# Colorado Stream Quantification Tool

# User Manual (v1.0)

Army Corps of Engineers

# Colorado Stream Quantification Tool (Version 1.0)

# User Manual

July 2020

**Lead Agencies:**
U.S. Army Corps of Engineers, Albuquerque District, Pueblo Regulatory Office
U.S. Army Corps of Engineers, Omaha District, Denver Regulatory Office
U.S. Army Corps of Engineers, Sacramento District, Grand Junction Regulatory Office

**Contractors:**
Stream Mechanics
Ecosystem Planning and Restoration

**Contributing Agencies:**
U.S. Environmental Protection Agency
Colorado Parks and Wildlife
Colorado Department of Public Health and the Environment
Colorado Water Conservation Board

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# Acknowledgments

The Colorado Stream Quantification Tool and supporting materials are adapted for Colorado from the Wyoming Stream Quantification Tool v1.0 (USACE 2018) which was developed by the Wyoming Stream Technical Team, whose members include Will Harman, Cidney Jones, Julia McCarthy, Paul Dey, Jeremy Zumberge, and Paige Wolken.

The Colorado Stream Quantification Tool (CSQT) CSQT is the collaborative result of federal and state agency representatives, collectively referred to as the CSQT steering (advisory) committee (CSQT SC). The development of the CSQT and supporting documents for Colorado was funded by USEPA Region 8, USEPA Headquarters and USACE Albuquerque through a contract with Ecosystem Planning and Restoration and Stream Mechanics (contract # EP-C-17-001). Steering (advisory) committee members include:

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Many others provided valuable contributions to the Colorado and Wyoming documents, including: Will Harman (Stream Mechanics) and Cidney Jones (EPR) who provided technical support; Andy Treble and Jay Skinner (CPW) who provided input on fish metrics and assemblage data; Kiel Downing (USACE Omaha/Albuquerque District), Karlyn Armstrong (CPW), and Jack Lander (CWCB) who provided valuable review and comment; Mike Robertson and other Aquatic Staff with Wyoming Game and Fish Department who assisted with data collection and provided input on fish metrics; Wyoming Department of Environmental Quality, Water Quality Division staff who assisted with data collection; Barbara Chongtoua with the Urban Drainage and Flood Control District (also known as the Mile High Flood Control District) who provided important context within urban environments; and Sara Donatich, LeeAnne Lutz, and Amy James (EPR). Valuable peer review on the CSQT Beta Version and supporting documentation was provided by Sarah Miller (USACE ERDC). This document also benefited from others who provided feedback and comment on the CSQT Beta Version through the Public Notice issued by the Colorado Regulatory Offices.

# Table of Contents

## List of Figures

# List of Tables

## List of Examples

# Preface

### *Document History*

- The Colorado Stream Quantification Tool (CSQT) v1.0 was revised from the CSQT Beta Version. CSQT Beta Version was released for testing and public comment by the U.S. Army Corps of Engineers (USACE) Albuquerque, Omaha, and Sacramento Districts in May 2019. The CSQT Steering (Advisory) Committee (CSQT SC) gratefully received technical comments from multiple agencies and practitioners. The CSQT SC reviewed the technical comments received and revised and updated the CSQT accordingly. Larger revisions included simplification of the tool, including reducing the number of metrics and parameters; and improving clarity regarding experience requirements, methods, proposed conditions, and monitoring. Additional detail was also added to inform restoration potential and reference stream type.
- The CSQT Beta Version was developed using the Wyoming Stream Quantification Tool (WSQT) v1.0 and associated documents as a starting point. This manual, the CSQT workbook and Debit Calculator workbook, and the scientific support for the CSQT have been edited from the WSQT v1.0 for use in Colorado.
- The WSQT v1.0 was released by USACE for program implementation in Wyoming along with an updated Wyoming Stream Mitigation Procedures (v2) document in July 2018.
- The WSQT Beta Version was released for testing and public comment by the U.S. Army Corps of Engineers (USACE) Omaha District Wyoming Regulatory Office in August 2017. The USACE and Wyoming Stream Technical Team (WSTT) gratefully received technical comments from ten agencies and six practitioners. The WSTT reviewed the technical comments received and revised and updated the WSQT accordingly. Larger revisions included simplification of the tool; consideration of other methods, approaches, parameters, and metrics; and the development of a separate support document to provide the scientific rationale of the WSQT.

### *Document Availability and Revisions*

A digital copy of the CSQT and associated documents can be obtained on the Regulatory In-lieu fee and Bank Information Tracking System (RIBITS) website under Assessment Tools for Colorado:

https://ribits.usace.army.mil/

A copy may also be requested from any of the USACE Regulatory Offices in Colorado.

The following spreadsheets and documents are available:

- CSQT workbook – Microsoft Excel workbook described in detail in the User Manual.
- Debit Calculator workbook – Microsoft Excel workbook described in detail in the Colorado Mitigation Procedures (COMP; USACE 2019) and the User Manual.

- Colorado Stream Quantification Tool User Manual – This manual describes the CSQT workbook and Debit Calculator workbook, all calculations performed by the workbooks, and how to collect data and calculate input for the CSQT.

- Scientific Support for the CSQT – A comprehensive review of the function-based parameters and metrics, reference standards, stratification methods, scoring, and references used in the CSQT. The Scientific Support for the CSQT also includes a list of metrics summarizing this information.

- Colorado Mitigation Procedures (COMP; USACE 2020) – USACE procedures for using the CSQT workbook and Debit Calculator workbook to calculate credits and debits.

This suite of documents was revised following public comment and testing. Future versions of the tool will be updated and revised periodically as additional data are gathered and reference standards and metrics are refined. Field data supporting refinement of reference curves and evaluation of metrics are appreciated. The CSQT architecture is flexible and future versions of the tool can accommodate additional parameters and metrics. If a user is interested in proposing additional parameters or metrics for incorporation into the tool, they should provide a written proposal for consideration. The written proposal should include a justification and rationale (e.g., data sources and/or literature references) and should follow the framework for identifying reference curves, threshold values, and index scores that is outlined in the Scientific Support for the CSQT (CSQT SC 2020). Field data supporting refinement of reference curves and evaluation of metrics are appreciated. Feedback may be submitted at any time to the USACE Pueblo Regulatory Office at 201 West 8th Street Suite 350, Pueblo, Colorado, 81003, or contact the office at (719) 744-9119. An email address can be provided on request.

***Disclaimer***

The Colorado Stream Quantification Tool (CSQT), including workbooks and supporting documents, are intended for the evaluation of Clean Water Act Section 404 (CWA 404) compensatory mitigation projects and impact sites, and their departure from reference standards in terms of functional lift or loss, respectively. The metrics are scored based on their current condition as compared to a reference standard. Consultation with the local Corps office is recommended prior to the use of this tool related to any CWA 404 activities. In part, or as a whole, the function-based parameters, metrics, and index values are not intended to be used as the basis for engineering design criteria. The U.S. Army Corps of Engineers assumes no liability for engineering designs based on these tools. Designers should evaluate evidence from hydrologic and hydraulic monitoring, modeling, nearby stream morphology, existing stream conditions, sediment transport requirements, and site constraints to determine appropriate restoration designs.

# Version

| **CSQT Version** | **Date finalized** | **Description** |
| --- | --- | --- |
| CSQT Beta Version | May 2019 | Original version |
| CSQT v1.0 | July 2020 | Various updates following public review and comment |
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## Acronyms

**BEHI/NBS** – Bank erosion hazard index / near-bank stress
**BHR** – Bank height ratio
**BKF** – Bankfull
**CDPHE** – Colorado Department of Public Health and Environment
**CDPS** – Colorado Discharge Permit System
**CFR** – Code of Federal Register
**COMP** – Colorado Mitigation Procedures
**CS** – Cold stream
**CSQT** – Colorado Stream Quantification Tool (refers to both the CSQT workbook and Debit Calculator workbook)
**CSQT SC** – Colorado Stream Quantification Tool steering (advisory) committee
**Corps** – United States Army Corps of Engineers (also, USACE)
**CPW** – Colorado Parks and Wildlife
**CWA 404** – Section 404 of the Clean Water Act
**DO** – Dissolved oxygen
**EPA** – United States Environmental Protection Agency
**ER** – Entrenchment ratio
**FAM** – Flow alteration module
**FF** – Functional feet
**GSR** – Greenline stability rating
**HUC** – Hydrologic unit code
**IHA** – Indicators of hydrologic alteration
**LWD** – Large woody debris
**LWDI** – Large woody debris index
**MMI** – Multi-metric index
**MWAT** – Maximum weekly average temperature
**MWR** – Meander width ratio
**NLCD** – National Land Cover Database
**NRCS** – Natural Resource Conservation Service
**NRSA** – National Rivers and Streams Assessment (dataset)
**O/E** – Ratio of observed/expected
**Q** – Discharge, also stream flow or flow
**SEM** – Stream evolution model
**SET** – Stream evolution triangle
**SFPF** – Stream Function Pyramid Framework
**SGCN** – Species of greatest conservation need
**TMDL** – Total maximum daily load
**USACE** – United States Army Corps of Engineers (also, Corps)
**USDOI** – United States Department of Interior
**USEPA** – United States Environmental Protection Agency (also, EPA)
**USFWS** – United States Fish and Wildlife Service
**USGS** – United States Geologic Survey
**W/D** – Width-to-depth ratio
**WQCD** – Water Quality Control Division
**WS** – Warm stream
**WSQT** – Wyoming Stream Quantification Tool
**WSTT** – Wyoming Stream Technical Team

# Glossary of Terms

Alluvial valley – Refer to definitions for confined alluvial valley and unconfined alluvial valley.

Affected stream length – Pertaining to the flow alteration module (FAM), the length of stream defined at the upstream end where impacts or flow protection would initiate, and at the downstream end by the location of the next water rights user, tributary junction, or terminus beyond which the flow modification has no material effect on CSQT parameters.

Bankfull – 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).[1]

Bedrock valley – Valleys dominated by bedrock, typically exhibiting confined channels which lack an alluvial bed. Bedrock valleys are supply-limited; thus, sediment movements are primarily driven by the sediment load delivered to the reach via inflowing water. Two types of bedrock valleys have been classified: 1) steep bedrock valleys where transport capacity exceeds sediment supply, and 2) low-order streams dug to bedrock by debris flows (Montgomery and Buffington 1997).

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

Colluvial or V-shaped valleys – Valley formed by the deposition of sediment from hillslope erosion processes. Colluvial valleys are bowl-shaped and typically confined by terraces or hillslopes. Colluvium is material that originates on the hillslopes and moves through mass wasting processes to the valley bottom where the material interacts with stream flow. These valleys are confined and support straighter, step-pool type channels (e.g., A, B, Bc, F). These valley types typically have a valley width ratio less than 7.0 and a meander width ratio (MWR) ratio less than 3. V-shaped valleys are often found in steep gradient headwater valleys.

Confined alluvial valley – Valley formed by the deposition of sediment from fluvial processes, typically confined by terraces or hillslopes that supports transitional stream types between step-pool and meandering or where meanders intercept hillslopes (e.g., C, Bc). These valley types typically have a valley width ratio less than 7.0 and a meander width ratio (MWR) between 3 and 4.

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 (33 CFR 332.2).

[1] The CSQT does not require Natural Channel Design restoration approaches. Bankfull can also be referred to as the effective discharge, dominant discharge, or channel forming discharge.

Condition score – Metric-based index values are averaged to characterize condition for each parameter and functional category.

ECS = Existing Condition Score

PCS = Proposed Condition Score

CSQT workbook – The Microsoft-Excel workbook file used to evaluate change in condition at project reaches.

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

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

Debit Calculator workbook – The Microsoft-Excel workbook file used to evaluate loss at impact sites.

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

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

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

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

Functional feet (FF) – Functional feet is the primary unit for communicating functional lift and loss. The functional feet for a stream reach is calculated by multiplying an overall reach condition score by the stream reach length. The change in functional feet (ΔFF) is the difference between the Existing FF and the Proposed FF.

Functional lift – The difference in the condition or functional feet before and after restoration or a permitted impact, which results in improved function.

Functional loss – The difference in the condition or functional feet before and after restoration or a permitted impact, which results in a loss of function.

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).

Geomorphic pools – Large pools that remain intact over time and across a range of flow conditions and are associated with planform features. Examples include pools associated with the outside of a meander bend (streams in alluvial valleys) and downstream of a large cascade or step (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 standards. These values are derived from reference curves for each metric. Index values are calculated for each metric and then combined to create parameter and functional category scores.

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

Measurement method – A specific tool, equation, or assessment method used to inform a metric. Where a metric is informed by a single data collection method, metric and measurement method are used interchangeably (see Metric).

Metric – A specific tool, equation, measured values, or assessment method used to evaluate the condition of a structural measure or function-based parameter. Some metrics can be derived from multiple measurement methods. Where a metric is informed by a single data collection method, metric and measurement method are used interchangeably (see Measurement Method).

Micro-pools – Small pools, typically less than half the width of the channel that may be temporary or move following a large flow event. Micro-pools can be found in riffles and cascades. An example is a scour pool downstream of a single piece of large wood.

Multi-thread channel – A multi-thread channel consists of at least 3 primary flow paths that are active at baseflow for most of the reach length.

Native flow –Native flows are the estimates of the stream flows that would result from natural hydrologic processes such as rainfall-runoff and snowmelt-runoff without anthropogenic influence at a given location.

Performance standards – Observable or measurable physical (including hydrological), chemical and/or biological attributes that are used to determine if a compensatory mitigation project meets its objectives (33 CFR 332.2).

