example (Additional monitoring columns are provided in the SQT).

6.3. Existing and Proposed Condition Assessments

Immediately under the Site Information and Reference Curve Stratification section of the Quantification_Tool spreadsheet are the Existing and Proposed Condition Assessments. Metrics are listed by functional category and then parameter (Figure 10). 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 metric, which is selected from a drop-down.

Functional Category	Function-based Parameters	Metric
Hydrology	Reach Runoff	Land Use Coefficient Concentrated Flow Points (#/1000 LF)
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft) Entrenchment Ratio (ft/ft)
	Flow Dynamics	Width/Depth Ratio State (O/E)
Geomorphology	Large Woody Debris	LWD Index LWD Piece Count (#/100m)
	Lateral Migration	Erosion Rate (ft/yr) Dominant BEHI/NBS Percent Streambank Erosion (%) Percent Streambank Armoring (%)
	Riparian Vegetation	Buffer Width (ft) Average DBH (in) Tree Density (#/acre) Native Shrub Density (#/acre) Native Herbaceous Cover (%) Monoculture Area (%)
	Bed Form Diversity	Pool Spacing Ratio (ft/ft) Pool Depth Ratio (ft/ft) Percent Riffle (%)
Physicochemical	Temperature	Summer Daily Maximum (°F)
	Bacteria	E. Coli (MPN/100 ml)
	Nitrogen	Total Nitrogen (mg/L)
	Phosphorus	Total Phosphorus (mg/L)
	Suspended Sediment	Total Suspended Solids (mg/L) Turbidity (NTU)
Biology	Macroinvertebrates Fish	EPT Taxa Present South Carolina Biotic Index

Figure 10. Functional Category, Parameters, and Metrics in the SC SQT Existing and Proposed Condition Assessments.

<u>Existing Condition</u> – Existing condition field values are measured prior to any permitted impact or the implementation of restoration activities (e.g., grading or planting).

- 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 (e.g., Total Nitrogen), multiple sampling events will improve the accuracy of the field value used to calculate lift by quantifying inter- or intra-annual variability.

Proposed Condition – Field values that describe the proposed condition should consist of reasonable values for restored or impacted conditions. For preservation reaches, no field values are entered into the SQT for proposed condition. For other reaches, proposed condition is 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.

> 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.

Table 5 provides the expected range of values for each metric. **Guidance on collecting and analyzing data to calculate field values for the condition assessments is provided in the Data Collection and Analysis Manual**. Additionally, Appendix A includes a list of all function-based parameters, metrics, reference curve thresholds, and applicable references used to develop reference curves.

Table 5. Expected range of values for metric field values.

Metric	Field Value Range	Metric	Field Value Range
Land Use Coefficient	0 – 100	Native Shrub Density (#/Ac)	≥ 0
Concentrated Flow Points (#/1000 LF)	≥ 0.0	Native Herbaceous Cover (%)	0 – 100
Bank Height Ratio	≥ 1.00	Monoculture Area (%)	0 – 100
Entrenchment Ratio	≥ 1.0	Invasive/Non-native Cover (%)*	0 – 100
Width/Depth Ratio State	≥ 0.0	Pool Spacing Ratio	≥ 0.0
LWD Index	≥ 0	Pool Depth Ratio	≥ 1.00
LWD Piece Count (#/100m)	≥ 0	Percent Riffle (%)	0 – 100
Erosion Rate (ft/yr)	≥ 0.00	Summer Daily Maximum (°F)	≥ 0.0
Percent Streambank Erosion (%)	0 – 100	E. coli (MPN/100ml)	≥ 0
Percent Streambank Armoring (%)	0 – 100	Total Nitrogen (mg/L)	≥ 0.00
Buffer Width (ft)	≥ 0	Total Phosphorus (mg/L)	≥ 0.00
Average DBH (in)	≥ 0.0	TSS or Turbidity (mg/L or NTU)	≥ 0
Tree Density (#/Ac)	≥ 0	EPT Taxa Present	≥ 0
		South Carolina Biotic Index	-1.00 – 1.00

** This metric is for tracking purposes only. It is not used for scoring and is only included in the monitoring condition assessments.*

6.4. Monitoring Condition Assessments

Immediately below the existing and proposed condition assessments is a table where the user can input the calendar year, monitoring year (since as-built), and field values for each metric (Figure 11). This table contains the input field values for 11 post-project condition assessments. The first column is identified as the As-Built Condition followed by 10 condition assessment tables for monitoring.

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

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.

Additionally, an invasive/non-native cover metric is included for tracking purposes. This metric does not factor into quantification of the riparian vegetation parameter score or functional foot score and is not included in the existing or proposed condition assessments.

