

Rapid Data Collection Methods for the Tennessee Stream Quantification Tool



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Disclaimer:

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

1. Introduction and Purpose

Rapid assessments can be useful tools and are appropriate for site selection purposes, concept plans, one-time only condition assessments, or other applications where detailed data are not required. This document provides instruction on how to collect and analyze data needed to run the Tennessee Stream Quantification Tool (TN SQT) using a rapid method. This method is a suite of office and field techniques specific to the TN SQT for quickly collecting quantitative data for input into the spreadsheet. However, the TN SQT tool itself should **not** be populated with data collected using the rapid method when determining total functional loss or lift. Once a stream mitigation project has been selected, detailed methods for data collection are required to determine functional lift and as part of a mitigation plan or monitoring report. This document compliments the TN SQT *Data Collection and Analysis Manual* (data collection manual; TDEC 2017) and will reference that manual for more detail on topics such as determining reach breaks and bankfull verification.

This rapid assessment data collection method will typically take one to three hours per project reach. Standard surveying equipment like laser levels or a total station are not used. Instead, survey tapes, hand levels, and stadia rods are used to take the measurements in the field (a complete equipment list for the fieldwork component is provided in section 5). Cross sections can be plotted using this method, however, during the project planning and design phase, practitioners should collect both cross sections and longitudinal profile information that is tied to vertical control points.

Few measurements are unique to the TN SQT and procedures are often detailed in other instruction manuals or literature. Where appropriate, this manual will reference other documents and make clear any differences in data collection or calculation methods needed for the TN SQT. TDEC has attempted to compile these resources and make them available on our website, however, not all resources are listed here.

A TN SQT Rapid Assessment Form (field form) is included in section 7 of this document and can be used with these instructions to collect field data. This field form is also available as a Microsoft Excel Workbook where data can be entered upon returning from the field. ¹

2. Rapid Method Parameter List

Users will note that not all function-based parameters included in the TN SQT are assessed in the rapid method. Table 1 lists the parameters and measurement methods that are included in the rapid assessment method for the TN SQT v1.0 and are covered in this manual. The rapid method is divided into two efforts: an office / desktop component and a field component as shown in Table 1 and described in greater detail in sections 4 and 5.

For each measurement method, the value that gets entered into the TN SQT Condition Assessment is referred to as the field value. The TN SQT uses this field value to calculate index values, or scores for each measurement method, parameter and functional category. Details on how the TN SQT performs scoring is provided in the *Spreadsheet User Manual*.

¹ Microsoft Excel version of the field form is available from: <http://www.tn.gov/environment/article/permit-water-arap-compensatory-mitigation>

Table 1: Parameters and Measurement Methods included in the Rapid Method.

Function-Based Parameter	Measurement Method	Effort Category
Catchment Hydrology	Land Use Curve Number Value	Desktop
Reach Runoff	Stormwater Infiltration	Desktop
	Concentrated Flow Points	Field
Floodplain Connectivity	Bank Height Ratio	Field
	Entrenchment Ratio	Field
Large Woody Debris	# Pieces	Field
Lateral Stability	Dominant BEHI/NBS	Field
	Percent Streambank Erosion (%)	Field
Riparian Vegetation	Canopy Coverage (%)	Field
	Buffer Width (feet)	Field
	Basal Area (sq.ft/acre)	Field
Bed Form Diversity	Pool Spacing Ratio	Field
	Pool Depth Ratio	Field
	Percent Riffle (%)	Field
	Aggradation Ratio	Field
Plan Form	Sinuosity	Desktop or Field
Bacteria	E. Coli (Cfu/100 mL)	Desktop
Nitrogen	Nitrate-Nitrite (mg/L)	Desktop
Phosphorus	Total Phosphorus (mg/L)	Desktop
Macroinvertebrates	Tennessee Macroinvertebrate Index	Desktop

3. Getting Started with the TN SQT

In preparation for field work it is necessary to understand the setting and context of the project site. Users should familiarize themselves with the region, river basin, soils, available topography data, local geology and climate of the project. Some of these data will inform values for the Site Information and Stratification section of the TN SQT but all are informative in interpreting field data.

The TN SQT is a reach based tool and requires one Microsoft Excel Workbook for each reach contained within a project. There are multiple worksheets within the TN SQT workbook, these are described in detail in the *Spreadsheet User Manual*. For long homogenous reaches, a sub-reach can be assessed to represent the overall reach. Refer to section 2 of the data collection manual for detailed guidance on reach segmentation. Identify potential reach breaks and establish separate TN SQT workbooks and field forms for each reach identified. Delineate the catchment for each reach. The catchment is the land area draining to the downstream end of the reach; its delineation is necessary to complete the Watershed Assessment form and the reach runoff measurement method. Additionally, the drainage area of the reach is used calculate bankfull dimensions from the regional curve.

At this point, the user can enter values for project name, reach ID, drainage area, ecoregion, existing stream length, and valley type into the Site Information and Stratification sections of the TN SQT (Figure 1) and field forms for each reach. The Site Information and Reference Standard Stratification section is on the Quantification Tool worksheet within the TN SQT.

Figure 1: Site Information and Reference Standard Stratification from the TN SQT.

Site Information and Reference Standard Stratification	
Project Name:	Field Site Test
Reach ID:	Reach 1
Existing Stream Type:	
Proposed Stream Type:	
Ecoregion:	66d
Drainage Area (sqmi):	0.68
Proposed Bed Material:	
Existing Stream Length (feet):	520
Proposed Stream Length (feet):	
Proposed Stream Slope (%):	
Proposed Flow Type:	Perennial
Data Collection Season:	
Macro Collection Method:	
Riparian Soil Texture:	
Valley Type:	Colluvial

For each stream within the project site, the user can complete a Watershed Assessment worksheet from the TN SQT. Methods and links to relevant online data sources for each category in the Watershed Assessment are provided in section 3 of the data collection manual. Background data are used to identify possible constraints and conditions that limit the restoration potential of the reach. The Watershed Assessment form should accompany every TN SQT workbook within a project even though values may be similar for reaches located on the same stream.

