South Carolina Stream Quantification Tool

Version 1.0

Data Collection and Analysis Manual

US Army Corps of Engineers®

StreamMechanics

ECOSYSTEM PLANNING & RESTORATION

South Carolina Stream Quantification Tool

Version 1.0

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June 2021

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 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 (EPA).

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Citation:

South Carolina Steering Committee. 2021. South Carolina Stream Quantification Tool: Data Collection and Analysis Manual, SC SQT v1.0. South Carolina Department of Natural Resources, Columbia, SC.

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Version

SC SQT Version	Date finalized	Description
Version 1.0	June 2021	Original version

Acronyms

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

BHR – Bank height ratio

BKF – Bankfull

CFP – Concentrated flow points

CVS – Carolina Vegetation Survey

DHEC – South Carolina Department of Health and Environmental Control

DNR – South Carolina Department of Natural Resources

D_{max} – Maximum bankfull riffle depth

EPT – Ephemeroptera, Plecoptera, and Trichoptera

ER – Entrenchment ratio

FF – Functional feet

GIS – Geographic Information System

LWD – Large woody debris

LWDI – Large woody debris index

MWR – Meander width ratio

NLCD – National Land Cover Database

NPDES – National Pollutant Discharge Elimination System

SC – South Carolina

SC SQT – South Carolina Stream Quantification Tool

SC DOT – South Carolina Department of Transportation

SFPF – Stream Function Pyramid Framework

STIP – State Transportation Improvement Program

TMDL – Total maximum daily load

TN – Total nitrogen

TP – Total phosphorus

WARSSS – Watershed Assessment of River Stability and Sediment Supply

W/D – Width/depth ratio

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.

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

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

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

Condition – The relative ability of an aquatic resource to support and maintain a community of organisms having a species composition, diversity, and functional organization comparable to reference aquatic resources in the region (USACE & USEPA, 2008).

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

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 process (expressed as a rate) that describes and supports the functional statement of each functional category (Harman et al., 2012).

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)

Geomorphic pools – Large pools that remain intact over many years and various flow conditions that are associated with planform features. Examples include pools associated with the outside of a meander bend (i.e., streams in alluvial valleys) and downstream of a large cascade or step feature (i.e., streams in colluvial valleys).

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

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

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

Rapid method – The rapid method assesses the basic suite of metrics within the hydrology, hydraulics, and geomorphology functional categories utilizing rapid survey procedures described in Appendix A. When performed by experienced professionals, the field component of the rapid method will typically take a team of three people 2-4 hours to complete per project reach.

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).

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 area.

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).

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

Significant pools – Geomorphic pools (see geomorphic pool definition) AND pools associated with wood, boulders, convergence, and backwater that have a width that is at least one-half the channel bottom width, a concave profile, and a water surface slope flatter than the riffle.

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 standards (performance standards) to assess the functional categories of the Pyramid (Harman et al., 2012).

Stream restoration – The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural 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 Federal Mitigation Rule. (USACE & USEPA, 2008)

Chapter 1. Introduction

The Data Collection and Analysis Manual provides instruction on how to collect and analyze data for the South Carolina Stream Quantification Tool (SC SQT). Few measurements are unique to the SQT and procedures are often detailed in other instruction manuals or literature. Where appropriate, this document will reference other data collection manuals and make clear any differences in data collection or calculation methods needed for the SQT.

When using the SQT workbook, this manual supports and compliments the *South Carolina Stream Quantification Tool Spreadsheet User Manual* (SQT Spreadsheet User Manual). The Spreadsheet User Manual describes the purposes and uses of the SQT and provides user guidance and background information for the SQT excel workbook.

When using the Debit Calculator workbook, this manual supports and compliments the South Carolina Debit Calculator Manual. The Debit Calculator Manual describes method options for data collection and data entry into the Debit Calculator.

The SQT **requires a multi-disciplinary team of professionals** who collectively have the academic background and practical training in each assessment method. Required experience and expertise includes the following disciplines: ecology, aquatic biology, plant biology, hydrology, and geomorphology. **Interdisciplinary teams of at least two people with a combination of these skill sets are necessary** to ensure consistent and accurate data collection and analyses.

SC SQT Manual Guide

1. **SQT Spreadsheet User Manual –** *Describes rules and procedures for using the SQT Microsoft Excel Workbook.*
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***.** (This document)

1.1. Manual Overview

This manual is organized as follows:

Chapter 2: Provides instruction to collect data for the Catchment Assessment. The Catchment Assessment is used to assess watershed condition and identify stressors.

Chapter 3: Provides instruction for reach segmentation, collection of parameters at the reach or sub-reach level, and bankfull verification. Introduces survey method options (rapid vs. detailed; See Appendix A for more detail). Provides instruction for data collection of general site information and entry into the Site Information and Reference Standard Stratification section of the Quantification_Tool spreadsheet.

Chapter 4: Describes assessment methods for hydrology, hydraulics, and geomorphology metrics. Provides instruction for determining or calculating existing or monitoring assessment field values and estimating proposed condition field values.

Chapter 5: Describes assessment methods for physicochemical and biology metrics. Provides instruction for determining or calculating existing or monitoring assessment field values and estimating proposed condition field values.

Chapter 2. Catchment Assessment and Stressors

The Catchment Assessment assists in characterizing watershed processes and stressors that exist outside of the project reach but affect functions and processes within the reach. The data collected in the Catchment Assessment will be similar or identical for project reaches that are on the same stream.

The purpose of the assessment is to help practitioners identify anthropogenic stressors that may have altered the underlying stream processes, including hydrologic, sediment transport, physicochemical and biological processes. It also highlights factors necessary to consider or address during the project design to maximize the likelihood of a successful project. Oftentimes, stressors cannot be changed as part of a reach-scale project; thus, they are beyond the practitioner's control. The assessment primarily includes an investigation upstream of the project reach; however, some metrics like impoundment locations also investigate downstream.

There are 12 defined categories with space for an additional user-defined category. The catchment assessment requires digital data available from various online or local resources and some site data that can be obtained through windshield surveys or site walks. Footnotes provide links to online data resources. For each category, there are three choices to describe the catchment condition: good, fair, or poor. Instructions necessary to assess each category are provided below. Data to support each selection should be documented.

Catchment Assessment Highlights

- For restoration projects, the purpose of the catchment assessment is to assist in determining restoration potential.
- The catchment assessment does not pertain to stressors within the project reach that will be treated as part of a restoration activity.
- The catchment assessment evaluates conditions upstream and sometimes downstream of the project reach.

2.1. Concentrated Flow Points

Concentrated flow points (CFPs) accelerate the natural hydrologic routing upstream of the project reach, often contributing sediment and pollutants that degrade the stream condition and may limit restoration potential. CFPs are defined as storm drains or erosional features, such as swales, gullies, or other channels, that are created by anthropogenic impacts (Figure 1 Examples of concentrated flow points). Natural ephemeral tributaries and outlets of stormwater control measures are not considered CFPs.

<u>Catchment assessment ratings:</u> A good quality catchment has no untreated CFPs to the channel immediately upstream of the reach or adjacent land uses. A fair condition has potential for CFPs, but existing measures are in place to treat them. A poor-quality catchment has CFPs entering the project reach from adjacent land uses and/or upstream without treatment.

<u>Field/Desktop procedure:</u> CFPs can be identified through aerial photo analysis, windshield surveys, or field reconnaissance. County GIS maps may also include stormwater infrastructure layers to aid in CFP identification. The potential for CFPs can also be identified using topographic data, such as a digital elevation model (DEM), and/or a review of adjacent land uses. However, this assessment should be field verified as the topographic data may be

outdated or too coarse to delineate CFPs and stormwater drainage networks may have treatments in place to mitigate pollution.

Figure 1. Examples of concentrated flow points: an agricultural ditch (left) and a storm drain (right).

2.2. Impervious Cover

Runoff from impervious surfaces arrives at a stream channel faster and with lower water quality than runoff from undeveloped ground. While stormwater control measures can help reduce pollutant loads from urban runoff, the percent of impervious cover in a catchment has been found to be indicative of stream health (Schueler et al., 2009). Therefore, this category can provide insight into the quality of water entering a restoration reach. A poor or fair catchment condition in this category would indicate that physiochemical or biological restoration would be difficult or impossible unless a large percentage of the catchment is being restored or stormwater control measures are prevalent in the catchment and reduce the impact of the impervious cover on the project reach.

Catchment assessment ratings: When impervious cover makes up 10% or less of the drainage area, the catchment condition is considered good. Impervious cover greater than 10% and less than 25% of the drainage area is considered a fair catchment condition. When impervious cover makes up 25% or more of the drainage area, the catchment condition is considered poor. (Schueler et al., 2009)

Field/Desktop procedure: An estimate of percent impervious cover can be derived from the National Land Cover Database (NLCD).[1] For smaller catchments, it is possible to delineate impervious surfaces using recent aerial imagery, which provides a more accurate estimate than the NLCD.

[1] National Land Cover Dataset: https://www.mrlc.gov/

2.3. Urbanization

Land use is temporally variable and catchments that are currently in good or fair condition can degrade quickly with development. Active construction within a catchment can cause excessive erosion and sediment supply. Urban and residential development can drastically change the hydrology and quality of water coming into the project reach.

Catchment assessment ratings: A catchment in good condition based on land use change consists of rural, or otherwise slow growth potential or primarily forested communities. Catchments with some growth potential, or perhaps uncertain growth potential are considered fair. Fair catchments might consist of single-family homes or suburban land uses. Catchments evaluated as poor in this category, such as urban or urbanizing communities, have ongoing development or imminent large-scale development.

Desktop procedure: Trends in land use can be determined through conversations with landowners, examining aerial imagery from the last 20 years or by examining the NLCD trends. Zoning designations and development plans can also be obtained from local governments and assessed for the project catchment.

2.4. Development Activities

Development near the project area can significantly impact the functioning and restoration potential of a stream reach depending on the type of development and its proximity to the project area. This category addresses large scale land uses common to South Carolina that are often independent from urbanization, including utility rights-of-way, roads, silviculture activities, energy infrastructure (oil, gas), and mining. For example, roads or other infrastructure adjacent to or crossing a project reach is a design constraint that may limit the restoration potential of the project. Road embankments alter hydraulics while roads themselves can directly connect impervious surfaces to the stream channel and serve as a source of fine sediment. This category asks the user to assess whether activities are likely to occur within a 1-mile radius of the project, and the potential for those activities to adversely affect stream function. Existing or planned development with a high potential to impact the project reach would include sites that are significant sources of contaminants and/or sediment during rain events.

Catchment assessment ratings: A catchment in good condition exhibits no development activities or potential for impacts. A catchment in fair condition exhibits moderate development activities or potential for impacts, but none within one mile of the project reach. A catchment in poor condition exhibits a 1) high level of development or potential for impacts in the watershed within one mile of the project reach, or 2) *high potential* for impacts to the project reach from greater than one mile away.

Field/Desktop procedure: The presence of utility rights-of-way, roads, silviculture activities, energy infrastructure (oil, gas), and mining near the project area can be determined in the field or using available aerial imagery and/or spatial data. Geographic Information System (GIS) data are available from the SC GIS Council and county government websites. The Department of Health and Environmental Control's (DHEC) Watershed Atlas and the Active Mine Viewer are both useful tools to assess development in a catchment[2]. Additionally, planned development of roads can be investigated using the SCDOT's State Transportation Improvement Program (STIP) E-STIP map and table describing planned STIP projects by county[3]. The E-STIP table includes projects expected to receive funding in a five-year time span.

For roads specifically, the Watershed Assessment of River Stability and Sediment Supply (WARSSS; Rosgen 2006) provides a more detailed method for evaluating the sediment impact risk of roads. The result provides an overall risk rating that could be used to determine the catchment assessment rating (See Figure 4-6 in the WARSSS book).

2.5. Percent Forested

Forested land has a lower runoff potential than developed land. The processes that prevent or lower runoff include interception, surface retention, plant uptake, flow resistance caused by vegetation, and higher rates of soil infiltration. Forested ecosystems also provide more groundwater contributions to stream channels than their urban counterparts. The lack of forested land cover can limit physicochemical and biological restoration potential as reduced forest land cover lessens the ability of the landscape to filter excess sediments and nutrients from surface water prior to draining to the project reach.

Catchment assessment ratings: Catchment areas that are 70% or more forested land are in good condition. Catchments that consist of greater than 20% and less than 70% forested land are considered fair condition. Catchments that consist of 20% or less forested land are in poor condition.

Field/Desktop procedure: The forested percentage of the catchment can be derived from the most recent NLCD. For smaller catchments, it is possible to delineate forested areas using recent aerial imagery.

2.6. Riparian Vegetation

Riparian vegetation protects the stream channel from erosive runoff velocities and provides physicochemical benefits to surface runoff and groundwater contributions to stream channels. Wider riparian corridors provide more nutrient and pollutant removal benefits, but the relationship between width and benefit is not linear (Mayer et al., 2005).

Catchment assessment ratings: Riparian corridors estimated at more than 82-feet (25-meters) wide provide stream stability to the stream channel. Thus, catchments in good condition have streamside vegetation more than 25-meters wide on average along more than 80% of the contributing stream length (channel and tributary length *upstream* of the project reach). Catchments in fair condition have streamside vegetation more than 25-meters wide on average along 50 to 80% of the contributing stream length. Catchments in poor condition have

[2] SC Watershed Atlas: www.dhec.sc.gov/atlas and the DHEC Active Mine Viewer: https://gis.dhec.sc.gov/activeminesviewer/
[3] SCDOT STIP Reports and E-STIP: https://www.scdot.org/inside/planning-stip.aspx

streamside vegetation more than 25-meters wide on average along less than 50% of the contributing stream length.

Field/Desktop procedure: The prevalence of riparian vegetation on streams draining to the project reach can be determined using recent aerial imagery and/or by driving around the catchment and performing a windshield survey.

2.7. Sediment Supply

The sediment supply entering a project reach plays an important role in determining restoration potential and reference stream type. Unnaturally high sediment loads from upstream bank erosion, upland erosion, roadways, land management practices, or from the movement of sediment stored in the bed may create a challenging design problem. Note that this category addresses human-altered sediment regimes; systems with naturally high sediment supplies would not score poorly unless the natural sediment transport processes were altered.

An analysis of the sediment regime for the reach should inform whether it is likely a source, transport, or response reach. Transport reaches are morphologically resilient, supply-limited systems that have sufficiently competent flows to move sediments through the reach (Montgomery and Buffington, 1998). For transport systems, the restoration project could aggrade if the design does not adequately address alterations in the sediment load.

Catchment assessment ratings: If there are only a few small sources of anthropogenic-caused sediment from upstream bank erosion and surface runoff, then the catchment condition is good. If there are moderate anthropogenic-caused sediment supply from upstream bank erosion and surface runoff, the catchment condition is fair. If there are multiple, large anthropogenic-caused sources of sediment supply from upstream bank erosion and surface runoff then the catchment condition is poor.

Field/Desktop procedure: Users should review recent aerial imagery of the catchment and walk as much of the upstream channel as possible looking for bank erosion, mid-channel bars, lateral bars, and other sources of sediment that can be mobilized (Figure 2).

Figure 2. Alternating point bars indicate sediment storage in the channel that can be mobilized during high flows. Bank erosion is also supplying sediment.

There are also simple tools available to estimate the sediment load that may come from surrounding land use such as the Spreadsheet Tool for Estimating Pollutant Loads (STEPL v4.4; Tetra Tech, Inc., 2018). The potential sediment supply could also be determined using WARSSS if the data will be required elsewhere in the project (Rosgen, 2006). WARSSS is an intensive level of effort that is not necessary for this catchment assessment. Another, less intensive option, is the Rapid Evaluation of Sediment Budgets (Reid and Dunne, 1996).

2.8. Proximity to 303(d) or TMDL-Listed Waters

Impaired waters are those that fail to meet water quality standards for their designated uses. DHEC can develop a total maximum daily load (TMDL) to improve water quality in these waters when one or more pollutants can be identified as causing the impairment. DHEC also provides funds for development of watershed-based plans to improve water quality.

There are many impaired waters that do not make the 303(d) list. The rest of the categories in this catchment assessment will assist in identifying impairments and possible impairments for waters that are not listed. Additionally, if recent water quality data have been collected for the project reach, then it can be used to justify a poor condition rating in this category even if the water is not listed as impaired by DHEC. Most stream restoration projects do not restore a sufficient portion of the stream or catchment to overcome poor water quality.

Catchment assessment ratings: If the project reach is not on the 303(d) list, it is considered good condition. A project reach located on, upstream, or downstream of a 303(d) water with a TMDL/watershed management plan is considered fair condition. A project reach located on, upstream, or downstream of a 303(d) water without a TMDL/watershed management plan is considered poor condition.

Field/desktop procedure: Information about DHEC's water quality monitoring strategy and water quality monitoring data are available from DHEC.[4] Information on 303(d) listed waters, approved TMDLs, and TMDLs that are in development is available from DHEC.[5] A list of DHEC-funded watershed-based plans available from DHEC.[6] Information on DHEC water quality monitoring stations, use attainment status and trends, impaired waters, approved TMDLs, priority watersheds, and watershed-based plans is also available through the DHEC Watershed Atlas.[7] USEPA hosts an interactive website entitled "How's My Waterway" that includes data from integrated reports as well.[8]

Note: Once a TMDL is created, the impaired waterbody is removed from the 303(d) list even though the water quality standards may not be met. It is therefore important to check for both 303(d) listed waters and active TMDLs in the catchment.

2.9. Agricultural Land Use

Runoff from agricultural lands often carries fecal bacteria, pesticides, excess sediment, and excess nutrients. The presence of pasture or crop land along streambanks, especially when there is little to no riparian buffer, can degrade water quality sufficiently to limit restoration potential of a stream restoration project (Figure 3).

Catchment assessment ratings: A catchment in good condition will have little to no agricultural land uses or there are forested buffers between the agriculture land uses and/or livestock and receiving waters. A catchment in fair condition will have agricultural land uses, but the negative impacts of the land uses are somewhat attenuated in the project reach. In areas where there is cattle access or cropland immediately upstream of a restored project reach, the catchment condition is poor.

Field/desktop procedure: The prevalence, proximity, and connectivity of agricultural land uses for the project area can be determined from onsite investigations, windshield surveys, and examining aerial imagery. The prevalence of agricultural lands throughout the catchment can be determined using recent aerial imagery or the NLCD.

[4] DHEC water quality monitoring strategy and water quality monitoring data: https://scdhec.gov/environment/your-water-coast/how-dhec-measures-surface-water-quality

[5] Information on 303(d) listed waters, approved TMDLs, and TMDLs in development: https://scdhec.gov/bow/south-carolina-303d-list-impaired-waters-tmdls.

[6] DHEC-funded watershed-based plans: https://scdhec.gov/environment/your-water-coast/watersheds-program/dhec-funded-watershed-based-plans.

[7] SC Watershed Atlas https://scdhec.gov/environment/your-water-coast/watersheds-program/sc-watershed-atlas.

[8] USEPA How's My Waterway: https://mywaterway.epa.gov/aquatic-life

Figure 3. Cropland immediately adjacent to stream channel and without a sufficient vegetated buffer.

2.10. NPDES Permits

The National Pollutant Discharge Elimination System (NPDES) program regulates point source discharges to water bodies, for example imposing effluent limits and monitoring and reporting requirements through permits. While the purpose of the program is to ensure the protection of water quality, these discharges can nevertheless be stressors to stream ecosystems and can limit physiochemical and biological restoration potential.

Catchment assessment ratings: A catchment in good condition has no NPDES facilities in the catchment or within one mile of the project reach. A catchment in fair condition has a few NPDES permits within the catchment but none within one mile of the project reach. A catchment in poor condition has multiple NPDES facilities in the catchment and/or one within one mile of the project reach.

