Tennessee Stream Quantification Tool

Spreadsheet User Manual

TN Department of Environment & Conservation

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TN SQT v1.0

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Lead Agency:

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Stream Mechanics

Ecosystem Planning and Restoration

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Tennessee Wildlife Resources Agency

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Disclaimer:

The Tennessee Stream Quantification Tool (TN SQT), including the spreadsheet and measurement methods manuals are intended for the evaluation of impact sites and compensatory mitigation projects and their departure from reference conditions in terms of functional lift or loss. In part or as a whole, the function-based parameters, measurement methods, and index values are not intended as engineering design criteria and do not serve as the basis of engineering design. The Tennessee Department of Environment and Conservation assumes no liability for engineering designs based on TN SQT. Designers should evaluate evidence from hydrologic and hydraulic monitoring, modeling, nearby stream morphology, existing stream conditions, sediment transport requirements, and site constraints in order to determine appropriate restoration design variables and specifications.

Table of Contents

Acronyms

BEHI/NBS – Bank Erosion Hazard Index / Near Bank Stress

BMP – Best Management Practice

CFR – Code of Federal Register

CN – Curve numbers

ECS – Existing Condition Score

EPT – Ephemeroptera, Plecoptera, and Trichoptera

F – Functioning

FAR – Functioning-At-Risk

FFS – Functional Foot Score

LWD – Large Woody Debris

NF – Not Functioning

PCS – Proposed Condition Score

SFPF – Stream Function Pyramid Framework

TMDL – Total Maximum Daily Load

TN – Tennessee

TN SQT –Tennessee Stream functional lift Quantification Tool

Glossary of Terms

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

Best Management Practice (BMP) – A method that is recognized as an efficient, effective, and practical means of preventing or reducing the movement of pollutants into the waters of the state. A BMP may be a physical facility or a management practice achieved through action.[1]

Buffer – Zone or area extending outwards from top of bank on either side of the channel, to the edge of the conservation easement.

Catchment – Portion of the project watershed that drains to the uppermost end of the project reach. The catchment is the total drainage area above the project reach.

[1] http://tnpermanentstormwater.org/manual.asp

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

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

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

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

Confined Alluvial Valley – Valley formed by the deposition of sediment from fluvial processes but confined between adjacent hillslopes. These valleys typically have noticeable slope changes in very short distances.

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

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

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

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

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

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

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

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

Measurement Method – Specific tools, equations, assessment methods, etc. that are used to quantify a function-based parameter.

Rapid Method – Collection of office and field techniques specific to the TN SQT for collecting quantitative data to inform functional lift and loss calculations. Rapid methods, if available, are provided in this manual for each measurement method and collected in the *Rapid Assessment Method Manual*. The rapid method will typically take one to three hours to complete per project reach.

Reference Condition – A stream condition that is considered fully functioning for the parameter being assessed. It does not simply represent the best condition that can be achieved at a given site; rather, a functioning condition score represents an unaltered or minimally impacted system.

Reference Standard – Determines functional capacity of a measurement method using a 0.00 to 1.00 scale. Reference standards are stratified by functioning, functioning-at-risk, and not functioning. Measurement method reference standards are then averaged to create parameter reference standards.

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

Stream Restoration - Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource. (see 33CFR 332 / 40CFR 230)

1. Introduction, Purpose, and Use

The purpose of this document is to provide instruction on how to use the Tennessee Stream Quantification Tool (TN SQT) in Tennessee streams. The instructions below will help the user input data into the Microsoft Excel Workbook by providing rules and procedures that must be followed. The instructions will also provide guidance on selecting function based parameters and measurement methods. This manual will refer to stream restoration in accordance with the definition used by the federal mitigation rule (33CFR 332 / 40 CFR 230):

> "Restoration means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource."

This definition encompasses all activities aimed to improve stream functions performed for compensatory mitigation or other purposes.

In 2006, the Ecosystem Management and Restoration Research Program of the US Army Corps of Engineering (Corps) noted that specific functions for stream and riparian corridors had yet to be defined in a manner that was generally agreed upon and suitable as a basis for which management and policy decisions could be made (Fischenich, 2006). In an effort to fill this need for Corps programs, an international committee of scientists, engineers, and practitioners defined 15 key stream and riparian zone functions aggregated into 5 categories. These five categories include system dynamics, hydrologic balance, sediment processes and character, biological support, and chemical processes and pathways. This work informed the development of the Stream Functions Pyramid Framework (SFPF; Harman et al., 2012) which provides the scientific basis of the TN SQT. The functional pyramid enables restoration practitioners and reviewers to develop and identify clear goals, have improved site selection and key in on a suite of measurements for assessing these functions in an objective manner. This document, the TN SQT Spreadsheet User Manual, assumes the reader has a basic knowledge of stream processes and the SFPF; therefore, it does not provide extensive definitions of terms such as bankfull, thalweg, riffle, etc.

<u>TN SQT Manual Guide</u>

1. *Spreadsheet User Manual* – Rules and procedures for entering data into the Microsoft Excel Workbook. (This document)
2. *Data Collection and Analysis Manual* – Provides instruction on how to collect and analyze data needed to run the TN SQT.
3. *Rapid Data Collection Methods* –Provides data collection and analysis instruction for applying the TN SQT rapid assessment method.

This Spreadsheet User Manual supports and compliments the *Tennessee Stream Quantification Tool Data Collection and Analysis Manual* (Data Collection Manual) which provides guidance on data collection and analysis techniques for the TN SQT. This manual does not provide the methodology for determining compensatory mitigation credits or debits from the TN SQT, this is detailed in the TN Stream Mitigation Guidelines (2018).

Frequently asked questions about the SQT and its development have been collected in Appendix A. It is recommended that anyone using the TN SQT read through this document to gain a better understanding of the TN SQT and how it has been developed.

This version of the TN SQT and this Spreadsheet User Manual have been tailored for Tennessee.

1.1. Purpose and Uses of the TN SQT

The primary purpose of the TN SQT is to calculate functional lift and loss associated with stream impact and restoration projects. In addition, the TN SQT **can assist** in mitigation site selection, determining project specific function-based goals and objectives, understanding the potential for functional lift at a site, determining success criteria, and developing a monitoring plan. Additional detail on these uses is provided below.

Uses of the TN SQT:

1. Restoration Potential – The Watershed Assessment form can be used to aid in determining factors that limit the potential stream functional lift that can be achieved by a restoration project, including those for the purpose of compensatory mitigation.
2. Site Selection – The tool can help determine if a site can benefit from a restoration project and if the site has significant limitations that would inhibit a project from being successful. Site selection is critical to determine whether a proposed stream restoration project can achieve enough functional lift to meet programmatic goals and project objectives. Rapid field assessment methods, coupled with the Watershed Assessment form can be used to assess and select a site at the development phase of a project.
3. Function-Based Goals and Objectives – This tool can be used to describe project goals that match the restoration potential of a site. Quantifiable objectives and performance criteria can be developed that link restoration activities to measurable changes in stream functional categories and function-based parameters assessed by the tool.
4. Functional Lift– The tool can quantify functional lift from a proposed or active stream restoration project. Lift is estimated during the design or mitigation plan phase and is calculated for each post-construction monitoring event.
5. Compensatory Mitigation – The tool can be applied to on- or off-site and in-or out-of-kind compensatory mitigation projects. These include in-lieu fee mitigation, permittee responsible mitigation, and mitigation banks. The tool can help determine if the proposed mitigation activities will provide sufficient functional lift to offset unavoidable adverse impacts to streams. It can also be used to develop monitoring plans and gage a project’s success against established reference standards.
6. Stormwater Best Management Practices (BMPs) in Conjunction with Stream Restoration – The TN SQT was developed with careful consideration to how stream restoration projects using BMPs to treat adjacent runoff could achieve lift. However, the TN SQT should not be used for projects that only install stormwater BMPs and do not include stream restoration (in channel) work.

NOTE:

The Tennessee Department of Environment and Conservation (TDEC) currently uses the TN SQT as a mechanism to evaluate the current site conditions and projected functional lift of a project, and to aid in establishing success criteria for monitoring of compensatory mitigation.

This tool assists the state (and IRT) in determining the suitability of a project proposal, its relationship to current crediting ratios, and project success.

1.2. Downloading the TN SQT and Supporting Information

The TN SQT and supporting documents can be downloaded from the TDEC website at www.BLANK.org

The following documents are available at the above website:

- TN Stream Quantification Tool (TN SQT) – Microsoft Excel Workbook described in detail in the Spreadsheet User Manual.
- TN SQT Example – A populated version of the TN SQT provided as an example.
- List of Metrics – The List of Metrics is a spreadsheet file that provides a comprehensive list of the function-based parameters with their measurement methods, reference standards, stratification methods, and references.
- Spreadsheet User Manual – A manual describing the TN SQT and all calculations performed by the workbook.
- Data Collection and Analysis Manual – This manual. A manual describing how to collect data and calculate input for the TN SQT.
- Rapid Data Collection Methods – A manual outlining the rapid assessment method for the TN SQT.

The TN SQT and accompanying documents will be updated periodically as additional data are gathered and reference standards and measurement methods are refined. The latest version of the TN SQT manuals and tool can be downloaded from the TDEC website.

2. Background

The TN SQT is based on the original Stream Quantification Tool (SQT) developed for North Carolina. This tool has been regionalized for use in Tennessee. The SQT was developed primarily for stream restoration projects completed as part of a compensatory mitigation requirement. However, the tool can be used for any stream restoration project, regardless of the funding driver. The benefits of using the SQT for evaluating stream restoration include:

1. Establishes a calculator to determine the numerical differences between an existing (degraded) stream condition and the proposed (restored or enhanced) stream condition. This numerical difference is known as functional lift or uplift. It is related to, and could be part of, a stream credit determination method as defined by the 2008 Federal Mitigation Rule.[2]
2. Provide a link for restoration activities to changes in stream functions by primarily selecting function-based parameters and measurement methods that can be manipulated by stream restoration practitioners.
3. Links restoration goals to restoration potential. Encourages assessments and monitoring that matches the restoration potential.