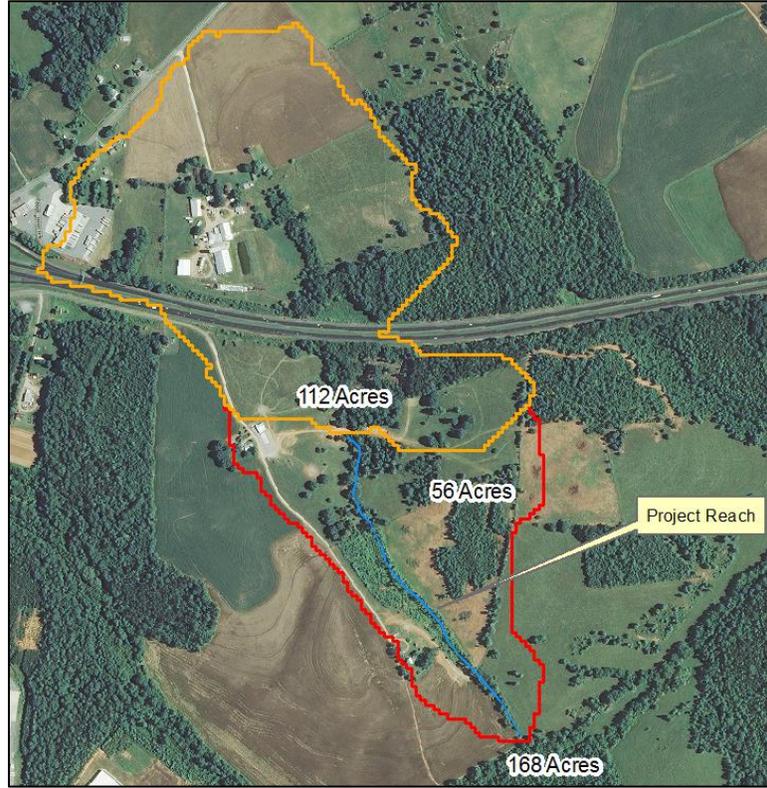
4. Desktop Component

During the desktop component, the user will collect data and calculate field values for the following measurement methods: land use curve number, stormwater infiltration, sinuosity, E. Coli, nitrate-nitrite, total phosphorus, and TN macroinvertebrate index. The procedures for determining field values for each measurement method are provided in this section. In addition to determining field values for these measurement methods, this section ends by outlining a few steps the user can take to prepare for the fieldwork component.

4.1. Land Use Curve Number (CN) Value – Catchment Hydrology

The curve number is an area-weighted value used to characterize the catchment land use *upstream* of the project reach (an example is provided in Figure 2) and is required to assess the catchment hydrology parameter of the TN SQT. The curve number is used to represent the effect of land uses that are known to degrade stream ecosystems (impervious cover, agriculture, high or low density residential development, etc.) and is not used to calculate runoff volumes or estimate infiltration.

Figure 2: Upstream Catchment (Orange) and Lateral Drainage Area (Red) Delineation Example



To determine the field value:

1. Delineate the different land use types using the best matching description from Tables 2-2a, 2-2b, and 2-2c in TR-55 TR-55 (NRCS, 1986). This can be accomplished using recent orthoimagery of the site or, less accurately, using land use data from the National Land Cover Dataset (NLCD).²
2. Download the soil data for the catchment from the Web Soil Survey³ and delineate each land use by the underlying hydrologic soil group (HSG).
3. Calculate the percent of the total upstream drainage area that is occupied by each land use and HSG pairing.
4. Assign each land use and HSG pairing the associated Curve Number (CN) from Tables 2-2a, 2-2b, and 2-2c in TR-55 TR-55 (NRCS, 1986).
5. For each land use, multiply the percent of the total upstream drainage area (step 3) by the CN that corresponds to the land use from step 4.
6. Calculate an area-weighted curve number for the upstream drainage area of the reach by summing the results from step 5. This is the field value for the CN measurement method in the Quantification Tool worksheet of the TN SQT.

² <https://gapanalysis.usgs.gov/gaplandcover/data/download/>

³ Soil data is available across Tennessee from the Web Soil Survey:
<https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>

This calculation will yield an existing condition curve number. Most stream restoration projects will not change the catchment hydrology score between the existing and proposed condition. In this scenario, the catchment hydrology score simply reflects the overall hydrology. If the expected planting area or easement boundary includes a large portion of the catchment upstream of the stream restoration reaches, then a new area-weighted curve number for the catchment upstream of the stream reach can be calculated for the proposed condition.

4.2. Stormwater Infiltration – Reach Runoff

The stormwater infiltration measurement method characterizes the amount of the lateral drainage area (LDA) that is treated by best management practices (BMP). In order to calculate the field value for the TN SQT the user must delineate the following variables:

- Runoff Source Area (RSA)
 - Drainage area from agricultural or urban land uses that increase runoff or generate pollutants.
- Stormwater Design Area (SDA)
 - Drainage area contributing runoff to be treated by the stormwater BMP
 - Portion of RSA treated by the stormwater BMP that generates a design volume for the stormwater BMP.
 - Note that the SDA will be equal to 0 for the Existing Condition (i.e. pre-BMP implementation)
- Stormwater Infiltration Factor (SIF)
 - Ratio of the BMP design volume that will be infiltrated by the stormwater BMP during small storms. Once these values are determined, the equation below can be used to calculate the field value for this measurement method.

$$\text{Field value} = \frac{(SDA \times SIF) + (LDA - RSA)}{LDA}$$

4.3. Sinuosity – Plan Form

Given the prevalence and quality of aerial imagery, sinuosity can most often be measured from the office. For small streams and/or streams with significant canopy cover it may be difficult to determine sinuosity in the office and it should be noted to measure or confirm sinuosity in the field. Sinuosity is measured from the plan form of the stream reach and calculated by dividing the stream centerline distance by the straight-line valley length between two common points. Sinuosity calculations are described in more detail on page 2-32 of Rosgen (2014).⁴ This measurement should be assessed over a length that is 40 times the bankfull width (Rosgen, 2014).