CONDITION ASSESSMENT		Year	As-Built	2023
Functional Category	Function-based Parameters	Time since as-built (yr)	0	1
		Metric		
Hydrology	Reach Runoff	Land Use Coefficient	60	60
		Concentrated Flow Points (#/1000 LF)	0	0
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft)	1	1
		Entrenchment Ratio (ft/ft)	2.2	2.2
	Flow Dynamics	Width/Depth Ratio State (O/E)	1	1
Geomorphology	Large Woody Debris	LWD Index	400	400
		LWD Piece Count (#/100m)		
	Lateral Migration	Erosion Rate (ft/yr)		
		Dominant BEHI/NBS	L/L	L/L
		Percent Streambank Erosion (%)	3	4
		Percent Streambank Armoring (%)		
	Riparian Vegetation	Buffer Width (ft)	130	130
		Average DBH (in)	4	5
		Tree Density (#/acre)	150	150
		Native Shrub Density (#/acre)		
		Native Herbaceous Cover (%)		
		Monoculture Area (%)		
		Invasive/Non-native Cover	0	30
	Bed Form Diversity	Pool Spacing Ratio (ft/ft)	3	3
		Pool Depth Ratio (ft/ft)	3	3
		Percent Riffle (%)	55	55
Physicochemical	Temperature	Summer Daily Maximum (°F)	55	56.5
	Bacteria	E. Coli (MPN/100 ml)		
	Nitrogen	Total Nitrogen (mg/L)		
	Phosphorus	Total Phosphorus (mg/L)		
	Suspended Sediment	Total Suspended Solids (mg/L)		
		Turbidity (NTU)		
Biology	Macroinvertebrates	EPT Taxa Present		
	Fish	South Carolina Biotic Index		

Figure 11. As-built and Monitoring Condition Assessments example showing as-built and monitoring year 1 data (Additional monitoring columns are provided in the SQT).

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

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 or pieces), and percent armoring metrics field values should be measured post-construction or documented in record drawings.
- Channel dimensions should verify bankfull elevations and metric field values for bank height, entrenchment ratio, and width/depth ratio state.
- Floodplain grading should verify flood-prone width for the entrenchment 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. If these values are not measured following construction, **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.[8] An adaptive management plan may be needed if these field values are not obtained during monitoring and the data collected show that the condition is trending away from the predicted value. 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 spreadsheet, 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 previously measured metrics should be measured for a final time at project closeout. Note that the user should consult with regulatory entities for guidance if stressors and changes to catchment-scale processes are suspected to affect the measured condition at project closeout.

[8] Regulatory agencies may require additional performance standards beyond what is used in the SQT.

Chapter 7. Reference Curves Spreadsheet

The Reference Curves spreadsheet 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 by metric. Index values are dimensionless values between 0.00 and 1.00 that express the relative condition of a metric field value compared with reference condition (Section 2.2). Metric index values are categorized into functional capacity categories: functioning (F; 0.70 - 1.00), functioning-at-risk (FAR; 0.30 - <0.70), or not functioning (NF; 0.00 - <0.30). The definitions of these functional capacity categories are provided in Table 1 (Section 2.2).

The user cannot make changes to the reference curves. However, the user can view the reference curves and suggest data-driven changes (e.g., local reference reach data or better modeling). Refer to Chapter 1 for instructions in submitting proposals or additional data.

On the spreadsheet, metric reference curves are organized into columns based on the functional category. To account for natural variability among stream systems, reference curves may be stratified by differences in stream type, ecoregion, or stream temperature. The full list of functional capacity thresholds and reference curve 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 2.2). Three approaches were taken to identify threshold values:

1. Where possible, thresholds were derived from field values already identified in the State of South Carolina’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 condition to identify the threshold values. For example, the interquartile range of reference reach data may be used to identify the 0.70 and 1.00 threshold values to define the functioning range of a reference curve. This is similar to other approaches that identify benchmarks or index values (e.g., BLM, 2017). In the use of existing datasets, the developers relied on the definitions of reference condition provided by the authors.
3. Where existing data or literature were limited, expertise of the developers was relied on to identify threshold values. In some instances, the decision was made to not identify reference standard thresholds for all functional capacity categories and instead interpolate or extrapolate index values from a best fit line developed using available data or literature values.

The references used to develop reference curves are provided in Appendix A.

Following the identification of these reference 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 two example metrics, total nitrogen (Figure 12) and total phosphorus (Figure 13), are described below (Example 3).

Example 3: Reference curve development for total nitrogen and total phosphorus

Nutrients such as nitrogen and phosphorus are natural components of healthy aquatic ecosystems. In excess, anthropogenic nutrient inputs can lead to enrichment, which causes harmful algal blooms, poor water quality, and reduced biodiversity.