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

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, bed material composition, and level of anthropogenic influence. Multiple project reaches may exist in a project area where there are variations in stream physical characteristics and/or differences in project designs.

Process Drivers – Refers to high-level drivers of stream form and process: geology, hydrology, and biology (Castro and Thorne 2019).

Reference aquatic resources – A set of aquatic resources that represent the full range of variability exhibited by a regional class of aquatic resources as a result of natural processes and anthropogenic disturbances (33 CFR 332.2).

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

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

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

Response reach – A channel that is transport-limited, such that the sediment supply exceeds the competence of flows. Morphological adjustment occurs in response to increased sediment supply. (Montgomery and Buffington 1998)

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 commonly referred to as fast-water channel units (Hawkins et al. 1993; Montgomery and Buffington 1998). For purposes of the CSQT, 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.

Ripple – Ripples are small-scale bed forms in sand bed channels. As sand accumulates and the size of the ripple grows, it becomes a dune. Other sand-bed forms include plane beds and anti-dunes (Knighton 1998).

Riparian extent – The percentage of the historic or expected riparian area that currently contains riparian vegetation and is free from utility-related, urban, or otherwise soil disturbing land uses. The expected riparian area corresponds to (Merritt et al. 2017):

Substrate and topographic attributes -- the portion of the valley bottom influenced by fluvial processes under the current climatic regime,

Biotic attributes -- riparian vegetation characteristic of the region and plants known to be adapted to shallow water tables and fluvial disturbance, and

Hydrologic attributes -- the area of the valley bottom flooded at the stage of the 100-year recurrence interval flow.

Riparian vegetation – Plant communities contiguous to and affected by shallow water tables and fluvial disturbance.

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, and a concave profile.

Source reach – A channel that is transport-limited, where flows lack the competence to move larger grain sizes. Headwater, colluvial channels that are subject to intermittent debris flow scour. (Montgomery and Buffington 1998)

Stream Functions Pyramid Framework (SFPF) – The Stream Functions Pyramid is comprised of five functional categories stratified based on the premise that lower-level functions support higher-level functions and that they are all influenced by local geology and climate. The SFPF includes the organization of function-based parameters, metrics (measurement methods), and performance standards to assess the functional categories of the Stream Functions Pyramid. (Harman et al. 2012)

Stream restoration – The manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource (33 CFR 332.2). The term is used more broadly in this document to represent stream compensatory mitigation methods including establishment, re-habilitation, re-establishment, and enhancement as defined in the 2008 Compensatory Mitigation for Losses to Aquatic Resources; Final Rule (2008 Rule) (USACE 2008a).

Threshold values – Criteria used to develop the reference curves and index values for each metric. These criteria differentiate between three condition categories: functioning, functioning-at-risk, and not-functioning, and relate to the Performance Standards defined in Harman et al. (2012).

Transport reach – A channel that has sufficiently competent flows to move sediments through the reach. Transport reaches are morphologically resilient, supply-limited systems. (Montgomery and Buffington 1998)

Unconfined alluvial valleys – Wide, low gradient (typically less than 2% slope) valleys that support meandering and anastomosed stream types (e.g., 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).

Wyoming Stream Quantification Tool (WSQT) – The WSQT is the Stream Quantification Tool from Wyoming that has been adapted and modified for use in Colorado.

Wyoming Stream Technical Team (WSTT) – The group who worked on the development of the WSQT and associated documents.

# Purpose and Use of the CSQT

The purpose of the CSQT is to **calculate functional lift and loss associated with restoration and impact activities** within streams that fall within the scope of the Clean Water Act Section 404 (CWA 404) regulatory program. The tools are calculators to quantify change between an existing and future stream condition. The future stream condition can be a proposed or active stream restoration project or a proposed stream impact requiring a CWA 404 permit. The CSQT can also be applied to restoration projects outside of the CWA 404 regulatory context. A main goal of the CSQT is to produce **objective, verifiable, and repeatable results** by consolidating well-defined procedures for quantitative measures of structural or compositional attributes of a stream and its underlying processes.

On the restoration side, functional change can be estimated during the design or mitigation plan phase and verified during post-construction monitoring events in the CSQT workbook. The 2008 Compensatory Mitigation for Losses to Aquatic Resources; Final Rule (2008 Rule; USACE 2008a) defines restoration as the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource (33 CFR 332.2). The term is used more broadly in this document to represent compensatory mitigation methods including establishment, re-habilitation, re-establishment, and enhancement as defined in the 2008 Rule (USACE 2008a).

On the impact side, the CSQT workbook can be used to evaluate change in condition within the project reach or functional loss can be estimated several ways using the Debit Calculator workbook (Section 1.2.8).

Not all portions of the CSQT workbook or Debit Calculator workbook will be applicable to all projects. Figure 1 can assist in navigating the user manual for specific project types.

The CSQT workbook can also help determine if a proposed site has the potential to be considered for a stream restoration or mitigation project and provides a framework to guide restoration planning. The process drivers, catchment assessment, and restoration potential process accompanying the CSQT (described in Chapter 3) can be used to help determine factors that may limit what can be achieved by a stream restoration or mitigation project. This information can be used to develop project goals that match the restoration potential of a site. Quantifiable objectives, performance standards, and monitoring plans can be developed that link restoration activities to measurable changes in functional category condition and function-based parameters assessed by the tool.

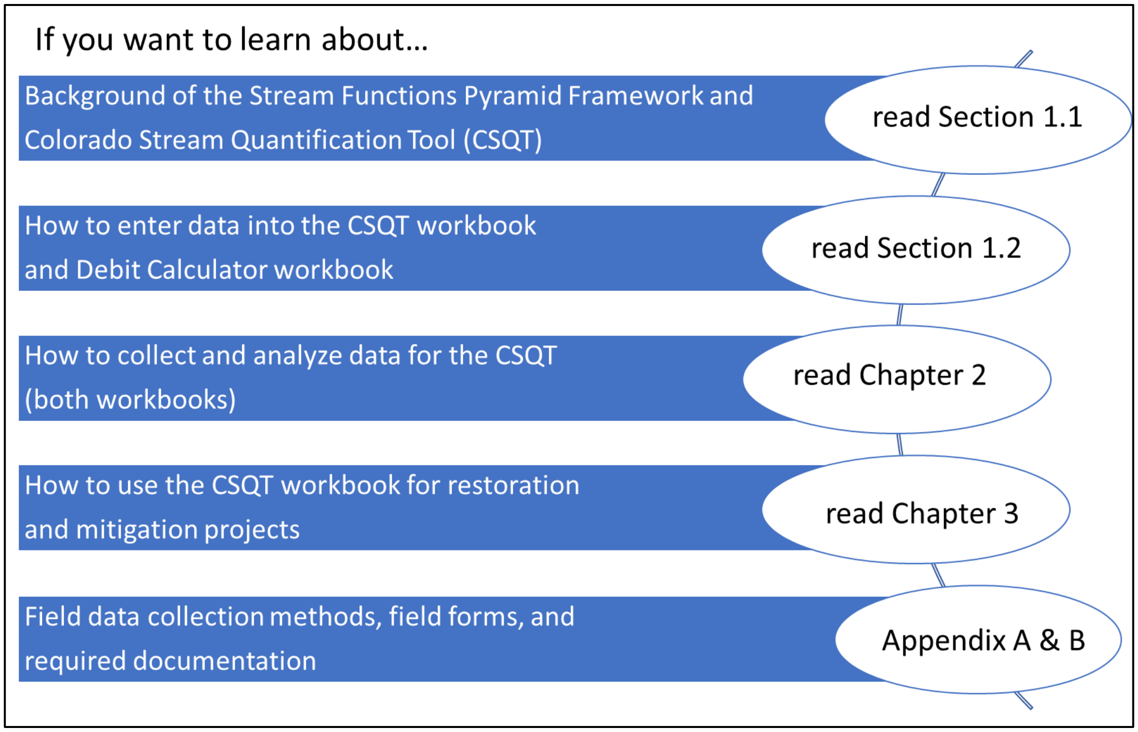



***Figure 1: Manual Directory***

### *Key Considerations*

The CSQT and supporting documentation have been developed primarily for use in the CWA 404 program to meet the function-based approaches set forth in the 2008 Rule (USACE 2008a). Therefore, the following concepts are critical in understanding the applicability and limitations of this tool:

- The parameters and metrics in the tool were, in part, selected due to their sensitivity in responding to reach-scale changes associated with the types of activities commonly encountered in the CWA 404 program and commonly used in stream restoration. These parameters do not comprehensively characterize all structural measures or processes that occur within a stream.
- The CSQT is designed to assess the same metrics at a site pre- and post-activity to provide information on the degree to which the condition of the stream system changes following impacts or restoration activities. Unless the same parameters and metrics are used across all sites, it would not be appropriate to compare scores across sites.
- The CSQT itself does not score or quantify watershed condition. Watershed condition reflects the external elements that influence functions within a project reach and may affect project site selection or the restoration potential of a site (see Chapter 3).
- The CSQT is not a design tool. There may be more appropriate function-based parameters and analyses which are critical to a successful restoration design, but sit outside of the scope of the CSQT. The CSQT instead measures the hydraulic, geomorphological and ecological responses or outcomes related to a reach-scale project.

# Chapter 1. Background and Introduction

The Colorado Stream Quantification Tool (CSQT) consists of two spreadsheet-based calculators designed to inform permitting and compensatory mitigation decisions within the CWA 404. The CSQT and Debit Calculator Excel Workbooks have been developed to evaluate a suite of metrics that represent structural or compositional attributes of a stream and its underlying processes. Metrics in the CSQT represent parameters that are often impacted by authorized projects or affected (e.g. enhanced or restored) by mitigation actions undertaken by restoration providers. As such, **the CSQT is not a comprehensive assessment of stream function**. The CSQT is an application of the Stream Functions Pyramid Framework (SFPF; Harman et al. 2012) and uses function-based parameters and metrics to assess four functional categories: reach hydrology and hydraulics, geomorphology, physicochemical, and biology.

The CSQT includes 29 metrics within 12 parameters that can be evaluated at a project site. A basic suite of metrics within 5 parameters are required at all project sites evaluated for CWA 404 purposes to provide consistency between impacts and compensatory mitigation and to allow for more consistent accounting of functional change. Application of the basic suite of metrics is considered rapid, as field data can be collected by a team of 2 in less than a day. Users can include additional parameters and metrics on a project-specific basis (see Section 2.3 on Parameter Selection). The User Manual provides methods for collecting and processing data related to each parameter. Teams collecting and analyzing these data should have experience and expertise in botany, aquatic ecology, hydrology, and geomorphology as well as experience and expertise applying the assessment methods used to calculate the metrics included in the SQT. **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**.

This manual describes the CSQT workbook and Debit Calculator workbook, how to collect and analyze data, and how to input data into these workbooks. Companion documents include the Colorado Mitigation Procedures (COMP; USACE 2020), which provides direction for how and when the CSQT workbooks can be applied in the CWA 404 regulatory program in Colorado; and the Scientific Support for the CSQT, which provides rationale for scoring in the CSQT and describes how measured stream conditions were converted into dimensionless index scores (CSQT SC 2020). Debit and credit determination methods are not included in this manual but are outlined in the COMP. Users are strongly encouraged to contact the Corps to obtain project-specific direction.

The CSQT has been modified from the Wyoming Stream Quantification Tool Version 1.0 (WSQT v1.0; USACE 2018a) and regionalized for use in Colorado. Many of the parameters, metrics, and reference curves within the CSQT are the same as those in the WSQT v1.0 (USACE 2018a). Other stream quantification tools and user manuals have been developed for use in other states, including North Carolina (Harman and Jones 2017a,b), Tennessee (TDEC 2018), Georgia (USACE 2018b), and Minnesota (MNSQT SC 2019).

## 1.1 Stream Functions Pyramid Framework (SFPF)

The CSQT is an application of the Stream Functions Pyramid Framework (SFPF). The Stream Functions Pyramid (Figure 2), includes five functional categories: Level 1: Hydrology, Level 2: Hydraulics, Level 3: Geomorphology, Level 4: Physicochemical, and Level 5: Biology.[2] The organization of the Stream Functions Pyramid asserts that lower-level functions generally support higher-level functions (although the opposite can also be true) and that all functions are influenced by local geology and climate. Each functional category is defined by a functional statement as shown in Figure 2.