The rapid way to measure sinuosity is from recent orthoimagery. The TDEC [Water Resources mapviewer](#)⁴, Google Earth, and other online sources may be useful.

1. Download recent orthoimagery available for the site.
2. Determine the minimum length required using the bankfull width from the regional curve.
3. Trace out the path on the recent orthoimagery for at least the distance determined in Step 2.

⁴ Guidance on calculating sinuosity also available from:
https://nctc.fws.gov/courses/CSP/CSP3200/resources/documents/Geometry_AFG2013.pdf

4. Measure the straight-line valley distance between the beginning and the end of the traced stream path.
5. Calculate sinuosity by dividing the stream length by the valley length.

If recent orthoimagery is not available, or the stream channel is not visible in the imagery, then sinuosity must be measured in the field. Field instructions are provided in section 5.10 of this manual.

4.4. Bacteria, Nitrogen, and Phosphorus Measurement Methods

TDEC maintains a [dataset and map](#) of the Use Support Assessment status of Waterbodies within the state. Data for the physicochemical functional category may be available through TDEC water quality monitoring databases. These data are updated daily and can be viewed online.⁵ Information may also be retrieved from the TDEC database, [Waterlog](#).⁶

These data should be reviewed for the project reaches or surrounding water bodies to determine whether physicochemical parameters are likely functioning, functioning-at-risk or not functioning for each reach. The user should enter defensible field values for the E. Coli, nitrate-nitrite, and total phosphorus measurement methods into the existing condition assessment of the TN SQT. Data from sites outside of the project reach should be presented with discussion and justification of the assumptions made in interpreting the available data to score the project reach.

4.5. Macroinvertebrates

Data for measurement methods within the biology functional category may be available through [state monitoring databases](#) as well.⁴ In addition to water quality, macroinvertebrate communities are evaluated as part of the Surface Water Classifications assessment. Data is available at the resource listed in the previous section. These data can also be retrieved from the TDEC Integrated Report published every two years on EPA STORET.

These data should be reviewed for the project reaches or surrounding water bodies to determine whether macroinvertebrate and fish communities are functioning, functioning-at-risk or not functioning for each reach. The user should enter defensible field values for the TN Macroinvertebrate Index measurement method into the existing condition assessment of the TN SQT. Data from sites outside of the project reach should be presented with discussion and justification of the assumptions made in interpreting the available data to score the project reach.

4.6. Preparing for Fieldwork

Before the field component, it is recommended to calculate regional curve dimensions and review the valley characteristics for each reach.

The field form asks for bankfull regional curve dimensions. The state of Tennessee has worked with consultants to develop ecoregion-based regional curves across the state. These curves represent a dataset of wide ranging drainage areas and cover large geographic areas. This information is a point of reference to build on for a specific restoration project. Ideally, practitioners would develop a site-specific regional curve representative of the watershed in

⁵ <http://tdeconline.tn.gov/dwr/>

⁶ http://environment-online.tn.gov:8080/pls/enf_reports/f?p=9034:34510:::

addition to using the ecoregion based regional curves. TDEC regional curves can be accessed on the TDEC mitigation [webpage](#).⁷

Using the appropriate regional curve and the delineated catchment area, calculate regional curve dimensions for each reach. The regional curve dimensions should be entered on the field forms and will be compared to the bankfull indicators observed in the field. The field form also provides space for the user to enter the TN Ecoregion for the bankfull regional curve (e.g. Ecoregion 71 Interior Plateau). Bankfull verification is discussed in more detail in section 4.2 of the data collection manual.

The user should also review recent orthoimagery and elevation data to measure or estimate valley widths and riparian buffer widths. These desktop estimates can be confirmed in the field and assist in determining locations to take measurements for entrenchment ratio and riparian buffer width. On maps that will be taken into the field, mark locations where valley width changes and valley measurements will need to be taken.

5. Fieldwork Component

This section follows the TN SQT Rapid Assessment Form (field form) provided in section 7. The field form is also available for download as a Microsoft Excel Workbook. There is a shading key for the field form indicating which cells of the workbook are intended to be filled out in the office versus the field, and which cells in the workbook perform calculations. The calculation cells are blank and can be filled out on a printed field form. In the workbook version these cells will automatically calculate values from provided field data. Below sections cover each of the field form sections that reflect the following steps in the assessment:

1. Fill out any desktop values on the field forms for all reaches and print. This includes data in section I (site information and stratification) and some of section III (bankfull verification) of the field form.
2. Walk the reach (section II of the field form).
3. Survey a stable riffle and verify bankfull (section III of field form).

Once bankfull is verified, stretch a tape along the centerline of the assessment segment. Start and end the assessment segment at the head of a riffle. Record assessment segment length on the field form.

4. Working from upstream to downstream, take measurements at every riffle within the assessment segment (section IV of the field form).
5. Estimate the reach slope (section V of the field form).
6. Working from upstream to downstream, take measurements at every pool within the assessment segment (section VI of the field form).
7. Identify 100 meters (328 feet) within assessment segment with the highest number of pieces of large wood and count the number of pieces (section VII of the field form).
8. Perform a BEHI/NBS assessment along the outside of every meander bend (whether it is eroding or not) and for all eroding banks within the riffle or straight sections (section VIII of the field form).

⁷ <http://www.tn.gov/environment/article/permit-water-arap-compensatory-mitigation>

9. Assess riparian vegetation and soil compaction for the entire stream reach (section IX of the field form).
 - a. Measure canopy density, basal area, and soil compaction at representative points throughout the riparian buffer of the project reach.
 - b. Measure riparian buffer width using valley transects throughout reach.
10. If sinuosity was not determined during the desktop component, take measurements to calculate sinuosity in the field (section X of the field form).