For both metrics, reference curve thresholds were developed using the National Rivers and Streams Assessment (NRSA) national dataset from 2008-2009, and supported by regional datasets from North Carolina, including: Donatich et al. (2020) and data from the Heath Dairy restoration project (Line, 2014). The NRSA dataset characterizes sites by good, fair, and poor condition (USEPA, 2016). The 75th percentile of each condition category was assigned to a reference curve threshold as follows:

- 75th percentile value for poor condition sites was set to the 0.00 index value.
- 75th percentile value for fair condition sites was set to the 0.70 index value.
- 75th percentile value for good condition sites was set to the 1.00 index value.

While fair condition sites would not be expected to represent reference conditions, the data from reference sites in the Piedmont from Donatich et al. (2020) provided sufficient evidence to use these breaks.

Linear relationships were established between the reference curve thresholds for each metric.

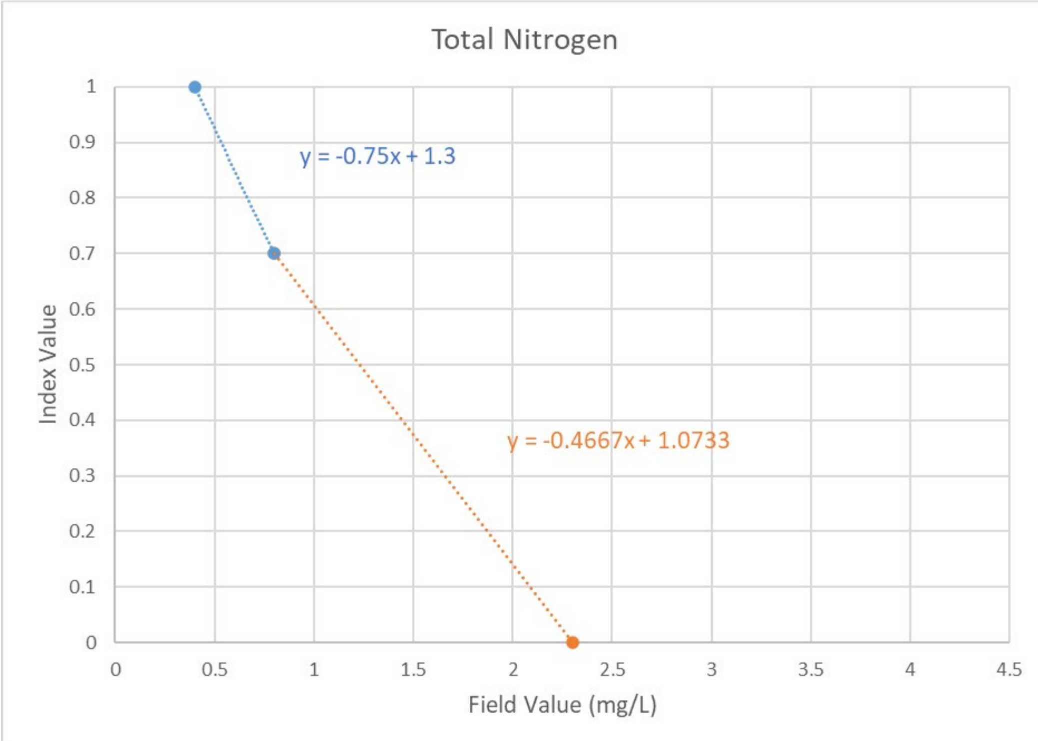


Figure 12. Total nitrogen reference curve

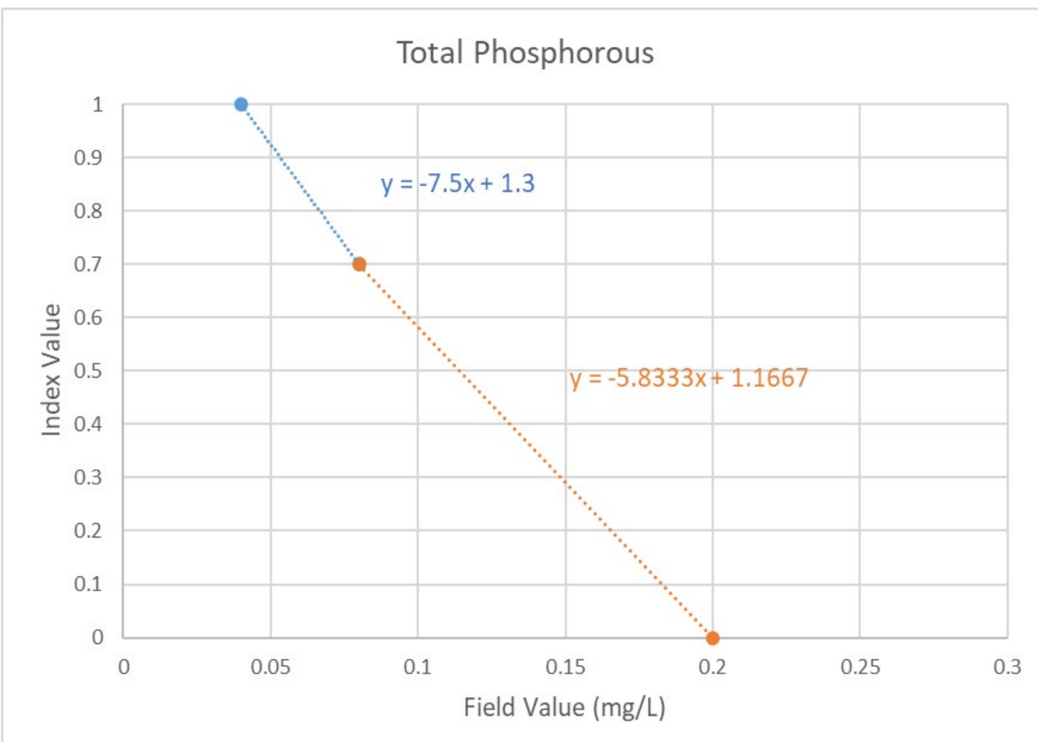


Figure 13. Total phosphorus reference curve

References

Bureau of Land Management (BLM). 2017. AIM National Aquatic Monitoring Framework: Field Protocol for Wadeable Lotic Systems. Tech Reference 1735-2. Denver (CO): US Department of the Interior, Bureau of Land Management, National Operations Center. https://www.blm.gov/download/file/fid/17970

Castro, J. M., & Thorne, C.R. 2019. The stream evolution triangle: Integrating geology, hydrology, and biology. *River Research and Applications*, *35*(4), 315-326.

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

Donatich, S., Doll, B., Page, J., & Nelson, N. 2020. Can the Stream Quantification Tool (SQT) Protocol Predict the Biotic Condition of Streams in the Southeast Piedmont (USA)? *Water,* 12(5), 1485.

Harman, W.A. & Jones, C.J. 2017. North Carolina Stream Quantification Tool: Data Collection and Analysis Manual, NC SQT v3.0. Environmental Defense Fund, Raleigh, NC.

Harman, W.A., Starr, R., Carter, M., Tweedy, K., Clemmons, M., Suggs, K., & Miller, C. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006.

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