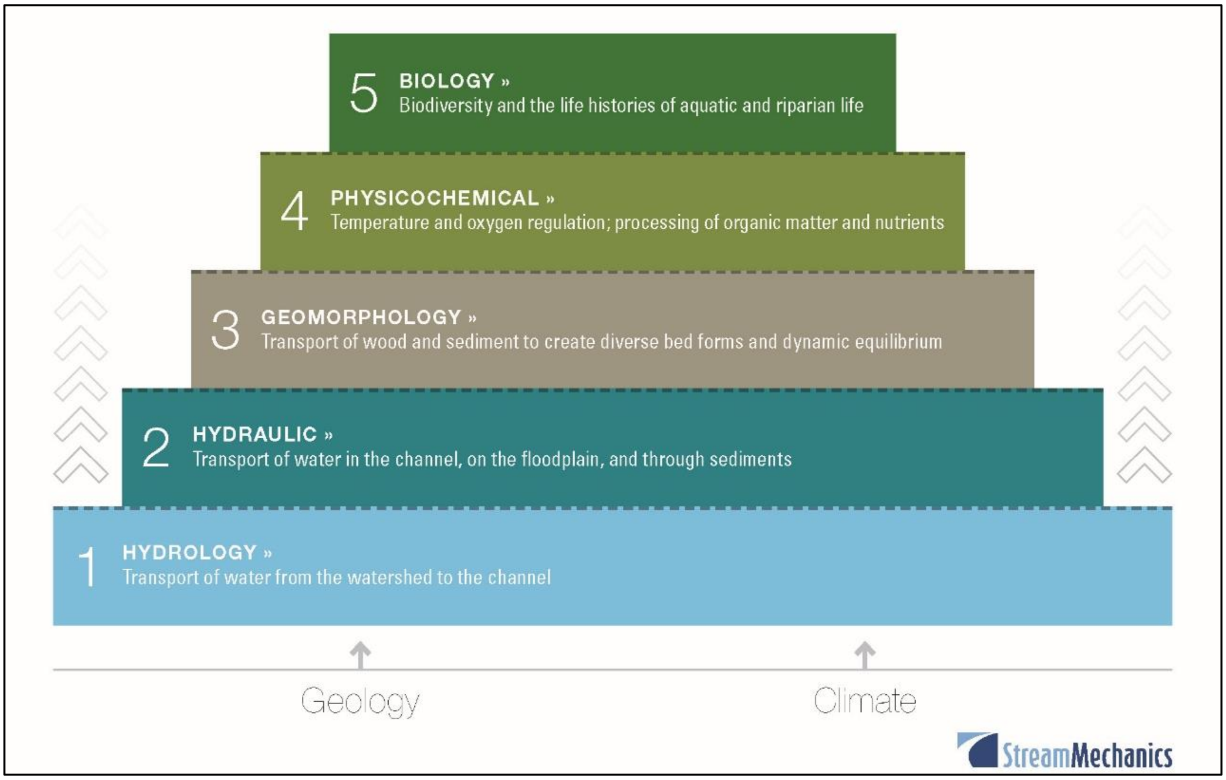



*Figure 2: Stream Functions Pyramid (Image from Harman et al. 2012)*

The SFPF illustrates a hierarchy of stream functions but does not provide specific mechanisms for addressing functional capacity, establishing performance standards, or communicating functional change. The diagram in Figure 3 expands the Pyramid concept into a more detailed framework to quantify functional capacity, establish performance standards, evaluate functional change, and establish function-based goals and objectives.

[2] The CSQT merges the original Hydrology and Hydraulics categories into a new combined category (referred to as the Reach Hydrology and Hydraulics Category).

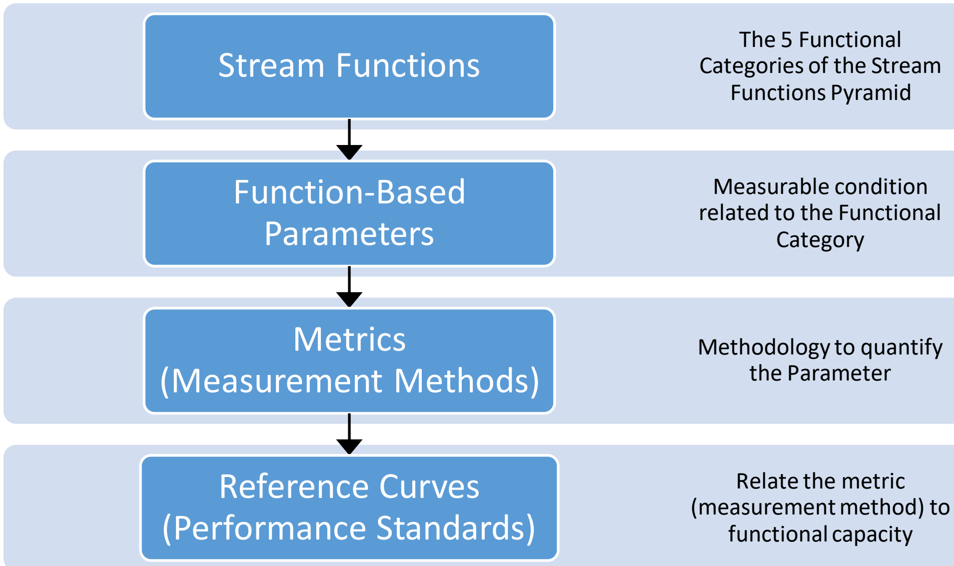



***Figure 3: Stream Functions Pyramid Framework***

The SFPF details forms of analysis to quantify stream functions and functional indicators of underlying stream processes. In this framework, function-based parameters describe and support the functional statements of each category, and metrics (measurement methods) are specific tools, equations, and/or assessment methods used to characterize site condition and inform function-based parameter scores. Performance standards are measurable or observable end points of stream restoration.

## 1.2 Colorado Stream Quantification Tool and Debit Calculator (CSQT)

A main goal of the CSQT is to produce objective, verifiable, and repeatable results by consolidating well-defined procedures for quantitative measures of structural or compositional attributes of a stream and its underlying processes.

The CSQT workbook (CSQT_v1.0.xlsx) is a Microsoft Excel Workbook comprised of 8 worksheets. This workbook can be used to calculate functional change and track monitoring events within project reaches (credits or debits). There are no macros in the workbook and all formulas are visible, though some worksheets are locked to prevent editing. One workbook should be assigned to each project reach within a project area. Each of the following worksheets is described in this Section.

The CSQT worksheets include:

- Project Assessment
- Catchment Assessment
- Quantification Tool (locked)
- Flow Alteration Module (locked)

- Monitoring Data (locked)
- Data Summary (locked)
- Reference Curves (locked)
- Pull Down Notes – This worksheet is hidden and contains all the inputs for drop down menus throughout the workbook.

The Debit Calculator workbook (CSQT Debit Calculator_v1.0.xlsx) is a Microsoft Excel Workbook comprised of 6 worksheets. This workbook provides a simplified approach to calculate functional loss in a project reach (debits). There are no macros in the workbook and all formulas are visible, though some worksheets are locked to prevent editing. One workbook should be assigned to each project reach within a project area. Each of the following worksheets is described in this Section.

The Debit Calculator worksheets include:

- Project Assessment
- Quantification Tool (locked)
- Debit Tool (locked)
- Flow Alteration Module (locked)
- Reference Curves (locked)
- Pull Down Notes – This worksheet is hidden and contains all the inputs for drop down menus throughout the workbook.

The CSQT includes selected function-based parameters and metrics to quantify stream condition across the ecoregions and stream types found in the western U.S. Each metric is linked to reference curves that relate measured field values to a regional reference condition. In the CSQT, field values for a metric are assigned an index value (0.00 – 1.00) using the applicable reference curves. The numeric index value range is standardized across metrics by determining how field values relate to functional capacity, i.e., functioning, functioning-at-risk, and not-functioning conditions (Table 1). The reference curves in the CSQT are tied to specific benchmarks (thresholds) that represent the degree to which the aquatic resources are functioning and/or the degree to which condition departs from reference standard.[3]

[3] Additional detail on function-based parameters and metrics, along with specific information on stratification and reference curve development is provided in the Scientific Support for the CSQT (CSQT SC 2020).

*Table 1: Functional Capacity Definitions Used to Define Threshold Values and Develop Reference Curves for the CSQT*

| Functional Capacity | Definition | Index Score Range |
|---|---|---|
| Functioning | A functioning value means that the metric is quantifying the functional capacity of one aspect of a function-based parameter in a way that **fully supports aquatic ecosystem structure and function**. A score of 1.00 represents an un-altered or pristine condition (native or natural condition). The range of values (0.70-1.00) accounts for natural variability in reference datasets and the potential for reference datasets to include least disturbed sites. | 0.70 to 1.00 |
| Functioning-at-risk | A functioning-at-risk value means that the metric is quantifying one aspect of a function-based parameter in a way that **may support aquatic ecosystem structure and function**, but not at a reference standard. In many cases, this indicates the parameter is adjusting in response to changes in the reach or the catchment towards lower or higher function. | 0.30 to 0.69 |
| Not-functioning | A not-functioning value means that the metric is quantifying or describing one aspect of a function-based parameter in a way that **does not support aquatic ecosystem structure and function**. An index value less than 0.29 represents an impaired or severely altered condition relative to reference standard, and an index value of 0.00 represents a condition that provides no functional capacity for that metric. | 0.00 to 0.29 |

### 1.2.1 Project Assessment Worksheet

The Project Assessment worksheet allows for a description of the project reach, the purpose of the project, and other information. This worksheet is included in both the CSQT workbook and Debit Calculator workbook, but contains different components, as described below.

For projects with multiple reaches (and thus multiple workbooks), the project information on this worksheet may be the same across workbooks except for a unique reach-specific description. Information on delineating project reaches is provided in Chapter 2.

***Components of the Project Assessment Worksheet***

To complete the Project Assessment worksheet, users will need to complete the following components for each project reach.

Programmatic Goals (CSQT workbook only) – Programmatic goals represent big-picture goals that are often broader than function-based goals and are determined by the project proponent or funding entity. A drop-down menu is provided with the following options: Mitigation – Credits, Voluntary Restoration, Enhancements, or Other.

Reach Description (CSQT workbook and Debit Calculator) – In the CSQT workbook, space is provided to describe the project reach, including the individual reach ID, location (latitude/longitude), process drivers information, and reference stream type (includes type, bed material and existing/proposed sinuosity). Process-drivers information, reference reach, and bed material are all drop-down selections. **Refer to Sections 2.1 and 2.2 for more information on how to determine these inputs.**

In the Debit Calculator workbook, space is provided to describe the project reaches, including the individual reach ID, location, proposed impacts, and whether the project reach occurs within an Outstanding Water segment of stream.[4] Note that the Debit Calculator workbook allows up to 10 project reaches to be entered in the same workbook.

Aerial Photograph of Project Reach (CSQT workbook and Debit Calculator) – Provide a current aerial photograph of the project reach. The photo could include labels indicating where work is proposed, the project area boundaries or easement, and any important features within the project site.

Restoration Approach (CSQT workbook only) – In Box 1, the user should explain programmatic goals, discuss restoration potential, and define project goals and objectives (see Example 1).

The restoration potential can be classified as partial or full restoration, refer to Section 3.2.

Box 2 should be used to explain the connection between the restoration potential and the programmatic goals.

Finally, Box 3 should be used to describe the function-based goals and objectives of the project.

More information on restoration potential and developing goals and objectives is provided in Chapter 3.

***Example 1: Restoration Approach***

If the programmatic goal is to create mitigation credits, then the first text box could provide more information about the type and number of credits desired.

If the restoration potential is partial restoration, then the second text box would explain how improvements to reach hydrology and hydraulics, and/or geomorphology would create the necessary credits and identify whether there are constraints that may limit restoration of physicochemical and biological functions to a reference standard.

The goals of the project would match the restoration potential, e.g., target reference standard habitat condition and partial restoration of biological condition. Accompanying objectives could identify parameters to be restored and which metrics will be used to monitor restoration progress.

### 1.2.2 Catchment Assessment Worksheet

This worksheet is included in the CSQT workbook, but not the Debit Calculator workbook. The Catchment Assessment worksheet assists in characterizing watershed processes and stressors that exist outside of the project reach but affect functions and processes within the reach. It also highlights factors necessary to consider or address during the project design to maximize the likelihood of a successful project. Space is provided on the form to list the applicable reach(es) within the project area. This is for project areas with multiple reaches, but the same, or similar, catchment. For a project reach where the Catchment Assessment has been completed in a separate Excel workbook, provide the file name for the completed form.

[4] Outstanding Waters relies on the CDPHE designation; maps can be found on the CDPHE website or the CNHP Watershed Planning Toolbox https://cnhp.colostate.edu/cwic/tools/toolbox/

This worksheet contains 12 categories to be rated as Good, Fair, or Poor. Most of the categories describe potential stressors upstream of the project reach since the contributing catchment influences the hydrology, water quality, and biological condition within the project reach. However, there are a few categories, such as impoundments, that consider influences both upstream and downstream of the project reach. Based on the category ratings, the user should provide an overall watershed condition and describe how any of the categories rated as poor were considered in the selection of restoration potential. Details on rating the 12 categories is provided in Section 2.3.

### 1.2.3 Quantification Tool, Existing Conditions, and Proposed Conditions Worksheets

This worksheet is included in the CSQT workbook. The Debit Calculator workbook includes separate worksheets for entering existing and proposed condition information for multiple reaches, called the Existing Condition and Proposed Condition worksheets, respectively. These worksheets calculate the change in functional feet based on data entry describing the existing and proposed length of the project reach.

- The Quantification Tool worksheet contains three areas for data entry: Site Information and Reference Selection, Existing Condition Assessment field values, and Proposed Condition Assessment field values.
- The Existing Condition and Proposed Condition worksheets contain two areas for data entry: Site Information and Reference Selection, and Condition Assessment field values. These worksheets have space to enter data for up to ten project reaches.

Cells that allow input are shaded gray and all other cells are locked. Each section of the worksheet is discussed below.

#### *Site Information and Reference Selection*

The Site Information and Reference Selection section consists of general site information and classifications to determine which reference curve(s) to apply in calculating index values for relevant metrics (Figure 4). Information on each input field and guidance on how to select values are provided in Section 2.4. In the CSQT workbook, information entered on the Project Assessment worksheet (e.g., valley type, sediment regime and reference stream type) will auto-populate in the table.