[2] Compensatory Mitigation for Losses of Aquatic Resources, 33 CFR 332 (2012). https://www.gpo.gov/fdsys/pkg/CFR-2012-title33-vol3/xml/CFR-2012-title33-vol3-part332.xml

4. Incentivizes high-quality stream mitigation by calculating functional lift associated with physicochemical and biological improvements.

2.1. Stream Functions Pyramid Framework

Conceptually, the Stream Functions Pyramid Framework (SFPF) provides the scientific basis of the TN SQT (Harman et al., 2012). The Stream Functions Pyramid (Figure 1) consists of five functional categories: Level 1 = Hydrology, Level 2 = Hydraulics, Level 3 = Geomorphology, Level 4 = Physicochemical, and Level 5 = Biology and is built on the premise that lower-level functions support higher-level functions which are all influenced by local geology and climate. Each functional category is defined by a functional statement. For example, the functional statement for Level 1, Hydrology is “the transport of water from the watershed to the channel”. Hydrology supports all higher-level functions.

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

Figure 1: Stream Functions Pyramid from (Harman et al., 2012)

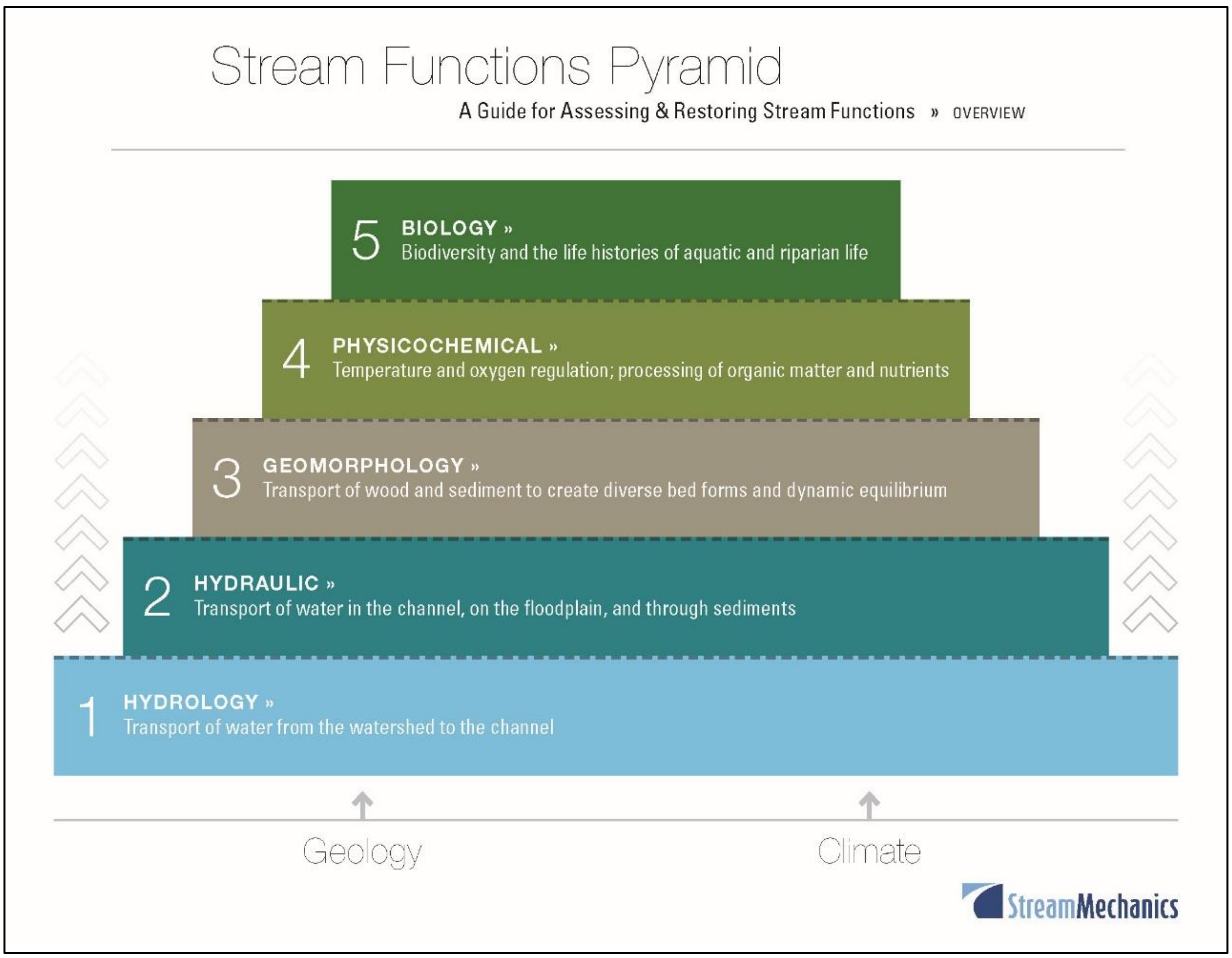
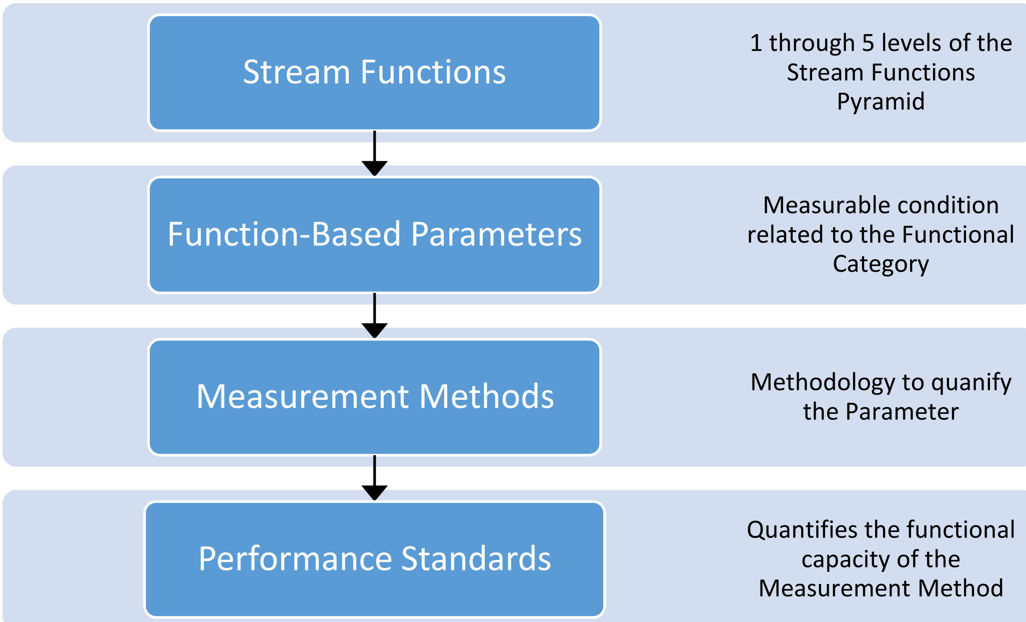


Figure 2: Stream Functions Pyramid Framework



The Stream Functions block (top of Figure 2) represents the five levels of the Pyramid shown in Figure 1. The remainder of the framework is a "drilling down" approach that provides more detailed forms of analysis to quantify stream functions. The function-based parameters describe and support the functional statements of each functional category. Measurement methods are specific tools, equations, assessment methods, etc. that are used to quantify the function-based parameter. There can be more than one measurement method for a single function-based parameter.

- Reference standards are used to determine functional capacity compared to reference conditions at the measurement method level on a 0.00 to 1.00 scale. The reference condition concept does not simply represent the best condition that can be achieved at a given site; rather, a functioning condition score represents an unaltered or minimally impacted system. The TN SQT uses this concept and the definition of reference condition for biological integrity developed by Stoddard, et al (2006). Collectively, these reference conditions indicate stream ecological integrity and functional health.

Definitions for functional capacity descriptions are as follows:

- <u>Functioning</u> – Score ranges from 0.70 to 1.00 are indicative of a reference condition. A functioning score indicates the measurement method is describing, quantifiably, one aspect of a function-based parameter that **supports** a healthy aquatic ecosystem.
- <u>Functioning-At-Risk</u> – Score ranges from 0.30 to 0.69. A functioning-at-risk score means that the measurement method is describing, quantifiably, one aspect of the function-based parameter that **may support** a healthy aquatic ecosystem or may be trending away from reference conditions. In some cases, this may indicate the function-based parameter is adjusting in response to changes in the reach or the catchment. The trend may be towards lower or higher function. A functioning-at-risk score implies that the aspect of the function-

based parameter, described by the measurement method, is between functioning and not functioning.

- Not Functioning – Score ranges from 0.00 to 0.29. A not functioning score means that the measurement method is describing, quantifiably, one aspect of the function-based parameter that **does not support** a healthy aquatic ecosystem. It is not functioning at or near reference condition.

A single measurement method, out of several measurement methods, may not define the functional capacity of the parameter or stream process. Multiple measurement methods are often recommended to describe a function-based parameter. The TN SQT averages measurement method scores to calculate a parameter score. Therefore, a functioning measurement method score averaged with a not functioning score could yield a functioning-at-risk parameter score. For example, pool spacing, pool depth, and percent riffle are three measurement methods for the bed form diversity function-based parameter. Understanding how each measurement method result contributes to the overall bed form condition is more important than a single measurement method result, like the depth of one pool. Functioning bed form diversity would have an appropriate number of pools (pool spacing), good variability in depth, and an appropriate split of riffles and pools.