Line, D.E. 2014. Final Report: Heath Dairy Livestock Exclusion and Stream BMP. North Carolina Department of Environment and Natural Resources, Contract Number 3649, Raleigh, NC.

Michigan Department of Environment, Great Lakes, and Energy (EGLE). 2020. Michigan Stream Quantification Tool: Spreadsheet User Manual, MiSQT v1.0., EGLE, Lansing, MI.

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

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

Rosgen, D.L., 2006. Watershed Assessment of River Stability and Sediment Supply (WARSSS), Wildland Hydrology Books, Fort Collins, Colorado.

South Carolina Department of Health and Environmental Control (DHEC). 2020. South Carolina Code of Regulations: Chapters 61-69: Classified Waters. South Carolina Legislature. Columbia, South Carolina.

South Carolina Steering Committee. 2022 South Carolina Stream Quantification Tool: Debit Calculator Manual, SC SQT v1.1. South Carolina Department of Natural Resources, Columbia, SC.

Stoddard, J.L., Larsen, D.P., Hawkins, C.P., Johnson, R.K. & Norris, R.H. 2006. Setting Expectation for the Ecological Condition of Streams: The Concept of Reference Condition. *Ecological Applications*, 16(4): 1267-1276.

Strahler, A. 1957. Quantitative Analysis of Watershed Geomorphology. Transactions, American Geophysical Union, 38: 913-920. http://dx.doi.org/10.1029/TR038i006p00913.

Tennessee Department of Environment and Conservation (TDEC). 2018. Tennessee Stream Quantification Tool: Spreadsheet User Manual. TN SQT v1.0. Nashville (TN): Tennessee Department of Environment and Conservation. https://www.tn.gov/content/dam/tn/environment/water/documents/ppo_water_arap-tn-sqt-spreadsheet-user-manual-DRAFT.PDF

United States Army Corps of Engineers (USACE), Department of Defense, & United State Environmental Protection Agency (USEPA). 2008. Compensatory Mitigation for Losses of Aquatic Resources: Final Rule. 33 CFR Parts 325 and 332 & 40 CFR Part 230. [EPA–HQ–OW–2006–0020; FRL–8545–4].

USACE. 2018a. Wyoming Stream Quantification Tool (WSQT) User Manual and Spreadsheet. Version 1.0, Omaha District, Wyoming Regulatory Office, Cheyenne Wyoming.

USACE. 2018b. Georgia Interim Stream Quantification Tool and User Manual. In: 2018 Standard Operating Procedures for Compensatory Mitigation. Burford (GA): USACE Savannah District, Georgia Regulatory Branch.