**Note that incorrect information in the Site Information and Reference Selection section may result in applying reference curves that are not suitable for the project.**

| Site Information and Reference Selection | |
|---|---|
| Project Name: | Half Moon Creek |
| Reach ID: | Example |
| Restoration Potential: | Partial |
| Project Reach Stream Length - Existing (ft): | 523 |
| Project Reach Stream Length - Proposed (ft): | 523 |
| Drainage Area (sq.mi.): | 23.4 |
| Flow Permanence: | Perennial |
| Strahler Stream Order: | Fourth |
| Ecoregion: | Mountains |
| Biotype: | 2 |
| Proposed Bankfull Width (ft): | 25 |
| Stream Slope (%): | 0.6 |
| River Basin: | Arkansas |
| Stream Temperature: | |
| Reference Vegetation Cover: | Woody |
| Stream Productivity Class: | |
| Valley Type: | Confined Alluvial |
| Reference Stream Type: | C |
| Sediment Regime: | Transport |

***Figure 4: Half Moon Creek Example Site Information and Reference Selection Input Fields***

## *Existing and Proposed Condition Assessment Data Entry*

Once the Site Information and Reference Selection section has been completed, the user can input data into the field value column of the Condition Assessment tables (Figure 5). Note, in the Debit Calculator workbook, these tables are contained in two separate worksheets: Existing Condition and Proposed Condition worksheets, which include space to enter data for up to ten project reaches.

A user will rarely input data for all metrics or parameters within the tool. Guidance on parameter selection is provided in Section 2.5. The function-based parameters and metrics are listed by functional category, starting with Reach Hydrology and Hydraulics. Multiple tables in the CSQT are color-coded to show the delineation between functional categories: blue for reach hydrology and hydraulics, orange for geomorphology, yellow for physicochemical, and green for biology.

| Function-Based Parameter | Metric | Field Value |
|---|---|---|
| Reach Runoff | Land Use Coefficient | 60 |
| | Concentrated Flow Points (#/1000 LF) | 0 |
| Baseflow Dynamics | Average Velocity | |
| | Average Depth (ft) | |
| Floodplain Connectivity | Bank Height Ratio | 1 |
| | Entrenchment Ratio | 3.5 |
| | Percent Side Channels (%) | |
| Large Woody Debris | LWD Index | |
| | No. of LWD Pieces/ 100 meters | 13 |
| Lateral Migration | Greenline Stability Rating | |
| | Dominant BEHI/NBS | L/M |
| | Percent Streambank Erosion (%) | 10 |
| | Percent Armoring (%) | |
| Bed Form Diversity | Pool Spacing Ratio | 3.9 |
| | Pool Depth Ratio | 2 |
| | Percent Riffle (%) | 56 |
| | Aggradation Ratio | 2.1 |
| Riparian Vegetation | Riparian Extent (%) | 100 |
| | Woody Vegetation Cover (%) | 50 |
| | Herbaceous Vegetation Cover (%) | |
| | Percent Native Cover (%) | 70 |
| Temperature | Daily Maximum Temperature ($^{o}$C) | |
| | MWAT ($^{o}$C) | |
| Dissolved Oxygen | Dissolved Oxygen Concentration (mg/L) | |
| Nutrients | Chlorophyll a (mg/m2) | 30 |
| Macroinvertebrates | CO MMI | 45 |
| Fish | Native Fish Species Richness (% of Expected) | |
| | SGCN Absent Score | |
| | Wild Trout Biomass (% Change) | |

***Figure 5: Half Moon Creek Example Field Value Data Entry in the Condition Assessment Table***

The Existing Condition Assessment field values are derived from data collection and analysis methods outlined in Chapter 2. Recommended worksheets for documenting metric field values are provided in Appendix B. An existing condition score (ECS) relies on baseline data collected from the project reach before any work is completed. For some metrics, methods include both rapid and more detailed forms of data collection; field values can be calculated using data from either rapid or more detailed methods. Refer to Chapter 3 and coordinate with the Corps to determine if/when rapid data collection methods are acceptable for stream restoration projects.

Rapid field data collection alternatives are acceptable to assess the existing condition at impact sites in the Debit Calculator.

The Proposed Condition Assessment field values should consist of reasonable values for restored and impacted conditions. For the Proposed Condition Assessment, the user should rely on available data to estimate proposed condition field values. Proposed field values that describe the physical post-project condition of the stream reach should be based on project design studies and calculations, drawings, field investigations, and best available science. Proposed condition field values should be appropriate for the setting, stream type, and watershed conditions within the project area; consistent with the process drivers and restoration potential of the site; and representative of the site conditions likely to occur at the end of an established monitoring period. Refer to relevant metric sections in Chapter 2 for additional information.

The same parameters and metrics must be used for the existing and proposed condition assessments. Therefore, field values for the proposed post-project condition must be determined for all metrics used to assess the existing stream reach. Note that field value here refers to where data are entered into the worksheet and not the actual collection of field data to yield a field value.

### Scoring Functional Lift and Loss

Scoring occurs automatically as field values are entered into the Existing Condition Assessment or Proposed Condition Assessment tables. A field value will correspond to an index value ranging from 0.00 to 1.00 for that metric. Where more than one metric is used per parameter, these index values are averaged to calculate parameter scores. Similarly, multiple parameter scores within a functional category are averaged to calculate functional category scores. Functional category scores are weighted and summed to calculate functional change.

Index Values – The reference curves available for each metric are visible in the Reference Curves worksheet. When a field value is entered for a metric on the Quantification Tool worksheet, these reference curves are used to calculate an index value.

As a field value is entered in the Quantification Tool worksheet, the neighboring index value cell should automatically populate with an index value (Example 2a). If the index value cell returns FALSE instead of a numeric index value, the Site Information and Reference

**Example 2: Populating Index Values in CSQT**

*(a) Index values automatically populate when field values are entered.*

| Metric | Field Value | Index Value |
|---|---|---|
| Pool Spacing Ratio | 5 | 1.00 |
| Pool Depth Ratio | | |
| Percent Riffle (%) | 60 | 1.00 |
| Aggradation Ratio | | |

*(b) If FALSE, check the Site Information and Reference Selection section of the worksheet.*

| Metric | Field Value | Index Value |
|---|---|---|
| Pool Spacing Ratio | 5 | FALSE |
| Pool Depth Ratio | | |
| Percent Riffle (%) | 60 | FALSE |
| Aggradation Ratio | | |

Selection section may be missing data (Example 2b).

If the worksheet does not return a numeric index value, the user should check the Site Information and Reference Selection for data entry errors and then check the stratification for the metric in the Reference Curve worksheet. Note that incorrect information in the Site Information and Reference Selection section may result in applying reference curves that are not suitable for the project.

Scoring – In the CSQT, scores are averaged within each functional category. Metric index values are averaged to calculate parameter scores and parameter scores are averaged to calculate category scores (Figure 6). There are two exceptions to this scoring in the CSQT: baseflow dynamics and lateral migration.

- There are two metrics for baseflow dynamics, but one metric (average velocity) does not yield an index value. Instead, where baseflow velocity is less than 1 foot per second, the parameter will score a 0.00.
- There are four metrics for lateral migration, including a metric that reflects the amount of artificial bank hardening present (percent armoring; refer to Section 2.5 for direction on metric selection). Where percent armoring exceeds 50% of the total bank length, the parameter as a whole will score a 0.00 regardless of any other metric field values entered.

Category scores are weighted and summed to calculate overall scores, although the overall score is not displayed on the Quantification Tool worksheet. Score weighting by category is shown in Table 2. Because category scores are additive, a maximum overall score of 1.00 is only possible when parameters within all four categories are evaluated. For example, if only Reach Hydrology & Hydraulics and Geomorphology parameters are evaluated, the maximum overall score will be 0.60. Additional discussion of and rationale for scoring is provided in the Scientific Support for the CSQT (CSQT SC 2020).

***Table 2: Functional Category Weights***

| Functional Category | Weight |
|---|---|
| Reach Hydrology and Hydraulics | 0.30 |
| Geomorphology | 0.30 |
| Physicochemical | 0.20 |
| Biology | 0.20 |

| Functional Category | Function-Based Parameter | Parameter | Category | Category |
|---|---|---|---|---|
| Reach Hydrology & Hydraulics | Reach Runoff | 0.89 | 0.92 | Functioning |
| | Baseflow Dynamics | | | |
| | Floodplain Connectivity | 0.94 | | |
| Geomorphology | Large Woody Debris | 0.70 | 0.70 | Functioning |
| | Lateral Migration | 0.85 | | |
| | Bed Form Diversity | 0.62 | | |
| | Riparian Vegetation | 0.63 | | |
| Physicochemical | Temperature | | 0.59 | Functioning At Risk |
| | Dissolved Oxygen | | | |
| | Nutrients | 0.59 | | |
| Biology | Macroinvertebrates | 0.54 | 0.54 | Functioning At Risk |
| | Fish | | | |

*Figure 6: Half Moon Creek Scoring Example*

Calculating Functional Feet – Change at an impact or mitigation site is the difference between the existing (pre-project) and proposed (post-project) scores. Existing condition scores (ECS) and proposed condition scores (PCS) are multiplied by existing and proposed stream length, respectively, to calculate the change in functional feet (ΔFF).

The Quantification Tool worksheet calculates change in functional feet (FF) as follows:

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

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

$$\text{Change in FF } (\Delta FF) = Proposed\ FF - Existing\ FF$$

Functional lift is generated when the proposed function feet value is greater than the existing functional feet value and the third equation above yields a positive value. A negative value would represent a functional loss.

ΔFF values are displayed in the Quantification Tool worksheet for the reach as a whole and for each functional category. In the Debit Calculator workbook, this information is displayed on the Debit Calculator worksheet (Section 1.2.8).

> The Quantification Tool worksheet does not provide overall reach scores since these scores are additive across functional categories and thus do not total 1.0 unless all functional categories are evaluated. If the overall score only considers reach hydrology and hydraulics and geomorphology, the maximum possible overall score would be 0.60, and would not reflect the functional capacity definitions used in Table 1. The overall scores for the reach are calculated on the Data Summary worksheet (refer to Section 1.2.5) and these scores are used for multiple calculations in the functional lift and loss summary tables.

Color-Coded Scoring – When index values are populated in the Quantification Tool worksheet, cells will automatically change color to identify where on the reference curve the field value lies (Figure 6). Green coloring indicates field values and index scores that represent a functioning (reference standard) range of condition; yellow indicates field values and index scores that represent a functioning-at-risk range of condition; and red indicates field values and index scores that represent a not-functioning range of condition (see Table 1 for definitions). This color-coding is provided as a communication tool to illustrate the relative condition of the various metrics and parameters assessed. This is particularly useful when comparing existing to proposed condition, as well as reviewing the summary tables and monitoring data included in the CSQT workbook (both are described below).

### *Functional Lift and Loss Summary Tables*

The Quantification Tool worksheet summarizes the scoring at the top of the worksheet, next to and under the Site Information and Reference Selection section. There are four summary tables: Functional Change Summary, Mitigation Summary, Functional Category Report Card, and Function-Based Parameters Summary.

Functional Change Summary – This summary (Figure 7) provides the change in overall condition based on information entered in the Existing Condition Assessment and Proposed Condition Assessment sections, and incorporates the length of the project to calculate the existing and proposed FF change in functional feet (ΔFF).

The change in overall condition is the difference between the reach ECS and PCS as calculated using the weights in Table 2. The summary includes the existing and proposed stream lengths to calculate and communicate functional feet (FF). Since the condition score is 1.00 or less, the functional feet of a stream reach are always less than or equal to the actual stream length.

The ΔFF is the amount of functional lift or loss resulting from the project. Yield is also calculated in this table as ΔFF divided by the proposed length of the project reach.

This summary table also includes the ΔFF calculated in the Flow Alteration Module and adds that value to the ΔFF for the project reach to generate the total ΔFF calculated in the CSQT. The Flow Alteration Module is described in the Section 1.2.6.

| FUNCTIONAL CHANGE SUMMARY | |
|---|---|
| Change in Overall Condition | 0.24 |
| Existing Stream Length (ft) | 523 |
| Proposed Stream Length (ft) | 523 |
| Change in Stream Length (ft) | 0 |
| Existing Functional Feet (FF) | 149.1 |
| Proposed Functional Feet (FF) | 276.1 |
| Proposed FF - Existing FF (ΔFF) | 127.1 |
| Yield (ΔFF/ Proposed LF) | 0.24 |
| ΔFF from Flow Alteration Module | 2098.09 |
| Total Proposed FF - Existing FF (ΔFF) | 2225.2 |

***Figure 7: Example Functional Change Summary Table***

<u>Mitigation Summary</u> –This summary table (Figure 8) reports the change in functional feet (ΔFF) that results from the reach-scale restoration activities and the Flow Alteration Module. If this value is a positive number, then functional lift is occurring at the project site. A negative number represents a functional loss. The flow permanence (perennial, intermittent, or ephemeral) and the Strahler stream order (Strahler 1957) provide context for the ΔFF value generated.

| MITIGATION SUMMARY | |
|---|---|
| Perennial Fourth Order Stream | |
| 2225.2 | (FF) Lift |

***Figure 8: Example Mitigation Summary Table***

For projects that include multiple reaches, the results from the Mitigation Summary for each reach can be summed to calculate the total change in functional feet for an entire project. Note that the Flow Alteration Module covers an affected stream length that is separate from the project reach length (Section 2.11). Where multiple project reaches are covered by the affected stream length of the Flow Alteration Module, the user would only enter data into the Flow Alteration Module of one workbook.