2.2. Restoration Potential

Any practitioner attempting some level of restoration on a stream should evaluate the potential for the restoration to be successful, both short and long term. The TN SQT uses the concept of restoration potential to help convey the amount of functional lift a project can achieve. Restoration potential is defined as the highest degree of function restoration activities are likely to return a project reach towards reference stream conditions based on results of the catchment assessment, identification of anthropogenic constraints, and the results of the reach-scale function-based assessment. The potential for full or partial restoration to a functioning condition should be evaluated through each level of the functional pyramid, and site selection and project proposals should attempt to achieve as much functional lift as the restoration potential evaluation indicates is possible. Many factors influence the amount of functional lift a project can reasonably achieve. Site constraints, ability to place land use restrictions on property, and existing and proposed infrastructure all may affect the restoration potential of a site. The TN SQT requires the user to evaluate the restoration potential for each reach in a project. This evaluation is then used to create function-based goals and objectives for a site. Information gathered when determining the restoration potential of a project is entered into the Watershed Assessment worksheet of the TN SQT. All of this information is critical to determine if a project is feasible, if the goals and objectives are reasonable and appropriate, and if the restoration potential is adequate to justify the proposed project.

Components beyond the actual stream channel strongly influence, and may severely limit the restoration potential of a site. Investigators need to explore all types of site constraints that may affect the success of a restoration project. Examples of anthropogenic constraints include adjacent sewer and other utility lines, existing easements, master plans for community development, and other infrastructure, including current and planned transportation projects. This evaluation does not consider natural features, such as hillslope processes, the presence of bedrock or other natural barriers to fish migration. Natural conditions are not included in the constraints analysis or the determination of restoration potential because they are not anthropogenic stressors that would limit a project's ability to achieve biological lift. It is possible that natural conditions, such as bedrock waterfalls, could prevent fish passage, but this would be natural for that watershed. These natural conditions should be explained separately from the restoration potential analysis to keep the cause and affect relationships between watershed drivers and stream function clear. Natural conditions create biodiversity, providing suitable habitats for some species and not others. Anthropogenic stressors limit the biology that would naturally occur in a watershed (Harman et al., 2012).

Wide conservation easements can provide protection for systems against current and future impacts or changes in the watershed. The restoration potential for a project can be greatly reduced if land use restrictions are not prohibited or limited. Sites attempting to receive credit for compensatory mitigation must, with few exceptions, have the right to place perpetual restrictions on property. Greenways and public parks may seem to partner well with restoration activities, however, park management missions, active use parcels, and simple landscaping and maintenance activities can limit functional lift. The return of and/or protection of threatened and endangered species within the limits of a project may seem to align well with project goals. However, rare plants and animals may similarly restrict activity. Finally, financial constraints for long term management can also play a part in the success or limitations of the restoration.

Developing function based goals and objectives based on the restoration potential is covered in the following section but this workflow assumes that the project site has already been targeted as a potential project reach. Site selection is critical to the success of stream restoration projects and all attempts at stream restoration should evaluate the potential for both short term and long term success. Final site selection requires a thoughtful assessment of whether the site will be able to achieve programmatic and project goals given land use restrictions, utility easements, financial constraints, and a myriad of other factors. The assessment of restoration potential can aid in the site selection process but the site selection process is dependent on many factors and is not limited to this assessment. Once a site has been selected however, understanding the potential for full or partial restoration through each functional level of the pyramid allows a practitioner to tailor restoration design goals and objectives, as well as monitoring efforts, to focus on appropriate and achievable functional lift.

When evaluating a site for restoration potential practitioners should focus on projects that, at a minimum, can restore or improve on the reach floodplain connectivity, riparian vegetation, lateral stability, and bedform diversity. These "Big Four" parameters, are typically restored to a functioning condition by restoration projects, including those considered for compensatory mitigation.

If the contributing catchment is somewhat impaired and/or anthropogenic constraints place overall limits on restoration activities, then the restoration potential to achieve full function may be limited the geomorphology, or level 3 of the pyramid. These types of projects, with stability-focused goals and objectives, can improve floodplain connectivity, lateral stability, bed form diversity, and riparian vegetation (function-based parameters describing hydraulic and geomorphology functions) to or closer to a reference condition, but may not lift physicochemical or biological functions to the same extent. Biological or physicochemical improvement can still be obtained; however, the improved condition would not likely achieve a reference condition.

Projects whose goals and objectives are aimed at fully restoring the water quality parameters, corresponding to the pyramid level 4, are not as commonly proposed for purposes of mitigation as primarily geomorphic-focused projects, but can result in higher overall functioning at the project site. Improving the physicochemical functioning of a stream can be more challenging than addressing issues with hydraulic and geomorphic functioning. Control of the entire project watershed (catchment and lateral drainage area) is often key to restoring physicochemical functions towards a reference condition. These types of restoration projects typically include stormwater or agricultural best management practices (BMPs), restoration of riparian buffers, or other adjacent land use changes. Some reductions in nutrients and bacteria can also be accomplished by eliminating livestock access to streams, providing buffers along edges of cropland, or fixing problematic infrastructure. Similar to projects whose goals and objectives primarily target geomorphic (level 3) parameters, biological communities may improve, but the improved biological condition may remain in the functioning-at-risk or not functioning category due to other limiting factors.

Some projects may have conditions conducive to fully restoring biological functions (level 5) to a reference condition. This is considered the highest level of restoration potential a project can achieve. Significant biologic recovery may occur when catchment hydrology and water quality conditions that support a healthy aquatic ecosystem, and site constraints are minimal. Practitioners should evaluate the aquatic biology at every potential restoration site to gage current ecological health, and restoration potential. If biological recovery is one of the project's primary goals, practitioners should be strategic and thoughtful when designing habitat niches and providing in-stream detritus and organic material. Epifaunal substrate stability and groundwater connectivity also play a key role in providing conditions for a healthy aquatic community. A suitable monitoring plan that can track functional trajectory should also be developed, acknowledging that recovery of sensitive communities to fully functioning may take longer than projects are required to monitor.

It is important to note that a project may have good potential for restoration, but may never reach reference condition, or be a fully functioning system through all parameters and levels of the functional pyramid. This does not mean a project should be abandoned or passed over because of these limitations. Improving and revitalizing urban and rural systems in spite of site constraints and project limitations can play a valuable role individually and cumulatively in improving overall water resource health. It should also be noted that even a site with a healthy catchment and a high restoration potential may not see a return to a fully functioning system until long after the monitoring period has ended. Restoration potential alone cannot determine the amount of a lift a project will achieve within the time constraints use of the TN SQT (or any method of calculating functional lift) requires. All projects will need detailed monitoring and evaluation of each parameter proposed for lift to gage the level of success a restoration has achieved.

2.3. Function-Based Design Goals and Objectives

Function-based design goals and objectives can be developed once the restoration potential has been determined. Design goals are statements about *why* the project is needed at the specific project site. They are general intentions and often cannot be validated. This is different than programmatic goals Programmatic goals are bigger-picture goals that are often independent of the project site and may be related to funding sources. For example, a programmatic goal might be to create mitigation credits for sale to the Department of Transportation.

Objectives compliment design goals by explaining *how* the project will be completed. Objectives are tangible and can be validated, typically by reference standards.

The Stream Functional Pyramid Framework (SFPF) can aid designers in effectively communicating goals and objectives through the use of the pyramid level terms. Examples of design goals using the pyramid levels include: restore native brook trout habitat (pyramid level 3 goal), restore native brook trout biomass (pyramid level 5), restore the stream biology to a functioning condition (pyramid level 5), reduce sediment supply from eroding streambanks (pyramid level 3), and reduce nutrient inputs (pyramid level 4). All of these goals communicate why the project is being undertaken. Example objectives include: increasing floodplain connectivity, establishing a riparian buffer, and increasing bed form diversity. These objectives can't stand alone, but with the goals, they can describe what the practitioner will do to address the functional impairment. The objectives can be quantitative as well. For example: floodplain connectivity will be improved by reducing the bank height ratio from 2.0 to 1.0. Now, functional lift is being communicated and the reference standard is established for monitoring.

The design goals and objectives are communicated in a narrative form and entered into the TN SQT. The design goals are then compared to the restoration potential to ensure that the goals do not exceed the restoration potential. For example, it is not possible to have a design goal of restoring native brook trout biomass (pyramid level 5) to reference levels if the restoration potential is limited through geomorphology, meaning that the catchment stressors and reach constraints will not support brook trout, e.g., because the catchment is developed and water temperature entering the project reach is too high for brook trout. However, the goal could be revised to restore the physical habitat for native brook trout, e.g. provide riffle-pool sequences, cover from a riparian buffer, and appropriate channel substrate. This is a pyramid level 3 goal that matches the restoration potential. If native brook trout populations in the project reach are to be monitored, increasing native brook trout biomass could be possible even with a restoration potential of pyramid level 3 but restoring native brook trout populations to reference conditions would not be expected or necessarily possible. If catchment-level improvements are implemented, over time, the restoration potential could shift from a pyramid level 3 to 5. Notice however, that this requires reach-scale *and* catchment-scale restoration.

3. Spreadsheet User Manual

The Tennessee Stream Quantification Tool (TN SQT) is a Microsoft Excel Workbook with seven visible worksheets and one background worksheet that is hidden from view. There are no macros in the spreadsheet and all formulas are visible but some worksheets are locked to prevent editing. The worksheets include:

- Project Assessment
- Watershed Assessment
- Parameter Selection Guide
- Quantification Tool (locked)
- Reference Standards (locked)
- Monitoring Data (locked)
- Data Summary (locked)

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

The Quantification Tool, Reference Standards and Monitoring Data worksheets are locked to protect the formulas that provide scores and calculate functional lift. This chapter will describe each of the visible worksheets in detail. A general work flow is described below.

Project Initialization – Once the TN SQT is downloaded, the Project Assessment worksheet is completed first, followed by the Watershed Assessment form. For each site, project reaches will need to be delineated. General guidance on selecting project sites and identifying project reaches is provided below; more detailed instructions are provided in the *Data Collection and Analysis Manual*.