Field/desktop procedure: The SC Watershed Atlas hosts information on NPDES permitted facilities.[9]

2.11. Inline Watershed Impoundments

Inline watershed impoundments are structures that can impede aquatic connectivity. The presence of a dam downstream of the project would make a goal of increasing fish biomass difficult without sufficient fish passage over the dam. A dam upstream of the project may allow

[9] SC Watershed Atlas: www.dhec.sc.gov/atlas

organism recruitment from downstream; however, it may still limit connectivity, impact stream hydrology, and impede delivery of organic material to the project reach.

Catchment assessment ratings: Catchments in good condition have no impoundments upstream or downstream of the project area, including farm ponds. If natural impoundments such as beaver dams exist that allow for fish passage at times, then the catchment is in good condition. A catchment in fair condition has a few small impoundments within the catchment, but none within one mile of the project reach. A catchment in poor condition contains an impoundment near the project area (within one mile upstream or downstream) or an impoundment that has a negative hydrologic (e.g., flow alteration) or geomorphic effect (e.g., reduced sediment supply) on the project area and fish life cycles.

Field/desktop procedure: The location of dams or other impoundments near the stream reach can be determined through field walks, recent aerial imagery, or by performing a windshield survey. The SC Watershed Atlas hosts information on State regulated dams.[10] County GIS maps and hydro layers/datasets may also include impoundments.

2.12. Organism Recruitment

Aquatic organisms rely on a variety of channel substrate sizes and characteristics to survive and reproduce. Impaired channel substrates, and other factors that limit the presence of aquatic organisms surrounding the project reach, can negatively impact macroinvertebrate community recruitment. Recruitment and colonization of aquatic organisms within stream reaches is affected by the presence of desired communities in proximity to the project area (Blakely et al., 2006; Hughes, 2007; Lake et al., 2007; Sundermann et al., 2011; Tonkin et al., 2014).

Impairments to the channel, such as hardened substrates, excessive sedimentation, culverts, or piping, may prevent macroinvertebrate communities from inhabiting a stream reach, and where extended length of channel impairments may reduce the possibility of organism recruitment. The most important source of recolonization of benthic insects is drift from upstream. If upstream reaches or tributaries are hardened, recolonization of restored reaches will take much longer. Emphasis needs to be given to the quality of upstream reaches for organism recruitment. This category may not limit the future restoration potential, because benthic insects can recolonize via adult egg deposition from nearby catchments if drift from upstream reaches is unlikely. However, this kind of recruitment process may take much longer.

Catchment assessment ratings: A catchment is in good condition if the channel immediately upstream or downstream of the project reach (e.g., within 1 km or 0.62 miles) has native bed and bank material. If the channel substrate immediately upstream or downstream of the project reach (e.g., within 1 km or 0.62 miles) has native bed and bank material that is highly embedded by fine sediment, but some proximate stream reaches support natural aquatic communities, then the catchment is in fair condition. A catchment is in poor condition if there are substantial channel impairments immediately upstream or downstream of the project reach (e.g., within 1 km or 0.62 miles) excluding natural aquatic communities from the reach. Channel impairments can include, but are not limited to, excessive deposition of fine sediments, hardened or armored

[10] SC Watershed Atlas: www.dhec.sc.gov/atlas

channels (e.g., concrete channels or grouted riffles), culverts or piped channels or other similar modifications to the channel substrate.

Field procedure: This category can be assessed by walking the site and the stream reaches immediately upstream and downstream of the project reach to determine if there are any impairments such as hardened substrates, excessive sedimentation, culverts, or piping, that may prevent macroinvertebrate communities from inhabiting a stream reach and where extended length of channel impairments may reduce the possibility of organism recruitment.

2.13. Other

This option is provided for the user to identify and document any stressor observed in the catchment that is not listed above but could limit the restoration potential or impair the functioning of the project reach. An example could be a specific contaminant of particular interest (rated using category 8 but more detail could be provided in this category) or specific conductivity downstream of a mine.

Chapter 3. Getting Started

Data collection and processing **requires a multi-disciplinary team of professionals** who collectively have the academic background and practical training in each assessment method. Required experience and expertise includes the following disciplines: ecology, aquatic biology, plant biology, hydrology, and geomorphology. **Interdisciplinary teams of at least two people with a combination of these skill sets are necessary** to ensure consistent and accurate data collection and analyses. Field trainings in specific field methods and the Stream Functions Pyramid Framework are recommended.

Prior to field data collection, several steps will inform how data will be collected:

1. Catchment assessment
2. Delineate reaches and sub-reaches.
3. Select the appropriate function-based parameters and metrics.
4. Determine if the survey methods will be rapid-based or detailed-based.
5. Review available regional curves and local data to verify bankfull stage.

Each step is described below except for step 3 (function-based parameter and metric selection) which is discussed in the SQT Spreadsheet User Manual and Debit Calculator Manual.

3.1. Reach Segmentation

The SQT is a reach corridor assessment methodology (Figure 4) with each reach evaluated separately. A large project may be subdivided into multiple reaches as stream condition or character can vary widely from the upstream end of a project to the downstream end.

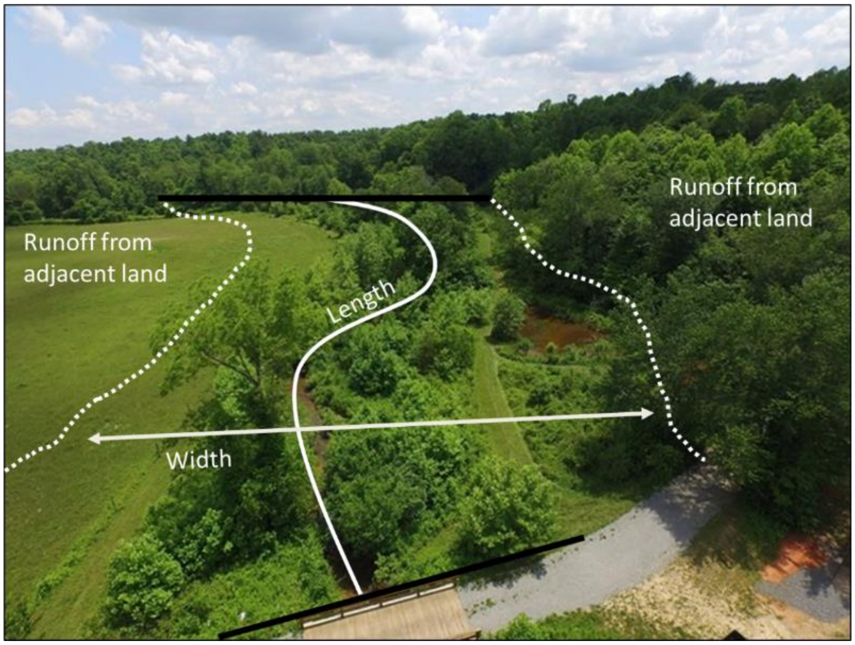


Figure 4. Reach-scale SQT assessment includes measurements within the stream channel, riparian area, floodplain, and the catchment.

Delineating stream reaches within a project area occurs in two steps:

1. The first step is to identify whether there are multiple reaches within the project area based on differences in stream physical characteristics and/or differences in restoration design approach.
2. The second step is to identify the appropriate locations within each reach to meet metric assessment requirements (Section 3.2).

The user should determine whether their project area encompasses a single homogeneous reach or multiple potential reaches. A reach is defined as a stream segment with similar processes and morphology, including characteristics such as such stream type (Rosgen, 1996), stability condition, riparian vegetation type, and bed material composition. Reaches within a project area may vary in length depending on the variability of the physical stream characteristics within the project area (Example 1).

Specific guidance is provided below to assist in making consistent reach identifications. Practitioners can use aerial imagery, National Hydrography Dataset (NHD)[11] and other desktop tools to preliminarily determine reach breaks; these delineations should be verified in the field.

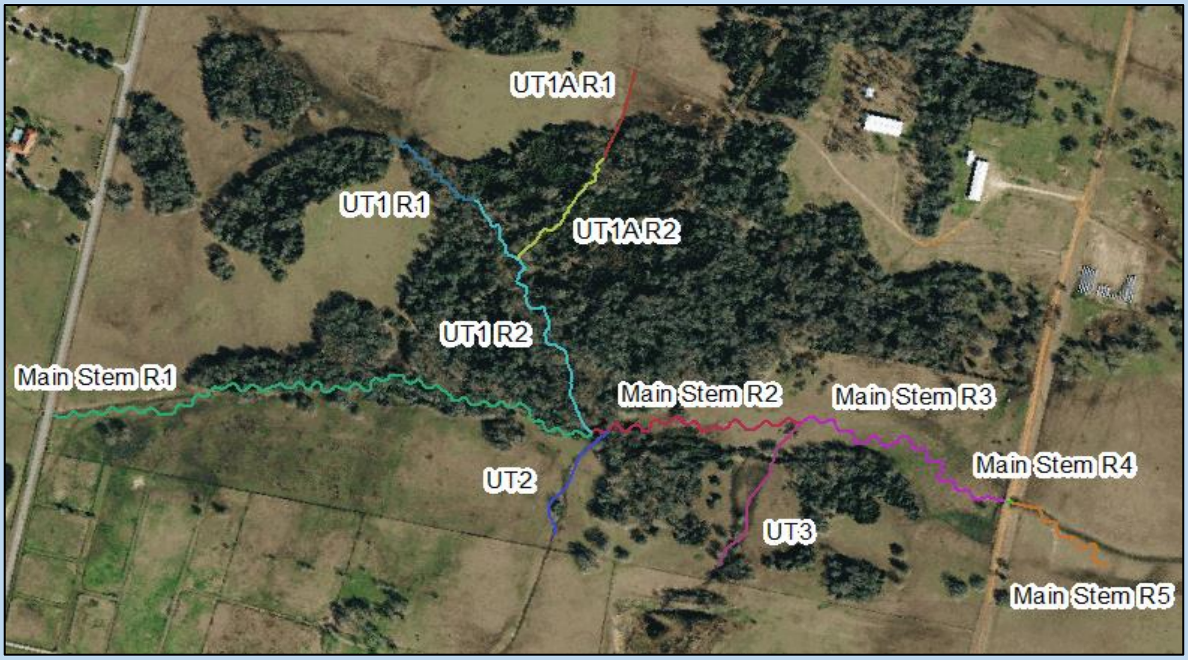
Separate streams (e.g., tributaries vs. main stem) are considered separate project reaches.

- A tributary confluence should lead to a reach break. Where a tributary enters the main stem, the main stem should be split into two project reaches - one upstream and one downstream of the confluence. Small tributaries, as compared to the drainage area of the main stem channel, may not require a reach break.
- Reach breaks should occur where there are changes to process drivers (Castro and Thorne, 2019), valley morphology, stream type (Rosgen, 1996) or bed material composition.
- Reach breaks should occur where there are diversion dams, culverts, or other structures on the stream with separate reaches upstream and downstream of the structure. The structure would also be considered a standalone reach.
- Reach breaks should occur where there are distinct changes in the level of anthropogenic modifications, such as narrowed riparian width from road embankments, concrete lined channels, dams, or stabilization practices. For example, the impounded length of stream on a large dam would be evaluated as a separate project reach from the reaches immediately up and downstream of the dam. As noted above, as a structure, the dam footprint would be a standalone reach as well.
- Multiple project reaches are needed where there are differences in the magnitude of impact or mitigation approach (e.g., enhancement vs. restoration) within the project area. For example, restoration approaches that reconnect stream channels to their original floodplain versus bank stabilization activities.

[11] National Hydrography Dataset: https://www.usgs.gov/core-science-systems/ngp/national-hydrography

Example 1: Project Reach Delineation

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



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

3.2. Parameter-based Segmentation

The SQT is an assessment of the stream channel, floodplain, riparian area, and lateral drainage area, where parameters are measured at different scales: reach and sub-reach (Figure 5). Selecting a representative sub-reach avoids quantitatively assessing very long stream lengths with similar physical conditions.

The representative sub-reach should be 20 times the bankfull width or two meander wavelengths (Leopold, 1994), whichever is longer. **If the entire reach is shorter than 20 times the bankfull width, then the entire project reach should be assessed.**

A project reach will only contain one representative sub-reach in which measurements for all applicable parameters and metrics will be taken (Figure 5).

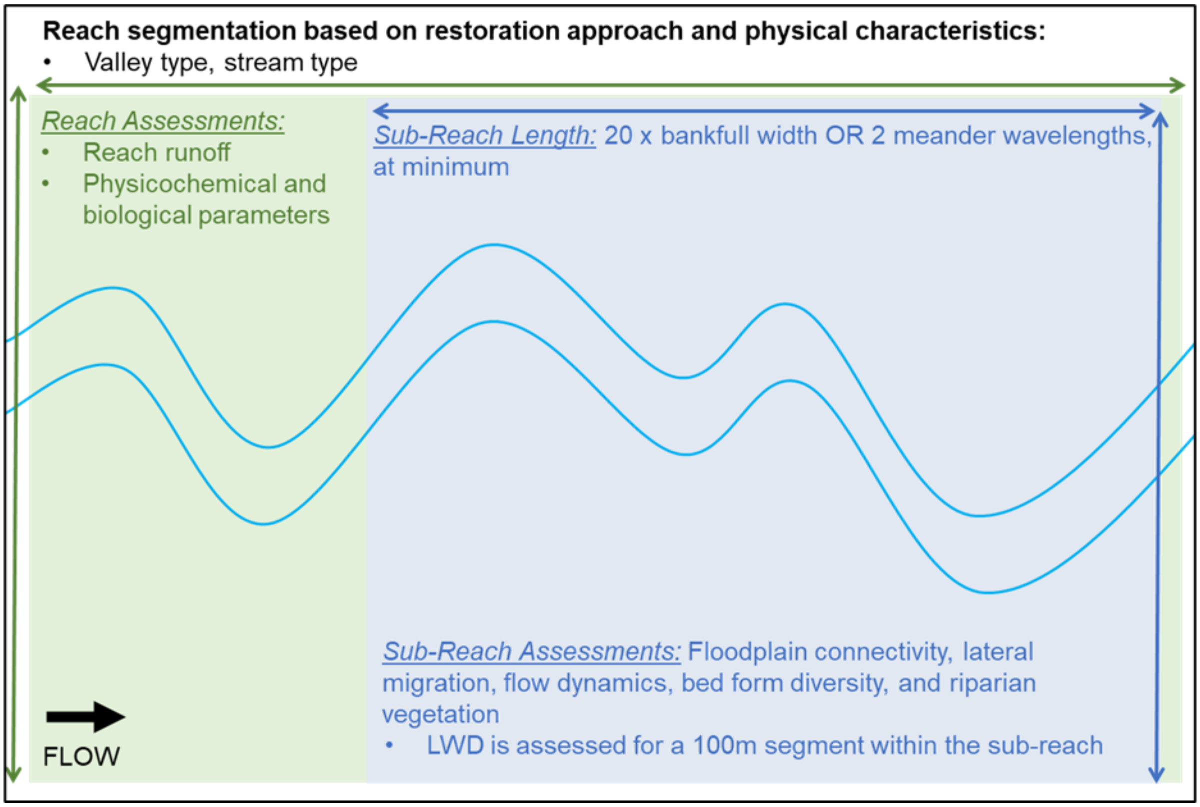


Figure 5. Reach and sub-reach segmentation and associated parameter measurements.

3.3. Rapid Versus Detailed Survey Assessment Methods

Multiple metrics used to quantify hydraulic and geomorphology parameters require data from cross-sections and longitudinal profiles. There are rapid and detailed survey procedures for collecting this data. For the detailed method, a longitudinal profile consists of at least four profiles: thalweg, water surface, bankfull, and low bank. Standard survey methods can be used to collect these data using a survey-grade GPS, laser or standard level, total station, or similar equipment (Harrelson et al., 1994; Rosgen, 2014).

Appendix A of this manual outlines the rapid survey method, in lieu of surveying cross-sections and longitudinal profiles. Parameters are quantitatively measured using tapes and stadia rods instead of standard surveying equipment like laser levels or a total station. Keep in mind that profiles cannot be plotted using this method. Rapid assessments are appropriate during the site selection and project approval process. One-time only condition assessments may also use the rapid method, or other applications where cross-section and profile plots are not required. These situations are typically associated with non-mitigation projects.

The advantage of the detailed method is that the survey data can be used to create plots/graphs and the field value calculations can be replicated in an office setting by others. The only way to replicate measurements from the rapid method is to repeat the field survey.

Rapid Assessments:

When performed by an **experienced field crew of three people**, a rapid assessment field data collection will typically take two to four hours per project reach for the basic suite of 7 parameters: reach runoff, floodplain connectivity, flow dynamics, large woody debris, lateral migration, bed form diversity, and riparian vegetation.

3.4. Bankfull Verification

Bankfull (BKF) is a discharge that forms, maintains, and shapes the dimensions of the channel as it exists under the current climatic regime. The bankfull stage or elevation represents the break point between channel formation and floodplain processes (Wolman and Leopold, 1957). Bankfull stage and bankfull dimensions are required to calculate field values for several metrics: bank height ratio (BHR), entrenchment ratio (ER), width/depth ratio (W/D) state, large woody debris index (LWDI), dominant bank erosion hazard index/near-bank stress (BEHI/NBS), pool spacing ratio, and pool depth ratio. Additionally, the SQT uses bankfull to identify the representative sub-reach length. Because several metrics rely on bankfull dimensions, correctly identifying bankfull stage is crucial to ensuring measurements and calculated field values are correct. Thus, the user should identify and verify bankfull using multiple lines of evidence. **The primary line of evidence is always field indicators;** field indicators of bankfull should be verified using regional curves or return interval analyses. Each line of evidence is described below in detail.

3.4.1. LINES OF EVIDENCE – FIELD INDICATORS

Methods for identifying the bankfull stage and calculating the bankfull dimensions can be found in Harrelson et al. (1994) and Rosgen (2014). Bankfull indicators should be identified throughout the entire project reach and can be surveyed using rapid or detailed methods (Section 3.3). The rapid method instructions for collecting data from the longitudinal profile and a stable riffle are provided in Appendix A.

The detailed method requires a longitudinal profile. Rosgen (2014) provides step-by-step instructions on how to survey a longitudinal profile and compare best-fit-lines through the water surface and bankfull points. The bankfull determination is suspect if the bankfull slope is different from the water surface slope and/or if the best-fit line through the bankfull points has a correlation coefficient (R^2 value) of less than 0.80. If values vary by more than this, the practitioner may be including other geomorphic features, such as an inner berm or a terrace.

In addition to the longitudinal profile, a cross-section must be collected from a stable riffle within the study reach. Rosgen (2014) and Harrelson et al. (1994) provide detailed methods on how to survey a cross-section.

Selection of the stable riffle is critical; the criteria below can aid in the selection of a suitable riffle:

- Stable width and depth, no signs of bank erosion or headcutting. The BHR is near 1.0.
- Cross-sectional area plots within the range of scatter used to create the regional curve. More information is provided in the next section.
- The W/D is on the lower end of the range for the reach.

In a highly degraded reach, a stable riffle cross-section may be used from an **adjacent** upstream or downstream reach. If a stable riffle meeting these criteria cannot be found within or adjacent to the reach, then the user will survey a riffle within the reach that contains the strongest bankfull indicator.