At a minimum, the following gear will be needed to perform the field portion of a rapid assessment:

- Field forms and maps
- Waders
- Stadia rod
- Hand level (line level can be used for small streams)
- Metric Ruler
- 100' Tape
- Enough 300' tapes for the assessment segment length
- Basal area wedge prism
- Canopy Densiometer
- Cone nose penetrometer
- GPS unit* (helpful with lateral stability and sinuosity field measurements)
- Range finder* (helpful with sinuosity and floodprone width field measurements)

*Denotes item is optional.

5.1. Site information and Stratification

As shown in Figure 1 (page 3), some of the information in the Site Information and Reference Standard Stratification section of the TN SQT can be filled in prior to the fieldwork component of the rapid method. Section I of the field form is similar to the section of the TN SQT shown in Figure 1 and requires the following to inputs that are determined during the Desktop Component:

- Project name,
- Reach ID,
- Drainage area (measured in square miles),
- Valley type (can be verified in the field), and
- Stream reach length (measured in feet; can be verified in the field).

The fieldwork component will determine the existing stream type, bed material, and stream slope. The existing stream type is an input in the TN SQT while the existing bed material and stream slope, are needed for bankfull discharge calculations and stream classification, and are likely to inform the proposed bed material and proposed stream slope.

5.2. Reach Walk

It is recommended to walk the entire reach to begin the field work component. During the reach walk, the following tasks should be completed.

1. Determine the location of the assessment segment and a stable riffle cross section.

The assessment segment for floodplain connectivity, bed form diversity, and lateral stability parameters is roughly 20 times the bankfull width or two meander wavelengths. The assessment segment should capture the bed form diversity that is typical of the stream reach and contains the stretch of channel with the greatest amount of large woody debris.

Selection of the stable riffle is critical. Select a suitable riffle that has stable width and depth, no signs of bank erosion or headcutting, bank height ratio is near 1.0, and bankfull width/depth ratio that is on the lower end of the range for the reach. Dimensions of this riffle are used for bankfull verification and to create dimensionless ratios for pool spacing and pool depth, which are measurement methods for the bedform diversity parameter. Dimensions from a stable riffle are used in these ratios in order to quantify the departure from a stable condition.

Note: In a highly degraded reach, a stable riffle cross section may be used from an adjacent upstream or downstream reach. More detail on identifying a stable riffle is provided in section 4.2 of the data collection manual.

2. Count concentrated flow points.

The number of concentrated flow points is a measurement method for the reach runoff parameter. The measurement method assesses the number of concentrated flow points caused by anthropogenic impacts that enter the project reach per 1,000 linear feet of stream. Anthropogenic causes of concentrated flow include agricultural drainage ditches, impervious surfaces, storm drains, land clearing, and others.

The number of concentrated flow points along the entire stream reach should be tallied during a reach walk on Line II.A of the field form. The number of concentrated flow points is normalized to a count per 1,000 LF of stream. Space is provided for this calculation on Line II.B of the field form and the workbook version of the field form will automatically divide the count by the reach length provided in section I.

5.3. Bankfull Verification

Multiple parameters in the TN SQT require bankfull dimensions. These include: floodplain connectivity, large woody debris, lateral stability, and bed form diversity. Prior to making field measurements for these parameters, the user should identify and verify the bankfull (BKF) stage and associated dimensions. Methods for identifying the bankfull stage and calculating the bankfull dimensions can be found in Rosgen (2014) and Harrelson et al. (1994). Section III of the field form should be populated with the bankfull area, width, and mean depth as calculated from regional curves before going out in the field.

During the reach walk, identify bankfull features throughout the reach and measure the difference between bankfull stage and water surface elevation. For the detailed method, the water surface and bankfull profiles are surveyed and best fit lines are used to assist in bankfull verification. Since the measurements taken during the rapid method are not tied to an established vertical datum, the distance between bankfull and water surface is used to estimate the bankfull profile on the day of the survey. Measuring the distance between bankfull indicators and water surface elevation throughout the reach increases the accuracy of bankfull determinations compared to bankfull that is determined at a single location within the reach. Additionally, the measured difference between bankfull stage and water surface elevation can be useful in calculating bankfull dimensions at degraded bed features (in sections IV and VI of the field form).

Throughout the site walk, measure the difference between water surface elevation and bankfull indicators using a stadia rod and a hand level. This data can be recorded in section III of the field form. Use these data to come to a consensus on the difference between the bankfull (BKF) elevation and water surface (WS) elevation and record the value in section III.A of the field form.

At the stable riffle cross section identified earlier, stretch a level tape across the bankfull elevation and survey a riffle cross section with a level, tape, and stadia rod or just with a tape and stadia rod. There is space in section III of the field form to enter station and depth readings for this riffle cross section. Use the cross-section data to calculate the bankfull dimensions of area, width, and mean depth and populate lines B, C, and D of section III of the field form.

These dimensions are compared to the bankfull regional curve data to verify the bankfull indicators. The field data for the site should fall within the range of scatter of the regional curve in order for the site to be verified. If the field data are drastically different than the regional curve, the user will need to determine if the wrong indicator was selected or if the regional curve represents a different hydro-physiographic region than the field site. More detail on bankfull verification is provided in section 4.3 of the data collection manual.

5.4. Riffle Data (Floodplain Connectivity and Bed Form Diversity)

Sections VI through VIII of the field form are performed for the assessment segment of the stream reach. The assessment segment for floodplain connectivity, bed form diversity, and lateral stability parameters is roughly 20 times the bankfull width or two meander wavelengths (Harrelson et al., 1994). The assessment segment should capture the bed form diversity that is typical of the stream reach and contain the stretch of channel with the most pieces of large woody debris within the reach.