Determining Stream Reaches – The TN SQT is a reach-based assessment and one Microsoft Excel Workbook should be assigned to each reach in a project. If there are multiple reaches in a single project, then multiple workbooks are needed. A reach is defined as a stream segment with similar valley morphology and stream type, stability condition, vegetation, bed material, and restoration potential. Stream length is not used to delineate a stream reach, i.e., stream reaches can be short or long depending on their characteristics. For example, a culvert removal reach may be short and a channelized stream through cropland may be long. Reach segmentation is discussed in detail in section 2 of the Data Collection Manual.

Quantifying Lift at a Site – The Quantification Tool worksheet in the TN SQT determines the functional lift as the difference between the proposed and existing condition of a stream reach by calculating the difference in overall condition scores and/or the functional foot scores for the reach. Functional lift is also summarized for functional categories and function-based parameters.

If the user is deciding between multiple sites, rapid assessment methods can be used to collect data and estimate functional lift using the TN SQT. This estimate of lift, along with the data collected to complete the Watershed Assessment form, and an assessment of whether the site is able to achieve programmatic and project goals can assist in site selection. Rapid assessment methods are compiled in *Rapid Data Collection Methods for the TN SQT*. Once a site has been selected for a project, a detailed assessment should be completed using the methods in the *Data Collection and Analysis Manual*. This will include taking quantitative measurements of the function-based parameters selected for the project. Guidance on how to select function-based parameters is included in section 3.3. of this manual.

3.1. Project Assessment Worksheet

The purpose of the Project Assessment Worksheet is to communicate the goals of the project related to the funding drivers and the restoration potential of the specific site. Guidance on completing this worksheet follows.

Programmatic Goals – The programmatic goals relate to the funding source of the project. These are bigger-picture goals that are often independent of the project site. Select Mitigation, TMDL, Grant, or Other from the drop-down menu. There is space provided to expand on the programmatic goals. For example, if the programmatic goal is to create mitigation credits, then the text box could be used to provide more information about the type and number of credits proposed.

Restoration Potential – The connection between the restoration potential and the programmatic goals should be explained. The restoration potential is described as a combination of the site constraints, watershed health, and reach condition potential. Practitioners can use the concept of the pyramid levels (Level 3: Geomorphology, Level 4: Physicochemical, or Level 5: Biology) to aid in the rationale and justification for a project's restoration potential. The restoration potential is also entered on the Quantification Tool Worksheet. Restoration potential is defined in section II.2. *Restoration Potential*.

Function-Based Goals and Objectives – Space is provided to describe the function-based goals and objectives of the project. These goals should match the restoration potential. More information on developing goals and objectives is provided in the section II.3. *Function-Based Design Goals and Objectives*.

Reach and reach break description – The TN SQT is a reach-based assessment and one workbook should be assigned to each reach in a project site. Space is provided to describe the reach and the characteristics that separate it from the other reaches in the project.

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

3.2. Watershed Assessment Worksheet

The purpose of the Watershed Assessment is to assist in determining the restoration potential of the project reach.

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

Categories of watershed conditions and stressors are listed by functional category. The categories considered are provided in Table 1 on the following page.

A condition of good, fair, or poor is assessed for each category in Table 1. Once the categories are assessed there is space at the top of the form to enter the user's evaluation of the overall watershed condition. The overall watershed condition is a combination of averaging conditions and best professional judgement. There is not an automatic scoring methodology.

The overall watershed condition is left as a subjective determination so that the user and reviewer can assess and interpret the information gathered about the watershed. It is possible that the watershed condition score is heavily influenced by one or more categories that severely limits the ability to implement a restoration project. If the proposed functional lift cannot overcome certain watershed stressors, practitioners may see fit to abandon the project. Critical and substantive evaluation of watershed stressors, costs to overcome impacts, and any other site constraints need to be considered carefully to determine project feasibility. For example, a high specific conductivity in a stream impacted by mining operations could indicate there is little potential for biological lift even if the other categories in the Watershed Assessment showed a good condition. If the project was being considered to restore biomass of a rare species, then this goal may be unachievable at this site. However, this specific conductivity impairment would not prevent the restoration from achieving goals related to stability and limiting sediment input to a receiving water body.

The restoration potential is also based on best professional judgement and not an automatic scoring methodology. Guidance on selecting the restoration potential based on the Watershed Assessment is provided in the following section.

Table 1: Watershed Assessment Categories

Categories (Functional Category Affected)		Descriptions
1	Impervious cover in Watershed (Hydrology)	Percent of catchment upstream of the restoration site that is impervious surface.
2	Percent Land Use Change in Watershed (Hydrology)	Rapidly urbanizing versus rural and primarily forested.
3	Road Density in Watershed (Hydrology)	Proximity of existing and planned roads to the restoration site.
4	Percent Forested (Catchment) (Hydrology)	Percent of catchment that is forested upstream of the restoration site.
5	Catchment Impoundments (Hydrology) These include small dams, farm ponds, and large impoundments which are greater than 20 feet in height or structures with the capacity to have 30 acre-feet in storage	Presence and size of impoundments upstream of the restoration site likely to limit flow in the reach.
6	Catchment Forested Riparian Corridor (Geomorphology)	Presence of riparian corridors on streams contributing to the restoration site.
7	Fine Sediment Deposition (Geomorphology)	Extent of fine sediment present in the project reach. Category used to assess sediment supply upstream of the project site.
8	Streams within the Catchment Area Currently Assessed as Impaired (Physicochemical)	Extent of streams contributing to the restoration site known to be impaired
9	Agricultural Land Use (Physicochemical)	Livestock access to stream and/or intensive cropland in the catchment likely to impact restoration site conditions.
10	Process Wastewater Outfalls in Watershed (Physicochemical)	Proximity of Process Wastewater Outfalls (PWOs) and NPDES permits to the restoration site.
11	Impoundments and Fish Barriers (Biology)	Proximity of impoundments impacting fish passage to the restoration site, both upstream and downstream.
12	Organism Recruitment (Biology)	Proximity of desired taxa to the restoration site.
13	Other	This space is left for the user to describe another stressor identified for the stream reach that limits restoration potential.

The results of the Watershed Assessment should be evaluated to aid in the determination of the restoration potential of the reach. The restoration potential communicates whether the proposed restoration activities intend to restore geomorphology, physicochemical, or biology functions to a reference reach condition. Many projects may not propose or achieve reference conditions for all functional categories. This does not imply these projects are not beneficial or would not receive credit for compensatory mitigation. Designers are not required to restore all aspects of channel functions to reference conditions, however, those that do will see the most functional lift. Refer to section 2.1 for more detail on restoration potential.

3.3. Parameter Selection Guide Worksheet

The Parameter Selection Guide can help the user determine which parameters are most appropriate for different types of stream restoration projects. A project would rarely, if ever, enter field values for all parameters included in the TN SQT. **However, if a parameter is evaluated in the Existing Condition Assessment, it <u>must</u> also be evaluated in the Proposed Condition Assessment and all monitoring events.** The TN SQT is a calculator and will score a functional category if only one parameter within that category is assessed. It's application as a condition assessment should therefore be limited and results evaluated based on what parameters have been included in the assessment.

The Parameter Selection Guide worksheet and this section provides recommendations on when parameters in the TN SQT are applicable to a project. However, these recommendations are not policy and users performing stream restoration for compensatory mitigation should consult the TN Stream Mitigation Guidelines (2018). It is recommended that work with the IRT to determine a list of parameters suitable for each project that will determine whether project goals and objectives are being met.

The following parameters should be included for all assessments throughout Tennessee:

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

In order to provide a minimum condition achieved by restoration, it is recommended that **ALL** projects try to bring floodplain connectivity, lateral stability, riparian vegetation, and bed form diversity to a functioning condition at the end of the project. These four parameters are referred to as "The Big Four" parameters. Since the riparian vegetation reference standards are based on a functioning forest, restoration sites with newly-planted trees will not achieve a functioning score within the typical five- to seven-year monitoring period. Regardless, it should be included in minimum quality requirements by achieving a parameter score of 0.60, which is well within the functioning-at-risk range. The Quantification Tool worksheet will display a warning message reading "WARNING: Sufficient data are not provided" if data are not entered for at least the big four parameters: floodplain connectivity, lateral stability, riparian vegetation and bed form diversity.

The TN SQT can be applied to stream restoration projects installed in combination with BMPs. Projects performed for compensatory mitigation may not propose stand-alone BMPs or BMPs installed independently of/not adjacent to a stream restoration reach for mitigation credit. If your project is proposing BMPs, add any of the following applicable parameters to the list above based on what the BMP will treat:

- Nutrients
- Nitrogen
- Phosphorus

Note that the measurement method for the nutrients parameter is a biological-response surrogate for nutrient monitoring (Nutrient-Tolerant Macroinvertebrate metric) and may not require additional monitoring of nitrogen and/or phosphorus. At least one of these parameters (nutrients, nitrogen, or phosphorus) should be required for projects with physicochemical restoration potential.

The following additional parameters should be required for projects with biology restoration potential but are encouraged for use at all sites:

- Macroinvertebrates
- Fish for streams large enough to have a reference standard capable of supporting a level of species diversity adequate for the measurement methods.

Not all regions in Tennessee have reference standards for fish. If a project lies outside of these areas, monitoring is still encouraged to document change but scoring will not be available in the TN SQT. If the user monitors the project reach and a reference reach, site-specific reference standards could be developed and incorporated into the TN SQT.

The rest of the parameters and their measurement methods can be selected based on their applicability to the project reach.

- Catchment Hydrology is recommended for projects with easements that include a large portion of the catchment upstream of the stream restoration reaches.
- Bed Material Characterization is recommended for streams with gravel beds and sandy banks, where there is potential to coarsen the bed.
- Bacteria is recommended where livestock have access to the stream.