USACE. 2020. Colorado Stream Quantification Tool (CSQT). User Manual and Spreadsheets. Version 1.0. U.S. Army Corps of Engineers, Albuquerque District, Pueblo Regulatory Office.

USACE. 2021. South Carolina Debit Calculator Manual. Version 1.0. U.S. Army Corps of Engineers, Charleston District.

United States Environmental Protection Agency (USEPA). 2016. Office of Water and Office of Research and Development. National Rivers and Streams Assessment 2008-2009: A Collaborative Survey (EPA/841/R-16/007). Washington, DC. http://www.epa.gov/national-aquatic-resource-surveys/nrsa

Appendix A

List of Metrics

for the SC SQT v1.1

Functional Category	Function-Based Parameters	Metrics (Units)	Reference Curve Stratification Type	Reference Curve Stratification Description	Threshold Index Values i= 0.00	i= 0.30	i= 0.70	i= 1.00
Hydrology	Reach Runoff	Land Use Coefficient			-	-	62	≤ 55
		Concentrated Flow Points			-	-	1	0
Hydraulics	Floodplain Connectivity	Bank Height Ratio (ft/ft)			-	1.5	-	≤ 1.0
		Entrenchment Ratio (ft/ft)	Reference Stream Type	B	≤ 1.0	-	1.4	≥ 2.0
			Reference Stream Type	C	≤ 1.0	-	2.2	≥ 7.3
			Reference Stream Type	E	≤ 1.0	-	2.2	≥ 10.0
	Flow Dynamics	Width/Depth Ratio State (O/E)			≥ 1.8 ≤ 0.2	-	-	1.0
Geomorphology	Large Woody Debris	LWD Index			0	-	355	≥ 731
		LWD Piece Count (#/100m)			0	-	16	≥ 28
	Lateral Migration	Erosion Rate (ft/yr)			≥ 0.71	0.40	0.20	≤ 0.10
		Dominant BEHI/NBS			Ex, VH & H ratings; M ratings; L & VL ratings i= 0.0 - 0.3; i=0.3 - 0.7; i=0.7 - 1.0			
		Percent Streambank Erosion (%)			≥ 50	-	11	≤ 5
		Percent Streambank Armoring (%)			≥ 30	-	-	0
	Riparian Vegetation	Buffer Width (ft)	Dominant Buffer Land Use, Buffer Valley Slope	Single Family Residential, <5% Slope	0	-	50	300
			Dominant Buffer Land Use, Buffer Valley Slope	Single Family Residential, 5-20% Slope	0	-	100	300
			Dominant Buffer Land Use, Buffer Valley Slope	Single Family Residential, 21-40% Slope	0	-	150	300
			Dominant Buffer Land Use, Buffer Valley Slope	Single Family Residential, >40% Slope	0	-	200	300
			Dominant Buffer Land Use, Buffer Valley Slope	Multi-Family Residential, <5% Slope	0	-	60	300
			Dominant Buffer Land Use, Buffer Valley Slope	Multi-Family Residential, 5-20% Slope	0	-	120	300
			Dominant Buffer Land Use, Buffer Valley Slope	Multi-Family Residential, 21-40% Slope	0	-	180	300
			Dominant Buffer Land Use, Buffer Valley Slope	Multi-Family Residential, >40% Slope	0	-	240	-
			Dominant Buffer Land Use, Buffer Valley Slope	Commercial/Golf Course/Agriculture/Silviculture, <5% Slope	0	-	150	300
			Dominant Buffer Land Use, Buffer Valley Slope	Commercial/Golf Course/Agriculture/Silviculture, 5-20% Slope	0	-	150	300
			Dominant Buffer Land Use, Buffer Valley Slope	Commercial/Golf Course/Agriculture/Silviculture, 21-40% Slope	0	-	225	-
			Dominant Buffer Land Use, Buffer Valley Slope	Commercial/Golf Course/Agriculture/Silviculture, >40% Slope	0	-	300	-
			Dominant Buffer Land Use, Buffer Valley Slope	Industrial/Landfill, <5% Slope	0	-	150	300
			Dominant Buffer Land Use, Buffer Valley Slope	Industrial/Landfill, 5-20% Slope	0	-	250	-
			Dominant Buffer Land Use, Buffer Valley Slope	Industrial/Landfill, 21-40% Slope	0	-	350	-