The surveyed dimensions from this cross-section are used to calculate bankfull cross-sectional area, width, and mean depth. Bankfull discharge can also be calculated from the stable riffle cross-section if channel slope and bed material samples have been collected. A variety of single-section analyzers are available for calculating discharge using the cross-section survey, average slope, and bed material data. The Reference Reach Spreadsheet version 4.3 developed by Dan Mecklenburg with the Ohio Department of Natural Resources is a free, user-friendly tool that will calculate discharge and several other hydraulic variables.[12]

3.4.2. LINES OF EVIDENCE – REGIONAL CURVES

Due to the range of climatic conditions and underlying geology, regional curves can vary significantly throughout the state. Regional curves can only be used when they are applicable to the project area. Ideally, practitioners will develop site-specific regional curves representative of the project catchment. If catchment-specific regional curves are not available, the user can overlay the field data with established curves. The SC DNR contracted with Jennings Environmental, PLLC to collect reference geomorphic data to develop regional curves tailored to South Carolina and for comparison to North Carolina's regional curves.[13] Regression hydraulic geometry regional curve relationships are available for four South Carolina ecoregions: 1) ecoregion 66 (Blue Ridge), 2) ecoregion 45 (Piedmont), ecoregion 65 (Southeastern Plains), and ecoregion 63 (Middle Atlantic Coastal Plain) (Jennings Environmental, PLLC, 2020). Note that the regional curve relationships for ecoregion 66 include data from South Carolina, North Carolina, and Tennessee.

[12] The spreadsheet is available at https://stream-mechanics.com/resources/ under spreadsheet tools.
[13] SC Regional Curves and Geomorphic reference data: https://www.dnr.sc.gov/environmental/streamrestoration.html

The cross-sectional area from stable riffle(s) are plotted on their corresponding bankfull regional curve (Figure 6). The field data should fall within the range of scatter of the regional curve. If the field data are outside the range of scatter, the practitioner will need to determine if the wrong indicator was selected (e.g., an inner berm or terrace) or if the regional curve represents a different hydro-physiographic region. If the measured area plots below the range of scatter, the indicator could be an inner berm feature. If the measured area plots above the range of scatter, the feature could be a terrace.

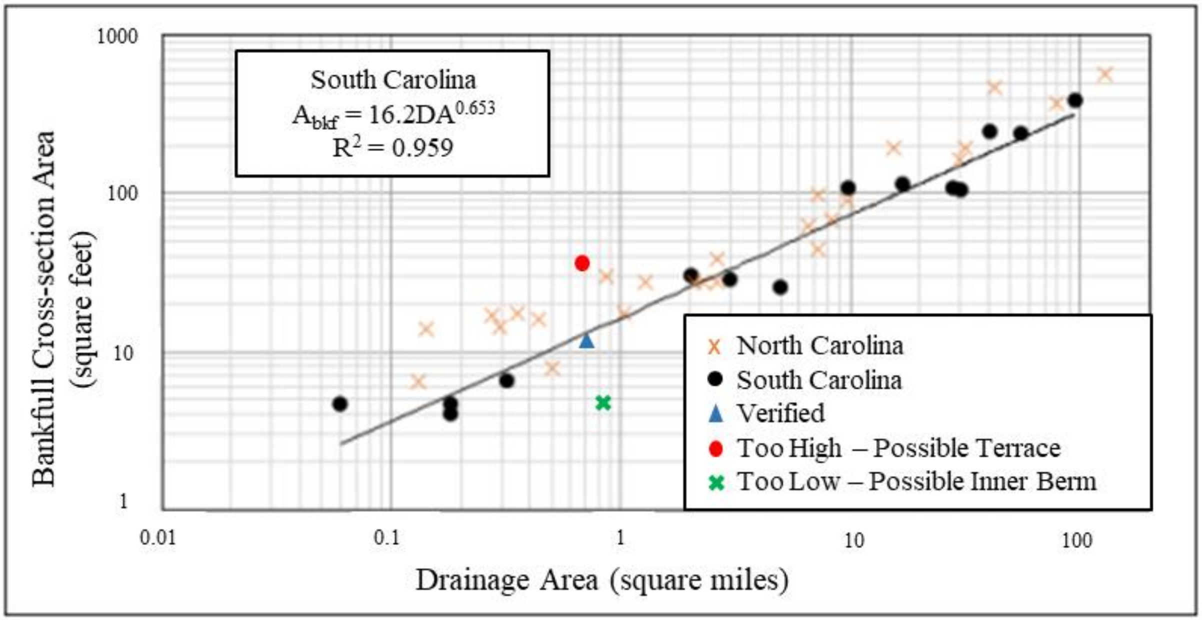


Figure 6. South Carolina Piedmont (ecoregion 45) regional curve, bankfull cross-sectional area versus drainage area. (Note: North Carolina data points are shown for comparison only and should not be used for assessment or design in South Carolina.; Jennings Environmental, PLLC, 2020).

3.4.3. LINES OF EVIDENCE – RETURN INTERVAL

The standard procedure for estimating flood frequency uses the log Pearson frequency analysis as described in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). The program PeakFQ[14] implements the Bulletin 17C procedures (England et al., 2018) for flood-frequency analysis of streamflow records. One of the simplest methods to determine return intervals, or flood frequency, for streams in South Carolina is USGS StreamStats.[15]

The common range of bankfull return intervals is 1.01- to 2-years. If the discharge calculated from the bankfull feature in the surveyed riffle cross-section is between the 1.01- and 2-year return interval discharges, the feature is verified.

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[14] PeakFQ: https://water.usgs.gov/software/PeakFQ/#:~:text=Program%20PeakFQ%20implements%20the%20Bulletin,range%20of%20annual%20exceedance%20probabilities.

[15] USGS Stream Stats: https://streamstats.usgs.gov/ss/

3.5. Site Information and Reference Standard Stratification

The Site Information and Reference Standard Stratification section consists of general site information and classifications to determine which reference curves are used to calculate index values for relevant metrics. Guidance on how to select values for this section is provided below.

The user should fill in site information such as the project name and a unique reach ID (refer to Section 3.1 for guidance on delineating project reaches). This section in the SQT workbook requires restoration potential to be selected as full or partial; refer to the SQT Spreadsheet User Manual to follow the stepwise process to determine restoration potential.

Ecoregion – Select the ecoregion in which the project reach is located from the drop-down menu. The five USEPA level III ecoregions of South Carolina are depicted in Figure 7. This value is automatically populated from the Project Summary spreadsheet. This input is used to score macroinvertebrates.[16]

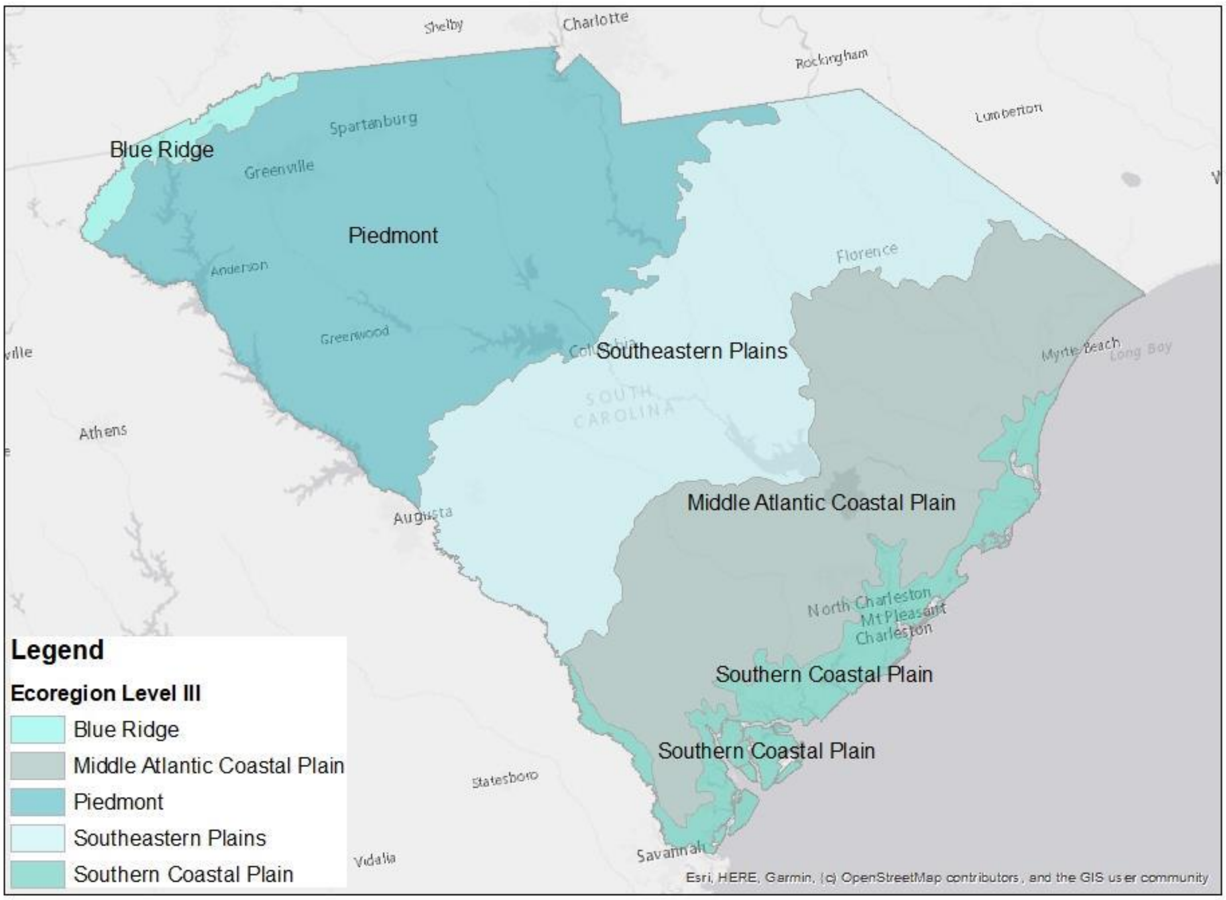

Figure 7. USEPA III ecoregions for South Carolina.

[16] Biology was not regionalized in this version of the SC SQT and reference curves for macroinvertebrates are only available for ecoregions that overlap with the North Carolina reference curves.

River Basin – Select the river basin in which the project reach is located from the drop-down menu. River basins are depicted in Figure 8. Additionally, river basins can be determined using the SC Watershed Atlas.[17] This input is a placeholder for the SC IBI for fish.

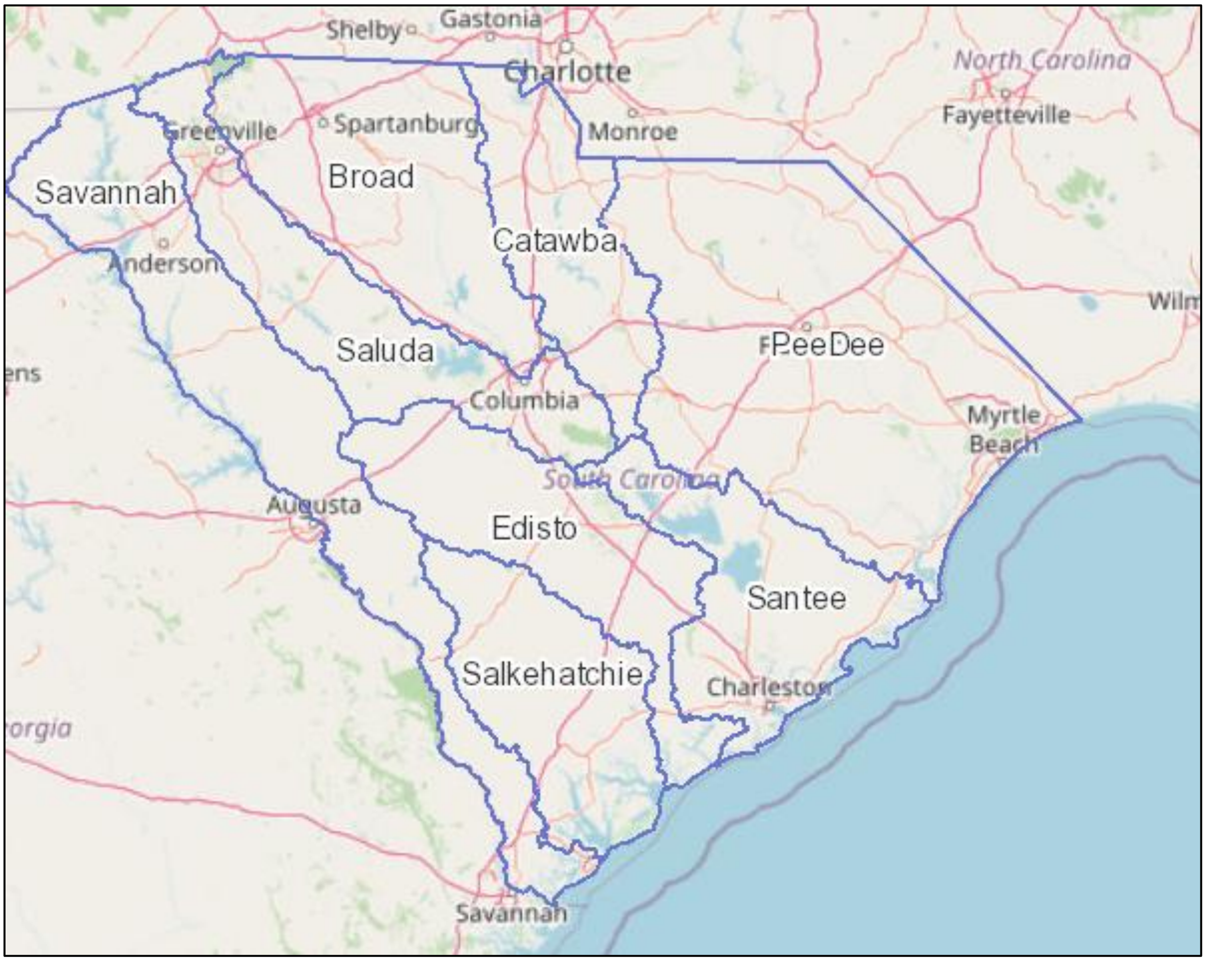

Figure 8. South Carolina major river basins generated from the SC Watershed Atlas.

Existing Stream Length (ft) – Existing project reach stream length extends from the upstream to the downstream end of the project reach. This can be determined by surveying the profile of the stream, stretching a tape in the field, or remotely by tracing the stream centerline pattern from aerial imagery or LiDAR derived data.[18] Stream length is used to calculate functional feet and is not used for reference curve stratification.

Proposed Stream Length (ft) – Proposed project reach stream length extends from the upstream to the downstream end of the project reach based on estimates from project design documents that are later verified using as-built conditions (using the above-mentioned approaches described in Existing Project Reach Stream Length). Where stream length does not

[17] SC Watershed Atlas: www.scdhec.gov/atlas
[18] USGS 2018 StreamStats Stream Lines: https://www.sciencebase.gov/catalog/item/5cf01a85e4b0b51330e22aa6

change post-project, the same value is entered for the Existing and Proposed Project Stream Length. Stream length is used to calculate functional feet and is not used for reference curve stratification.

Existing Stream Type – Select the existing Rosgen stream type (Rosgen, 1996) from a drop-down menu. The existing stream type is determined through a field survey of pre-project conditions in the project reach. This stream classification system and the basic fluvial landscapes in which the different stream types typically occur are described in detail in *Part 654 Stream Restoration Design National Engineering Handbook* (NRCS NEH, 2007). The existing stream type is provided for communication and to inform channel evolution scenarios and reference stream type selection. Existing stream type is not used for reference curve stratification.

Reference Stream Type – Select the Rosgen stream type (Rosgen, 1996) from a drop-down menu. Reference stream type represents a stream type that should occur in a specific landscape setting given the current hydrogeomorphic watershed- and reach-scale processes. This selection determines the correct reference curves for the entrenchment ratio, pool spacing ratio, pool depth ratio, and percent riffle metrics.

For restoration projects, this represents the target stream type at the end of monitoring/project closeout; more detail is provided in the SQT Spreadsheet User Manual.

Valley Type – Select the valley type from a drop-down menu as unconfined alluvial, confined alluvial, or colluvial. Definitions are provided below. The valley type is provided for communication and to inform channel evolution scenarios and stream type selections. Valley type is not used for reference curve stratification.

- Unconfined Alluvial Valleys: Wide, low gradient (typically less than 2% slope) valleys that support meandering and anastomosed stream types (e.g., Rosgen C, E, DA). In alluvial valleys, rivers adjust pattern without intercepting hillslopes. These valleys typically have a valley width ratio greater than 7.0 (Carlson, 2009) or a meander width ratio (MWR) greater than 4.0 (Rosgen, 2014).
- Confined Alluvial Valleys: Valleys that support transitional stream types between step-pool and meandering or where meanders intercept hillslopes (e.g., Rosgen C, Bc). These valley types typically have a valley width ratio less than 7.0 and a MWR between 3 and 4.
- Colluvial Valleys: Valleys that are confined and support straighter, step-pool type channels (e.g., Rosgen A, B, Bc). These valley types typically have a valley width ratio less than 7.0 and a MWR less than 3.

Drainage Area (sq. mi.) – The drainage area is the land area draining water to the downstream end of a project reach and is delineated using available topographic data (e.g., USGS maps, USGS Stream Stats, LiDAR, or other digital terrain data). Drainage Area is not used for reference curve stratification; it is used for bankfull verification.

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

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

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

(Proposed) Bed Material[19] – (Proposed) bed material represents the D_{50} (median diameter of particle sizes) of a reach-wide pebble count. The (proposed) bed material is not used to stratify any reference curves but is used for communication purposes and to determine stream type.

Buffer Valley Slope (%) – Select the range which includes the buffer valley slope from the drop-down menu (<5%, 5-20%, 21-40%, >40%). In combination with dominant buffer land use, this selection determines the correct reference curve for buffer width.

Dominant Buffer Land Use – Select the dominant land use category within the riparian buffer area from the drop-down menu (single-family residential, multi-family residential, commercial/golf course/agriculture/silviculture, or industrial/landfill). In combination with buffer valley slope, this selection determines the correct reference curve for buffer width.

Proposed Canopy Cover at project closeout (%) – Select <20% or >20% canopy coverage from the drop-down menu. This selection determines which riparian vegetation metrics to measure.

Stream Temperature – Select coldwater or warmwater from the drop-down menu based on the expected/reference fish species assemblage for the project reach. This selection is not used for reference curve stratification; the summer daily maximum metric is applicable to coldwater streams only. Coldwater streams for the purpose of the SC SQT are streams that are designated Trout (Natural; Put, Grow, and Take; and Put and Take) streams under SC Code of Regulation 61-69 (DHEC, 2020).[20]

Macroinvertebrate Sampling Method – Select full scale or qual-4/ EPT from the drop-down menu. This determines the correct reference curve for EPT taxa present. For more information, refer to the *Standard Operating Procedures for the Collection and Analysis of Benthic Macroinvertebrates* (NC DEQ, 2016).

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[19] Proposed bed material applies to the SQT. Bed material applies to the Debit Calculator.
[20] SC Code of Regulation 61-69: https://scdhec.gov/sites/default/files/Library/Regulations/R.61-68.pdf

Chapter 4. Hydrology, Hydraulics, & Geomorphology Functional Categories

This section describes data collection and analysis procedures for every parameter and associated metric(s) in the SC SQT condition assessments.

4.1. Reach Runoff Parameter

The reach runoff parameter evaluates the infiltration and runoff processes of the land that drains laterally into the stream reach.

Definition: Reach runoff is the runoff from the lateral drainage area (Figure 9) that drains directly to the reach from adjacent land uses. The lateral drainage area is the portion of the catchment draining to the project reach between the upstream and downstream end points.