Parameter Selection Example

Consider a typical level 3 project with a potential to restore geomorphology to a channel in a pastureland setting. The catchment is small and consists mostly of rural and agricultural land uses. The overall watershed assessment is fair and stressors would not prevent at least some biological lift (but not back to reference condition). 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 bedform diversity; 3) adding woody debris to the channel to provide channel complexity and fish habitat; and 4) planting woody riparian vegetation along the streambank and across the floodplain. The parameter list would likely consist of:

- Reach Runoff
- Floodplain Connectivity (Should be brought to a functioning condition)
- Lateral Stability (Should be brought to a functioning condition)
- Riparian Vegetation (Should be brought to a functioning condition or, if this is not possible within the monitoring period, on a trajectory towards a functioning condition)
- Bed Form Diversity (Should be brought to a functioning condition)
- Large Woody Debris
- Sinuosity
- Bacteria
- Organic Enrichment
- Macroinvertebrates
- Fish

While the project only has the potential to improve geomorphology, there is monitoring at levels 4 and 5 because the project is expected to show some improvement in these functional categories. If the project does functionally lift these categories, appropriate credit can be awarded. However, the project is not expected, nor is required to return macroinvertebrates and fish biomass back to a reference condition.

3.3.1. Measurement Method Selection

Recall measurement methods are specific tools, equations, assessment methods, etc. that are used to quantify the function-based parameter. Some function-based parameters in the TN SQT have more than one measurement method. Some parameters have measurement methods that complement each other, while some measurement methods are redundant. The Parameter Selection Guide can help the user determine which measurement methods are most appropriate for the selected parameters. Like parameters, **if a measurement method is evaluated in the Existing Condition Assessment, it <u>must</u> also be evaluated in the Proposed Condition Assessment and all monitoring events.** Due to differences in scoring, it is not

Hydrology Functional Category

1. <u>Catchment Hydrology Parameter</u>. Catchment hydrology assesses the catchment upstream of the project reach. This parameter currently has only one measurement method: Land Use Curve Number (CN) Value.

2. Reach Runoff Parameter. Reach runoff addresses the land that drains directly to the project reach while the catchment hydrology parameter refers to the catchment upstream of the project reach. The reach runoff parameter consists of four measurement methods: stormwater infiltration, concentrated flow points, soil compaction, and soil bulk density. Stormwater infiltration, concentrated flow points, and one of either soil compaction or soil bulk density should be assessed for all projects.

Hydraulics Functional Category

3. Floodplain Connectivity Parameter. This parameter contains two measurement methods: entrenchment ratio (ER) and bank height ratio (BHR). Bank height ratio quantifies the frequency that the floodplain is inundated and the entrenchment ratio quantifies the lateral extent of floodplain inundation. Both measurement methods should be used for all projects.

Geomorphology Functional Category

4. Large Woody Debris Parameter. This parameter contains two measurement methods: a large woody debris (LWD) piece count and a LWD index. It is recommended to use either the piece count or the LWD index. The piece count is considered more rapid than the index.
5. Lateral Stability Parameter. There are three measurement methods for this parameter: erosion rate, dominant BEHI/NBS, and percent streambank erosion. It is recommended to use the percent eroding bank measurement method **and** either the erosion rate or dominant BEHI/NBS. It is not suggested to use both erosion rate and dominant BEHI/NBS. It is suggested to use percent eroding bank to supplement the data from either erosion rate or dominant BEHI/NBS and not use it by itself to describe lateral stability.
6. Riparian Vegetation Parameter. There are four measurement methods for riparian vegetation and each measurement method assesses the left and right bank separately resulting in 8 possible field values. The measurement methods are canopy coverage, basal area, buffer width, and stem density. Buffer width and canopy coverage should be assessed for all projects. It is recommended to use either basal area or stem density to assess all projects, not both. While basal area is preferred, this measurement may not be practical where vegetation is being established. The index score for the stem density measurement method is capped at 0.50.
7. Bed Material Characterization Parameter. There is one measurement method for this parameter: Size Class Pebble Count Analyzer spreadsheet tool.[3]
8. Bed Form Diversity Parameter. This parameter should be assessed for all projects. There are four measurement methods for this parameter: pool spacing ratio, pool depth ratio, percent riffle, and aggradation ratio. The first three measurement methods should be used for all projects. The aggradation ratio is optional for those projects where symptoms of aggradation are present, such as mid-channel or transverse bars.
9. Plan Form Parameter. There is one measurement method for this parameter: sinuosity.

Physicochemical Functional Category

[3] http://www.stream.fs.fed.us/publications/software.html

10. Bacteria Parameter. There is one measurement method for this parameter: E. Coli.
11. Nutrients Parameter. There is one measurement method for this parameter: percent nutrient-tolerant macroinvertebrates.
12. Nitrogen Parameter. There is one measurement method for this parameter: Nitrate-Nitrite.
13. Phosphorus Parameter. There is one measurement method for this parameter: Total Phosphorus.

Biology Functional Category

14. Macroinvertebrates Parameter. There are four measurement methods for this parameter: Tennessee Macroinvertebrate Index (TMI), percent clingers, percent EPT-Cheumatopsyche, and percent Oligochaeta and Chironomidae. Users may choose to attempt functional lift by reporting either the TMI or the other three biometrics. However, sample collection methods (following the TDEC SOP) will yield a score of TMI (a suite of 7 biometrics) where the clingers; Cheumatopsyche; and Oligochaeta and Chironomidae are a subset. Depending on the health of the reach catchment, the proposed restoration may not be able to achieve lift if the TMI is used. The index scores for the three biometric measurement methods are capped at 0.50.
15. Fish Parameter. There are two measurement methods for this parameter: native fish score index and fish catch per unit effort (CPUE) score. These measurement methods must be applied in consultation with the IRT to determine the stream size and scoring criteria appropriate for the project watershed.

3.4. Reference Standards Worksheet

The purpose of the Reference Standards worksheet is to provide equations that convert field values for measurement methods into index values. The field value is measured while the index value is a score between 0.00 and 1.00. The reference standards determine the functional capacity of a measurement method as functioning (F), functioning-at-risk (FAR), or not functioning (NF) compared to a reference condition. The following delineations apply to all index values:

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

Best-fit equations were applied to the known breaks between F, FAR and NF based on published research or best professional judgement of the author and contributors.

The Reference Standards worksheet is locked to protect the reference standard calculations. The user cannot make changes to the reference standards. However, the user can see all of the reference standards, may contribute to the database for the reference standards, and can make suggested changes based on that data. This could include local reference reach data or better modeling, depending on the parameter and measurement method.

This worksheet organizes measurement method reference standards into columns based on the functional category. For each measurement method, the field value is translated into an index value ranging from 0.00 to 1.00 using reference standards. One measurement method can have multiple sets of reference standards depending on the stratification requirements. For example, the entrenchment ratio (one of two measurement methods determining the functional capacity of floodplain connectivity) has different reference standards based on the proposed stream type (shown in Table 2). The full list of reference standards and their stratification is provided in in the List of Metrics workbook.

Table 2: Entrenchment Ratio Reference standards

Measurement Method (Units)	Reference standard Stratification		NF Score		FAR Score		F Score	
	Type	Description	Min	Max	Min	Max	Min	Max
Entrenchment Ratio (ft/ft)	Proposed Stream Type & Rosgen Priority Level 3	C or E or Bc & Rosgen Priority Level 3	< 2.0		2.0	2.3	2.4	≥ 5.0
	Proposed Stream Type & Rosgen Priority Level 3	A, B or Bc & Not Rosgen Priority Level 3	< 1.2		1.2	1.3	1.4	≥ 2.2

For a C-type channel, an entrenchment ratio of 2.4 or greater is considered functioning while an entrenchment ratio of less than 2.0 is considered not functioning. An entrenchment ratio of 5.0 or greater will give the maximum index value possible in the TN SQT. The reference standard sheet uses these breaks to define equations that relate field values (x) to index values (y). The reference standard curve for entrenchment ratio of C or E channels is shown in Figure 3 on the following page.

The Quantification Tool worksheet links to the coefficients on the Reference Standards worksheet to calculate index values (y) from the field values (x). The red line shown at the bottom of Figure 3 indicates where a cliff occurs in the reference standard curve. For C and E proposed stream types, it is not possible to receive an index value of between 0.00 and 0.30; therefore, any entrenchment ratio less than 2.0 will yield an index value of 0.00. The equation for calculating the entrenchment ratio index value is provided on the following page.

Figure 3: Entrenchment Ratio Reference standards for C and E Stream Types

Entrenchment Ratio (ER) C and E Streams						
Field Value			2		2.4	5
Index Value	0	0.29	0.3	0.69	0.7	1
	Coefficients - Y = a * X + b					
	F	FAR& NF				
a	0.1154	1				
b	0.4231	-1.7				