Stretch a tape or multiple tapes along the edge of the channel or top of streambank. Begin and end this assessment segment at the head of a riffle feature. Enter the assessment segment length in section VI.A of the field form.

Measure the following at riffles within the assessment segment and record values in section IV.B of the field form:

- Start station – the station along the tape where the riffle begins.
- End station – the station along the tape where the riffle ends or, if there is a run, the station that the run ends.
- Low bank height – Measure at the midpoint of every riffle.
- Bankfull max depth – Measure at the midpoint of every riffle.
- Bankfull mean depth – Estimate at any riffle with aggradation features and/or the widest riffle in the assessment segment. Mean depth is the cross sectional area divided by the width and 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.
- Bankfull width – Measure at every riffle.
- Floodprone area width – Measure at the midpoint of the riffle, but only if the valley width changes or if the BHR is greater than 2.0.

These data are used to calculate the BHR, ER, aggradation ratio, and percent riffle measurement method field values. BHR and ER assess the floodplain connectivity parameter in the hydraulic functional category while aggradation ratio and percent riffle assess the bed form

diversity parameter in the geomorphology functional category. Each measurement method is described in more detail below.

Bank Height Ratio (BHR)

BHR is a direct measurement of channel incision. The BHR is calculated by dividing the low bank height by the maximum bankfull riffle depth (Dmax). The low bank height is the lower of the left and right streambanks, indicating the minimum water depth necessary to inundate the floodplain.

To improve consistency, the TN SQT requires BHR to be measured at every riffle within the assessment segment. The BHR should be measured at the midpoint of the riffle, half way between the head of the riffle and the head of the run or pool if there isn't a run. Using this dataset, a weighted BHR is calculated using the question below.

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

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

Using a stadia rod and a hand level:

1. Record the station along the tape that the riffle begins and ends. If there is a run, the end station should be at the end of the run feature. Record the stations in the table of section IV.B of the field form.
2. Identify the middle of the riffle feature and the lower of the two streambanks.
3. 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 in section IV.B of the field form.
4. Measure the difference in stadia rod readings from the thalweg to the bankfull indicator, and record this value as the bankfull max depth in section IV.B of the field form.
 - o Alternatively, if no obvious signs of bankfull 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 (section III.A on the field form).
5. Repeat these measurements for every riffle.
6. Calculate the weighted BHR per the equation above.

Section IV.B of the field form provides space to multiply the BHR by the riffle length at each riffle (numerator of the equation above), sum the riffle lengths for the assessment segment (denominator), and enter the final weighted BHR. These values are automatically calculated in the workbook version of the field form and can be used to check field calculations. The weighted BHR is the field value entered into the TN SQT existing condition assessment.

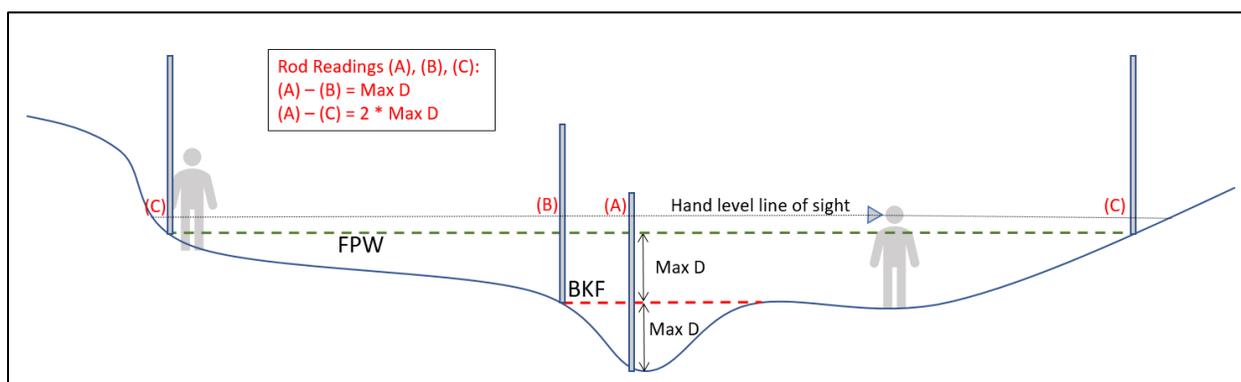
Entrenchment Ratio (ER)

The entrenchment ratio (ER) is, in part, a measure of floodplain connectivity and describes the ability of a stream to access the floodplain and dissipate energy. ER is the flood prone width divided by the bankfull width of a channel. The flood prone width (FPW) is measured as the width of the cross section at an elevation two times the bankfull (BKF) max depth.

The ER does not have to be measured at every riffle, as long as the valley width is fairly consistent. For valleys that have a variable width or for channels that have bank height ratios that range from 1.8 to 2.2, it is recommended that the ER be measured at all riffles and to calculate the weighted ER. Locations where valley width changes in the reach were noted during the desktop component of the rapid method.

The ER should be measured at the midpoint of the riffle, i.e. half way between the head of the riffle and the head of the run or pool if there isn't a run. In the middle of the riffle, locate and flag the point along the cross section in the floodplain where the difference in stadia rod readings between the thalweg and that point is twice the maximum bankfull depth (refer to Figure 3). Rosgen (2014) shows examples of ER calculations.⁸

Figure 3: Surveying Entrenchment Ratio



Using this data set, 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.

Space is provided in section IV.B. of the field form to record the floodprone area width, bankfull width and calculate entrenchment ratio at each riffle. Section IV.B of the field form also provides space to multiply the ER by the riffle length at each riffle (numerator of the equation above), sum the riffle lengths for the assessment segment (denominator), and enter the final weighted ER. These values are automatically calculated in the workbook version of the field form and can be used to check field calculations.

The final entrenchment ratio, either one representative value for the reach or the weighted entrenchment ratio, is the field value entered into the TN SQT existing condition assessment.