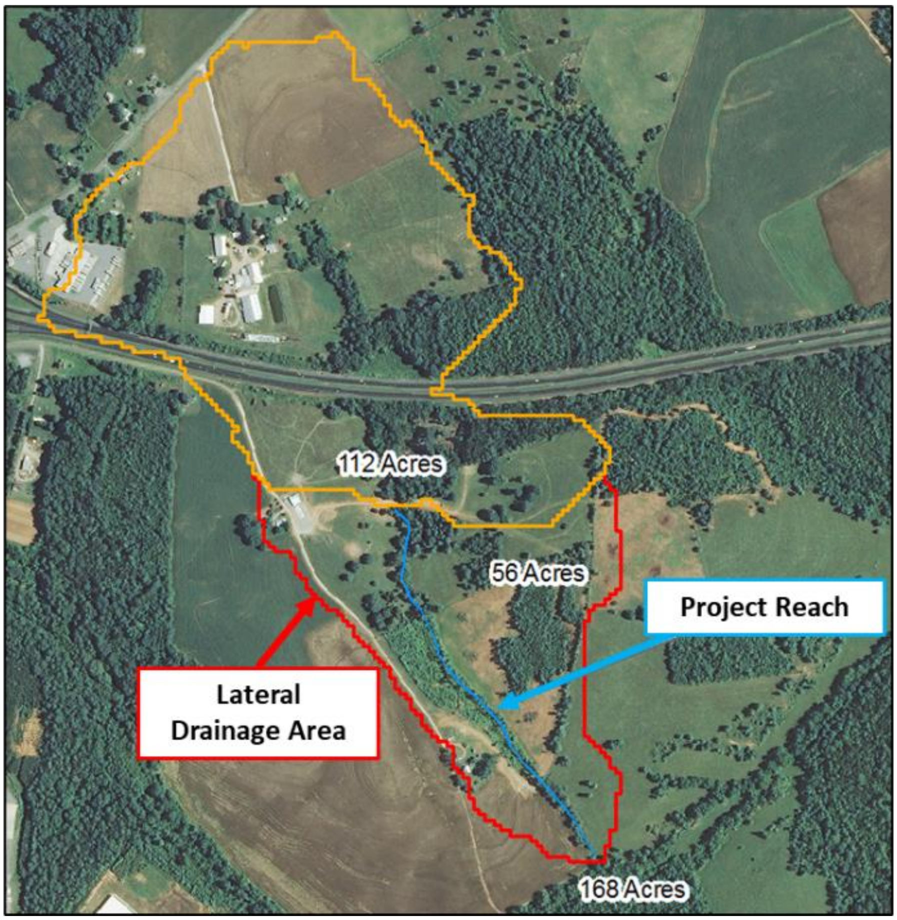

Figure 9. Example delineation of the lateral drainage area (outlined in red) within the larger catchment (outlined in orange and red) for Reach Runoff.

The reach runoff parameter consists of two metrics:

1. Land use coefficient
2. Concentrated flow points

4.1.1. LAND USE COEFFICIENT

Vegetation removal and land cover change alters natural hydrologic processes including evapotranspiration, infiltration, and interception volumes.

Definition: Land use coefficients serve as an indicator of runoff potential from various land uses. Higher values, nearer 100, indicate more runoff potential while lower values, nearer 0, indicate less runoff. Land use coefficients are shown in Table 1.

Method: Several techniques can be employed to calculate an area-weighted land use coefficient, including programs such as ArcGIS and ArcHydro and manual hand delineations and calculations. Users can choose either method, but the same method must be implemented for all assessments (existing, proposed, as-built, and monitoring).

1. Delineate the lateral drainage area adjacent to the project reach and calculate the total lateral drainage area (Figure 9).
2. Using recent aerial imagery and/or the NLCD, delineate the different land use types within the lateral drainage area.
3. The user has the choice to be more rapid or detailed in land use delineation which will result in more coarse or fine results, respectively. Using the National Land Cover Database (NLCD) dataset can be coarser, especially if the size of the lateral drainage area is small compared to the NLCD grid sizes (30 by 30 m). Meanwhile, manual hand delineations and calculations or manual delineation in addition to the NLCD-delineated land uses *can* be finer, especially if the user delineates all land uses within Table 1 (if present). This finer delineation has the potential to capture more functional change, especially if the size of the project area is large compared to the size of the lateral drainage area.
4. Using Table 1, assign each land use type a land use coefficient value and document any assumptions.
5. Calculate an area-weighted land use coefficient. For each land use type, multiply the land use coefficient by the area of that land use type; sum all products and divide by the total lateral drainage area (equation below).

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

Estimating proposed condition field values: Proposed field values for the land use coefficient can be calculated based on anticipated areas of land use change in the lateral drainage area associated with the proposed project. Stream restoration projects may convert land uses within the project area to natural land cover, particularly in the riparian area adjacent to the channel. Development can negatively impact reach runoff adjacent to the project area by removing native vegetation communities or by increasing impervious cover or other developed areas.

Table 1. Land use change coefficients derived from NRCS TR-55 (1986) regionalized for the SC SQT.

Land Use Description	Land Use Coefficient
Natural Land Cover	
Forested or scrub-shrub vegetation communities	55
Herbaceous – mixture of grass, weeds, and low-growing brush, with brush the minor element	62
Open Water	0
Urban Areas Land Uses	
Open Space (lawns, parks, golf courses, cemeteries, etc.)	69
Impervious areas	98
Gravel Roads	85
Dirt Roads	82
Commercial and business districts	92
Industrial districts	88
Residential districts by average lot size:	
1/8 acre or less (town houses)	85
1/4 acre	75
1/3 acre	72
1/2 acre	70
1 acre	68
2 acres	65
Agricultural & Silvicultural Lands	
Pasture, grassland, or range – continuous forage for grazing	69
Meadow – continuous grass, protected from grazing and generally mowed for hay	58
Brush – brush-weed-grass mixture with brush major element	56
Woods – silviculture lands or woods and grass combination (orchard or tree farm)	65
Farmsteads – buildings, lanes, driveways, and surrounding lots	74
Cultivated agricultural lands	72

4.1.2. CONCENTRATED FLOW POINTS (CFPs)

Anthropogenic impacts can lead to concentrated flows that accelerate storm runoff routing and erode soils, transporting sediment into receiving stream channels. Anthropogenic causes of concentrated flow may include agricultural drainage ditches, impervious surfaces, storm drains, and others (Figure 1 on pg. 4 and Figure 10 below).

Figure 10. This agricultural drainage ditch is an example of a concentrated flow point.

Definition: CFPs are defined as 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 CFPs.

Method: This metric assesses the number of CFPs that enter the project reach per 1,000 linear feet of stream.

$$\text{Field Value} = \frac{\#\ CFPs}{Reach\ length\ (ft)} *\ 1000\ ft$$

1. Review terrain and aerial imagery of the lateral drainage area to help identify natural drainages before going in the field.
2. Walk the **entire project reach**, including both sides of the stream channel, and record the number and notes on any observed CFPs.
3. Normalize the number of CFPs counted using the equation above.

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

Development can negatively impact stream channels by adding CFPs such as stormwater outfalls or additional erosional or runoff features. Proposed grading and stormwater management plans for development should be consulted to determine whether, and how many, CFPs are likely to result from adjacent land use development associated with the proposed development.

4.2. Floodplain Connectivity

Definition: The floodplain is the area adjacent to the channel that should be inundated during flow events greater than the bankfull discharge. This parameter includes two metrics which evaluate whether flows can access the floodplain and the extent of the flood-prone width:

1. Bank height ratio (BHR)
2. Entrenchment ratio (ER)

4.2.1. BANK HEIGHT RATIO (BHR)

Definition: BHR is a measure of channel incision and an indicator of whether flood flows can access and inundate the floodplain (Rosgen, 2014). BHR is measured in a riffle and calculated as the low bank height divided by the maximum bankfull riffle depth (D_{max}). The low bank height is defined as the left or right streambank that has a lower elevation, indicating the minimum water depth necessary to inundate the floodplain.

$$BHR = \frac{Low\ bank\ height}{Bankfull\ maximum\ depth}$$

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 3.4).

At **every riffle** within the representative sub-reach:

1. Measure the length of the riffle. For purposes of the SQT, riffles broadly represent the section between lateral-scour pools known as a crossover, regardless of bed material size (refer to Glossary of Terms).
2. Identify the bankfull and top of low bank features. Use the bankfull verification process to help identify the bankfull feature. If a physical indicator that has been verified is present, use that feature. For top of low bank, use the break between the channel and a floodplain or terrace that has a lower elevation. Further instruction for incised channels is provided in this section.
3. At the approximate mid-point of the riffle, record the low bank elevation and the thalweg elevation and calculate the low bank height.[21]

[21] Users cannot select the best or worse location in a riffle feature. Make sure the approximate mid-point has a BHR that is representative of the entire riffle length. The measurement location can be shifted if there is a CFP or other feature that makes the mid-point measurement the best or worst location within the riffle.

4. Record the bankfull elevation and the thalweg elevation, calculate the bankfull maximum depth.
5. Calculate the BHR for that riffle. Note, when the top of low bank and the bankfull feature are the same, the BHR equals 1.0.
6. Using the BHR and riffle length for every riffle feature within the representative sub-reach, calculate the weighted BHR using the equation below. Example 2 demonstrates the weighted BHR calculation.

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

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

Example 2: Weighted BHR Calculation in an assessment segment with four riffles

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

In incised channels with a bankfull bench, determining when bankfull and the top of bank are equal to each other can be challenging. There are two common scenarios described below:

Scenario 1: If bankfull is identified as the back of the bench, then the top of the low bank is the lower elevation of the left and right top of bank, i.e., a terrace (Figure 11).

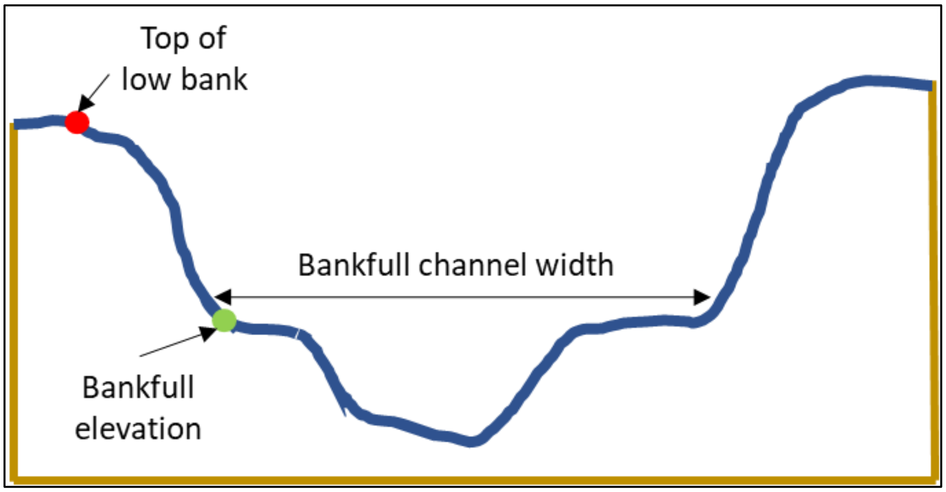

Figure 11. Scenario 1, where bankfull elevation is the back of the bench, and bankfull and top of low bank are not equal.

<u>Scenario 2:</u> If bankfull elevation is identified as the front of the bench, then the width of that bench must be measured before the top of bank can be determined. The bench width includes the left and right bench plus the bankfull channel width. Specific criteria include:

- For Rosgen C or E reference stream types, if the total floodplain bench width (left bench + bankfull channel + right bench) is greater than 2.2 times the bankfull channel width, then the top of low bank is equal to bankfull (BHR=1.0) (Figure 12).
- For Rosgen B reference stream types, if the total floodplain bench width (left bench + bankfull channel + right bench) is 1.4 times greater than the bankfull channel width, then the top of low bank is equal to bankfull (BHR=1.0) (Figure 12).
- If values are less than or equal to 2.2 for Rosgen C or E reference stream types and 1.4 for Rosgen B reference stream types, then the top of the low bank is the top of the left or right bank which breaks onto the terrace (Figure 13).

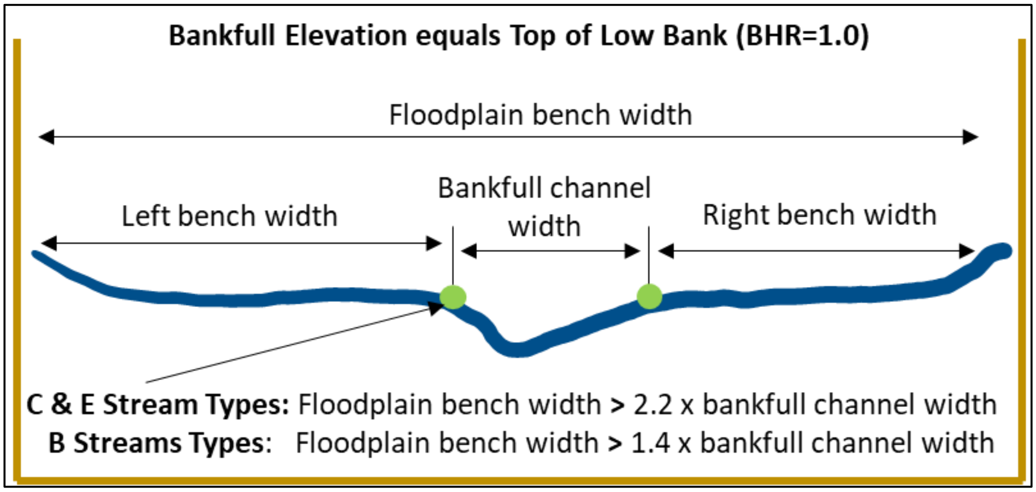

Figure 12. Scenario 2, where bankfull elevation is the front of the bench, and calculations determine location of low bank.

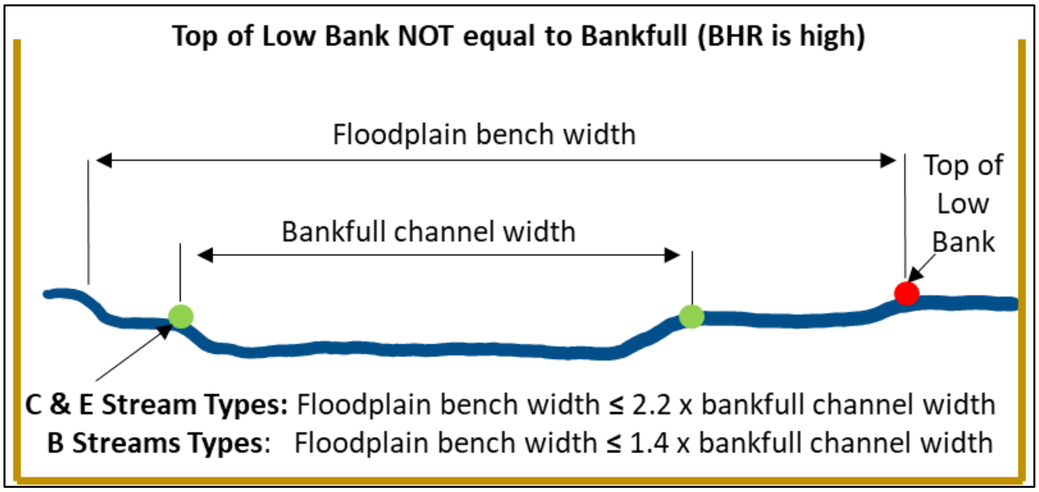

Figure 13. Scenario 2, where bankfull elevation is the front of the bench, and calculations determine location of low bank.

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

4.2.2. ENTRENCHMENT RATIO (ER)

Definition: ER characterizes the vertical containment of the river by evaluating the ratio of the flood-prone width to the bankfull width measured at a riffle cross-section (Rosgen, 1996). This metric is described in depth by Rosgen (2014). The flood-prone width is the cross-section width at a riffle feature **perpendicular to the valley** at an elevation of two times the bankfull max depth at that riffle.

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

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 3.4).

The ER should be measured at the mid-point of the riffle, i.e., halfway between the head of the riffle and the head of the run or pool if a run is not present. Unlike the BHR, the ER does not necessarily have to be measured at every riffle, as long as the valley width is consistent. When valley widths are consistent within a project reach, one measurement from within the representative sub-reach is sufficient to characterize this metric, unless the channel BHR is near 2.0.

For valleys that have a variable width or for channels that have BHR's near 2.0, it is recommended that the ER be measured at each riffle and to calculate the weighted ER. Using this dataset, a weighted ER is calculated as follows:

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

Where, RL_i is the length of the riffle where ER_i was measured. Example 3 demonstrates the weighted entrenchment ratio calculation.

Example 3: Weighted ER Calculation in an assessment segment with four riffles

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

Estimating proposed condition field values: The proposed condition field value for ER will be based on the proposed channel cross-section in a representative sub-reach of the proposed channel. Calculations should consider any proposed activities that may alter the cross-section, including floodplain excavation, raising the streambed elevation, and construction of berms or levees.

4.3. Flow Dynamics

Definition: The dynamic flow conditions created by the interaction of flowing water against the stream bed and banks (Harman et al., 2012).

There is one metric to assess flow dynamics: width/depth (W/D) ratio state.

4.3.1. WIDTH/DEPTH RATIO STATE (OBSERVED/EXPECTED)

Definition: Width/depth (W/D) ratio is measured as the bankfull channel width divided by the bankfull mean depth. The W/D ratio state described by Rosgen (2014) is the W/D measured in a project reach divided by a reference W/D.

$$\frac{W}{D}\,Ratio\ State = \frac{\frac{W_{riffle}}{D_{mean\ riffle}}}{Reference\ W/D}$$

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 3.4).

At every riffle within the representative sub-reach:

1. Measure the length of the riffle. For purposes of the SQT, riffles broadly represent the section between lateral-scour pools known as a crossover, regardless of bed material size (refer to Glossary of Terms).
2. At the approximate mid-point of the riffle, identify the bankfull elevation and survey the bankfull cross-section with sufficient detail to calculate bankfull area.
3. Calculate the bankfull width, cross-sectional area, mean depth, and W/D for each riffle.
4. Using the W/D and riffle length for every riffle feature within the representative sub-reach, calculate the weighted W/D using the equation below.

$$W/D_{weighted} = \frac{\sum_{i=1}^{n}(W/D_i * RL_i)}{\sum_{i=1}^{n} RL_i}$$

Where, RL_i is the length of the riffle where W/D_i was measured.

5. Determine the reference W/D. Since the W/D can play a large role in the design process and is often linked to slope and sediment transport assessments, the reference W/D is selected by the user. The reference W/D can come from the stable riffle cross-section (Section 3.4), a riffle cross-section adjacent to the project reach, or through the design process. Recent reference reach data available in South Carolina (Jennings Environmental, PLLC, 2020)[22] or available hydraulic and sediment transport models may be used to select a channel dimension and slope that yields a stable W/D.
6. Calculate the field value for the metric by dividing the results of step 4 by the reference W/D (step 5).

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

4.4. Large Woody Debris (LWD)

Definition: Large woody debris (LWD) is defined as dead and fallen wood over 3.28 feet (1m) in length and at least 3.9 inches (10 cm) in diameter at the largest end. The wood must be within the stream channel or touching the top of the streambank to be counted. LWD that lies in the floodplain but is not at least partially in the active channel is not counted.

There are two options to assess LWD and the user must select one metric to measure, not both:

1. LWD index (LWDI)
2. LWD piece count

[22] SC Geomorphic reference data: https://www.dnr.sc.gov/environmental/streamrestoration.html

4.4.1. LARGE WOODY DEBRIS INDEX (LWDI)

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

Method: Identify a 328-ft (100-m) segment of the sub-reach that contains the most LWD. If the project reach is less than 328 ft, the LWDI should be determined within the entire project reach length and the index value normalized to represent a value per 328 ft.

Follow the guidance within Davis et al. (2001) and the *Application of the Large Woody Debris Index: A Field User Manual Version 1* (Harman et al., 2017) to score LWD pieces and dams and calculate the reach LWDI.[23] The LWDI is entered as the field value in the SQT.

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

Care should be taken to not overestimate the amount of wood that can be sustainable in a restoration/mitigation project. Large amounts of wood in a newly constructed channel that is devoid of riparian vegetation may experience considerable lateral adjustments during monitoring years.