Functional Category Report Card – This summary presents a side-by-side comparison of the functional category scores based on the ECS and PCS from the Condition Assessment sections of the worksheet (Figure 9). This table provides a general overview of the functional changes pre- and post-project to illustrate where the change in condition and ΔFF are anticipated.

| FUNCTIONAL CATEGORY REPORT CARD | | | | |
|---|---|---|---|---|
| Functional Category | ECS | PCS | Change in Condition Scores | ΔFF |
| Reach Hydrology & Hydraulics | 0.47 | 1.00 | 0.53 | 219.0 |
| Geomorphology | 0.69 | 0.86 | 0.17 | 102.6 |
| Physicochemical | 0.41 | 0.44 | 0.03 | 23.6 |
| Biology | 0.32 | 0.36 | 0.04 | 22.4 |

*Figure 9: Example Functional Category Report Card*

Function-based Parameters Summary – This summary provides a side-by-side comparison for individual parameter scores (Figure 10). Values are pulled from the Condition Assessment sections of the worksheet. This table can be used to better understand how the category scores are determined and serves as a quality control check to see if a parameter was assessed for both the existing and proposed condition assessments. For example, the parameter summary table illustrates that all parameters within the geomorphology functional category were assessed in the existing and proposed condition assessments.

| FUNCTION BASED PARAMETERS SUMMARY | | | |
|---|---|---|---|
| Functional Category | Function-Based Parameters | Existing Parameter | Proposed Parameter |
| Reach Hydrology & Hydraulics | Reach Runoff | 0.87 | 1.00 |
| | Baseflow Dynamics | | |
| | Floodplain Connectivity | 0.90 | 1.00 |
| Geomorphology | Large Woody Debris | 0.41 | 0.65 |
| | Lateral Migration | 0.85 | 0.90 |
| | Bed Form Diversity | 0.75 | 0.88 |
| | Riparian Vegetation | 0.52 | 0.80 |
| Physicochemical | Temperature | 1.00 | 1.00 |
| | Dissolved Oxygen | 0.23 | 0.35 |
| | Nutrients | 0.35 | 0.35 |
| Biology | Macroinvertebrates | 0.51 | 0.59 |
| | Fish | 0.12 | 0.12 |

*Figure 10: Example Function-Based Parameters Summary Table*

### 1.2.4 Monitoring Data Worksheet

This worksheet is included in the CSQT workbook, but not the Debit Calculator workbook. The Monitoring Data worksheet contains 11 condition assessment tables identical to the Existing and Proposed Condition Assessment sections in the Quantification Tool worksheet. The first table on the Monitoring Data worksheet is identified as the As-Built condition followed by 10 condition assessment tables for monitoring. The user can enter the monitoring date and year at the top of each condition assessment table, e.g., 1 for the first growing season post-project. The methods for calculating index values and scoring are identical to the Quantification Tool worksheet (Section 1.2.3). The Monitoring Data worksheet does not include space to enter monitoring data for the Flow Alteration Module; space is provided in the Flow Alteration Module worksheet to enter the data.

In order to calculate functional change, the same metrics must be used in each condition assessment. In other words, if a value is entered for a metric in the Existing Condition Assessment, a field value must also be entered for the As-Built Condition and for monitoring events in the Monitoring Data worksheet. Monitoring schedule considerations for mitigation projects are described in Section 3.4.

### 1.2.5 Data Summary Worksheet

This worksheet is included in the CSQT workbook, but not the Debit Calculator. This worksheet provides a summary of project data from the existing condition, proposed condition, as-built condition, and monitoring assessments, as pulled from the Quantification Tool and Monitoring Data worksheets. The Data Summary worksheet features a function-based parameter summary, a functional category report card, and four plots showing this information graphically. *This worksheet is included for information purposes and does not require any data entry.*

### 1.2.6 Flow Alteration Module Worksheet

This worksheet is included in the CSQT workbook and Debit Calculator workbook. The module and metrics are provisional, and use will be at the discretion of the Corps. The Flow Alteration Module worksheet is a supplementary calculator where users enter data describing the existing and proposed hydrologic conditions for an affected stream length. The Flow Alteration Module worksheet contains three areas: Site Information, Condition Assessments, and the Functional Change Summary. Cells that allow input are shaded gray and all other cells are locked. Each section of the worksheet is discussed below.

<u>Site Information</u> – The Site Information section consists of general site information and the affected stream length. Guidance on how to determine the affected stream length is provided in Section 2.11.

<u>Condition Assessment Data Entry</u> – Once the Site Information section has been completed, the user can input data into the field value columns of the Existing, Proposed, or monitoring Condition Assessment tables. There is space to enter data for up to 10 monitoring events in the Flow Alteration Module worksheet. Data entry for monitoring events must follow the criteria described in Section 1.2.4. Monitoring years must be entered on this sheet and may not align with monitoring events in the project reach; monitoring schedule considerations for mitigation projects are described in Section 3.4.

The user will input field values for the applicable metrics within the module (Figure 11). Guidance on metric selection and calculation is provided in Section 2.11. Every metric is a ratio of Observed/Expected (O/E).

| Metric | Field Value | Index Value | Module |
|---|---|---|---|
| Mean Annual Q (O/E) | 0.52 | 0.58 | 0.70 |
| Mean Aug Q (O/E) | 0.65 | 0.72 | |
| Mean Sept Q (O/E) | 0.88 | 0.98 | |
| Mean Jan Q (O/E) | 0.71 | 0.79 | |
| Mean Annual Peak Daily Q (O/E) | 0.56 | 0.62 | |
| 7-Day Minimum (O/E) | 0.48 | 0.53 | |

Figure 11: Example Flow Alteration Module Condition Assessment

### Scoring Functional Lift and Loss

Scoring in the Flow Alteration Module is like the scoring described in Section 1.2.3. for the Quantification Tool worksheet. Scoring occurs automatically as field values are entered into the Condition Assessment tables. Metric index values are averaged to calculate a module score as shown in Figure 11.

Functional lift is generated when the existing condition is more functionally impaired than the proposed condition. A negative value would represent a functional loss. Existing and proposed module scores are multiplied by the affected stream length to calculate the existing and proposed functional feet (Figure 12). The module score is weighted by 20% (CSQT SC 2020). The weighted ΔFF is displayed in the Functional Change Summary Table and in the Quantification Tool worksheet, where it is added to the ΔFF for the project reach.

| FUNCTIONAL CHANGE SUMMARY | |
|---|---|
| Module Existing Condition Score (mECS) | 0.70 |
| Module Proposed Condition Score (mPCS) | 0.89 |
| Change in Functional Condition (mPCS - mECS) * | 0.04 |
| Affected Stream Length (ft) | 55213 |
| Existing Functional Feet (FF) | 38649 |
| Proposed Functional Feet (FF) | 49140 |
| Weighted ΔFF (Proposed FF - Existing FF) * | 2098 |
| Percent Change in FF (%) | 5% |
| ** Includes 20% multiplier for weighting* | |

Figure 12: Example Flow Alteration Module Functional Change Summary Table

### 1.2.7 Reference Curves Worksheet

The Reference Curves worksheet contains the reference curves used to convert metric field values into index values in the Quantification Tool, Monitoring Data, and Flow Alteration Module worksheets. This worksheet is present in both the CSQT workbook and Debit Calculator workbook.

*This worksheet is included for information purposes and does not require any data entry. This worksheet is locked to protect the calculations used to convert field values to index values.*

The numeric index value range (0.00 to 1.00) was standardized across metrics using the definitions of functional capacity, i.e., functioning, functioning-at-risk and not-functioning conditions provided in Table 1 (page 17). Reference curves are tied to specific benchmarks (thresholds) that represent the degree to which the reach condition departs from reference standard.

On this worksheet, reference curves are organized into columns based on functional category and appear in the order they are listed on the Quantification Tool worksheet. One metric can have multiple curves depending on how the reference curves were stratified. For example, the woody vegetation cover metric is stratified by ecoregion. All reference curves and their stratification are described in the Scientific Support for the CSQT (CSQT SC 2020).

There may be instances where better data to inform reference standard and index values are available for a project. The Corps can approve an exception to using the reference curves and index values for a metric within the CSQT where sufficient data are available to identify reference standards.

### 1.2.8 Debit Calculator Worksheet

This worksheet is only present in the Debit Calculator workbook, and not in the CSQT workbook. The Debit Calculator worksheet is where users enter data describing the impacts to each reach by selecting an impact severity tier, and where functional change is calculated. The worksheet consists of an input table, explanatory information on the proposed impact factors and activity modeling, and a summary of the results from the Existing and Proposed Conditions worksheet within the Debit Calculator workbook. Cells that allow input are shaded grey and most other cells are locked. Each section of the Debit Calculator worksheet is discussed below.

***Components of the Debit Calculator Worksheet***

Permit Number – Provide the name of the project and any permit or application number assigned. This information will automatically populate from the Project Assessment worksheet.

The Debit Tool Table (Figure 13) is the calculator where users enter data, describe the impact type and severity, and establish the existing condition for each stream reach in the project. This information, along with stream length is how resource value functional loss is quantified.

| FUNCTIONAL LOSS SUMMARY | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Stream ID by Reach | Outstanding Water | Debit Option | Existing Stream Length | Existing Condition Score | Proposed Length | Impact Severity Tier | Proposed Condition Score | Change in Functional Feet |
| STRM1 R1 | No | 2 | 500 | 0.56 | 400 | Tier 4 | 0.11 | -236.0 |
| STRM1 R2 | No | 3 | 390 | 0.48 | 400 | Tier 3 | 0.08 | -155.2 |
| 0 | 0 | | | 0.60 | | | | |
| 0 | 0 | | | 0.60 | | | | |
| 0 | 0 | | | 0.60 | | | | |
| 0 | 0 | | | 0.60 | | | | |
| 0 | 0 | | | 0.60 | | | | |
| 0 | 0 | | | 0.60 | | | | |
| 0 | 0 | | | 0.60 | | | | |
| 0 | 0 | | | 0.60 | | | | |
| | | | | | | | **Total Functional Loss (Debits in FF):** | **-391.2** |

*Figure 1: Debit Tool Table Example*

Stream ID by Reach – Applicants enter each impact site by reach. This information automatically populates from the Project Assessment worksheet. The user can score up to 10 reaches within each Debit Calculator workbook. If the project contains more than 10 reaches, more than one Debit Calculator workbook will need to be used.

Impact Description – This cell provides a description of the proposed impact and will automatically populate from the Project Assessment worksheet. The explanatory text should include a description of anticipated impacts to aquatic ecosystem functions and parameters within the project reach, and justification for Impact Severity Tier selection. Information to support tier selection may include project plans and documents, permit applications, and discussions between the permit applicant and the Corps.

Debit Option – There are three options for calculating functional loss at an impact site. Users should select Option 1, 2, or 3 from the dropdown menu. These options are described below and summarized in Table 3; additional detail is provided in the COMP (USACE 2020).

*Table 3: Summary of Debit Options*

| Debit Option | Existing Condition Score (ECS) | Proposed Condition Score (PCS) |
|---|---|---|
| 1 | Assess existing condition using Existing Condition worksheet | Estimate proposed condition using Proposed Condition worksheet |
| 2 | Assess existing condition using Existing Condition worksheet | Use Debit Calculator worksheet |
| 3 | Use Debit Calculator worksheet | Use Debit Calculator worksheet |

1. Option 1 calculates functional loss using data entered in the Existing Condition and Proposed Condition worksheets (Section 1.2.3). For this option, the user must conduct an existing condition assessment within the project reach.
    a. If a project has a Tier 0-3 level of impact (Table 4), only Reach Hydrology & Hydraulics and Geomorphology metrics need to be assessed. For this option, the user should be able to accurately predict the functional loss within the Reach Hydrology & Hydraulics and the Geomorphology categories using project design reports, drawings, and/or field investigations.
    b. For projects that impact physicochemical or biological functions (Tier 4-5 impacts), physicochemical and biological parameters should also be evaluated or a default ECS will automatically populate in the Existing Condition worksheets. The default ECS for these functional categories is 0.80, except in Outstanding Waters where the default score is 1.00. For Tier 4-5 impacts, the user must also be able to reasonably predict how the project will affect physicochemical and biology parameters.
2. Option 2 calculates functional loss using a combination of existing condition assessment data from the Existing Condition worksheet (Section 1.2.3) and the formulas in the Debit Calculator worksheet to calculate functional loss. For this option, the user must conduct an existing condition assessment of the project reach in the same way as Option 1. The Debit Calculator worksheet will automatically populate existing condition information entered in the Existing Condition worksheet. The user will then enter necessary information into the Debit Calculator worksheet, including an Impact Severity Tier (Table 4), and the worksheet will generate a PCS and a suite of summary information including the change in functional feet.
3. Option 3 calculates functional loss using only the Debit Calculator worksheet. Users do not need to conduct an existing condition assessment. For this option, the Debit Calculator worksheet relies on a default ECS for the reach. Just as with Option 2, the Debit Calculator calculates the proposed (post-impact) condition score (PCS) and functional loss. This option is the fastest and easiest method for determining functional loss.
    a. The default ECS for each functional category is 0.80, except in Outstanding Waters where the default score is 1.00.
    b. For impact severity tiers 0-3, where only Reach Hydrology & Hydraulics and Geomorphology functions are impacted, this equates to an overall ECS of 0.48, except in Outstanding Waters where the default score is 0.60.
    c. For impact severity tiers 4-5, this equates to an overall ECS of 0.80, except in Outstanding Waters where the default score is 1.00.

<u>Existing Stream Length</u> – Calculate the length of the stream that will be directly impacted by the permitted activity. Stream length should be measured along the centerline of the channel.