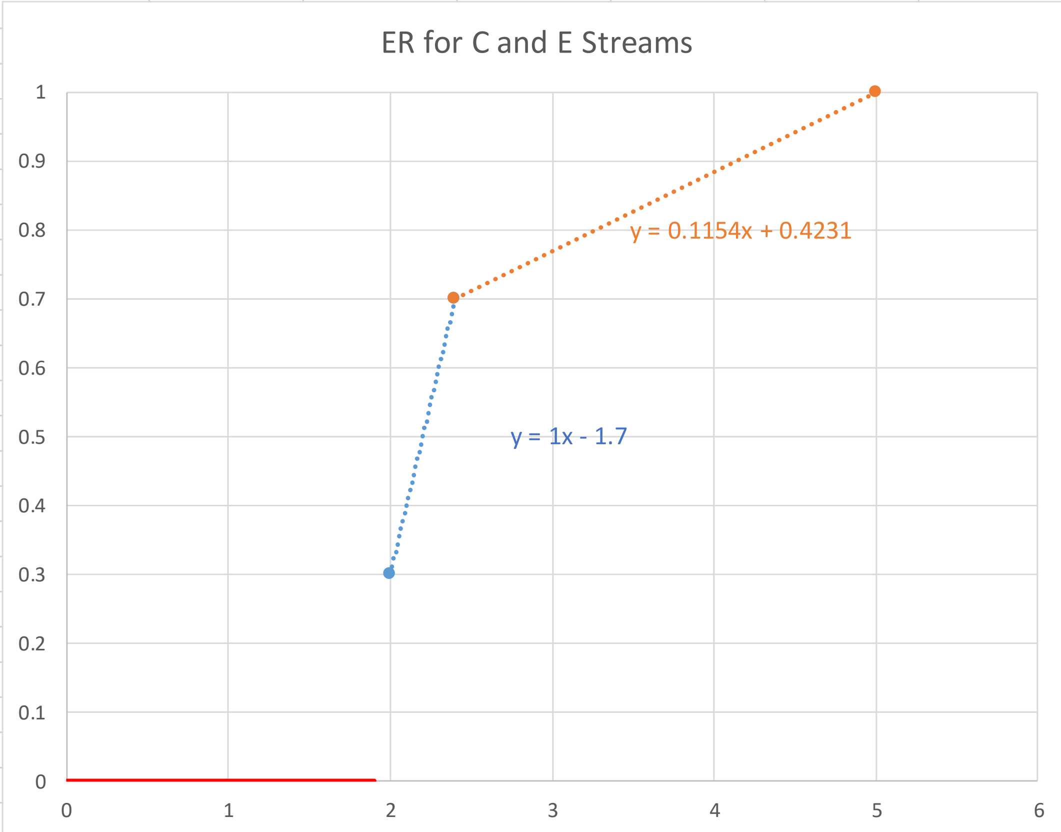


Figure 4: Index Value Equation Example for Entrenchment Ratio. Colors help match IF STATEMENTS to corresponding explanation.

Cell F52 of the Quantification Tool Worksheet:

```
“=IF(E49="","",IF(OR(B$7="A",B$7="B",B$7="Bc"), IF(E49<1.2,0, IF(E49>=2.2,1, ROUND(IF(E49<1.4,E49*'Performance Standards'!$K$84+'Performance Standards'!$K$85, E49*'Performance Standards'!$L$84+'Performance Standards'!$L$85),2))), IF(OR(B$7="C",B$7="E"),IF(E49<2.0,0, IF(E49>=5,1, ROUND(IF(E49<2.4,E49*'Performance Standards'!$L$49+'Performance Standards'!$L$50,E49*'Performance Standards'!$K$49+'Performance Standards'!$K$50),2))))))”
```

Translation:

If field value not entered, provide no index value.

If Proposed Stream Type is A, B, or Bc, then

If Field Value ≤ 1.2, then index value = 0

Else, if Field Value ≥ 2.2, then index value = 1,

Else, if Field Value < 1.4, then (Field Value) * $a_{FAR \& NF}$ + $b_{FAR \& NF}$,

Else, (Field Value) * a_F + b_F

If Proposed Stream Type is C or E, then

If Field Value < 2.0, then index value = 0

Else, if Field Value ≥ 5, then index value = 1,

Else, if Field Value < 2.4, then (Field Value) * $a_{FAR \& NF}$ + $b_{FAR \& NF}$,

Else, (Field Value) * a_F + b_F

3.5. Quantification Tool Worksheet

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

The Quantification Tool worksheet always requires data entry in three areas: Site information and Reference Standard Stratification, Existing Condition Field Values, and Proposed Condition Field Values. Cells that allow input are shaded grey and all other cells are locked. Each section of the worksheet is discussed below.

3.5.1. Site Information and Reference Standard Stratification

The Site Information and Reference Standard Stratification section (Figure 5) is briefly described in this section. The reference standards and stratification for each measurement method are summarized in the List of Metrics document.

Most of the inputs shown in Figure 5 are linked to the selection of reference standards where a field value is entered for a measurement method. If there are no reference standards for a selected measurement method, the spreadsheet may return an index value of FALSE. An index value of FALSE may also occur if there are data missing from the Site Information and Reference standard Stratification section. If the TN SQT is returning FALSE, the user should check this section in the TN SQT for data entry errors and then check the stratification for the measurement method in the List of Metrics to see if there are reference standards applicable to the project. Incorrect information in the Site Information and Reference standard Stratification section may result in applying reference standards that are not suitable for the project.

If there are no reference standards for a selected measurement method, the spreadsheet may return an index value of FALSE. An index value of FALSE may also occur if there are data missing from the Site Information and Reference standard Stratification section.

Figure 5: Site Information and Reference Standard Stratification Input Fields

Site Information and Reference Standard Stratification	
Project Name:	Field Test
Reach ID:	1
Existing Stream Type:	F
Proposed Stream Type:	C
Ecoregion:	66d
Drainage Area (sqmi):	1.2
Proposed Bed Material:	Sand
Existing Stream Length (feet):	1000
Proposed Stream Length (feet):	1200
Proposed Stream Slope (%):	0.8
Proposed Flow Type:	Perennial
Data Collection Season:	January - June
Macro Collection Method:	SQKICK
Riparian Soil Texture:	Sandy
Valley Type:	Confined Alluvial

Project Name – Enter the project name.

Reach Name or ID – Enter a unique name or identification number for the project reach. For example: Reach 1. Note, a single project can have multiple reaches.

Existing Stream Type – Select the existing Rosgen Stream Type from the drop-down menu. This input is not used in the scoring; it is only for communication purposes.

The TN SQT relies on the Rosgen Stream Type (Rosgen, 1996)[4] to stratify performance standards for some hydraulic and geomorphic measurement methods. This stream classification system and the fluvial landscapes in which the different stream types typically occur are described in detail in *Applied River Morphology* (Rosgen 1996). The existing stream type is determined through a field survey while the reference stream type is determined during the design process based on the fluvial landscape, historic channel conditions, and/or anthropogenic constraints. The design process is beyond the scope of this user manual; however, more detail can be found in the Natural Resources Conservation Service's National Engineering Handbook, Part 654 (Stream Restoration Design; 2007), Skidmore et al. (2011), and Yochum (2016).

Proposed Stream Type - Select the reference Rosgen Stream Type from the drop-down menu. The proposed stream type is used as a communication tool and to select the correct reference standard table for entrenchment ratio, pool spacing ratio, pool depth ratio, and sinuosity.

[4] Rosgen Stream Type information is also available through the EPA: https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1189

Ecoregion – Select the EPA Level IV Ecoregion[5] from the drop-down menu. This selection is used to determine the correct reference standard table for percent nutrient tolerant macros, nitrate-nitrite, total phosphorus, TMI, percent clingers, percent EPT- Cheumatopsyche, and percent Oligochaeta and Chironomidae.

Drainage Area – Enter the catchment drainage area in square miles. The reach catchment is the portion of the project watershed that drains to the uppermost end of the project reach. This value is used to determine the correct reference standard table for percent nutrient tolerant macros, nitrate-nitrite, total phosphorus, percent clingers, percent EPT- Cheumatopsyche, and percent Oligochaeta and Chironomidae.

Proposed Bed Material – Select the proposed bed material from the drop-down menu based on the dominant bed material for the project reach. The selection should be based on the proposed condition, so if the existing condition has sand and the proposed condition is gravel dominated, the selection should be gravel. This selection is used to determine the correct reference standard table to use for bed form diversity, plan form and bed material characterization.

Existing Stream Length – Enter the existing stream length in feet. The proposed and existing steam lengths are used in the functional foot calculation.

Proposed Stream Length – Enter the proposed stream length in feet. The proposed and existing steam lengths are used in the functional foot calculation.

Stream Slope (%) – Enter the proposed stream slope as a percent. This input is not used in the scoring; it is only for communication purposes.

Flow Type – Select perennial, intermittent, or ephemeral from the drop-down menu. This input is not used in the scoring; it is only for communication purposes.

Data Collection Season – Select the season in which macroinvertebrate data were collected. This value is used to determine the correct reference standard table to use for percent nutrient tolerant macros, percent clingers, percent EPT- Cheumatopsyche, and percent Oligochaeta and Chironomidae.

Macroinvertebrate Collection Method – Select the method that was used to collect macroinvertebrate data (e.g. SQSH-Kick or SQSH-Bank). This value is used to determine the correct reference standard table to use for percent clingers, percent EPT- Cheumatopsyche, and percent Oligochaeta and Chironomidae.

Riparian Soil Texture – Select the dominant soil texture for the land draining directly to the project reach. This value is used to determine the correct performance standards for soil bulk density.

Valley Type – Select the valley type from the drop-down menu. This value is used to determine the correct reference standard table to use for sinuosity.

The valley type options are unconfined alluvial, confined alluvial or colluvial. Alluvial valleys are wide low gradient (typically less than 2% slope) valleys that support meandering stream types. Confined-alluvial valleys are those that support transitional stream types between step-pool and

[5] ftp://newftp.epa.gov/EPADataCommons/ORD/Ecoregions/tn/tn_eco_lg.pdf

meandering or where meanders intercept hillslopes. Colluvial valleys are confined and support straighter, step-pool type channels.

- Alluvial Valley (Unconfined) – Valley formed by the deposition of sediment from fluvial processes.
- Confined Alluvial Valley – Valley formed by the deposition of sediment from fluvial processes but confined between adjacent hillslopes. The meander bends often intersect the hillslopes and the width of the valley is often less than seven times the width of the bankfull channel. These valleys typically have noticeable slope changes in very short distances.
- Colluvial Valley – Valley formed by the deposition of sediment from hillslope erosion processes. Colluvial valleys are typically confined by terraces or hillslopes.

3.5.2. Existing and Proposed Condition Assessment Data Entry

Once the Site Information and Reference standard Stratification section have been completed, the user can input data into the field value column of the Existing and Proposed Condition Assessment tables. There are separate tables for the Existing Condition Assessment and Proposed Condition Assessment. The user will input field values for the measurement methods associated with a function-based parameter (See Figure 6 on the following page as an example). The function-based parameters are listed by functional category, starting with hydrology. The Proposed Condition Assessment field values should consist of reasonable values that the project could achieve within the monitoring period. In other words, the proposed values are a prediction, which will be validated during the monitoring phase.