Functional Category	Function-Based Parameters	Metrics (Units)	Reference Curve Stratification		Threshold Index Values			
			Type	Description	i= 0.00	i= 0.30	i= 0.70	i= 1.00
Geomorphology	Riparian Vegetation	Average DBH (in)			0	-	-	≥ 9.3
		Tree Density (#/acre)			0	-	-	135 262
		Native Shrub Density (#/acre)			0	-	-	≥ 566
		Native Herbaceous Cover (%)			0	-	-	≥ 75
		Monoculture Area (%)			100	-	-	0
		Invasive/non-native Species Cover			No reference curve. This is a tracking metric.			
	Bed Form Diversity	Pool Spacing Ratio (ft/ft)	Reference Stream Type	A & B	≥ 6.5	-	5.0	≤ 4.0
			Reference Stream Type	Bc	≥ 8.0	-	6.0	≤ 5.0
			Reference Stream Type	C & E	≤ 1.0 ≥ 9.0	-	-	3.5 6.0
		Pool Depth Ratio (ft/ft)	Reference Stream Type	A	≤ 1.0	1.1	1.4	≥ 1.7
			Reference Stream Type	B	≤ 1.0	2.0	2.3	≥ 2.9
			Reference Stream Type	C	≤ 1.0	1.2	1.9	≥ 2.3
			Reference Stream Type	E	≤ 1.0	1.4	1.7	≥ 2.1
		Percent Riffle (%)	Reference Stream Type	A	0 100	-	-	54 62
			Reference Stream Type	B	0 100	-	-	53 61
			Reference Stream Type	C	0 100	-	-	45 65
			Reference Stream Type	E	0 100	-	-	43 63

Functional Category	Function-Based Parameters	Metrics (Units)	Reference Curve Stratification		Threshold Index Values			
			Type	Description	i= 0.00	i= 0.30	i= 0.70	i= 1.00
Physicochemical	Temperature	Summer Daily Maximum (°F)	Stream Temperature	Coldwater	≥ 77	-	64	≤ 58
	Bacteria	E.Coli (MPN/100 mL)			-	349	121	≤ 35
	Nitrogen	Total Nitrogen (mg/L)			≥ 2.30	-	0.80	≤ 0.40
	Phosphorus	Total Phosphorus (mg/L)			≥ 0.20	-	0.08	≤ 0.04
	Suspended Sediment	TSS (mg/L)			≥ 100	50	-	≤ 10
		Turbidity (NTU)			≥ 100	50	-	≤ 10
Biology	Macro-invertebrates	EPT Taxa Present	Region	Blue Ridge Mountains	0	19	28	≥ 36
			Region	Piedmont	0	14	21	≥ 28
			Region	Southeastern Plains & Middle Atlantic Coastal Plain	0	5	10	≥ 15
	Fish	South Carolina Biotic Index	Fish Bioassessment Class	1 - Upland Santee/Pee-Dee Basin	-1.000	-	0.050	1.000
			Fish Bioassessment Class	2 - Upland Savannah	-1.000	-	0.002	1.000
			Fish Bioassessment Class	3 - Lowland Perennial	-1.000	-	0.005	1.000
			Fish Bioassessment Class	4 - Lowland Stable Baseflow	-1.000	-	0.300	1.000

Note: "-" indicates the field value threshold was extrapolated or interpolated.

Functional Category	Function-Based Parameters	Metric	Reference Curve References
Hydrology	Reach Runoff	Land Use Coefficient	Field values adapted from: Natural Resources Conservation Service, 1986. Urban Hydrology for Small Watersheds, Tech. Release 55, Washington, DC. http://www.wcc.nrcs.usda.gov/water /quality/common/tr55/tr55.pdf. Refer to the *Scientific Support for the Colorado Stream Quantification Tool version 1.0* for more information: U.S. Army Corps of Engineers. 2020. Scientific Support for the Colorado Stream Quantification Tool. Version 1.0. U.S. Army Corps of Engineers, Albuquerque District, Pueblo Regulatory Office.
		Concentrated Flow Points	Based on best professional judgment. Refer to the Scientific Support for the Colorado Stream Quantification Tool version 1.0 for more information: U.S. Army Corps of Engineers. 2020. Scientific Support for the Colorado Stream Quantification Tool. Version 1.0. U.S. Army Corps of Engineers, Albuquerque District, Pueblo Regulatory Office.
Hydraulics	Floodplain Connectivity	Bank Height Ratio	Field values per Rosgen Classification System: Rosgen, D. 2014. River Stability Field Guide (Second Edition). Wildland Hydrology, Fort Collins, CO. The reference curve matches CSQT v1 for all transport regimes. Refer to the Scientific Support for the *Colorado Stream Quantification Tool version 1.0* for more information: U.S. Army Corps of Engineers. 2020. Scientific Support for the Colorado Stream Quantification Tool. Version 1.0. U.S. Army Corps of Engineers, Albuquerque District, Pueblo Regulatory Office.
		Entrenchment Ratio (ft/ft)	Field values per: Rosgen Classification System (set to the 0.7 index value) and a combined dataset of Donatich et al. (2020) reference sites in NC and Jennings Environmental reference sites in TN and SC (75th percentile set to 1.0 index value): **1.** Rosgen, D. 2014. River Stability Field Guide (Second Edition). Wildland Hydrology, Fort Collins, CO. **2.** Donatich, S., Doll, B., Page, J., & Nelson, N. 2020. Can the Stream Quantification Tool (SQT) Protocol Predict the Biotic Condition of Streams in the Southeast Piedmont (USA)?. Water, 12(5), 1485. **3.** Jennings Environmental, LLC. 2017. Tennessee Reference Stream Morphology and Large Woody Debris Assessment Report and Guidebook. Tennessee Department of Environment and Conservation, Nashville, TN. **4.** Jennings Environmental, PLLC. 2020. Stream Morphology Data Collection and Analysis: South Carolina Ecoregions 66, 45, 65, 63. South Carolina Department of Natural Resources, Columbia, SC.
	Flow Dynamics	Width/Depth Ratio State (O/E)	Width/depth (W/D) ratio state stability ratings from (Rosgen, 2014).