<u>Proposed Stream Length</u> – Calculate the length of stream channel anticipated from the proposed impact. For artificial water conveyances, the proposed length is the length of the conveyance. If the stream will be straightened by the permitted activity, the proposed stream length will be less than the existing stream length. Proposed stream lengths should not exceed the existing stream length; the debit calculator will highlight the cell if the proposed stream length is longer than the existing stream length.

Impact Severity Tier – Determination of an impact severity tier is needed to calculate a PCS. The impact severity tier is a categorical determination of the amount of adverse impact to stream functions, ranging from no loss to total loss from a proposed activity. Table 4 lists the impact severity tiers along with a description of impacts to key function-based parameters and example activities that may lead to those impacts. Note that **some activities could be in multiple tiers** depending on the magnitude of the impact and efforts taken to minimize impacts using bio-engineering techniques or other low-impact practices.

The Impact Severity Tier section includes a drop-down menu to select the Impact Severity Tier (1-5). Once the Impact Severity Tier has been selected, the PCS and proposed functional feet will automatically calculate in the Debit Calculator.

*Table 4: Impact Severity Tiers and Example Activities*

| Tier | Description (Impacts to function-based parameters) | Functional Categories Impacted | Example Activities |
|---|---|---|---|
| 0 | No permanent impact on any of the key function-based parameters | None | Bio-engineering of streambanks |
| 1 | Minor impacts to riparian vegetation and/or lateral migration | Geomorphology | Bank stabilization, utility crossings. |
| 2 | Moderate impacts to riparian vegetation, lateral migration, and bed form diversity | Geomorphology | Utility crossings, bridges, channel stabilization, bottomless arch culverts |
| 3 | Moderate to severe impacts to riparian vegetation, lateral migration, bed form diversity, and floodplain connectivity | Reach Hydrology & Hydraulics, Geomorphology | Channelization, grade control |
| 4 | Severe impacts to riparian vegetation, lateral migration, bed form diversity, and floodplain connectivity. Potential impacts to temperature, processing of organic matter, and macroinvertebrate and fish communities | All | Channelization, weirs/impoundments |
| 5 | Loss of all aquatic functions | All | Loss or relocation of waters |

ECS and PCS Summary Table – The overall ECSs and overall PCSs of all stream reaches from the Existing Conditions and Proposed Conditions worksheets are summarized in a table located below the Debit Tool Table. The overall proposed conditions score will automatically populate in the Debit Tool Table when Debit Option 1 is selected.

Calculating Functional Loss – The Debit Calculator worksheet calculates the PCS differently depending on which impact severity tier is selected (Table 5). These factors were based on projected functional loss and grouped by common impact activities with similar functional loss. For example, impacts within Tiers 1 – 3 result in functional losses to Reach Hydrology & Hydraulics and Geomorphology functions, while Tier 4-5 impacts result in loss across all functional categories. The percent loss associated with impact severity tiers 1 – 3 is calculated using an ECS based on an evaluation of functions within Reach Hydrology & Hydraulics

(RH&H) and Geomorphology (G). In these tiers, there is no anticipated permanent functional loss to physicochemical or biology functions. As such, **for impact severity tiers 1 – 3 the equation is based on a maximum ECS of 0.60**. For tiers 4 and 5, there is potential permanent loss in physicochemical and biological functions and thus, these equations consider a maximum ECS of 1.00.

***Table 5: Impact Severity Tiers and PCS Calculation, where ECS is the existing condition score and PCS is the proposed condition score***

| Impact Severity Tier | PCS Equation[1] | Percent Loss |
|---|---|---|
| 1 | $PCS = 0.71 * ECS_{0.60}$ | 29% of RH&H and G functions |
| 2 | $PCS = 0.42 * ECS_{0.60}$ | 58% of RH&H and G functions |
| 3 | $PCS = 0.16 * ECS_{0.60}$ | 84% of RH&H and G functions |
| 4 | $PCS = 0.20 * ECS_{1.00}$ | 80% |
| 5 | PCS = 0 | 100% |

[1] *Impacts within Tiers 1 – 3 result in functional losses to Reach Hydrology & Hydraulics (RH&H) and Geomorphology (G) functions and the ECS is only applied to loss in those functional categories. Tier 4-5 impacts result in loss across all functional categories.*

Once the PCS is calculated, the Debit Calculator worksheet uses the existing and proposed stream lengths to calculate the ΔFF using the equation described in Chapter 1.2.3. The Debit Calculator can only calculate loss and therefore, the change in functional feet can only be less than or equal to 0. The functional loss summary table summarizes all the necessary information for each impact reach (Figure 13). Multiple stream impacts can be reported within a single workbook. The worksheet will automatically total the ΔFF when data is entered for multiple project reaches.

# Chapter 2. Data Collection and Analysis

This chapter provides instruction on how to collect, analyze, and input data used in the CSQT workbook and Debit Calculator workbook. Figure 14 provides a flow chart of the typical process.

Teams collecting and analyzing these data should have experience and expertise in botany, aquatic ecology, hydrology, and geomorphology as well as experience and expertise applying the assessment methods used to calculate the metrics included in the SQT. **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 the methods outlined herein, as well as the Stream Functions Pyramid Framework, are recommended to ensure that the methods are executed correctly and consistently.

Each method in this chapter will describe the requisite experience for individuals applying the methods.

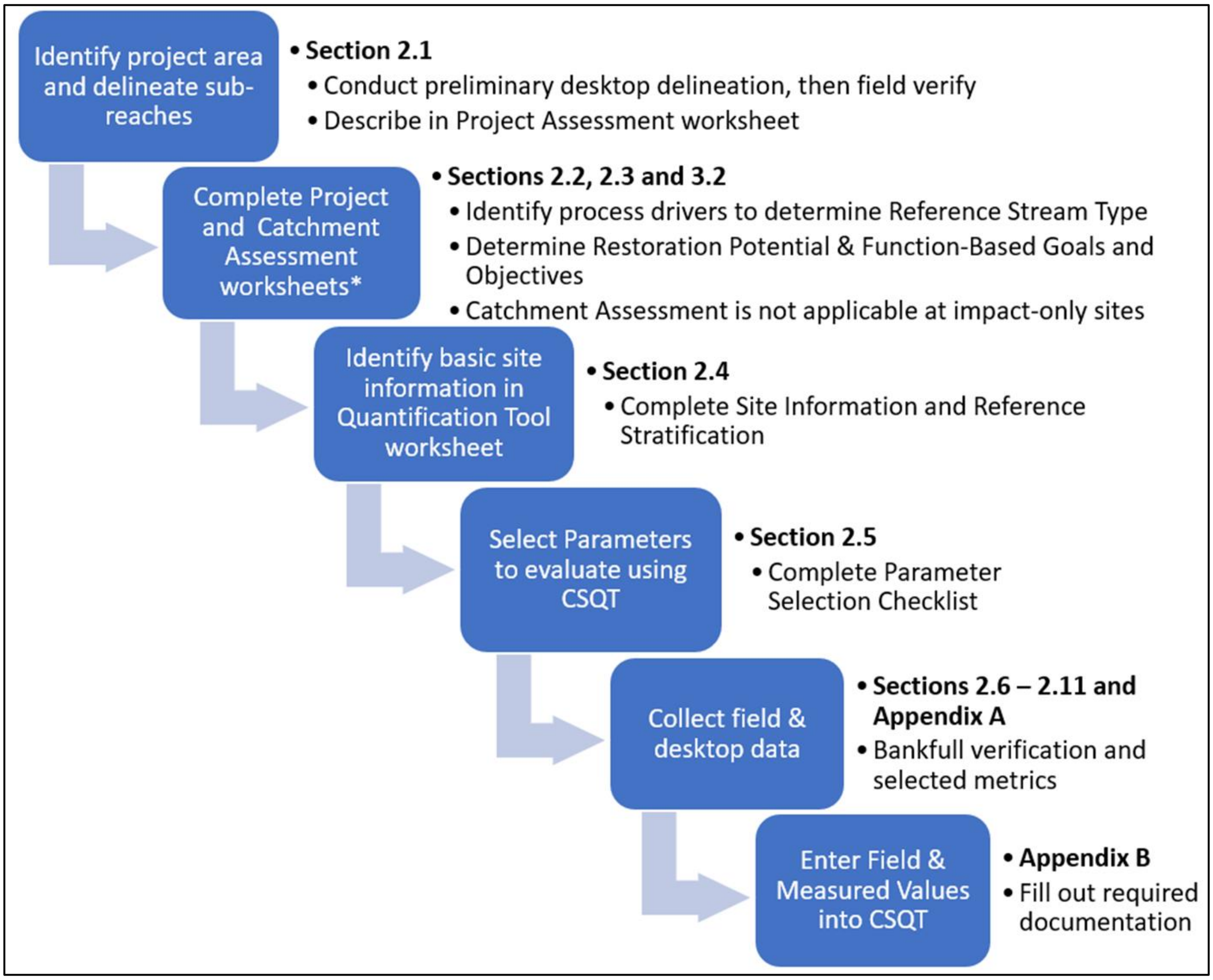



*Figure 14: CSQT Process Flow Chart*

This chapter includes methods for metrics that can be evaluated in the office, steps for calculating metrics, as well as a summary of field methods. Detailed field procedures are provided in Appendix A. For some metrics, multiple field methods are provided that will allow for either rapid or more comprehensive site assessment. **Few metrics are unique to the CSQT**, and data collection procedures are often consistent with other instruction manuals or literature. **Where appropriate, this chapter and Appendix A will reference the original methodology** to provide technical explanations and make clear any differences in data collection or calculation methods needed for the CSQT.

## 2.1 Reach Delineation and Representative Sub-Reach Selection

The CSQT is informed by reach-based assessment methods. A large project may be subdivided into multiple project reaches as stream condition or character can vary widely from the upstream end of a project to the downstream end. Thus, a separate workbook should be used for each reach.

Delineating stream reaches within a project area occurs in two steps. The first step is to identify whether there is a need to separate the project area into multiple reaches based on variations in stream physical characteristics and/or differences in project designs or magnitude of impacts. Once project reaches are determined, the user selects a representative sub-reach within each project reach to assess various metrics. The processes to define project reaches and representative sub-reaches are described in detail below in Sections 2.1.1 and 2.1.2 respectively.

The CSQT also includes an optional Flow Alteration Module that requires the user to determine the length of stream affected by a proposed change in flow regime, which may be distinct from the reach length entered in the Quantification Tool worksheet. More detail on the affected stream length is provided in Section 2.11.

### 2.1.1 Delineation of Project Reach(es)

The user should determine whether their project area encompasses a single homogeneous reach, or multiple potential reaches. For this purpose, **a reach is defined as a stream segment with similar processes and morphology, including characteristics such as such stream type (Rosgen 1996), stability condition, riparian vegetation type, and bed material composition**. Reaches within a project site may vary in length depending on the variability of the physical stream characteristics within the project area (Example 3).

Users can review aerial imagery, NHD data, and other desktop tools to preliminarily determine reach breaks; these determinations should be verified in the field. Users should provide justification for the final reach breaks in the Reach Description section of the Project Assessment worksheet. Specific guidance is provided below to assist in making consistent reach identifications:

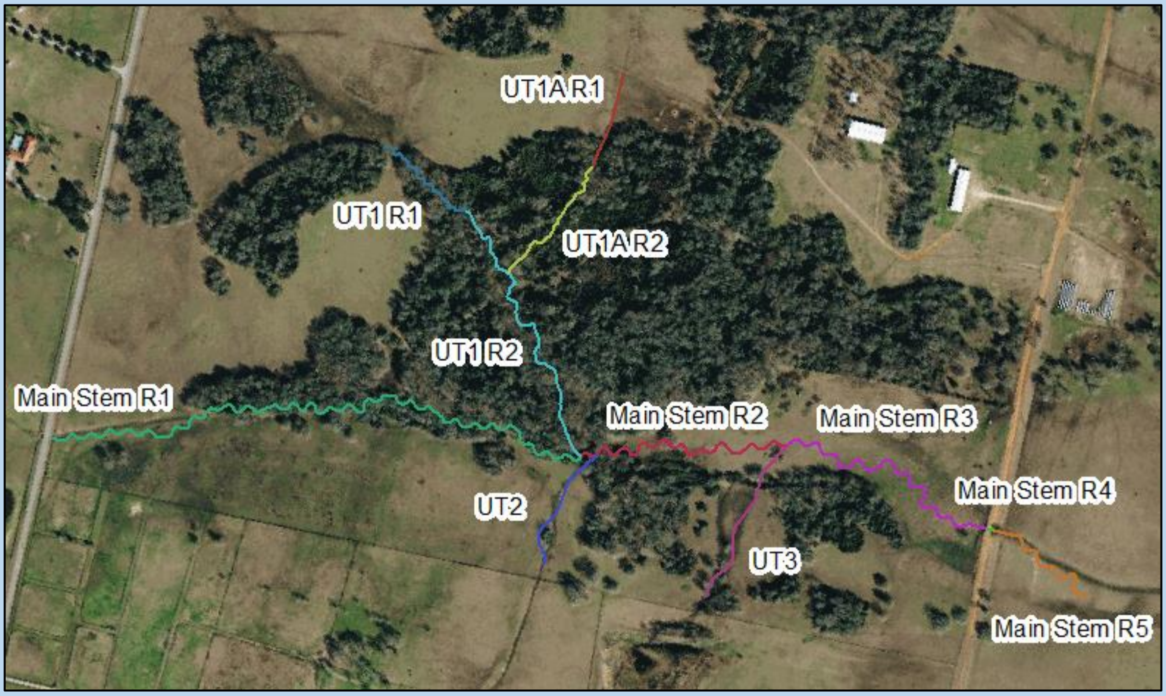
- Separate streams, e.g., tributaries vs. main stem, are considered separate project reaches.
- A tributary confluence should lead to a reach break. Where a tributary enters the main stem, the main stem should be split into two project reaches - one upstream and one downstream

of the confluence. The contribution of 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, valley morphology, stream type (Rosgen 1996), or bed material composition.
- Reach breaks should occur where there are diversion dams or other flow modification structures on the stream, with separate reaches upstream and downstream of the structure. The diversion dam or structure would also be its own 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, stabilization, or culverts/pipes. For example, a culvert's footprint would be evaluated as a separate project reach from the reaches immediately up and downstream of the culvert.
- Multiple project reaches are needed where there are differences in the proposed 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 would be evaluated in a separate reach from portions of a project that only include bank stabilization activities.