4.4.2. LWD PIECE COUNT

Definition: The LWD piece count metric is a count of the number of LWD pieces within a 328-foot (100 meters) section of the project reach.

Method: Identify a 328-ft (100-m) segment of the sub-reach that contains the most LWD. If the project reach is less than 328 ft, count the number of pieces within the entire project reach length and then normalize the index value to represent a value per 328 ft.

Count all pieces of dead and fallen wood wholly or partially within the active channel that are over 3.28 ft (1 m) in length and at least 3.9 in. (10 cm) in diameter at the largest end within the 328-ft reach. For debris dams, to the extent possible, count each piece within the dam that qualifies as LWD. The number of pieces observed per 328-ft is the field value for this metric.

Estimating proposed condition field values: The proposed condition field value is based on the proposed amount and anticipated recruitment of LWD in the project reach, normalized to represent a value per 328 ft. The proposed value should consider the removal of any existing LWD or installation of new LWD that would occur during project construction.

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[23] The field user manual, version 1 can be downloaded from https://stream-mechanics.com/resources/ under large woody debris assessment manual.

Care should be taken to not overestimate the amount of wood that can be sustainable in a restoration/mitigation project. Large amounts of wood in a newly constructed channel devoid of riparian vegetation may experience considerable lateral adjustments during monitoring years.

4.5. Lateral Migration

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

There are four metrics for this parameter:

1. Erosion rate
2. Dominant bank erosion hazard index (BEHI) / Near-bank stress (NBS)
3. Percent streambank erosion
4. Percent streambank armoring

Note that if the extent of streambank armoring exceeds 50%, then the other lateral migration metrics do not need to be assessed. The SQT will score the lateral migration parameter as a 0.00.

4.5.1. EROSION RATE

Definition: Erosion rate is a measure of the lateral erosion of streambanks per year.

The erosion rate of a bank can be measured using bank pins, bank profiles, or cross-sections that are assessed annually. All of these measurements can produce an estimate of bank erosion in feet per year. However, several years of pre- and post-project data are needed to make an accurate calculation. Since mitigation projects require five to seven years of post-project data, a good estimate of the lateral erosion rate is likely. However, if there are only two years of pre-project data (two years or less between site identification and construction is common), it is unlikely that a reasonable estimate of bank erosion can be determined for the pre-project condition.

Method: Methods for installing and monitoring cross-sections, bank pins, and bank profiles can be found in Harrelson et al. (1994) and Rosgen (2014). Additional guidelines are provided below.

1. Select bank segments within the project reach that represent high, medium, and low bank erosion rates. Record the length and height of each bank segment.
2. Establish cross-sections, profiles, and/or pins in each study bank. Bank profiles are recommended for undercut banks.
3. Establish a crest gauge or water level recorder. It is important to know the magnitude and frequency of moderate and large flow events between monitoring dates.
4. Perform annual surveys as close to the same time of year as possible. Measure changes in cross-sectional area and record number of bankfull events. If there were no bankfull events between monitoring years, monitor for one more year.

5. Calculate erosion rate as cross-sectional area of year 2 (A_{xsec-2}) minus cross-sectional area of year 1 (A_{xsec-1}) divided by the bank height.

$$Erosion\ Rate = \frac{A_{xsec-2} - A_{xsec-1}}{Bank\ Height}$$

6. To use the results in the SQT, calculate the weighted average of the erosion rates using the lengths of each bank segment.

$$Erosion\ Rate_{weighted} = \frac{\sum_{i=1}^{n}(Erosion\ Rate_i * L_i)}{\sum_{i=1}^{n} L_i}$$

It is also helpful to determine the BEHI/NBS rating of the banks being assessed as this data can be used to calibrate the Bank Assessment of Non-point source Consequences of Sediment (BANCS) model.

Estimating proposed condition field values: The proposed condition field value should be based on any anticipated changes to channel bank conditions or hydraulic conditions associated with the proposed project within the representative sub-reach of the proposed channel.

4.5.2. DOMINANT BEHI/NBS

Definition: The dominant BEHI/NBS is the mode, or most frequently occurring, BEHI/NBS rating for eroding banks within the representative sub-reach. The BEHI is a method used to estimate the tendency of a given stream bank to erode. NBS is an estimate of shear stress exerted by flowing water on the stream banks (Rosgen, 2014).

Method: Prior to calculating this metric, users need to complete the bankfull verification process (Section 3.4).

BEHI/NBS should be evaluated throughout the representative sub-reach. Procedures for this metric are described in Appendix D of the Function-Based Rapid Field Stream Assessment Methodology (Starr et al., 2015), or River Stability Field Guide, Second Edition (Rosgen, 2014). An optional field form is provided in Appendix B.

1. Identify banks to be assessed. These include the outside of meander bends and any bank that is actively contributing sediment. Banks that are armored should not be assessed. The outside of the meander bend is always assessed, even when it is not eroding, unless it is armored.

Note: Depositional zones, such as point bars, or other areas that are not actively eroding should not be evaluated (Rosgen, 2014). Riffle sections that are not eroding and have low potential to erode are also excluded.

2. Measure the bank length of all identified banks and determine the BEHI/NBS.
3. Add up the length of all assessed banks in the representative sub-reach to calculate the total assessed bank length.
4. Divide the length of each BEHI/NBS bank by the total *assessed* bank length (not the total bank length) to calculate the percent of each BEHI/NBS (Example 4).

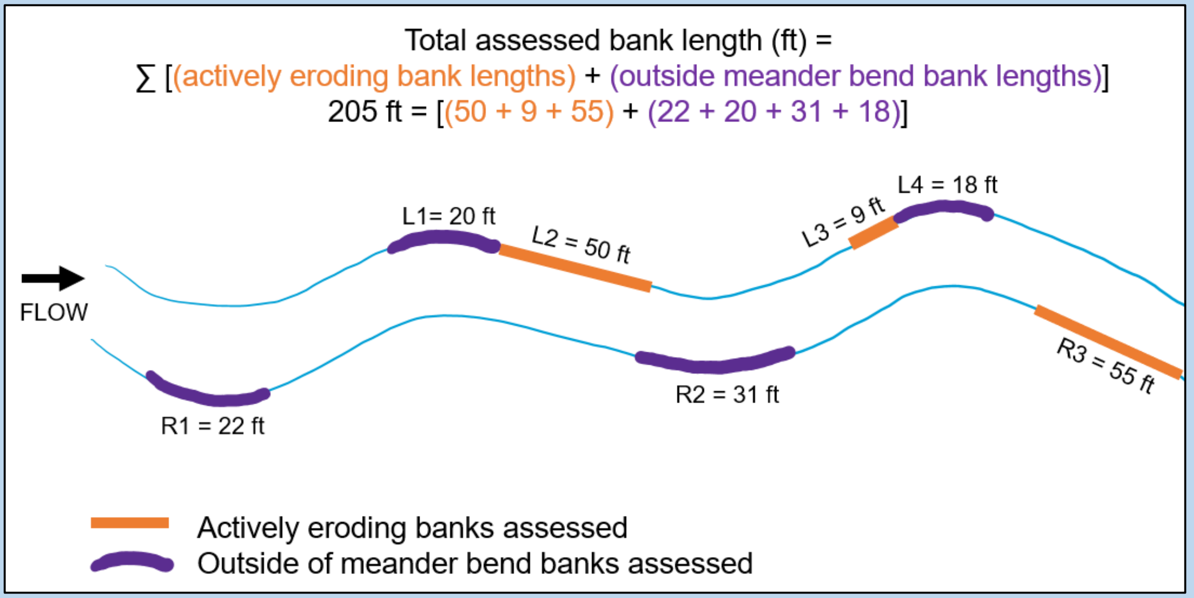
5. Sum the percentages for each BEHI/NBS category, e.g., all High/High banks are added together (Example 4).
6. The dominant BEHI/NBS is the category that represents the greatest cumulative bank length; it does not need to describe over 50% of the assessed banks.

If there are two or more BEHI/NBS categories with the same total percent, the category representing the highest level of bank erosion should be selected.

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

Example 4: Calculation of Dominant BEHI/NBS

In this example, data were collected in a 550 LF sub-reach. However, the assessed bank length is 205 feet. The outside bank of every meander bend and actively eroding banks were assessed using the BEHI/NBS methods.



Bank ID (Left and Right)	BEHI/NBS	Length (Feet)	Percent of Total (%)
L1	**High/High**	**20**	(20 / 205) * 100 = 10
L2	Low/Low	50	24
L3	Low/Mod	9	4
L4	**High/High**	**18**	9
R1	Mod/High	22	11
R2	**High/High**	**31**	15
R3	High/Low	55	27
	Total Length	**205**	100

There are five BEHI/NBS categories present. The length of each bank was summed and divided by the assessed bank length; the total percent is then calculated for each category (e.g., High/High = 10+9+15 = 34). The dominant BEHI/NBS category is High/High since that score is highest and describes 34% of the assessed banks.

4.5.3. PERCENT STREAMBANK EROSION

Definition: The percent streambank erosion is measured as the length of streambank that is actively eroding divided by the total length of bank (left and right) in the representative sub-reach.

Method:

1. Perform the dominant BEHI/NBS assessment methods as described in the previous section.
2. Sum the lengths of all banks within the BEHI/NBS categories that are considered actively eroding (Table 2). Omit banks that are not actively eroding from this calculation.
3. Divide the total length of actively eroding bank by the total length of streambank within the sub-reach (Example 5). The total length of streambank is the sum of the left and right bank lengths within the representative sub-reach (approximately twice the sub-reach length).
4. Multiply by 100, the field value is scored as a percent.

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

Table 2. BEHI/NBS Stability Ratings that Represent Actively Eroding and Non-Eroding Banks.

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

Estimating proposed condition field values: The proposed condition field value should be based on any anticipated changes to channel bank conditions or hydraulic conditions associated with the proposed project within the representative sub-reach of the proposed channel. For mitigation projects, this may include an estimate of the expected extent of bank erosion at the end of monitoring, keeping in mind that monitoring events will document whether the proposed condition is achieved.

Example 5: Calculation of Percent Erosion

This example uses the same BEHI/NBS results as Example 4. The sub-reach length is 550 LF and therefore the total bank length is 1100 feet, including left and right banks. In the table below, actively eroding banks are identified in bold per Table 2. These bank lengths are added together (20+18+22+31+55=146) and divided by the total bank length (1100). The total percent streambank erosion is (146/1100=0.13) 13%.

Bank ID (Left and Right)	BEHI/NBS	Length (Feet)
L1	**High/High**	**20**
L2	Low/Low	50
L3	Low/Mod	9
L4	**High/High**	**18**
R1	**Mod/High**	**22**
R2	**High/High**	**31**
R3	**High/Low**	**55**

4.5.4. PERCENT STREAMBANK ARMORING

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

Method: Percent armoring is calculated by measuring the total length of all armored banks within the project reach and dividing by the total length of streambank in the project reach. The total length of streambank is the sum of the left and right bank lengths within the project reach and can be calculated by multiplying the project reach length by two. Percent armoring is reported in percent as the field value.

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

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

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

4.6. Riparian Vegetation

Definition: Riparian vegetation is defined as the plant communities contiguous to and affected by surface and subsurface hydrology and fluvial disturbance within the stream corridor. Riparian vegetation supports channel stability, provides wood and leaf litter for aquatic species, and influences the types of aquatic species and the overall amount of water in the system (Palone & Todd, 1997). The riparian vegetation parameter in the SC SQT assesses the extent and structure of the riparian community in the project area and tracks invasive/non-native cover over the monitoring period.

There are seven metrics to assess riparian vegetation. Refer to the SQT Spreadsheet User Manual for metric selection guidance.

1. Buffer width
2. Average diameter at breast height (DBH)
3. Native tree density
4. Native shrub density
5. Native herbaceous cover
6. Monoculture area
7. Invasive/non-native cover: this metric is for monitoring only and is not scored.

4.6.1. BUFFER WIDTH

Definition: The buffer width is the extent of the riparian vegetation community measured horizontally from the top of bank.

Method: The measurement method is detailed in the Charleston District Compensatory Mitigation Guidelines (USACE, 2010). The buffer width is measured horizontally from the top of the stream bank to the edge of the riparian vegetation community if the riparian buffer is not disrupted by utility easements, roads, or other gaps in riparian vegetation cover. Buffer width measurements will be perpendicular to the fall-line of the valley.

1. Measurements can be taken in the field or from the desktop. Desktop measurements based on aerial imagery should be verified in the field to confirm the riparian buffer is free from disturbance.
2. Determine the average buffer width for the left and right streambank separately.
3. The average of the left and right buffer width values is the field value for the metric.

In South Carolina, stream compensatory mitigation projects must establish riparian buffers to the maximum extent practicable for all proposals involving stream restoration or enhancement activities and buffer preservation or enhancement activities. Minimum buffer widths are based on adjacent land use and buffer valley slope as detailed in the Charleston District Compensatory Mitigation Guidelines (USACE, 2010). For compensatory mitigation projects, both the existing and proposed buffer width must be within the conservation easement boundary. For impacts and other applications of the SQT, the buffer width is solely based on the contiguous vegetation community around the stream reach.

Estimating proposed condition field values: The proposed condition can be calculated based on anticipated areas of riparian vegetation planting.

4.6.2. RIPARIAN VEGETATION PLOTS

Sampling procedures are based on a modified Carolina Vegetation Survey (CVS) level 2 method (Lee et al., 2008). Riparian vegetation must be **assessed in representative locations throughout the representative sub-reach.** The vegetation plots must represent the diversity of vegetation communities, structure, and age throughout *undisturbed and disturbed* sections (due to project activities) within the project area. Data forms and more detail on the CVS level 2 protocol can be found on the CVS website.[24]

Determine the number of plots by calculating the approximate riparian buffer area as demonstrated in Example 6. **The total area of all sample plots must be equal to or greater than 2% of the total proposed riparian buffer area, with a minimum of four plots.** Plots must be within riparian or wetland areas. Each 10 x 10-m (100 m^2) plot represents 0.01 hectare of riparian area; plots that are 5 x 20-m are acceptable where the riparian area is less than 10m wide (Lee et al., 2008). Plots should be systematically distributed on both sides of the stream such that the minimum number of plots are evenly spaced along the known length of the sub-reach. Fewer plots may be evaluated if the representative sub-reach is short or if the riparian vegetation is very uniform in structure and composition throughout the sub-reach. Additional plots may be added at sites with variable riparian vegetation. Calculate the spacing interval of the plots by dividing the sub-reach length by the number of plots per side.

Example 6: Determine the # of riparian vegetation plots

Project total length = 4,500 LF

Sub-reach length = 2,000 LF

Average buffer width (left and right) = 50 ft

Approximate riparian buffer area = (2,000 LF * 50 ft) * 2 = 200,000 SF = 18,581 m^2

The plot area must be at least 2% of the riparian calculated riparian buffer area. Plots are 100 m^2.

Number of Plots for this reach =

$$\frac{18{,}581\ \mathrm{m}^2 * 0.02}{100\ \mathrm{m}^2} = 3.7 \rightarrow \mathbf{4}$$ **plots total, 2 on each side of the stream**

Further information on plot layout is detailed in the CVS level 2 protocol (Lee et al., 2008). If a riparian plot needs to be relocated, adjust the location to the minimum extent possible upstream or downstream from the designated station to avoid the problem (e.g., overlap of tight meander bend plots; inaccessible locations; or at the confluence of a tributary, etc.). If necessary,

[24] Carolina Vegetation survey Level 2 protocol: http://cvs.bio.unc.edu/methods.htm

vegetation plots may extend beyond the downstream end of the representative sub-reach but should not extend outside the project reach.

Data Collection:

Data must be collected between July 1 and leaf drop (USACE, 2010).

Woody Stem Data: Data is collected for woody stems following CVS Level 2 protocols; required measurements are summarized in Table 3. This data will be used to calculate metric field values for average DBH, tree density, and native shrub density metrics. Strata definitions for the metrics are provided in Table 4.[25]

Table 3. Required measurements for natural and planted woody stems (adapted from Lee et al. 2008).

Plant Height/ Type	Height [1] (cm)	DBH (cm)	Height above ground [2] (cm)
< 1.37m tall	Yes (cm)	No	Yes
1.37 – 2.5m tall	Yes (cm)	Yes	Yes
2.5 - 4m tall	Yes (dm)	Yes	Yes
> 4m tall	Yes (0.5m)	Yes	Yes
Live Stake	Yes (based on height as noted above)	If height ≥ 1.37m tall	Yes

[1] Height refers to the length of the woody (perennial) stem rather than the height above the ground, which is an important distinction when measuring bent or leaning stems. This also means that height is not measured to the tip of the tallest leaf, but rather the terminal bud of the longest woody stem.

[2] This is not included in the Level 2 CVS protocol but will be required to calculate field values.

Table 4. Strata Definitions (adapted from Summers et al., 2017).

Strata	Description
Herbaceous	All living soft-tissue, herbaceous plants regardless of height AND woody species whose height above ground is < 90cm.
Shrub	Woody stems <10cm in DBH and > 90cm in height above ground.
Tree	Living woody stem with DBH ≥ 10cm.

[25] Strata definitions from Summers et al. (2017) are used to match reference curves while data collection procedures are consistent with compensatory mitigation standards.

Herbaceous Data: The herbaceous cover metric and therefore herbaceous data collection is only applicable to project areas with Piedmont prairie vegetation community present or proposed.

Visually estimate the percent absolute cover of herbaceous plant material within two 1 m^2 plots. These nested corners are in the origin corner and the opposite corner of each vegetation plot. Herbaceous cover *does not* include woody species > 90cm in height (height in this case is measured above the ground rather than the height recorded in the CVS level 2 protocol for woody stems).

4.6.3. AVERAGE DIAMETER AT BREAST HEIGHT (DBH)

Definition: DBH is the standard for measuring trees and refers to the tree diameter measured 4.5 feet above the ground (Avery and Burkhart, 2002) shown in Figure 14. Trees are defined as living woody stems with a DBH of at least 10cm.

Method:

1. Collect woody stem data as described in the previous section within each 10 x 10-m plot.
2. Compile the values recorded for all trees in all the plots and calculate the average DBH across all plots. This value is entered into the SQT as the metric field value.
3. Do not calculate an average DBH for each plot separately.

Figure 14. Measuring DBH (1.37 m or 4.5 feet above ground level).

Estimating proposed condition field values: The proposed condition field value should be an estimate of average tree DBH at the site for conditions at project closeout. Users should consider the extent of preserved vegetation, vegetation removal, and the growth rates for planted and volunteer species over the monitoring period. Note riparian function takes time to establish and the definition of a tree as having a minimum DBH of 10cm means that this metric may not yield lift within the monitoring period of a site. This will incentivize keeping existing trees to avoid loss for this metric.

4.6.4. TREE DENSITY

Definition: The average number of trees per acre that are ≥ 10cm DBH (Summers et al., 2017).

Method:

1. Collect woody stem data as described in Section 4.6.2 within each 10 x 10-m plot.
2. Using the data collected, calculate the tree density in stems per acre for each plot.
3. Calculate the average tree density for the project reach using the results of Step 2. This value is entered as the metric field value.

Estimating proposed condition field values: The proposed condition field value should be an estimate of tree density at project closeout. Users should consider the expected frequency of surviving vegetation, vegetation removal, and expected cover for planted and volunteer vegetation community over the monitoring period. Note riparian function takes time to establish and the definition of a tree as having a minimum DBH of 10cm means that this metric may not yield lift within the monitoring period of a site. However, early tree growth can be measured, resulting in an increase in function within the Native Shrub Density metric.

4.6.5. NATIVE SHRUB DENSITY

Definition: This metric is the density of woody stems that are > 90cm in height above ground and <10cm DBH and includes shrub, saplings, and understory trees (Summers et al., 2017). Only native species are counted for this metric.