Functional Category	Function-Based Parameters	Metric	Reference Curve References
Geomorphology	Large Woody Debris	LWD Index	Based on a combined dataset from the Piedmont and Mountain regions of NC and Blue Ridge ecoregion of TN for forests aged 60+ years. The median value was set to the 0.7 index value and the 75th percentile value was set to the 1.0 index value. **1.** Donatich, S., Doll, B., Page, J., & Nelson, N. 2020. Can the Stream Quantification Tool (SQT) Protocol Predict the Biotic Condition of Streams in the Southeast Piedmont (USA)?. Water, 12(5), 1485. **2.** Jennings Environmental, LLC. 2017. Tennessee Reference Stream Morphology and Large Woody Debris Assessment Report and Guidebook. Tennessee Department of Environment and Conservation, Nashville, TN.
		LWD Piece Count (#/100m)	
	Lateral Migration	Erosion Rate (ft/yr.)	Based on values in Harman et al. 2012, unpublished data collected from NC streams and compared to national datasets, and best professional judgement.
		Dominant BEHI/NBS	Based on: Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012, A Function-Based Framework for Stream Assessment and Restoration Projects. US Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, DC EPA 843-K-12-006.
		Percent Streambank Erosion (%)	Based on data collected in the Piedmont ecoregion of NC (Donatich et al., 2020). The median value of the reference sites was set to the 0.7 threshold and the 75th percentile of the degraded sites was set to the 0.0 index value. **1.** Donatich, S., Doll, B., Page, J., & Nelson, N. 2020. Can the Stream Quantification Tool (SQT) Protocol Predict the Biotic Condition of Streams in the Southeast Piedmont (USA)?. Water, 12(5), 1485.
		Percent Streambank Armoring (%)	Reference curves based on best professional judgment. Refer to the *Scientific Support for the Colorado Stream Quantification Tool version 1.0* for more information: U.S. Army Corps of Engineers. 2020. Scientific Support for the Colorado Stream Quantification Tool. Version 1.0. U.S. Army Corps of Engineers, Albuquerque District, Pueblo Regulatory Office.
	Riparian Vegetation	Buffer Width (ft)	Based on the US Army Corps of Engineers Charleston District compensatory mitigation guidance for streams riparian buffers. **1.** US Army Corps of Engineers (ACE) Charleston District. (2010). Guidelines for Preparing a Compensatory Mitigation Plan. Charleston, South Carolina.
		Average DBH (in)	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 ERDC0, Wetlands Regulatory Assistance Program.
		Tree Density (#/acre)	
		Native Shrub Density	
		Native Herbaceous Cover (%)	
		Monoculture Area (%)	Best Professional Judgement from the South Carolina Steering Committee.
		Invasive/Non-native Cover (%)	No reference curve was developed. This is a tracking metric only.