***Example 3: Project Reach Delineation***

The following is an example showing how project reaches are identified based on physical observations. The project area includes 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 an Excel Workbook would need to be completed for each.




| 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. |

### 2.1.2 Representative Sub-Reach Determination

Some metrics will be evaluated along the entire project reach length, some will be evaluated at a specific point within the project reach and other metrics will be evaluated in a representative sub-reach (Figure 15). Selecting a representative sub-reach is necessary to avoid having to quantitatively assess very long stream lengths with similar physical conditions. The representative sub-reach should be at least 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. Assessment length and sampling locations are described below for each metric and parameter.

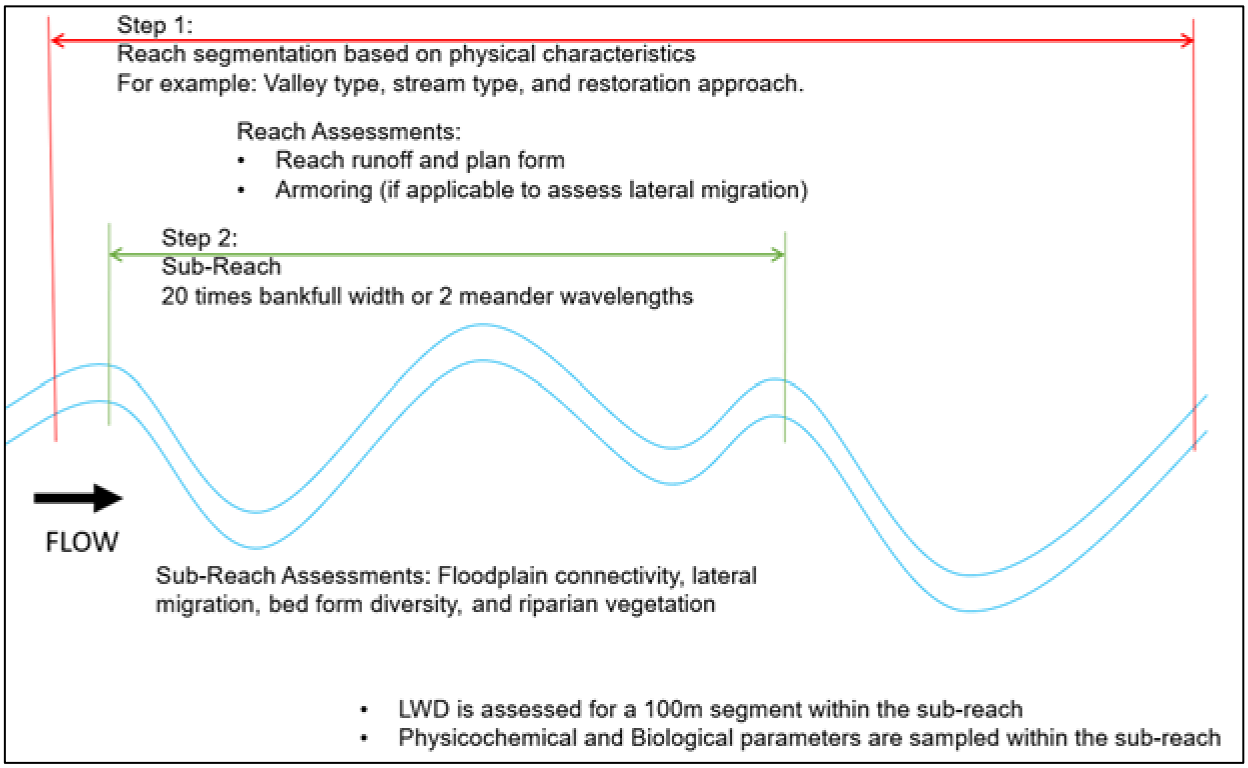



***Figure 15: Reach and Sub-Reach Segmentation***

<u>Reach Hydrology & Hydraulics Functional Category</u>:

- Reach runoff metrics are evaluated within the entire project reach.
- Baseflow dynamics metrics are evaluated at three riffles in the project reach.
- Floodplain connectivity is assessed within the representative sub-reach.

<u>Geomorphology Functional Category</u>:

- Large woody debris (LWD) is assessed within a 328-foot (100 meter) segment located, whenever possible, within the representative sub-reach. If the project reach is less than 328 feet, the LWD assessment should be performed within the entire reach length and the value normalized to represent a value per 328 feet.

- Lateral migration metrics (except armoring), bed form diversity, and riparian vegetation are assessed within the representative sub-reach.
- Percent armoring is assessed along the entire project reach.

<u>Physicochemical and Biology Functional Categories</u>:

- Sampling should occur within the project reach, but specific locations will vary by metric, and are described in the metric sections in this Chapter and in Appendix A.

## 2.2 Reference Stream Type

Reference stream type represents the stream type that should occur in a specific landscape setting given current hydrogeomorphic watershed- and reach-scale processes. To determine reference stream type, users should have experience and knowledge about channel evolution, process drivers, and the Rosgen Stream Classification system.

When using the Debit Calculator workbook, reference stream type is entered in the Existing Condition worksheet and users should select reference stream type after considering the existing stream type, channel succession, and process drivers (Example 4). The Rosgen Channel Succession Scenarios (Rosgen 2006) or other stream evolution models (Cluer and Thorne 2013) can be used as a guide for determining the reference stream type.

When using the CSQT workbook, reference stream type is entered in the Project Assessment worksheets and is the restoration target **at project closeout** informed by both channel evolution and process-driver context for the project reach. Historic, geomorphic, and stratigraphic evidence, and an evaluation of process drivers can be used to determine reference stream type. Information from the design process (e.g., fluvial landscape, historic channel conditions, watershed hydrology, sediment transport, and/or anthropogenic constraints) can also be used to inform reference stream type. Once the reference stream type has been selected, the evolution (past, present, and future) should be furthered explained (refer to restoration potential process in Chapter 3). This explanation provides further support for selection of reference stream type.

The CSQT relies on the Rosgen stream type classifications (Rosgen 1996) to determine reference stream type. **The CSQT does not require Natural Channel Design restoration approaches.** Reference stream type is used in the CSQT to stratify reference curves for the entrenchment ratio (ER) and pool spacing ratio metrics. Stream type classifications and 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).

***Example 4: Reference Stream Type Example***

Pre-restoration (existing) stream type: Gc

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

A Gc stream type in a low gradient, unconfined alluvial valley will often evolve into an F and then a C stream type. If the reach is in a wide alluvial valley, the reference stream type would likely be a C or E. $D_A$ stream type may be an appropriate evolutionary end point for the restored stream but it often takes time to re-establish flora and fauna communities necessary for anastomosing stream types to be stable.

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

Channels are referred to as single-thread and multi-thread throughout this manual. The Rosgen stream classification system describes six single-thread channels, and two multi-thread stream types: D and $D_A$ streams.

- In general, for a reach to be considered multi-thread it must have at least 3 primary flow paths that are active at baseflow for most of the reach length.
- D streams are braided systems with low biotic interaction resulting in active bank migration that adjust primarily through lateral extension and aggradation (Rosgen 1996). These systems are response reaches, often occurring downstream of a high sediment supply, where the system will adjust with every high flow event. In Colorado, examples include alluvial fans and non-perennial streams in arid landscapes.
- $D_A$ streams are anastomosed systems, typically in low gradient valleys with high biotic interaction (likely an obligate community, beaver dam complexes, beaver meadows, or large wood). These systems are response reaches that lack the stream power to transport incoming sediment.

### 2.2.1 Process-Drivers

The Stream Evolution Triangle (SET) can be employed to identify the dominant process drivers for the project reach following the guidance from Castro and Thorne (2019). Castro and Thorne (2019) identify three primary stream process drivers: geology (erosion resistance), hydrology (stream power), and biology (biotic interactions).

To determine whether the **erosion resistance** for a reach is high, moderate or low, a user should consider two aspects of the geological setting:

1. Is the reach in an unconfined alluvial, confined alluvial, colluvial/V-shaped or bedrock valley? Refer to valley definitions below, note these differ from the valley types listed in Castro and Thorne (2019) but span the spectrum of erosion resistance from low to high in the order listed.

Bedrock Valleys – Valleys dominated by bedrock, typically exhibiting confined channels which lack an alluvial bed. Bedrock valleys are supply-limited; thus, sediment movements are primarily driven by the sediment load delivered to the reach via inflowing water. Two types of bedrock valleys have been classified: 1) steep bedrock valleys where transport capacity exceeds sediment supply (e.g., A, B, F, G) and 2) low-order streams dug to bedrock by debris flows (e.g., C, D) (Montgomery and Buffington 1997).

Colluvial or V-shaped Valleys – Valley formed by the sediment from hillslope erosion processes. Colluvial valleys are typically confined by terraces or hillslopes. These valleys are confined and support straighter, step-pool type channels (e.g., A, B, Bc, F). These valley types typically have a valley width ratio less than 7.0 and a meander width ratio (MWR) ratio less than 3.

Confined Alluvial Valley – Valley formed by the deposition of sediment from fluvial processes, typically confined by terraces or hillslopes that supports transitional stream types between step-pool and meandering or where meanders intercept hillslopes (e.g., C, Bc). These valley types typically have a valley width ratio less than 7.0 and a meander width ratio (MWR) between 3 and 4.

Unconfined Alluvial Valleys – Wide, low gradient (typically less than 2% slope) valleys that support meandering and anastomosed stream types (e.g., 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).

2. What is the reach's sediment transport capability? An analysis of the sediment regime for the reach should inform whether it is likely a source, transport, or response reach. The sediment regime characterizes the inputs and outputs of mobile sediment for a reach of stream, and sediment storage within the channel and on the floodplain over a specified time interval (Wohl et al. 2015). This analysis can be qualitative or quantitative (e.g., sediment transport capacity/supply ratio (CSR) tool (Stroth et al. 2017)). These analyses would provide evidence for whether the reach would tend toward a braided, meandering, or straight plan form. A quantitative analysis of sediment transport is not required for completing the CSQT but is often developed as part of project design and the results can be applied to answer this question.

Source Reach – A channel that is transport-limited, where flows lack the competence to move larger grain sizes. Headwater, colluvial channels that are subject to intermittent debris flow scour. (Montgomery and Buffington 1998)

Transport Reach – A channel that has sufficiently competent flows to move sediments through the reach. Transport reaches are morphologically resilient, supply-limited systems. (Montgomery and Buffington 1998)

Response Reach – A channel that is transport-limited, such that the sediment supply exceeds the competence of flows. Morphological adjustment occurs in response to increased sediment supply. (Montgomery and Buffington 1998)

To determine whether the **stream power** for a reach is high, moderate, or low, a user should consider two aspects of hydrology:

1. Does the reach have regulated or free flowing hydrology? Stream power is affected when a stream is regulated versus free flowing. Many streams in Colorado are regulated and the catchment assessment (Section 2.3) includes a qualitative assessment of the significance of flow alteration. The user should consider whether the regulation in the stream is impacting the stream power and altering reach scale processes.
2. Is the flow regime of the reach dominated by baseflow, snow, rain, rain-on-snow, or storms? Many higher elevation streams in Colorado are dominated by snow melt, while the hydrograph in many lower elevation systems is strongly influenced by summer convective storm events. Additionally, an urban stream may have sufficient impervious cover to reduce watershed permeability and increase the stream power within a reach.

To determine whether the **biotic interaction** for a reach is high, moderate, or low, a user should consider three aspects of the reach ecology:

1. Is the adjacent riparian vegetation primarily made up of obligate, facultative, or upland species? Obligate species are indicative of a high water-table and wetland conditions while upland species are found in drier environments with lower water-tables. Where the riparian community consists of primarily obligate species biotic interaction is high. Resources for determining the rating of species can be found on the USDA NRCS website.[5]
2. Within the reach, is there channel-spanning large wood, some large wood accumulations or jams, individual large wood pieces, no large wood, or has large wood been removed? Generally, greater amounts of wood in the channel would indicate a higher degree of biotic interaction. It is important to note that there are some streams with naturally limited supplies of LWD, such as plains streams that do not have forested catchments or relatively narrow riparian gallery forests.
3. Are beaver meadows, beaver dam complexes, individual beaver dams, or other evidence of beaver present? Evidence that beaver have been removed from the reach should also be considered. Beaver presence indicates a higher degree of biotic interaction.

Based on answers to the above, the user should then make qualitative (low, moderate, high) assessments of the three stream process drivers (geology, hydrology, and biology). As shown in Example 5, the user can refer to Figures 6a and 6b from Castro and Thorne (2019) to determine the typical Rosgen stream type(s) that might be expected given an assessment of the dominant process drivers.