Percent Riffle

The percent riffle is the total length of riffles and runs within the assessment segment divided by the total assessment segment length. Riffle length is calculated from the provided start and end stations, indicating the head (beginning) of the riffle and the head of the pool respectively. Run

⁸ ER examples are also available from https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1259

features are included within the riffle length. For streams that have well-defined scour pools located within the riffle, these lengths should be measured and recorded on the field form (Additional Pool Lengths in section IV.B of the field form). The length of scour-pools within the riffles are subtracted from the total riffle length, this calculation is automatically performed in the workbook version of the field form.

Start and end stations are recorded in section VI.B of the field form (these data were also collected for the weighted BHR and ER calculations). Line VI.C of the field form provides space to sum the riffle lengths for the assessment segment while section VI.G provides space to divide the total riffle length by the length of the assessment segment (recorded in line VI.A). The total riffle length and percent riffle are automatically calculated in the workbook version of the field form and can be used to check field calculations.

Aggradation Ratio

Channel instability can result from excessive deposition that causes channel widening, lateral instability, and bed aggradation. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections. The aggradation ratio is the width depth ratio (WDR) at the widest riffle within the assessment segment divided by the expected WDR for the stream type (Table 2). It is recommended to survey multiple riffle cross sections with aggradation features to ensure that the widest value for the assessment segment is obtained and to document the extent of aggradation throughout the project reach.

At candidate riffle features:

1. Measure the bankfull riffle width.
2. Estimate the mean depth as the difference between the edge of channel and the bankfull stage.
3. Use these values to calculate the WDR at that riffle.

Space is provided in section VI.B. of the field form to record the bankfull mean depth, bankfull width and WDR at each riffle. The field value for the aggradation ratio measurement method that gets entered into the Existing Condition Assessment of the TN SQT is the maximum WDR ratio observed within the assessment segment divided by a reference WDR based on stream type. This step is not included in the field form. The maximum WDR ratio observed within the assessment segment is reported in section VI, line F of the field form.

Table 2: Reference Bankfull WDR Values by Stream Type

Stream Type	Reference WDR
B	16
C	13
E	9

5.5. Reach Slope

Reach slope is a key measurement for the energy present in a stream reach and part of stream classification. 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 distance between these two points. For the rapid-based assessment, the distance will be limited by the line of sight and magnification of the hand level being used. Estimate the slope of the channel by:

1. Taking a stadia rod reading of water surface at the head of similar features (i.e. riffle to riffle, pool to pool, etc.).
2. Calculate the difference in stadia rod readings.
3. Measure the centerline distance between the two shots.
4. Divide the difference in stadia rod readings by the centerline distance between these two points.

Space is provided in section V of the field form to record the station along the tape and stadia rod readings at the beginning and end of the slope measurements. The distance between the readings, change in elevation, and slope are automatically calculated in the workbook version of the field form and can be used to check field calculations.

NOTE: At this point the user has the required information to determine the existing stream type. The TN SQT relies on the Rosgen Stream Type (Rosgen, 1996) to stratify performance standards for some hydraulic and geomorphic measurement methods. This stream classification system and the fluvial landscapes in which the different stream types typically occur are described in detail in *Applied River Morphology* (Rosgen 1996).⁹ There is space provided in section I of the field form to record the existing stream type.

5.6. Pool Data (Bed Form Diversity)

This section uses the same tape(s) stretched along the centerline of the assessment segment as the Riffle Data section. Data to calculate the pool spacing ratio and pool depth ratio measurement methods are collected in section VI of the field form. Both of these measurement methods assess the bed form diversity parameter in the geomorphology functional category.

Working from upstream to downstream, record the following at every pool within the assessment segment:

- Maximum pool depth (measured from bankfull)
- Station of max pool depth (used in pool spacing ratio measurement)

Pool Spacing Ratio

The pool spacing ratio is the distance between sequential pools divided by the bankfull riffle width. The bankfull riffle width is from the stable riffle cross section (section III of the field form) rather than measured at each riffle. For use with the TN SQT, pools are only counted if they are geomorphically significant, large, and relatively permanent. Small, temporary pools within a riffle or cascade are not counted. In reference alluvial systems, this consists of pools located along the outside of meander bends and pools downstream of large, relatively stable flow obstructions such as steps formed by large trees or boulders. Pools in colluvial or v-shaped valleys should only be counted if they are downstream of a step or riffle/cascade.

The pool spacing ratio is calculated for each pair of pools in the assessment segment, working from upstream to downstream:

1. Record the station for the deepest point of each pool in section VI.A of the field form.

⁹ Rosgen Stream Type information is also available through the EPA:
https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1189

2. Calculate the pool-to-pool spacing in section VI.A of the field form (This is automated in the workbook version of the field form to check field calculations.)
3. Divide each spacing measurement by the bankfull riffle width from section III of the field form. (This is automated in the workbook version of the field form to check field calculations.)

Since the reference standard curve is bell-shaped for meandering channels, low and high field values (both non-functioning) could average to a functioning score. Therefore, the field value entered in the TN SQT is the median value based on at least three pool spacing measurements.

Pool Depth Ratio

The pool depth ratio is calculated by dividing the maximum bankfull pool depth by the mean bankfull riffle depth. The mean bankfull riffle depth is from a representative riffle cross section (section III of the field form) rather than measured at each riffle.

The pool depth ratio is calculated for each pool in the assessment segment, working from upstream to downstream:

1. Measure and record the maximum bankfull depth in section VI.A of the field form.
 - a. Alternatively, if no obvious signs of bankfull 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 recorded in section III.A on the field form.
2. Divide each bankfull pool depth measurement by the mean bankfull riffle depth from section III of the field form. (This is automated in the workbook version of the field form to check field calculations.)

The field value for the pool depth measurement method is the average of the pool depth ratios for pools within the assessment segment. Section VI.B provides space to average the pool depth ratios calculated in section VI.A, which is also automatically calculated in the workbook version of the field form and can be used to check field calculations.