Method:

1. Collect woody stem data as described in Section 4.6.2 within each 10 x 10-m plot.
2. Using the data collected, calculate the shrub density in stems per acre for each plot. Note that only native species are counted.
3. Calculate the average shrub density for the site using the results of Step 2. This value is entered as the metric field value.

Estimating proposed condition field values: The proposed condition field value should be an estimate of native shrub density at project closeout. Users should consider the expected frequency of surviving vegetation, vegetation removal, and expected cover for planted vegetation community over the monitoring period.

4.6.6. NATIVE HERBACEOUS COVER

Definition: Herbaceous cover is defined as all herbaceous vegetation (regardless of height) and woody stems that are < 90cm in height above ground (Summers et al., 2017). Only native species are counted for this metric.

Method:

1. Collect herbaceous data as described in Section 4.6.2 in two 1 m^2 plots within each 10 x 10-m plot.
2. Calculate the average herbaceous cover for the site. This value is entered as the metric field value.

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

4.6.7. MONOCULTURE AREA (%)

Definition: The aerial coverage (%) of a monoculture (e.g., engineered loblolly pine stands or pine plantations) within the riparian buffer area.

Method:

1. Delineate the monoculture area (sq. ft.).
2. Determine the riparian buffer area (sq. ft.).
3. Divide the monoculture area by the riparian buffer area, multiply by 100, and enter into the condition assessment as the metric field value (%).

Estimating proposed condition field values: The proposed condition field value should be an estimate of conditions at project closeout. Users should consider the extent of area removed from active silviculture operations as a result of the project.

4.6.8. INVASIVE/NON-NATIVE COVER

Definition: Invasive/non-native cover is the aerial coverage of all invasive and non-native vegetation, including herbaceous and woody vegetation.

Method:

1. Within each plot described in Section 4.6.2 estimate the aerial coverage by species for all invasive/non-native species.
2. Sum the coverage (%) in each plot (this can be greater than 100%).
3. Average the results of step 2 across all plots. This value is the metric field value.

Estimating proposed condition field values: This is not applicable for this metric. This metric is not scored and is only included in the monitoring condition assessment of the SQT workbook.

4.7. Bed Form Diversity

Definition: Bed forms include the various channel features that maintain heterogeneity and stability in the channel form, including riffles, runs, pools, and glides (Rosgen, 2014). Together, these bed features dissipate energy and create important habitats for aquatic life.

There are three metrics for this parameter: pool spacing ratio, pool depth ratio, and percent riffle. All metrics require identification of bed forms as described in the following section.

4.7.1. BED FEATURE IDENTIFICATION

The SQT assessment requires repeatable and verifiable identification of riffle and pool bed features. Transition features (e.g., runs or glides) are not characterized separately from riffles and pools.

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

The SQT requires identification of two pool types: **geomorphic pools** and **significant pools**. **Correct pool identification is critical to correctly quantify bed form diversity metrics.** Guidance for identifying pools in different valley types is provided below and guidance on pool identification for each bed form diversity metric is provided under each metric's description.

Geomorphic pools are associated with planform features that create large pools that remain intact over many years and various flow conditions. These pools are associated with the outside of a meander bend (in streams in alluvial valleys) and downstream of a large cascade or step feature (in streams in colluvial and v-shaped valleys). These pools are used exclusively with the pool spacing ratio metric.

Significant pools include geomorphic pools (see above) AND pools associated with wood, boulders, convergence, and backwater that meet the following criteria:

- have a width that is at least one-half the channel bottom width,
- are concave in profile, and
- have a water surface slope that is flatter than the riffle.

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

Geomorphic pools in alluvial valleys are located along the outside of a meander bend. Figure 15 provides an illustration of what is and is not considered a geomorphic pool. The figure illustrates a meandering stream, where the lateral scour pools located in the outside of the meander bend are counted for the pool spacing measurement, and the 'X' marks the approximate location of the deepest part of the pool. There are small pools associated with the large woody debris and boulder clusters in this figure that are not considered geomorphic pools.

Compound pools that are not separated by a riffle within the same bend are treated as one pool. However, compound bends with two pools separated by a riffle are treated as two pools. For further reference, Rosgen (2014) provides illustrations for these scenarios.

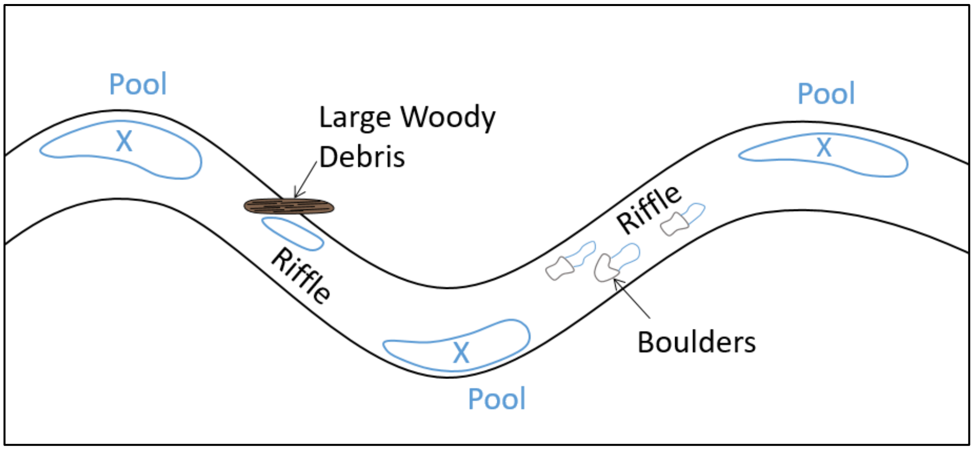


Figure 15. Pool Spacing in Alluvial Valley Streams, where pools counted as geomorphic are marked with an 'X'.

<u>Identifying Geomorphic Pools in Colluvial and V-Shaped Valleys:</u>

Pools in colluvial or v-shaped valleys should only be counted as geomorphic if they are downstream of a step, riffle, or cascade. Small pools within a riffle or cascade are not counted. An example of pool spacing in a colluvial or v-shaped valley is shown in Figure 16. For these bed forms, pools are only counted at the downstream end of the riffle or cascade; small pools within the cascade feature are not included.

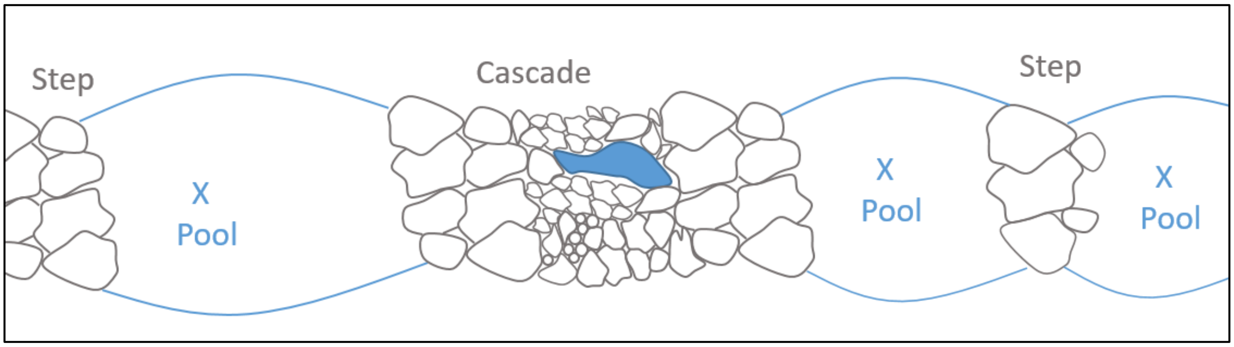


Figure 16. Pool Spacing in Colluvial and V-Shaped Valleys, where pools counted as geomorphic are marked with an 'X'.

4.7.2. POOL SPACING RATIO

Definition: Prior to calculating this metric, users need to complete the bankfull verification process. The pool spacing ratio compares the stream length distance between sequential geomorphic pools to the bankfull width at a riffle (Rosgen, 2014). Further explanation of pool types is provided in Section 4.7.1.

Method: The bankfull width of the stable riffle is required to calculate this metric (refer to Section 3.4).

1. Record the location along the longitudinal profile of the maximum pool depth of every geomorphic pool in the representative sub-reach.
2. Measure and record the spacing between the maximum depths of the sequential pools.
3. The pool spacing ratio is calculated for each pair of sequential geomorphic pools in the representative sub-reach using the equation below. As noted above, the bankfull width is from a stable riffle as described in Section 3.4.1.

$$P - P\ Spacing\ Ratio = \frac{Distance\ between\ sequential\ geomorphic\ pools}{Bankfull\ Width}$$

4. The field value is the median value of the calculated pool spacing ratios within the representative sub-reach.

When working in streams that have been straightened (channelized), a riffle-pool sequence may not be present. This typically occurs because the pool forming processes (meandering and scour processes) have been removed. The reach will be mostly riffle habitat. In this case, the user should enter a field value of 0.0. This indicates that a riffle-pool sequence should be present based on the reference stream type, but it is absent due to channelization.

Estimating proposed condition field values: The proposed condition field value will be based on the proposed channel profile in colluvial valleys and based on the proposed channel profile and meander geometry in alluvial valleys.

1.7.3. POOL DEPTH RATIO

Definition: The pool depth ratio is the maximum bankfull pool depth divided by the mean bankfull riffle depth. The riffle mean bankfull depth is from a stable riffle cross-section rather than measured at each riffle. The pool depth ratio is a measure of pool quality with deeper pools scored higher than shallow pools.

Method: Prior to calculating this metric, users need to complete the bankfull verification process. The bankfull mean depth of the stable riffle is required to calculate this metric (refer to Section 3.4).

1. Locate and measure the maximum bankfull pool depth of every significant pool in the representative sub-reach. **Further explanation of pool types is provided in Section 4.7.1.**
2. Pool depth ratio is calculated by dividing the maximum bankfull pool depth by the mean bankfull riffle depth from the stable riffle survey.

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

If a longitudinal profile is surveyed (detailed method), the best-fit-line through the bankfull points should be used to calculate the bankfull elevation associated with each max pool depth location. For the rapid survey, the difference in bankfull and water surface (established during the bankfull verification process) should be used at each max pool depth location.

3. The field value for this metrics is the average pool depth ratio using values from all significant pools in the representative sub-reach.

Estimating proposed condition field values: The proposed condition field value will be based on the proposed channel profile within a representative sub-reach of the proposed channel.

1.7.4. PERCENT RIFFLE

Definition: Riffles are shallow, steep-gradient channel segments typically located between pools. Riffles are the river's natural grade control feature (Knighton, 1998) and are sometimes referred to as fast-water channel units (Hawkins et al., 1993; Montgomery and Buffington, 1998). For purposes of the SQT, in meandering streams, riffles broadly represent the section between lateral-scour pools known as a **crossover**, regardless of bed material size. The term riffle also refers to ripples in sand bed streams and the cascade section of steep mountain streams. Riffles are measured from head of riffle to head of pool; thus, runs are considered riffles.

Method:

1. Measure the length of each riffle in the representative sub-reach. Riffle length is measured from the head (beginning) of the riffle downstream to the head of a **significant pool** (refer to pool definitions in Section 4.7.1).
2. Run features are included within the riffle length and glide features are classified as pools.
3. Sum the lengths of all riffles and runs within the representative sub-reach.
4. Divide the total length of riffles within the representative sub-reach (step 2) by the total sub-reach length.
5. Multiply the results of step 3 by 100 and enter it as the field value.

Estimating proposed condition field values: The proposed condition field value will be based on the proposed channel profile within a representative sub-reach of the proposed channel.

Chapter 5. Physicochemical and Biology Functional Categories

The SC SQT v1.0 was not regionalized for physicochemical and biology functional categories. Work is ongoing to regionalize these categories for South Carolina and future version of the SC SQT will include parameters, metrics, and reference curves developed specifically for South Carolina. Some parameters and metrics were carried over from the NC SQT for use in the SC SQT v1.0. Metrics and reference curves were applicable to some resources found in South Carolina and can be used to show lift or loss in these functional categories using the SQT. To assess these metrics for CWA 404 projects, coordinate with USACE prior to use. Refer to DHEC standard operating procedures[26] and the *NC SQT Data Collection and Analysis Manual* (version 3) for assistance with data collection procedures (Harman & Jones, 2017).

The SC SQT includes the following parameters and metrics carried over from the NC SQT to quantity the physiochemical and biology functional categories:

1. Temperature: Summer Daily Maximum
2. Bacteria: Fecal Coliform
3. Nitrogen: Total Nitrogen
4. Phosphorus: Total Phosphorus
5. Macroinvertebrates: EPT Taxa Present
6. Fish: North Carolina Index of Biotic Integrity

5.1. Temperature

Definition: Temperature in the SQT characterizes the in-stream summer temperatures within a reach. Temperature plays a key role in both physicochemical and biological functions. Water temperature influences conductivity, dissolved oxygen concentration, rates of aqueous chemical reactions, and toxicity of some pollutants. These factors directly impact the water quality and ability of living organisms to survive in the stream.

There is one metric used to assess temperature: Summer daily maximum.

5.1.1. SUMMER DAILY MAXIMUM

Definition: The summer daily maximum is the maximum temperature sustained for at least two hours from continuous data collected in the project reach during the summer sampling period (June – August). **Note, this metric is only applicable to coldwater streams.**

Method: Install continuous temperature gages following *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams* (USEPA, 2014). Note that this procedure requires the deployment of an air temperature sensor as well. Record data and perform any necessary maintenance throughout the summer months (June – August).

1. Sensor placement: Refer to USEPA (2014)

[26] DHEC standard operating procedures: https://scdhec.gov/macroinvertebrates

2. Sampling interval: Not to exceed 30-minute intervals.

Determine the daily maximum temperature (measured in degrees Fahrenheit) that is sustained for at least two hours during the sampling period. This is the metric field value.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in the summer daily maximum temperature field value resulting from the project. Practices that could impact in-stream summer temperatures include, but are not limited to, altering streamside vegetation and channel shading, groundwater connections, or summer baseflows (altered through management agreements).

5.2. Bacteria

Definition: The bacteria metric is focused on *excess* bacteria from animal waste inputs associated with livestock facilities (e.g., cow manure delivered directly by cows, or indirectly during a runoff event) the stream. Excess bacteria in streams can result in decreased levels of dissolved oxygen.

There is one metric used to assess bacteria: fecal coliform (CFU/100 mL).

5.2.1. FECAL COLIFORM

Definition: Fecal coliforms are the total of all fecal coliform species. Fecal coliforms are associated with pathogens that are a serious risk to human and animal health.

Method: Sample collection procedures are outlined in section 2.3 of the *Intensive Survey Branch Standard Operating Procedures Manuals: Physical and Chemical Monitoring* (NC DENR, 2013a). **Samples should not be collected during or immediately after a rain event.**

1. Five grab samples should be collected during a 30-day period within the growing season. The grab samples should be collected from the surface water at or near the downstream extent of the reach. For more instruction, see section 2.3 of the *Intensive Survey Branch Standard Operating Procedures Manuals: Physical and Chemical Monitoring* (NC DENR, 2013a).
2. Samples should be cooled to 4°C and taken to a certified laboratory within six hours, to prevent regrowth or death of the bacteria. Laboratories will determine fecal colonies using one of several EPA-approved methods[27] and report the results in colonies per volume of water.
3. The field value is the geometric mean of five consecutive samples (measured in colonies/100ml) examined during any 30-day period within the growing season.

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in fecal coliform resulting from the project. Practices that could impact fecal coliform levels include, but are not limited to, limiting or increasing cattle access to the project area and providing alternate water sources.

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[27] Fecal Coliform EPA-approved methods: https://www.epa.gov/cwa-methods/approved-cwa-microbiological-test-methods

5.3. Nitrogen

Definition: Nitrogen is a common component of manure, agricultural fertilizers, organic matter, and sewage. In excess, nitrogen can speed up eutrophication of rivers and lakes. During storm and high flood events in streams, nitrogen is transported from the floodplain into a stream, lake, or other water body.

There is one metric to assess nitrogen: total nitrogen (mg/L).

5.3.1. TOTAL NITROGEN (TN)

Definition: Total nitrogen (TN) is the total of total Kjeldahl nitrogen and nitrite/nitrate, measured by a laboratory.

Method:

1. Sample collection procedures are outlined in section 2.22 of the Intensive Survey Branch Standard Operating Procedures Manuals: Physical and Chemical Monitoring (NC DENR, 2013a).
2. Samples must be preserved, transported, and stored in accordance with state requirements (NC DENR, 2013a).
3. The field value is the measured value reported from the laboratory.

Only **one sampling event is required** to calculate a field value. It is **recommended** that multiple samples be collected within a single year and for multiple years to capture intra-and inter-annual variability.

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

5.4. Phosphorus

Definition: Phosphorus is a common component of manure, agricultural fertilizers, and organic wastes from industrial effluent and sewage. In excess, phosphorus can speed up eutrophication of rivers and lakes. During storm and high flood events in streams, phosphorus is transported from eroded streambanks and the floodplain into a stream, lake, or other water body.

There is one metric to assess phosphorus: total phosphorus (mg/L).

5.4.1. TOTAL PHOSPHORUS (TP)

Definition: Total Phosphorus (TP) refers to all forms of phosphorus in a sample (orthophosphate, condensed phosphate, and organic phosphate).

Method:

1. Sample collection procedures are outlined in section 2.22 of the Intensive Survey Branch Standard Operating Procedures Manuals: Physical and Chemical Monitoring (NC DENR 2013a).
2. Samples must be preserved, transported, and stored in accordance with state requirements (NC DENR, 2013a).
3. The field value is the measured value reported from the laboratory.

Only **one sampling event is required** to calculate a field value. It is **recommended** that multiple samples be collected if feasible to capture intra-annual variability. For the existing condition, it is recommended to sample during multiple years to capture interannual variability as well.

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

5.5. Macroinvertebrates

Definition: Macroinvertebrates are an integral part of the food chain that support healthy river ecosystems. Macroinvertebrates are useful biological monitors because they are found in all aquatic environments, are relatively sedentary and thus indicate local conditions, and are easy to collect due to their small size (NC DEQ, 2016).

There is one metric to assess macroinvertebrates: EPT Taxa Present.

5.5.1. EPT TAXA PRESENT

Definition: EPT taxa present (or EPT richness) is the total number of organisms within a sample classified as organisms of the Ephemeroptera (mayflies), Plecoptera (stoneflies), or Trichoptera (caddisflies) orders. Most EPT taxa are intolerant of pollution; in general, a high EPT count indicates excellent water quality.

For a rapid assessment during site selection, the existing conditions could be characterized using existing sampling data if available.[28]

Method: Sampling methods, post-collection procedures, laboratory techniques, and data interpretation are detailed in *Standard Operating Procedures for the Collection and Analysis of Benthic Macroinvertebrates* (NC DEQ, 2016). Care must be taken to note the ecoregion, stream size, and data collection season to inform the correct sampling method and data interpretation. Sampling should not occur during high or low flow periods, or immediately after a drought period.

The field value is the number of EPT organisms.

[28] https://scdhec.gov/macroinvertebrates

Note: Seasonal adjustments must be made prior to entry into the SQT if samples are collected outside of the summer season; refer to the *Standard Operating Procedures for the Collection and Analysis of Benthic Macroinvertebrates* (NC DEQ, 2016). The summer sampling season is defined as follows:

- Full Scale or Qual 4: June 1 – September 30, inclusive

Estimating proposed condition field values: The proposed condition field value should estimate/predict the expected change in the EPT taxa present resulting from the project. Projects that alter in-stream water quality, presence and extent of macroinvertebrate habitat, and landscape and aquatic connectivity could impact macroinvertebrate communities. Altering flow volumes could also lead to measurable changes in macroinvertebrate communities.