Important Notes:

- If a value is entered for a measurement method in the Existing Condition Assessment, a value must also be entered for the same measurement method in the Proposed Condition Assessment.
- For measurement methods that are not assessed (i.e., a field value is not entered), the measurement method is removed from the scoring. It is NOT counted as a zero.

A project would rarely, if ever, enter field values for all measurement methods included in the TN SQT. The Parameter Selection Guide worksheet and section 3.3. of this manual provide guidance on which parameters and measurement methods to assess. It is recommended that practitioners and regulators work together to determine a list of parameters and measurement methods suitable for each project that will determine whether project goals and objectives are being met. Likewise, the practitioners and regulators can work together to determine if any reference standards need to be adjusted based on local data.

For guidance on collecting and calculating the field values see the *Data Collection and Analysis Manual*. Additionally, the *List of Metrics* document includes a list of all function-based parameters, measurement methods, and reference standards with a reference citing the source of the reference standard and in some cases a link to tools and data collection guidance.

Figure 6: Example of Field Value Data Entry in the Condition Assessment

Functional Category	Function-Based Parameters	Measurement Method	Field Value
Hydrology	Catchment Hydrology	Land Use Curve Number Value	63
	Reach Runoff	Stormwater Infiltration	0.6
		Concentrated Flow Points	2
		Soil Compaction (inches)	5
		Soil Bulk Denisty (g/cm^3)	
Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.6
		Entrenchment Ratio	1.9
Geomorphology	Large Woody Debris	Large Woody Debris Index	198
		# Pieces	
	Lateral Stability	Erosion Rate (ft/yr)	0.5
		Dominant BEHI/NBS	
		Percent Streambank Erosion (%)	40
	Riparian Vegetation	Left Canopy Coverage (%)	0
		Right Canopy Coverage (%)	0
		Left Buffer Width (feet)	10
		Right Buffer Width (feet)	10
		Left Basal Area (sq.ft/acre)	0
		Right Basal Area (sq.ft/acre)	0
		Left Stem Density (stems/acre)	
		Right Stem Density (stems/acre)	
	Bed Material Characterization	Size Class Pebble Count Analyzer (p-value)	
	Bed Form Diversity	Pool Spacing Ratio	7
		Pool Depth Ratio	1.2
		Percent Riffle (%)	40
		Aggradation Ratio	
	Plan Form	Sinuosity	1.1
Physicochemical	Bacteria	E. Coli (Cfu/100 mL)	600
	Organic Enrichment	Percent Nutrient Tolerant Macroinvertebrates (%)	
	Nitrogen	Nitrate-Nitrite (mg/L)	50
	Phosphorus	Total Phosphorus (mg/L)	
Biology	Macroinvertebrates	Tennessee Macroinvertebrate Index	
		Percent Clingers (%)	15
		Percent EPT - Cheumatopsyche (%)	15
		Percent Oligochaeta and Chironomidae (%)	50
	Fish	Native Fish Score Index	1
		Catch per Unit Effort Score	3

3.5.3. Scoring Functional Lift

Scoring occurs automatically as field values are entered into the Existing Condition Assessment or Proposed Condition Assessment tables. A field value will correspond to an index value ranging from 0.00 to 1.00 for that measurement method. Measurement method index values are averaged to calculate parameter scores; parameter scores are averaged to calculate functional category scores. Functional category scores are multiplied by 0.20 and summed to calculate overall condition scores. Each of these components is explained below.

Note that the TN SQT will display a warning message above the Functional Category Report Card reading “WARNING: Sufficient data are not provided.” if data are not entered for at least the following parameters:

1. Floodplain Connectivity
2. Lateral Stability
3. Riparian Vegetation
4. Bed Form Diversity

Index Values. The reference standards available for each measurement method are visible in the Reference Standards worksheet and summarized in the List of Metrics workbook. When a field value is entered for a measurement method on the Quantification Tool worksheet an index value between 0.00 and 1.00 is assigned to the field value (An example is shown in Figure 7).

Figure 7: Index Values automatically populate when Field Values are entered.

Measurement Method	Field Value	Index Value
Land Use Curve Number Value	63	0.51
Stormwater Infiltration	0.6	0.6
Concentrated Flow Points	2	0.5
Soil Compaction (inches)	5	0.25
Soil Bulk Denisty (g/cm^3)		
Bank Height Ratio	1.6	0.2
Entrenchment Ratio	1.9	0.89

When a field value is entered on the Quantification Tool worksheet, the neighboring index value cell checks the data in the Site Information and Reference Standard Stratification section and either returns an index value based on the appropriate reference standard (Figure 7) or returns FALSE (Figure 8). Some of the reference standards have a limited range of application. For example, the pool spacing ratio for bed form diversity only has reference standards for B or Bc stream types with a gravel bed. If the reference stream is a B stream type with a sand bed, then the field value will return FALSE. An index value of FALSE may also occur if the Site Information and Reference Standard Stratification section is missing data, as is the case in Figure 8 where stream type was not entered into the TN SQT.

Figure 8: Index Value Errors

Measurement Method	Field Value	Index Value
Pool Spacing Ratio	7	FALSE
Pool Depth Ratio	2	FALSE
Percent Riffle	8	FALSE
Aggradation Ratio		

If the TN SQT does not return an index value as excepted, the user should check the Site Information and Reference Standard Stratification section in the TN SQT for data entry errors and then check the stratification for the measurement method in the List of Metrics to see if there are reference standards applicable to the project. Incorrect information in the Site

Information and Reference Standard Stratification section may result in applying reference standards that are not suitable for the project.

Roll Up Scoring. Measurement method index values are averaged to calculate parameter scores; parameter scores are averaged to calculate category scores. The category scores are then multiplied by 0.20 and summed to calculate overall condition scores (Figure 9). For measurement methods that are not assessed (i.e., a field value is not entered), the measurement method is removed from the scoring and no index value is provided. It is NOT counted as a zero in calculating the parameter score.

Recall that the following delineations apply to all index values:

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

The category scores are multiplied by 0.20 and summed to calculate overall condition scores. This roll-up scoring procedure will incentivize monitoring at levels 4 and 5 since the maximum overall condition score achievable without monitoring these levels is 0.60.

While the overall condition is described as not functioning or functioning-at-risk depending on the scoring outlined above, a functioning overall condition can only be achieved if all functional categories are functioning, as shown in Figure 9 where the overall condition score is 0.73 but the physicochemical and biology functional categories are functioning-at-risk and so the overall condition is described as functioning-at-risk.

Since the tool is a simple calculator, caution must be taken in interpreting the results. For example, while the tool may report that a stream is functioning at a physicochemical level, this may be because only temperature was monitored but there may be indicators in the watershed assessment to suggest that other parameters may be a concern in the stream. The Parameter Selection Guide can help ensure that all appropriate parameters are assessed.

Figure 9: Roll Up Scoring Example

Functional Category	Function-Based Parameters	Parameter	Category	Category	Overall	Overall
Hydrology	Catchment Hydrology	0.51	0.48	Functioning At Risk	0.29	Not Functioning
	Reach Runoff	0.45				
Hydraulics	Floodplain Connectivity	0.10	0.10	Not Functioning		
Geomorphology	Large Woody Debris	0.29	0.18	Not Functioning		
	Lateral Stability	0.20				
	Riparian Vegetation	0.02				
	Bed Material Characterization					
	Bed Form Diversity	0.40				
	Plan Form	0.00				
Physicochemical	Bacteria	0.60	0.46	Functioning At Risk		
	Organic Enrichment	0.32				
	Nitrogen					
	Phosphorus					
Biology	Macroinvertebrates	0.10	0.21	Not Functioning		
	Fish	0.33				

<u>Functional Change.</u> The Quantification Tool worksheet summarizes the scoring at the top of the sheet, next to, and under the Site Information and Reference Standard Stratification section. There are three summary tables: Functional Lift Summary, Functional Category Report Card, and Function Based Parameters Summary. The Functional Lift Summary (Figure 10) provides the overall scores from the Existing Condition Assessment and Proposed Condition Assessment sections.

Figure 10: Functional Change Summary Example

FUNCTIONAL LIFT SUMMARY	
Exisiting Condition Score (ECS)	0.29
Proposed Condition Score (PCS)	0.63
Functional Lift Score	0.34
Percent Condition Lift	117%
Existing Stream Length (feet)	1000
Proposed Stream Length (feet)	1200
Additional Stream Length (feet)	200
Existing Stream Functional Foot Score (FFS)	290
Proposed Stream Functional Foot Score (FFS)	756
Proposed FFS - Existing FFS	466
Functional Lift (%)	161%

The functional lift score is the difference between the PCS and the ECS (PCS-ECS). The percent condition lift 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.

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

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

The Proposed FFS – Existing FFS is the amount of functional lift generated by the restoration activities. The functional lift is the percent change in functional feet for a project reach.

$$Functional\ Lift = \frac{Proposed\ Stream\ FFS - Existing\ Stream\ FFS}{Existing\ Stream\ FFS} * 100$$

The Functional Category Report Card (Figure 11 on the following page) pulls the existing condition score (ECS) and proposed condition score (PCS) for each of the five functional categories from the Condition Assessment sections of the worksheet for a side-by-side comparison.

Figure 11: Functional Category Report Card Example

FUNCTIONAL CATEGORY REPORT CARD			
Functional Category	**ECS**	**PCS**	**Functional Lift**
Hydrology	0.48	0.63	0.15
Hydraulics	0.10	0.85	0.75
Geomorphology	0.18	0.79	0.61
Physicochemical	0.46	0.58	0.12
Biology	0.21	0.32	0.11

The Function Based Parameters Summary also provides a side-by-side comparison, but for individual parameter scores (Figure 12 on the following page). Values are pulled from the Condition Assessment sections of the worksheet. This table can be used to better understand how the category scores were determined. For example, while the physicochemical category may be functioning, which would suggest the stream could support biology functions, it is possible that only bacteria was assessed and water temperature is too high to support functioning biology. This table also makes it possible to quickly spot if a parameter was not assessed for both the existing and proposed condition assessments. Recall that if a value is entered for a measurement method in the Existing Condition Assessment, a value must also be entered for the same measurement method in the Proposed Condition Assessment. Finally, the table can be reviewed to determine if any required parameters were totally omitted from the assessment.