5.7. Large Woody Debris

For the rapid method, all pieces of LWD within a 100-meter long assessment segment (328 ft.) are counted. In this methodology, large woody debris is defined as dead wood over 1-meter in length and at least 10cm in diameter at the largest end. The wood must be within the stream channel or touching the top of the streambank. In a debris dam, the number of pieces of large wood within than dam should be counted. A debris dam is defined as three or more pieces of interlocking large woody debris. The 100-meter assessment segment should be within the same reach limits as the other geomorphology assessments and should represent the length that will yield the highest score. Record the number of pieces on line VII.A of the field form.

5.8. Lateral Stability

Section VIII of the field form allows space to assess the lateral stability of the assessment segment. This section uses the same tape(s) stretched along the centerline of the assessment segment as the Riffle Data section. Two measurement methods for the lateral stability parameter are included in the rapid assessment: dominant bank erosion hazard index (BEHI)/near bank stress (NBS), and percent streambank erosion. Dominant BEHI/NBS

characterizes the magnitude of bank erosion while percent eroding bank characterizes the extent of bank erosion within a reach.

Dominant BEHI/NBS

The dominant BEHI/NBS measurement method assesses all meander bends, whether they are eroding or not, and other banks that are eroding. Depositional zones and riffle sections that are not eroding and have a low potential to erode are not included. However, if a riffle is eroding, it is assessed.

For banks throughout the assessment segment:

1. Identify all meander bends.
2. Identify all other banks that are actively eroding.
3. Determine the BEHI/NBS rating for each bank identified as actively eroding or that is located in a meander bend. Record the rating in section VIII.A of the field form.
4. Measure and record the length of each bank assessed in section VIII.A of the field form. Bank lengths can be paced in the field or measured back in the office if a GPS unit is used to map assessed banks.

Using the data recorded in section VIII.A of the field form, the dominant BEHI/NBS rating can be determined and entered in to the TN SQT for the field value of this measurement method. The dominant BEHI/NBS is the single category that describes the longest bank length of the categories represented. For example, if an assessment segment evaluated 3 banks with scores and lengths shown in Table B.4 the dominant BEHI/NBS rating would be High/High (H/H).

Table 3: Example BEHI/NBS Data

BEHI/NBS Score	Bank Length (Feet)
Low/Low	50
High/High	12
Mod/High	22
High/High	31
Low/Mod	9
High/High	31

Enter the dominant BEHI/NBS value in section VIII.B of the field form. If there is a tie between BEHI/NBS categories, the category representing the highest level of bank erosion should be selected.

Percent Streambank Erosion

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 project reach. The total length of stream bank is the sum of the left and right bank lengths, approximately twice the centerline stream length.

The BEHI/NBS rating is used to identify reaches of bank that are actively eroding. Banks with a BEHI rating of Extreme, Very High or High are considered an eroding bank regardless of their

NBS rating. Additionally, banks with the following BEHI/NBS scores are considered as actively eroding:

- M/Ex, M/VH, M/H, M/M, M/L,
- L/Ex, L/VH, L/H

Using the data collected in section VIII.A of the field form to assist in determining the length of eroding bank and enter it in section VIII.C of the field form. Enter the total bank length for the assessment segment in section VIII.D of the field form. The percent bank erosion is calculated by dividing these two numbers; space to record this value is provided in section VIII.E of the field form and is automatically calculated in the workbook version.

5.9. Riparian Vegetation and Soil Compaction

Riparian vegetation can be highly variable along streams and creeks. It is recommended users assess the riparian vegetation for the entire stream reach rather than for the rapid geomorphic assessment segment alone. Three measurement methods are included in the rapid assessment: basal area, canopy coverage, and buffer width.

Basal Area

A wedge prism is used to estimate basal area in the rapid-based method. Instructions for using a wedge prism are described in Avery & Burkhart (2002).¹⁰ A 10 BAF (basal area factor of 10 ft²) wedge prism is recommended. The BAF of the wedge prism used is recorded in section IX.A of the field form.

1. Use aerial imagery and the reach walk to select multiple locations along the entire reach within the left and right riparian communities that will provide a representative sampling of the riparian vegetation community for the reach.
2. Each selected location should be at least 200 feet apart from the previous location to prevent overlap and duplication. If, for example, your reach is 300 linear feet, a location to measure basal area could be done at the midpoint of the reach (150 feet).
3. Areas of average tree density and size should be considered when selecting a location.
4. Record the tree count obtained with the wedge prism for each sample point along the reach in section IX.A of the field form.
5. The average basal area from all sampling locations is calculated for the left and right banks separately and entered as field values.

Space is provided to record individual tree counts and calculate an average tree count for the left and right sides of the channel in section IX.A of the field form. The average tree count will automatically calculate from data entered into this section in the workbook version of the field form. The basal area is calculated by multiplying average tree count by the BAF; these values will automatically calculate in the workbook version of the field form.

If vegetation is too small to measure, the basal area for the reach is zero square feet per acre.

¹⁰ Guidance on using wedge prisms is also readily available online from multiple sites including: <https://gabrielhemery.com/2011/12/05/how-to-use-a-wedge-prism-relascope-to-measure-basal-area/>

Buffer Width

The riparian buffer width is measured horizontally from the top of the stream bank to the proposed conservation easement boundary, project limits, or edge of valley. Buffer width is measured perpendicular to the fall-line of the valley on the left and right sides of the channel. This measurement does not include the channel width. An average buffer width should be reported for the right and left side of the channel separately. Buffers should be planted and/or maintained for native riparian trees and shrub species. Herbaceous vegetation can be included dependent on site.

Space is provided to record individual buffer width measurements and calculate an average buffer width for the left and right sides of the channel in section IX.B of the field form if the riparian corridor varies drastically over the reach assessed. The average buffer width will automatically calculate from data entered into this section in the workbook version of the field form.