Functional Category	Function-Based Parameters	Metric	Reference Curve References
Geomorphology	Bedform Diversity	Pool Spacing Ratio (ft/ft)	Based on a review of combined datasets comprised of published studies (Donatich et al., 2020; Lowther, 2008; Rosgen, 2014; Zink et al., 2012) and data collected by the Harman from reference streams throughout North Carolina and the Appalachian Mountains. A 1.0 was set to the 0.0 index value (minimum # for a ratio). The 25th percentile value was set to the 0.7 index value and the 75th percentile value was set to the 1.0 index value for each B, C, & E streams. **1.** Donatich, S., Doll, B., Page, J., & Nelson, N. 2020. Can the Stream Quantification Tool (SQT) Protocol Predict the Biotic Condition of Streams in the Southeast Piedmont (USA)?. Water, 12(5), 1485. **2.** Lowther, B. 2008. Stream Channel Geomorphology Relationships for North Carolina Piedmont Reference Reaches. North Carolina State University, Biological and Agricultural Engineering. **3.** Rosgen D. 2014. River stability field guide. 2nd ed. Fort Collins (CO): Wildland Hydrology Books. **4.** Zink JM, Jennings GD, Price GA. 2012. Morphology Characteristics of Southern Appalachian Wilderness Streams. Journal of the American Water Resources Association (JAWRA) 48(4):762-773. DOI: 10.1111/j.1752-1688.2012.00647.x
		Pool Depth Ratio (ft/ft)	Developed based on a review of published studies in NC reference streams (Donatich et al. 2020; Lowther, 2008), unpublished NC reference stream data (Harman & Clinton), and typical values (Rosgen, 2014). A 1.0 was set to the 0.0 index value (minimum # for a ratio). The 25th percentile value was set to the 0.7 index value and the 75th percentile value was set to the 1.0 index value for A, B, C, & E streams. **1.** Donatich, S., Doll, B., Page, J., & Nelson, N. 2020. Can the Stream Quantification Tool (SQT) Protocol Predict the Biotic Condition of Streams in the Southeast Piedmont (USA)?. Water, 12(5), 1485. **2.** Lowther, B. (2008). Stream Channel Geomorphology Relationships for North Carolina Piedmont Reference Reaches. North Carolina State University, Biological and Agricultural Engineering. **3.** Rosgen D. 2014. River stability field guide. 2nd ed. Fort Collins (CO): Wildland Hydrology Books.
		Percent Riffle (%)	Based on a review of a published study on NC reference streams (Donatich et al., 2020) and SC reference streams (Jennings Environmental, 2020), and unpublished NC reference stream data (Harman & Clinton). Field values of 0% and 100% were set to the 0.0 index values (minimum and maximum percent). For B, C, and E streams, the interquartile range (25th and 75th percentile values) from the combined reference site dataset was set to the 1.0 index value for B, C, and E streams. For A streams, the reference curve was developed with limited data and best professional judgement. **1.** Donatich, S., Doll, B., Page, J., & Nelson, N. 2020. Can the Stream Quantification Tool (SQT) Protocol Predict the Biotic Condition of Streams in the Southeast Piedmont (USA)?. Water, 12(5), 1485. **2.** Jennings Environmental, PLLC. 2020. Stream Morphology Data Collection and Analysis: South Carolina Ecoregions 66, 45, 65, 63. South Carolina Department of Natural Resources, Columbia, SC.

Functional Category	Function-Based Parameters	Metric	Reference Curve References
Physicochemical	Temperature	Summer Daily Maximum (°F)	Morrow, J.V. and C. Fischenich, 2000. Habitat Requirements for Freshwater Fishes. ERDC TN-EMRRP-SR-06. https://www3.epa.gov/region1/npdes/merrimackstation/pdfs/ar/AR-72.pdf
	Bacteria	E. Coli (MPN/100 mL)	Based on SC DHEC surface water quality standards for freshwater aquatic life (set to 0.30 index value) and DHEC reference dataset (70th percentile from sites meeting state WQ standard set to 0.70 index value). 1.00 index value set at 35 MPN/100mL using best professional judgement. The extrapolated 0.00 index value was evaluated using best professional judgement and found reasonable.
	Nitrogen	Total Nitrogen (mg/L)	National Rivers and Streams Assessment (NRSA) 2008-2009 dataset. Supported by Donatich et al. (2020) data for reference sites and Heath Dairy project data (Line, 2014). **1.** U.S. Environmental Protection Agency. Office of Water and Office of Research and Development. National Rivers and Streams Assessment 2008-2009: A Collaborative Survey (EPA/841/R-16/007). Washington, DC. March 2016. **2.** Donatich, S., Doll, B., Page, J., & Nelson, N. (2020). Can the Stream Quantification Tool (SQT) Protocol Predict the Biotic Condition of Streams in the Southeast Piedmont (USA)?. Water, 12(5), 1485. **3.** Line, D.E. 2014. Final Report: Heath Dairy Livestock Exclusion and Stream BMP. North Carolina Division of Environment and Natural Resources, Division of Water Quality. Contract Number 3649.
	Phosphorus	Total Phosphorus (mg/L)	
	Suspended Sediment	TSS (mg/L)	Best Professional Judgement from the South Carolina Steering Committee and SC DHEC surface water quality standards for trout waters (set to 1.00 index value).
		Turbidity (NTU)	
Biology	Macro-invertebrates	EPT Taxa Present	Best Professional Judgement from the South Carolina Steering Committee. DHEC reviewed statewide dataset to determine applicability of NC reference standards for the Blue Ridge Mountains and the Piedmont. Reference curves were developed using data provided by DHEC for the coastal plains.
	Fish	South Carolina Biotic Index	Scott, M., Kubach, K., Gelder, D., Lockaby, C. and Limehouse, M. (2022). Development of a Biological Index Using Fish for South Carolina Streams. SCDNR Office of Environmental Programs.