5.6. Fish

The SC DNR is working to develop an index of biotic integrity (IBI) for fish. At this time, the NC IBI remains in the SQT solely as a place holder for ease of insertion of the SC IBI when it is developed. The NC IBI is not available for use in the SC SQT.

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Appendix A

Rapid Field Data Collection Methods

for the SC SQT v1.0

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Acronyms

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

BHR – Bank height ratio

BKF – Bankfull

CFP – Concentrated flow points

CVS – Carolina Vegetation Survey

DBH – Diameter at breast height

D_{max} – Maximum bankfull riffle depth

ER – Entrenchment ratio

LWD – Large woody debris

W/D – Width/depth

WS – Water surface

A1. Introduction and Purpose

This appendix provides instruction on how to collect and analyze field data for the South Carolina Stream Quantification Tool (SC SQT) **rapid method.** The SC SQT can be applied at two levels of quantitative field data collection effort: (1) rapid method and (2) detailed method. The rapid method assesses the basic suite of metrics (Section A1.1) and uses rapid assessment and survey techniques when a rapid version exists. All basic suites metrics do not have a rapid method option. Data collection procedures for metrics without rapid assessment options are included in the Data Collection and Analysis Manual. Thus, **this appendix is used in conjunction with the Data Collection and Analysis Manual to implement the rapid method.**

Rapid Method:

The rapid method assesses the basic suite of metrics (Section A1.1). The field component of the rapid method will typically take two to four hours for a qualified team of 3 persons to complete per project reach. Field trainings in these methods and the Stream Functions Pyramid Framework are recommended.

This appendix provides instruction to implement the rapid survey procedures, including bankfull verification and field data collection for the following hydraulic and geomorphic metrics[1]:

- Bank height ratio
- Entrenchment ratio
- Width/depth (W/D) ratio state
- Pool spacing ratio
- Pool depth ratio
- Percent riffle

A1.1. Basic Suite of Metrics

A basic suite of metrics within 7 parameters are required for the rapid method at all project sites (Table A1). Refer to the SQT Spreadsheet User Manual or the Parameter and Metric Selection worksheet in the SQT workbook for guidance on metric selection for each parameter.

There is an optional rapid method **field form** provided in **Appendix B** of the Data Collection and Analysis Manual. Field forms cover data entry for the basic suite of metrics except for riparian vegetation and land use coefficient, which is a desktop-led data collection effort (Table A1). The field form is provided as an Excel workbook with programmed equations to calculate field values. [2] Thus, data can be entered upon returning from the field.

[1] Rapid field data collection procedures for metrics included in the rapid method, but not assessed using the rapid survey procedures, are outlined in the Data Collection and Analysis Manual. These metrics include: Land use coefficient, concentrated flow points, # LWD pieces (#/100m), dominant BEHI/NBS, percent streambank erosion, percent streambank armoring.
[2] Microsoft Excel version of the field form is available at: https://www.dnr.sc.gov/environmental/streamrestoration.html

Table A1. Basic Suite of Metrics, where '*' indicates the metric is included in the field form.

Parameter	Metric	Notes
Reach Runoff	Land use change coefficient	Methods are found in the Data Collection and Analysis Manual. This is a desktop exercise.
	Concentrated flow points (CFPs)*	Methods are found in the Data Collection and Analysis Manual.
Floodplain Connectivity	Bank height ratio (BHR)*	Rapid survey procedures include measurements required to calculate these metric field values.
	Entrenchment ratio (ER)*	
Flow Dynamics	Width/Depth(W/D) ratio state*	
Large Woody Debris (LWD)	# LWD pieces*	Methods are found in the Data Collection and Analysis Manual.
Lateral Migration	Dominant BEHI/NBS*	Procedures for BEHI/NBS described in Starr et al. (2015) and Rosgen (2014). Data Collection and Analysis Manual provides additional SQT-specific instructions.
	Percent streambank erosion*	Methods are found in the Data Collection and Analysis Manual.
	Percent streambank armoring*	
Riparian Vegetation	Buffer width	Methods are found in the Data Collection and Analysis Manual and Carolina Vegetation Survey (CVS) level 2 method (Lee et al., 2008).[3]
	Average DBH	
	Tree density	
	Native shrub density	
	Native herbaceous cover	
	Monoculture area	
	Invasive/non-native cover	
Bed Form Diversity	Pool spacing ratio*	Rapid survey procedures include measurements required to calculate these metric field values.
	Pool depth ratio*	
	Percent riffle*	

[3] Carolina Vegetation Survey Method: http://cvs.bio.unc.edu/methods.htm

A2. Rapid Assessment Field Preparation

Prior to going out in the field, collect background information on the project region, river basin, topography, and local geology to help understand and interpret the field data. Perform initial reach break estimates from the desktop and fill out data in the Site Information and Reference Stratification section and the field form (including drainage area, region, stream order, etc.). Before field data collection, it is also recommended to:

- Estimate bankfull dimensions from available regional curve(s). The field form requires the user to identify the regional curve used and provide dimensions for bankfull verification to be used in the field.
- Describe the valley morphology (e.g., confined versus unconfined) and estimate valley widths from recent aerial imagery. Mark locations on field maps where valley width changes and valley measurements will need to be taken.
- Measure buffer widths from recent aerial imagery and study riparian buffer heterogeneity. Plan to verify estimates in the field.
- Print field forms and maps.
- Sinuosity (used for stream classification only) can usually be measured at the desktop using high quality aerial imagery.

A2.1. Equipment List

At a minimum, the following field gear is required to assess the basic suite of metrics.

- Field forms and maps
- Waders
- Camera
- Metric ruler
- Clinometer
- GPS unit (helpful with lateral migration, buffer width, and sinuosity field measurements)
- DBH tape
- 1-meter square for herbaceous plots
- Survey equipment
    - Hand or line level
    - Enough 300’ tapes for the assessment reach length (note: a tape with feet on one side and metric on the other is recommended)
    - 100’ Tape
    - Stadia rod

Note about sampling periods: Riparian vegetation metrics requiring vegetation plots (e.g., average DBH, native tree density, native shrub density, native herbaceous cover, and invasive species cover) must be collected between July 1 and leaf drop.

A2.2. Bed Feature Identification

Measurements of floodplain connectivity and bed form diversity metrics require bed form identification. Bed forms focus on riffles and pools. Transition features (e.g., runs or glides) are not characterized separately from riffles and pools.

RIFFLE FEATURES

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

POOL FEATURES

The SQT requires identification of two pool types: **geomorphic pools** and **significant pools**. Guidance for identifying pools in different valley types is provided below.

Geomorphic pools are associated with planform features that create large pools that remain intact over many years and flow conditions. These pools are associated with the outside of meander bends (streams in alluvial valleys) and downstream of large cascades or steps (streams in colluvial valleys). These pools are used exclusively with the pool spacing ratio metric.

Significant pools are geomorphic pools (see above) AND pools associated with wood, boulders, convergence, and backwater that meet the following criteria:

- have a width that is at least one-half the channel bottom width,
- are concave in profile, and
- have a water surface slope that is flatter than the riffle.

Identifying Geomorphic Pools in Alluvial-Valley Streams:

Geomorphic pools in alluvial valleys are located along the outside of the meander bend. Figure A1 provides an illustration of what is and is not considered a geomorphic pool. The figure illustrates a meandering stream, where the lateral scour pools located at the outside of the meander bend are counted for the pool spacing measurement, and the 'X' marks the approximate location of the deepest part of the pool. The small pools associated with the large woody debris and boulder clusters in this figure are not considered geomorphic pools.

Compound pools that are not separated by a riffle within the same bend are treated as one pool. However, compound bends with two pools separated by a riffle are treated as two pools. Rosgen (2014) provides illustrations for these scenarios.

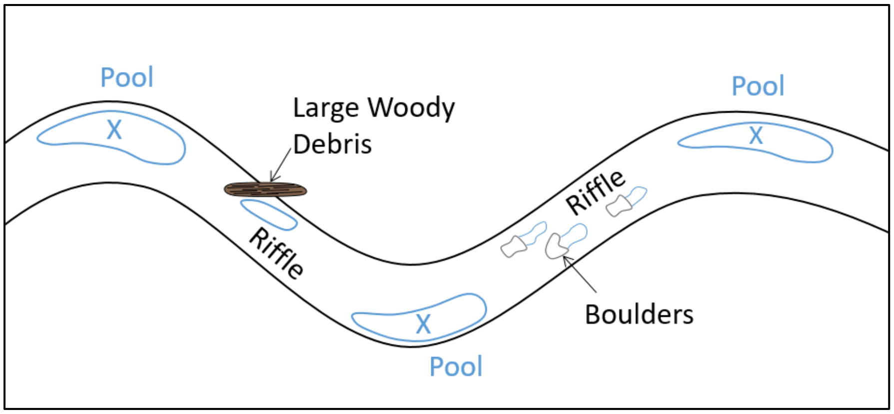

Figure A1. Pool Spacing in Alluvial Streams. Pools counted as geomorphic are marked with an 'X.'

Identifying Geomorphic Pools in Colluvial and V-Shaped Valleys:

Pools in colluvial or v-shaped valleys should only be counted as geomorphic if they are downstream of a step, riffle, or cascade. Small pools within a riffle or cascade are not counted. An example of pool spacing in a colluvial or v-shaped valley is shown in Figure A2. For these bed forms, pools are only counted at the downstream end of the riffle or cascade; small pools within the cascade feature are not included.

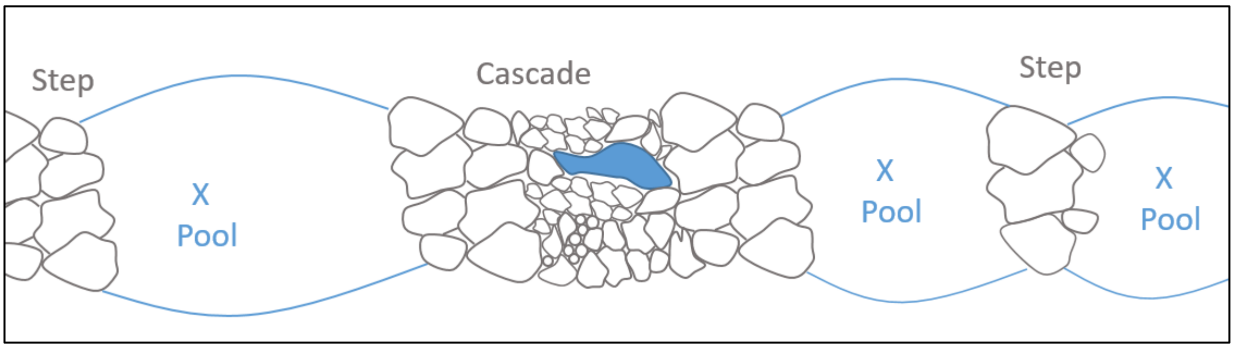

Figure A2. Pool Spacing in Colluvial and V-Shaped Valleys. Pools counted as geomorphic are marked with an 'X.'

A3. Rapid Assessment Field Data Collection

Data collected in this section will be used to fill out Sections II though IV on the field form.

A3.1. Reach Walk

It is recommended to walk the **entire reach** at the beginning of field work. **Data are recorded during the reach walk in Section II of the field form** (Figure A3). The reach walk should extend along the entire project reach and include both sides of the stream channel.

1. Locate and flag bankfull indicators throughout the reach. As bankfull indicators are noted, measure the difference between water surface elevation and bankfull indicators using a stadia rod and a hand level (or line level) and describe the feature (e.g., back of a point bar, top of bank, or break in slope). These data can be recorded in Section II of the field form and will be used to aid bankfull verification later. More detail is provided in Section A3.2.
2. Note any Concentrated Flow Points (CFPs) within the reach. Refer to the Data Collection and Analysis Manual.
3. Record armored bank lengths. Refer to the Data Collection and Analysis Manual.
4. Determine the location of the representative sub-reach. The representative sub-reach is roughly 20 times the bankfull width or two meander wavelengths, whichever is longer. The representative sub-reach should capture conditions that are typical of the stream reach.

The SQT requires that the existing stream type and reference stream type be determined according to the Rosgen classification system (Rosgen, 1996). Section A3.4 provides direction to determine the stream type representative of the reach based on data collected at each riffle in the representative sub-reach. Space is also provided in Section III of the field form to determine the stream type at the stable riffle.

II.	Reach Walk		
A.	Number of concentrated flow points:	3	
	Notes: Two storm drains - 15" CMP on LB at station 2+00 and 24" CMP on RB at station 7+00. Third is a head cut, up a ditch extending 200' into floodplain - RB Sta. 6+00.		
B.	Armored Bank Lengths (ft):	10	15
	Notes: Concrete bank protection, failing. See photos.		
C.	Difference between BKF stage and WS (ft)	Describe the bankfull indicator	
	0.58	Strong indicator, top of a mid-channel bar.	
	0.62	Scour line.	

Figure A3. Field Form Reach Walk Example.

A3.2. Field Indicators for Bankfull Verification

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

Data are recorded in Sections II and III of the field form. Verification of field indicators is required, and lines of evidence are laid out in the Data Collection and Analysis Manual. The field measurements must be compared to dimensions from regional curves or dimensions generated by a return interval analysis.

Tips for Identifying the Bankfull Feature:

1. Look for depositional features such as point bars. Bankfull is often the highest elevation or top of point bar.
2. Check the bank for a break between depositional processes and channel formation processes such as a slope break.
3. For incised channels with a developing floodplain, bankfull is typically the back of a sloping bench. The front of the bench is typically the inner berm.
4. Scour lines should only be used to reinforce indicators from depositional features.

DIFFERENCE BETWEEN BANKFULL STAGE AND WATER SURFACE

Longitudinal profiles allow the user to compare the slope of the bankfull line to the water surface slope as described in Rosgen (2014). The rapid method uses the difference between water surface and bankfull indicators to identify bankfull within the project reach. Measuring the distance between bankfull indicators and water surface elevation throughout the reach increases the accuracy of bankfull determinations compared to a bankfull indicator that is determined at a single location.

Identify bankfull features throughout the reach during the reach walk. As bankfull indicators are noted, measure the difference between water surface elevation and bankfull indicators using a stadia rod and a hand level (or line level) and describe the feature (e.g., back of a point bar, top of bank, or break in slope). **The difference between water surface and bankfull should only vary by a couple of tenths of a foot throughout the reach.** Bankfull determination is suspect if the difference between bankfull indicators and water surface elevation varies by more than two to three tenths. Based on data collected throughout the reach, form a consensus on the difference between the bankfull elevation and water surface elevation.

STABLE RIFFLE CROSS-SECTION DIMENSION SURVEY

Riffle dimensions are necessary to verify bankfull and to create dimensionless ratios for other measurements that quantify the departure of the stream from a stable condition. Therefore, a rapid survey of the bankfull channel at a single riffle cross-section within the reach is performed. Selection of the stable riffle is critical; the criteria below can aid in the selection of a suitable riffle:

- Stable width and depth, no signs of bank erosion or headcutting. The BHR is near 1.0.
- Cross-sectional area plots within the range of scatter used to create the regional curve. (More information is provided in the next section.)

- The bankfull W/D ratio is on the lower end of the range for the reach.

Note: In a highly degraded reach, a stable riffle cross-section may be used from an **adjacent** upstream or downstream reach. If a stable riffle meeting these criteria cannot be found within or adjacent to the reach, then the user will survey a riffle within the reach that contains the strongest bankfull indicator identified during the reach walk.

Survey the stable riffle cross-section as follows:

1. Stretch a tape from the left bankfull indicator to the right bankfull indicator. Use the primary bankfull indicator (left or right) to level the tape.
2. **Level the tape** by attaching a line level and measuring the distance from the water surface to the tape at the left and right edge of water surface; the location where the water meets the streambank. The distance should be the same on both sides and should be within the range recorded in Section II of the field form during the reach walk.
3. Record the bankfull width.
4. Working from left to right, record the station from the tape and the depth from the tape to the channel bottom using a stadia rod. Include major breaks in slope, the thalweg, points halfway between edge-of-channel and bankfull, and other points along the channel bottom. Record these data in Section III of the field form.
5. Calculate the bankfull mean depth and cross-sectional area. These calculations are automatically performed in the workbook version of the field form. A rough estimate of the mean depth can be calculated in the field by adding all the depth measurements (except for zeros at bankfull) and dividing by the number of observations. The area is the bankfull width multiplied by the mean depth.

A3.3. Representative Sub-Reach

All data outlined in this section should be recorded in **Section IV of the field form** (Figures A4 and A6) and the **BEHI/NBS field form**. Riffles, geomorphic pools, and significant pools are defined in Section A2.2.

Determine the minimum length of the representative sub-reach. Stretch a tape or multiple tapes along the edge of the channel or top of streambank. Begin and end the representative sub-reach at the head of a riffle feature.

IV.	Representative Sub-Reach								
A.	Assessment Segment Length At least 20 x the Bankfull Width			360		20*Bankfull Width			320
B.	Riffle Data								
		R1	R2	R3	R4	R5	R6	R7	R8
	Begin Station (Distance along tape)	0	52	108	240				
	End Station (Distance along tape)	20	60	130	250				
	Low Bank Height (ft)	1.8	1.1	1.2	1.6				
	Bankfull Max Depth (ft)	2	1.1	1	1.3				
	Bankfull Width (ft)	16	22	21	17				
	Flood Prone Width (ft)	27	32	34	34				
	Bankfull Mean Depth (ft)	1.6	0.9	0.8	1.5				

Figure A4. Field Form Representative Sub-Reach Riffle Data Example.

RIFFLE DATA

Measure the following at every riffle within the representative sub-reach and record values:

1. Record the station along the tape where the riffle begins.
2. Record the station along the tape where the riffle ends. If there is a run, the end station should be at the end of the run feature. Riffles end at the head of a geomorphic or significant pool.
3. Identify the middle of the riffle feature.
4. At the approximate mid-point of the riffle, identify the lower of the two streambanks and measure the difference in stadia rod readings from the thalweg to the top of the low streambank. Record this value as the low bank height.
   a. Note, when the top of low bank and the bankfull feature are the same, the bank height ratio equals 1.0.
   b. Useful scenarios for identifying bankfull and low bank height in incised channels are provided later in this section.

5. Measure the difference in stadia rod readings from the thalweg to the bankfull indicator and record this value as the bankfull max depth (Figure A5).
   a. Alternatively, if no bankfull indicators are present, measure the difference in stadia rod readings from the thalweg to the water surface then add the value recorded for the difference between bankfull stage and water surface.
6. Measure the bankfull width at the midpoint of every riffle by stretching a tape from the left bankfull indicator to the right bankfull indicator. Use the primary bankfull indicator and the difference between water surface elevation and bankfull that has been recorded on the field form to level the tape.
7. Flood-prone width – For reaches with changes in valley width or a bank height ratio near 2.0, flood-prone width should also be measured at the midpoint of each riffle. The flood-prone width is the width of the valley at a height that is twice the bankfull max depth. Locate and flag the points along the cross-section in the floodplain where the difference in stadia rod readings between the thalweg and that point is twice the maximum bankfull depth (Figure A5). Use tapes and/or a range finder to measure the distance between the flags. Rosgen (2014) shows examples of ER calculations.[4]

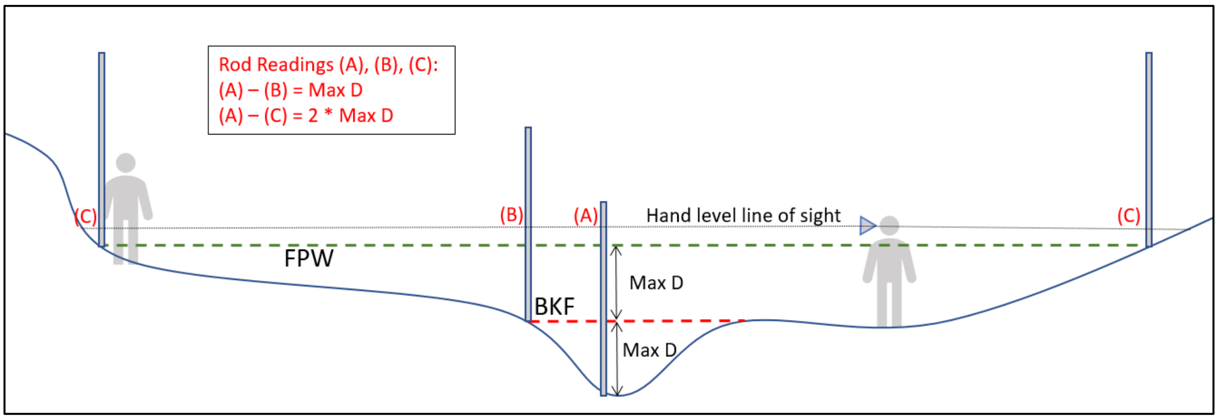

Figure A5. Measuring bankfull max depth (Max D) and flood-prone width (FPW).