Canopy Coverage

This measurement method is an assessment of riparian vegetation health rather than stream shading. Measurements should be taken within the riparian buffer rather than from the stream channel or on the stream banks. Canopy coverage is measured using a densitometer. For detail on how to use the densitometer refer to the device instructions or *Using Forest Densitometers* (Forestry Suppliers, Inc., 2008).

At each sampling location, a canopy cover measurement is taken facing each of the four cardinal directions. These measurements are the number of dots (or 1/8" square corners of the squares etched in the densitometer) that are either shaded or not shaded by canopy cover, whichever is easier to count.

- If the user is counting the number of dots ***occupied*** by canopy cover (i.e. shaded), enter "Canopy" as the method under the measurements. The canopy method will be easier where canopy cover is sparse.
- If the user is counting the number of dots ***not occupied*** by canopy cover (i.e. in the sun or not shaded), enter "No Canopy" as the method under the measurements. This method will be easier where canopy cover is prevalent and most of the densitometer is shaded.

The count is averaged for each sampling location. The average canopy cover from all sampling locations is calculated for the left and right banks separately and entered as field values.

Space is provided to record canopy cover measurements in section IX.C of the field form. The workbook version of the field form will automatically calculate the average count for each sampling location and, if the method is entered, calculate the percent canopy coverage for each sampling location and the average canopy coverage for each bank.

If there are no canopy species, then the canopy coverage for the reach is zero percent.

5.10. Sinuosity

Sinuosity is measured from the plan form of the stream reach and calculated by dividing the centerline distance by the straight-line valley length between two common points. Sinuosity

calculations are described in more detail on page 2-32 of Rosgen (2014).¹¹ Sinuosity is also covered in the desktop component, section 4.3 of this manual, as recent orthoimagery may be used to measure sinuosity if it is available. If recent orthoimagery is not available, or the stream channel is not visible in the imagery, then sinuosity must be measured in the field.

Sinuosity can be measured in the field using **either** of the following methods depending on available equipment:

- Use a GPS unit to map the stream centerline along a length that is at least 40 times the bankfull width. The stream length and valley length can then be measured in the office using the GPS data and then used to calculate sinuosity and enter the value in the TN SQT.
- Using either a range finder or available tapes, measure the centerline distance and the valley length between two common points. It is preferable to measure sinuosity over a length that is 40 times the bankfull width (Rosgen, 2014) but the distance over which sinuosity can be measured using this method may be limited by view or tape obstructions. There is space provided in section X of the field form to record the stream length and valley length. The workbook version of the field form will automatically calculate sinuosity from these values.

¹¹ Guidance on calculating sinuosity also available from:
https://nctc.fws.gov/courses/CSP/CSP3200/resources/documents/Geometry_AFG2013.pdf

6. References

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7. TN SQT Rapid Assessment Form

Date:
Investigators:

**TN SQT
Rapid Assessment Form**

IV. Riffle Data (Floodplain Connectivity & Bed Form Diversity)

A.	Assessment Reach Length At least 20 x the Bankfull Width			20*Bankfull Width	
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B. Bank Height & 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 Mean Depth (ft)								
Bankfull Width (ft)								
Floodprone Area Width (ft)								
Additional Pool Lengths (ft)								
Riffle Length (ft) <i>Including Run</i>								
Bank Height Ratio (BHR) Low Bank H / Bankfull Max D								
BHR * Riffle Length (ft)								
Entrenchment Ratio (ER)								
ER * Riffle Length (ft)								
WDR BKF Width / BKF Mean Depth								

C.	Total Riffle Length (ft) <i>Excludes Additional Pool Lengths</i>	
D.	Weighted BHR $\frac{\sum(\text{Bank Height Ratio}_i \times \text{Riffle Length}_i)}{\sum \text{Riffle Length}}$	
E.	Weighted ER	
F.	Maximum WDR	
G.	Percent Riffle (%)	

Date:
Investigators:

**TN SQT
Rapid Assessment Form**

V. Slope

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

VI. Pool Data (Bed Form Diversity)

A. Pool Data	P1	P2	P3	P4	P5	P6	P7	P8
Station								
P-P Spacing (ft)	X							
Pool Spacing Ratio Pool Spacing / BKF Width	X							
Pool Depth (ft) Measured from Bankfull								
Pool Depth Ratio Pool depth/BKF mean depth								

B. Average Pool Depth Ratio

C. Median Pool Spacing Ratio

Date:
Investigators:

**TN SQT
Rapid Assessment Form**

VII. Large Woody Debris

A. Number of Pieces per 100m	
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VIII. Lateral Stability

A. Bank Data

BEHI/NBS Score	Bank Length (ft)	BEHI/NBS Score	Bank Length (ft)

B. Dominant BEHI/NBS Score	
C. Total Eroding Bank Length (ft)	
D. Total Bank Length (ft)	
E. Percent of Bank Erosion (%) Total Eroding Bank Length/ Total Bank Length	

IX. Riparian Vegetation

A. Basal Area

Prism Factor (BAF)								
	Basal Area Plots - Tree Counts with Prism					Average	Basal Area (sq.ft./ac)	
Riparian Buffer	1	2	3	4	5			
Left (looking downstream)								
Right (looking downstream)								

B. Buffer Width

	Buffer Width Measurements (ft)							Average
Riparian Buffer	1	2	3	4	5	6	7	
Left (looking downstream)								
Right (looking downstream)								

Date:
Investigators:

**TN SQT
Rapid Assessment Form**

C. Canopy Coverage

Densimeter Factor								
	Canopy Coverage Plots							
Riparian Buffer	1		2		3		4	
Left (looking downstream)								
Method (No Canopy/ Canopy)								
Average Count								
Canopy Coverage (%)								
Right (looking downstream)								
Method (No Canopy/ Canopy)								
Average Count								
Canopy Coverage (%)								

Riparian Buffer	Average Canopy Cover
Left (%)	
Right (%)	

X. Sinuosity

A. Stream Length (ft)	
B. Valley Length (ft)	
C. Sinuosity	