Figure 12: Function Based Parameters Summary Example

FUNCTION BASED PARAMETERS SUMMARY			
Functional Category	**Function-Based Parameters**	**Existing Parameter**	**Proposed Parameter**
Hydrology	Catchment Hydrology	0.51	0.51
	Reach Runoff	0.45	0.76
Hydraulics	Floodplain Connectivity	0.10	0.85
Geomorphology	Large Woody Debris	0.29	0.74
	Lateral Stability	0.20	1.00
	Riparian Vegetation	0.02	0.36
	Bed Material		
	Bed Form Diversity	0.40	0.93
	Sinuosity	0.00	0.90
Physicochemical	Bacteria	0.60	0.69
	Organic Enrichment	0.32	0.46
	Nitrogen		
	Phosphorus		
Biology	Macroinvertebrates	0.10	0.14
	Fish	0.33	0.50

3.7. Monitoring Data Worksheet

The Monitoring Data worksheet contains 11 Condition assessment tables (as shown in Figure 6 on page 23). The first table is identified as the As-Built Condition followed by 10 Condition Assessment tables for monitoring. The user can enter the monitoring year at the top of each condition assessment table and the date of the monitoring event. In order to plot data on the Data Summary worksheet, the monitoring year is the number of years after project completion. For all projects, the As-Built Condition is considered monitoring year 0. For a project that was completed in 2015, a monitoring event in 2017 should be identified as monitoring year 2. Each table is identical to the Existing and Proposed Condition Assessments in the Quantification Tool worksheet. The reference standards link to the Site Information and Reference Standard Stratification section on the Quantification Tool worksheet and scoring is identical to the process described in section 3.5.c.

If a value is entered for a measurement method in the Existing and Proposed Condition Assessments, a field value <u>must</u> also be entered for the same measurement method for every monitoring event completed in the Monitoring Data worksheet. This is critical to being able to track progress over the monitoring period.

3.8. Data Summary Worksheet

This worksheet provides a summary of project data from the existing condition, proposed condition, as-built condition, and monitoring assessments, as pulled from the Quantification Tool and Monitoring Data worksheets. The Data Summary worksheet features two tables and four plots.

The Function-Based Parameters Summary table, shown in Figure 13, tracks the progress over the monitoring period of assessed parameters. Note that the table in Figure 13 is truncated, as the Data Summary worksheet contains 10 monitoring columns. It is recommended that **ALL** projects monitor and bring floodplain connectivity, lateral stability, and bed form diversity to a functioning condition at the end of the project. Riparian vegetation should be at a 0.60 or greater to show that vegetation growth is on a trajectory towards a fully functioning buffer. The condition of these parameters is shown graphically in the Big Four Parameters – Condition Score Tracking plot.

The Functional Category Report Card, shown in Figure 14, tracks the progress over the monitoring period of the functional categories. Note that the table in Figure 14 is truncated, as the Data Summary worksheet contains 10 monitoring columns. The Functional Category – Condition Score Tracking plot shows the condition score for each functional category throughout the monitoring period along with the overall condition score (Figure 15).

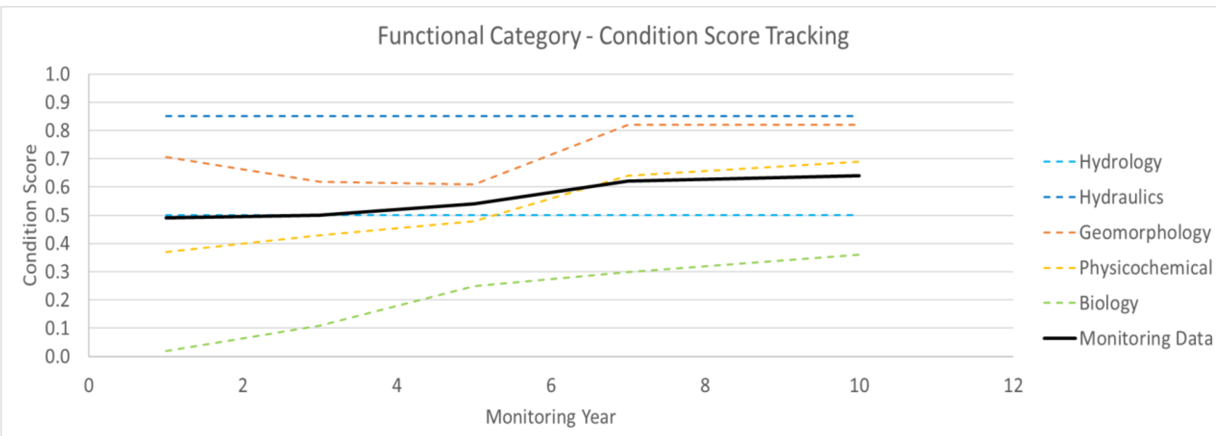
Figure 13: Function Based Parameters Summary

FUNCTION BASED PARAMETERS SUMMARY							
Functional Category	**Function-Based Parameters**	**Existing Parameter**	**Proposed Parameter**	**As-Built**	**Monitoring Year**		
					1	**3**	**5**
Hydrology	Catchment Hydrology						
	Reach Runoff	0.50	0.50	0.50	0.50	0.50	0.50
Hydraulics	Floodplain Connectivity	0.20	0.85	0.85	0.85	0.85	0.85
Geomorphology	Large Woody Debris						
	Lateral Stability	0.08	0.85	0.75	0.75	0.77	0.85
	Riparian Vegetation	0.00	0.61	0.46	0.50	0.55	0.63
	Bed Material Characterization						
	Bed Form Diversity	0.20	0.80	0.80	0.80	0.80	0.80
	Plan Form						
Physicochemical	Bacteria	0.37	0.48	0.37	0.37	0.43	0.46
	Organic Enrichment						
	Nitrogen						
	Phosphorus						
Biology	Macros	0.11	0.25	0.00	0.02	0.11	0.25
	Fish						

Figure 14: Functional Category Report Card

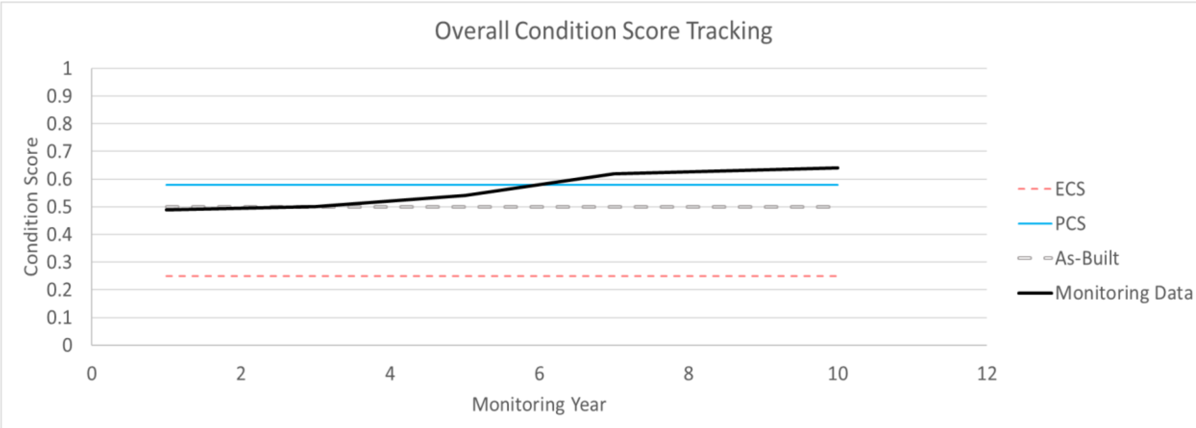
FUNCTIONAL CATEGORY REPORT CARD								
Functional Category	**ECS**	**PCS**	**As-Built**	**Monitoring Year**				
				1	**3**	**5**	**7**	**10**
Hydrology	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Hydraulics	0.20	0.85	0.85	0.85	0.85	0.85	0.85	0.85
Geomorphology	0.09	0.82	0.77	0.71	0.62	0.61	0.82	0.82
Physicochemical	0.37	0.48	0.37	0.37	0.43	0.48	0.64	0.69
Biology	0.11	0.25	0.00	0.02	0.11	0.25	0.30	0.36
Overall Score	**0.16**	**0.43**	**0.42**	**0.41**	**0.39**	**0.39**	**0.43**	**0.43**
Functional Feet	**16**	**65**	**63**	**62**	**59**	**59**	**65**	**65**

Figure 15: Functional Category Condition Score Tracking



Finally, the overall condition score and functional feet score for the project over the monitoring period are plotted graphically. The Overall Condition Score Tracking is shown in Figure 16 as an example; the Functional Feet Score Tracking plot is similar. These plots show the existing condition, proposed condition, and as-built condition as horizontal lines on the plot.

Figure 16: Overall Condition Score Tracking Plot



The worksheet is locked but if the user wishes to create additional plots of the results, it is possible to add a sheet and pull data from the locked sheets.

4. Example Spreadsheet

An example TN SQT spreadsheet populated with a fictional project has been provided to demonstrate how the TN SQT works. This example, the TN SQT and supporting documents can be downloaded from the TDEC web page (www.BLANK.org).

5. References

Fischenich, J.C. 2006. Functional Objectives for Stream Restoration. Vicksburg, M.S. U.S. Army Engineer Research and Development Center. EMRRP Technical Notes Collection, ERDC TN-EMRRP-SR-52.

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.

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

Appendix A Frequently Asked Questions

Appendix under construction.