8. Bankfull mean depth – Mean depth is the cross-sectional area divided by the width and is therefore a calculation rather than a measurement. The mean depth can be estimated as the difference between the edge of channel and the bankfull stage.

POOL DATA

[4] ER examples https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1259

Measure the following at every geomorphic and significant pool within the representative sub-reach and record values (Figure A6).

C.	Pool Data								
		P1	P2	P3	P4	P5	P6	P7	P8
	Geomorphic Pool?	G	G	G	G				
	Station At maximum pool depth	36	84	185	250				
	Geomorphic P-P Spacing (ft)	X	48.0	101.0	65.0				
	Pool Depth (ft) Measured from Bankfull	1.2	1.4	2	1.1				

Figure A6. Field Form Pool Data Example.

1. Identify pool features (refer to Section A2.2 of this appendix).
2. Record whether the pool is a geomorphic pool.
3. Locate and record the station of max pool depth.
4. At the point of max pool depth, measure the water depth then add the value recorded for the difference between bankfull stage and water surface.

SLOPE AND SINUOSITY

The slope of a stream reach is indicative of the energy within a channel and necessary for discharge calculations. Although energy and discharge calculations are not a part of the rapid method, reach slope is a component of the Rosgen stream classification system. Ideally, the average reach slope would be calculated for the entire stream reach as the difference between the water surface elevation at the head of the first riffle and at the head of the last riffle in the reach, divided by the centerline channel distance between these two points. For this assessment, the distance will be limited by the line of sight and magnification of the hand level being used. Record values in the field form (Figure A7).

D.	Slope				
		Begin	End	Difference	Slope (ft/ft)
	Station along tape (ft)	0	16	16.0	0.013
	Stadia Rod Reading (ft)	4.8	5	0.2	

E.	Sinuosity	
	Stream Length (ft)	500
	Valley Length (ft)	415
	Sinuosity	1.2

Figure A7. Field Form Slope and Sinuosity Example.

To estimate the slope of the channel:

1. Record the station and stadia rod reading of water surface at the head of similar features (i.e., riffle to riffle, or pool to pool, etc.). Measurements that span multiple riffle-pool sequences will provide a more accurate representation of the reach slope.
2. Calculate the slope as the difference in the two water surface readings divided by the difference in station (channel distance) between the two readings.

Sinuosity may be measured using aerial imagery, but it can also be measured in the field. Sinuosity calculations are described in more detail on page 2-32 of Rosgen (2014).[5] This measurement is a guide for stream classification (Section A3.4) and is not a measurement used in the SQT.

1. Sinuosity can be measured in the field using **either** of the following methods depending on available equipment:
    a. Use a GPS unit to map the stream centerline along the project reach length. The stream length and valley length can then be measured in the office using the GPS data.
    b. Using either a range finder or available tapes, measure the centerline channel distance and the valley length between two common points.
2. Divide stream length by valley length to calculate sinuosity.

LWD

LWD is assessed in the 328-ft (100-m) segment of the sub-reach that contains the most LWD. Refer to the Data Collection and Analysis Manual. These data can be recorded in Section IV.F of the Field Form.

BEHI/NBS

BEHI/NBS is assessed along the outside of all meander bends and eroding streambanks within the representative sub-reach. Refer to the Data Collection and Analysis Manual. These data can be recorded in the **BEHI/NBS field form**.

LOW BANK HEIGHT IN INCISED CHANNELS

The low bank height is the lower of the left and right streambanks, indicating the minimum water depth necessary to inundate the floodplain. In incised channels with a bankfull bench, determining when bankfull and the top of bank are equal to each other can be challenging.

[5] Guidance on calculating sinuosity also available from: https://nctc.fws.gov/courses/CSP/CSP3200/resources/documents/Geometry_AFG2013.pdf

Two common scenarios are detailed below. Note that both scenarios assume that bankfull has already been identified and verified within the reach.

Scenario 1: If bankfull is identified as the back of the bench, then the top of the low bank is the top of the left or right bank which break onto the terrace (Figure A8).

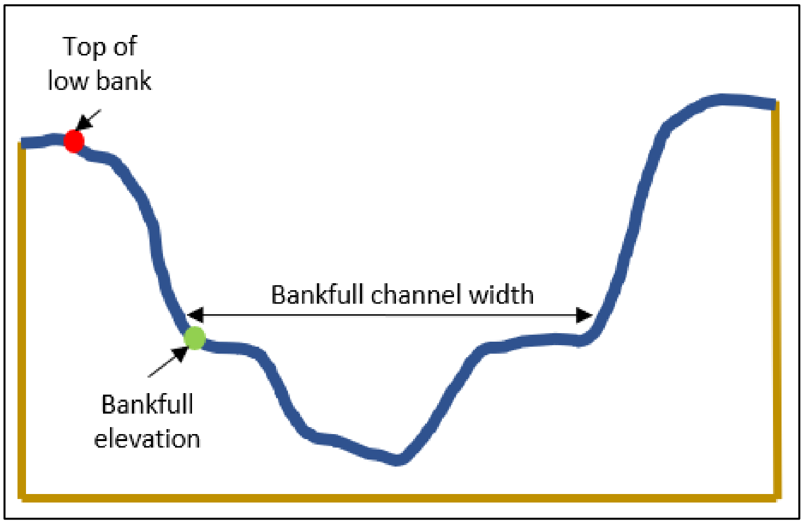

Figure A8. Scenario 1, where bankfull elevation is the back of the bench and bankfull and top of low bank are not equal.

Scenario 2: If bankfull elevation is identified as the front of the bench, then the width of that bench must be measured before the top of bank can be determined. Specific criteria include:

- For Rosgen C/E reference stream types, if the total floodplain bench width (left bench + bankfull channel + right bench) is greater than 2.2 times the bankfull channel width, then the top of low bank is equal to bankfull (BHR=1.0) (Figure A9).
- For Rosgen B reference stream types, if the total floodplain bench width (left bench + bankfull channel + right bench) is 1.4 times greater than the bankfull channel width, then the top of low bank is equal to bankfull (BHR=1.0) (Figure A9).
- If values are less than or equal to 2.2 for Rosgen C or E reference stream types and 1.4 for Rosgen B reference stream types, then the top of the low bank is the top of the left or right bank which breaks onto the terrace (Figure A10).

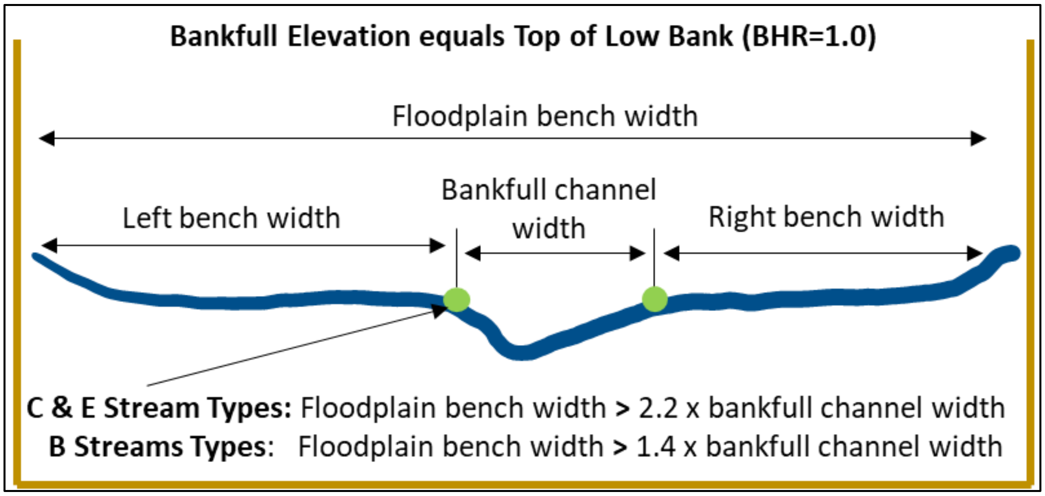

Figure A9. Scenario 2, where bankfull elevation is the front of the bench, and calculations determine location of low bank.

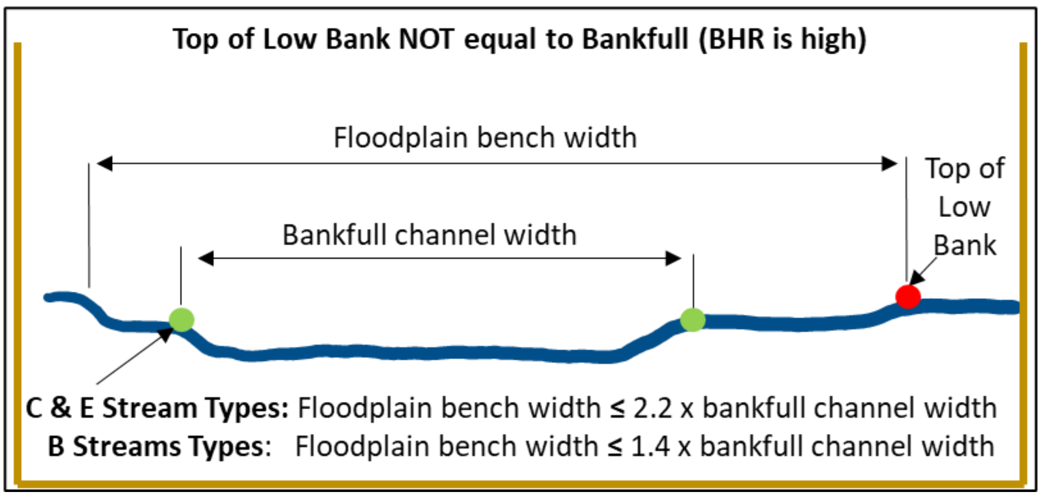

Figure A10. Scenario 2, where bankfull elevation is the front of the bench, and calculations determine location of low bank.

A3.4. Stream Classification

The SQT requires that the existing stream type and a reference stream type be determined according to the Rosgen classification system. 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).[6] Stream classification is based on valley type, entrenchment ratio, width/depth (W/D) ratio, bed material, sinuosity, and slope (Figure A11). The user can estimate bed material by performing a reach-wide pebble count (Rosgen, 2014). The pebble sizes that classify different materials are provided in Table A2.

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

Table A2. Sediment Size Ranges for Stream Classification

Channel Material	Size Range (mm)
Silt or Clay	< 0.062
Sand	0.062 – 2.00
Gravel	2.01 – 64
Cobble	64.01 – 256
Boulder	256.01 – 2048
Bedrock	

Data collected from the representative sub-reach (Section A3.3) provides necessary input to determine the Rosgen stream type that is typical of existing conditions in the project reach.

Instructions in this appendix have characterized a stable riffle for bankfull verification (Section A3.2) that is within or near the project reach. The stream type determined for this riffle could be representative of the existing stream type or useful in determining the reference stream type.

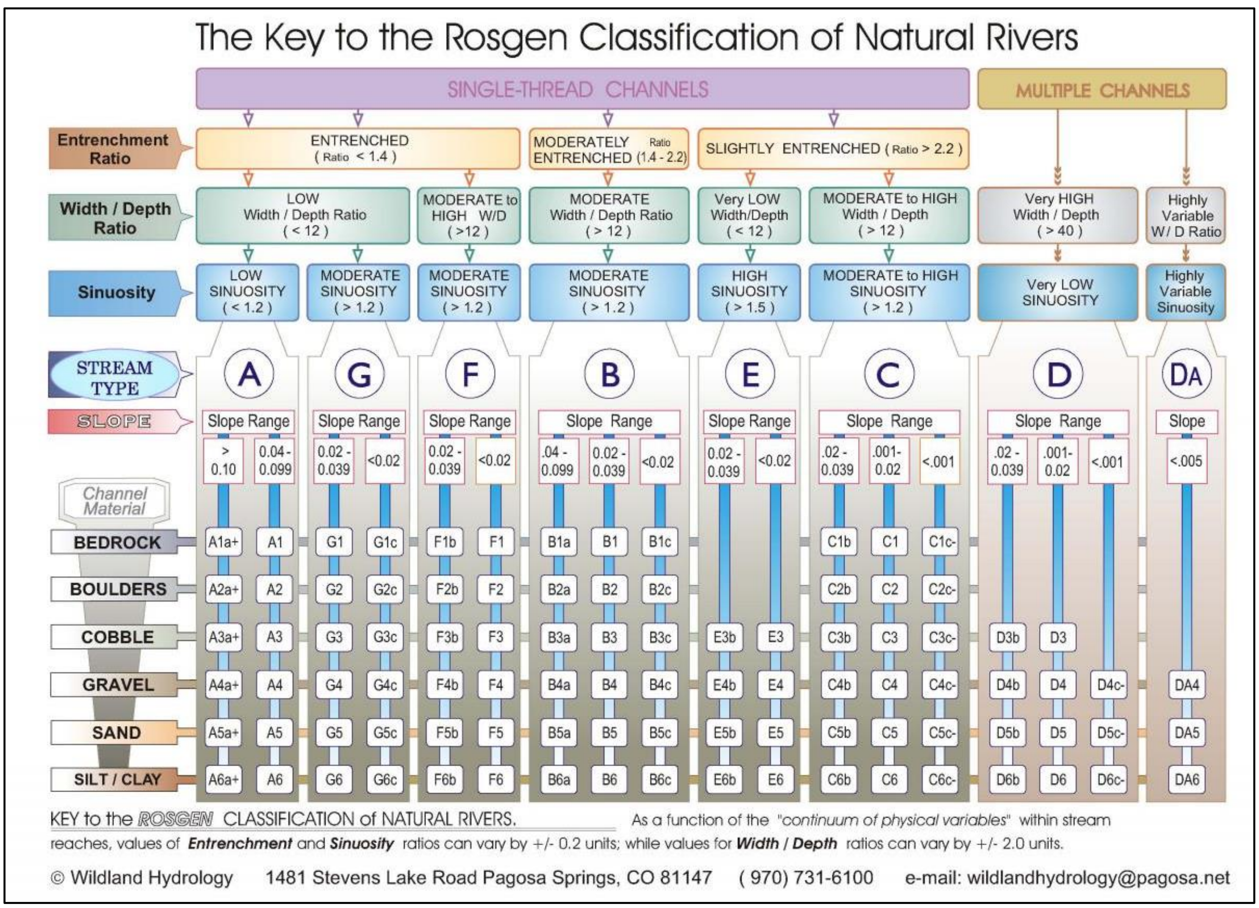

Figure A11. Key to Rosgen Classification of Natural Rivers (Rosgen, 1996).

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Appendix B

Rapid Field Data Collection Forms

for the SC SQT v1.0

Date:
Investigators:

I. Reach Information and Stratification

Project Name:	
Reach ID:	
Upstream Latitude:	
Upstream Longitude:	
Downstream Latitude:	
Downstream Longitude:	
Ecoregion:	
River Basin:	
Stream Reach Length (ft):	
Valley Type:	
Drainage Area (sq. mi.):	
Strahler Stream Order:	
Flow Type:	
Buffer Valley Slope (%):	
Dominant Buffer Land Use:	
Stream Temperature:	
Macroinvertebrate Sampling Method:	

Shading Key
Desktop Value
Field Value

II. Reach Walk

A. Number of concentrated flow points:

Notes:

B. Armored Bank Lengths (ft):

Notes:

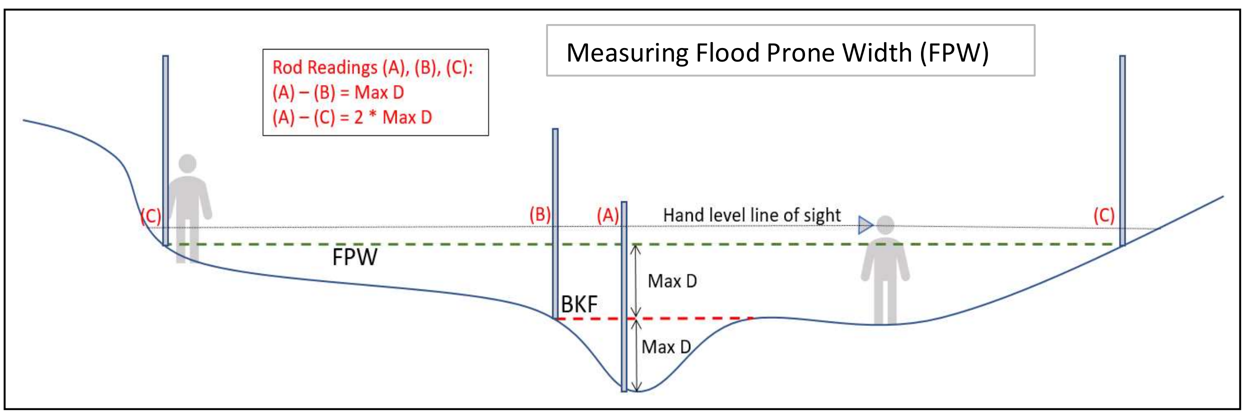
C.

Difference between BKF stage and WS (ft)	Describe the bankfull indicator

III. Bankfull Verification and Stable Riffle Cross Section

A.	Difference between BKF stage and WS (ft) *Average or consensus value from reach walk.*	
B.	Bankfull Width (ft)	
E.	Regional Curve Bankfull Width (ft)	
F.	Regional Curve Bankfull Mean Depth (ft)	
G.	Regional Curve Bankfull Area (sq. ft.)	
H.	Curve Used	
I.	Flood Prone Width (FPW; ft)	

Cross Section Measurements Depth measured from bankfull			
Station	Depth	Station	Depth



IV. Representative Sub-Reach

A.

Assessment Segment Length At least 20 x the Bankfull Width	100	20*Bankfull Width	

B. Riffle Data

	R1	R2	R3	R4	R5	R6	R7	R8
Begin Station (Distance along tape)								
End Station (Distance along tape)								
Low Bank Height (ft)								
Bankfull Max Depth (ft)								
Bankfull Width (ft)								
Flood Prone Width (ft)								
Bankfull Mean Depth (ft)								

C. Pool Data

	P1	P2	P3	P4	P5	P6	P7	P8
Geomorphic Pool?								
Station At maximum pool depth								
Geomorphic P-P Spacing (ft)								
Pool Depth (ft) Measured from Bankfull								

D. Slope

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

E. Sinuosity

Stream Length (ft)	
Valley Length (ft)	
Sinuosity	

F. LWD Piece Count *(find 328-feet segment within assessment sub-reach with the MOST LWD)*

# of LWD Pieces	
Assessment length (ft)	328
# of LWD Pieces/100 m	0

Date:

Investigators:

SC SQT

BEHI/NBS Field Form

Reach ID:

Valley Type:

Bed Material:

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