[5] https://plants.usda.gov/core/wetlandSearch

***Example 5: Process Drivers and Rosgen Stream Type Example***

The existing stream type is a C4 in a very broad, gently sloping alluvial valley. The reach cannot transport the sediment load from upstream and therefore is a response sediment regime and erosion resistance is low.

The stream hydrology is snow-dominated, there is some regulation in the watershed and the watershed is permeable. The stream power is low to moderate.

The low-gradient, alluvial valley supports an obligate/facultative plant community, but lacks a supply of large wood. While there is some beaver activity, there are only isolated beaver dams and the biotic interaction for the reach is moderate.

As shown in the figure, the existing process-drivers for the reach lead to a reference stream type of C, matching the existing stream type. If sediment deposition is causing instability, restoration activities could focus on increasing erosion resistance and stream power, shifting the channel toward a transport sediment regime.

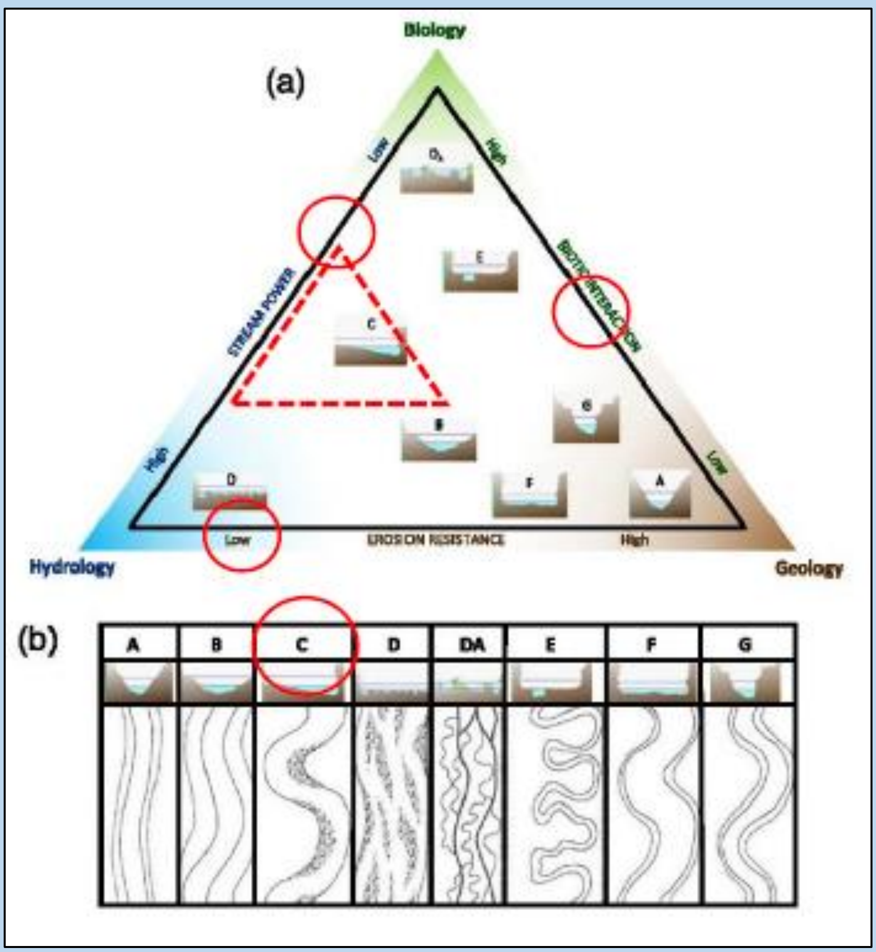



*Image edited from Castro and Thorne (2019).*

### 2.2.2 Sinuosity

Since channel length affects the functional feet output of the CSQT there is a concern that users may be incentivized to unnaturally increase stream length. However, single-thread channels with high sinuosity are only supported in specific reach-scale settings.

Sinuosity is calculated by dividing the stream thalweg distance by the straight-line valley length between the upstream and downstream extent of the project reach. Additional detail on calculating sinuosity can be found in Table 11-14 of *Part 654 Stream Restoration Design National Engineering Handbook* (NRCS NEH 2007). Sinuosity should be measured using recent aerial imagery and should be assessed over the entire project reach. If recent aerial imagery is not available or the stream channel is not visible on the imagery, then sinuosity should be measured in the field per the method outlined in Appendix A.

Sinuosity is not applicable to multi-thread channels and no input is required when the reference stream type is D or $D_A$.

## 2.3 Catchment Assessment (CSQT workbook only)

The primary purpose of the Catchment Assessment is to assist in determining restoration potential for restoration and mitigation projects (described in Section 3.2). It is a decision-support tool rather than a quantitative scoring tool. Therefore, results from the Catchment Assessment are not scored in the CSQT but are used to help inform a restoration potential decision. *The Catchment Assessment worksheet is included in the CSQT workbook, but not the Debit Calculator workbook.*

The Catchment Assessment worksheet includes descriptions of processes and stressors that exist outside of the project reach and may limit functional lift. The Catchment Assessment does not pertain to stressors occurring within the project area that can be addressed as part of restoration activities. The Catchment Assessment evaluates conditions primarily upstream, but sometimes downstream of the project reach. Instructions for collecting data and describing each process and stressor are provided in this section.

The Catchment Assessment relies on data available from various online or local sources and site-specific data that can be obtained through site walks within the project area. There are 11 defined categories, with space for an additional user-defined category. There are three choices to rate the catchment condition for each category: good, fair, and poor. Data needed to assess each category are described below; descriptions of good, fair, and poor are provided in the Catchment Assessment worksheet for each category. Data used to evaluate each selection should be documented. Once all categories of the Catchment Assessment are completed, the user should provide an overall watershed condition, based on best professional judgement, and determine the restoration potential for the reach. Restoration potential is described in Section

***Impoundments***

Impoundments are structures that can impede longitudinal (river corridor) connectivity. The presence of a dam or other barrier to fish passage downstream of a project may limit the potential to increase fish biomass in the project reach. A dam upstream of the project may allow organism recruitment from downstream; however, it may still alter longitudinal connectivity,

impact catchment hydrology, alter sediment and temperature regimes, and impede delivery of organic material to the project reach. Catchments in good condition have no impoundments upstream or downstream of a project area. An impoundment that is proximate or otherwise has an adverse effect on the project area and fish passage would result in a lower rating.
The location of dams or other impoundments within the catchment can be determined through field walks, aerial imagery, or review of other landscape-scale information. Generally, this metric can be evaluated at the local level (e.g., within several stream miles or at the HUC 12 or HUC 14 watershed level); however, consideration should be given to large impoundments or critical fish barriers that may be less proximate but affect a large catchment area.

***Flow Alteration***

Flow alteration represents the role impoundments, water allocation, and effluent discharges can play in altering catchment hydrology and stream physicochemical and aquatic habitat conditions. Users should consider any alterations to the timing, magnitude, frequency, duration, and rate of change, as compared with the natural flow regime. Examples of flow alteration include diversion dams withdrawing water for irrigation or municipal/industrial use, water storage reservoirs, hydroelectric operations, large effluent discharges, and trans-basin diversions (either depleting or augmenting flows). Landscape-scale information can be used to inform conclusions about flow alteration, including dam storage ratios, dam density, the density of agricultural ditches, active points of diversion, and decreed instream flow reaches. Dam storage ratios reflect the storage within the watershed compared with the average annual flow, and these data are available through EPA's 2017 Preliminary Healthy Watersheds Assessment for each HUC 12 watershed in Colorado (USEPA 2017).[6] Other sources of information may include local stream or integrated water management plans, the Colorado Watershed Planning Toolbox[7], and Division of Water Resources on-line water rights structure information[8]. In addition, consultation with the local Water Commissioner for the District may yield additional information regarding hydrologic conditions.

A catchment in good condition has a natural flow regime with little to no flow reduction or augmentation occurring upstream of the project reach. A catchment in poor condition has stream flows that are heavily depleted or augmented. A fair or poor rating may also occur where more than one aspect of the flow regime is altered (i.e., alterations to the timing, magnitude, frequency, duration, and rate of change), or where a single aspect of the natural flow regime is substantially modified.

In selecting the reference stream type for a reach, consider how altered hydrology affects the reach-scale process drivers as discussed in Section 2.2.

***Urbanization***

Urbanization represents the influence urban and residential development can have on hydrology and water quality in downstream reaches. Trends in land use can be determined through examining time-series aerial imagery or by examining land cover data available online through the National Land Cover Database (NLCD).[9] The NLCD includes datasets for percent

[6] https://www.epa.gov/hwp/download-2017-preliminary-healthy-watersheds-assessments
[7] https://cnhp.colostate.edu/cwic/tools/toolbox/
[8] https://dwr.state.co.us/tools/
[9] https://gapanalysis.usgs.gov/gaplandcover/data/download/

impervious cover, developed, and forested land from 1992, 2001, 2006, 2011, and 2016. Zoning designations and development plans can also be obtained from local governments and assessed for the project catchment. Landscape-scale information is also available through EPA's 2017 Preliminary Healthy Watersheds Assessment for each HUC 12 watershed in Colorado (e.g., natural cover within the watershed, population density, imperviousness, and road density) and in the Colorado Watershed Planning Toolbox (e.g., landscape disturbance index).

A catchment in good or fair condition for this category would include natural land cover, rural, or otherwise slow-growth-potential communities and land uses. Catchments rated as poor in this category, such as urban or urbanizing communities, have ongoing development or imminent large-scale development.

***Fish Passage***

This category considers the proximity and effects of anthropogenic barriers that may reduce the mobility of aquatic species or otherwise limit their natural ranges. These barriers can include impoundments but can also include other anthropogenic factors that limit natural movements of fish, such as culverts, low head dams, grade control structures, and other physical or hydraulic barriers. The user should consider whether the flow depth and velocity or vertical height across a structure or barrier may limit movement of certain species or life stages of species historically or naturally present within that catchment. The rating is primarily based on proximity of the project reach to known fish barriers; however, consideration may also be given to whether barriers farther away may have effects on fish populations within the reach. A catchment in poor condition for this category may have barriers that create severe limitations to fish passage that adversely affect fish populations within the project reach. A fair condition may represent a catchment where minor fish passage issues are occurring during some, but not all times of the year, or barriers present nearby have been shown not to affect fish populations within the project reach. A catchment in good condition would have no proximate fish barriers, or structures that do not have adverse effects on fish populations. If a structure is proximate to the project reach but has a beneficial effect like serving as a barrier to invasive species, then the catchment may be in good condition.

Information sources described in the flow alteration and impoundment sections can also be used to inform this metric. In addition, consultation with the area fish biologist from Colorado Parks and Wildlife may yield additional information regarding the presence and severity of barriers within the catchment.

***Organism Recruitment***

This category considers the effects of altered or impaired channel substrates on the potential for recruitment and colonization of aquatic organisms within the stream reach, recognizing that recruitment and colonization is affected by the presence of desired communities in proximity to the project site. Impairments to the channel, such as hardened or armored channels and substrates, excessive sedimentation, culverts, or piping may prevent macroinvertebrate and fish communities from inhabiting a stream reach and extended lengths of channel impairments may reduce the possibility of organism recruitment to the project reach. A catchment in poor condition may have substantial channel impairments preventing desirable species from inhabiting areas immediately upstream or downstream of the project reach (i.e., within 1 km or

0.62 mi), whereas good condition is represented by adjoining reaches with native bed and bank material.

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 future restoration potential, since benthic insects can immigrate from nearby catchments along non-water avenues (e.g., aerial dispersion). This category can be assessed by walking the site and the stream reaches immediately upstream and downstream of the project reach or reviewing aerial imagery to determine if there are any impairments to organism recruitment including excessive deposition of fine sediments, concrete, piped, or hardened stretches of channel.

***Colorado Integrated Report (305(b) and 303(d) status) for Aquatic Life Uses***

The Colorado Department of Public Health and Environment (CDPHE), Water Quality Control Division (WQCD) maintains a list of impaired waterbodies (category 5 waters; the 303(d) list) as part of its biennial Integrated Report to EPA. Category 5 waters with impaired aquatic life uses have exceeded water quality standards and require a Total Maximum Daily Load (TMDL) to determine pollutant reductions necessary to achieve standards. Once a TMDL is completed and approved by EPA, the impaired waterbody is removed from category 5 and placed in category 4 (TMDL completed but not yet restored) until additional monitoring shows water quality standards are achieved. It is therefore important to check the State's most recent Integrated Report for both category 4 and category 5 (303(d) listed) waters in the catchment. Spatial information on category 4 and 5 waters is available in the Colorado Watershed Planning Toolbox. Most stream restoration and compensatory mitigation projects do not improve a sufficient portion of the stream or catchment to overcome poor water quality. A poor or fair catchment rating in this category would indicate that full restoration potential would be difficult or impossible unless a large portion of the catchment is being restored.

There are many waters with degraded biological condition that are unassessed, thus they are absent from the 303(d) list. If recent water quality data have been collected for the reach, then it can be used to inform a condition rating in this category even if the water is not listed as impaired by Colorado WQCD.

***Development (oil, gas, wind, pipeline, mining, timber harvest, roads)***

Development near the project site can significantly impact the restoration potential of a stream, depending on the type of development and its proximity to the project site. This category addresses large scale land uses common to Colorado that are often independent from urbanization, including energy development and infrastructure (oil, gas, and wind), mining, timber harvest, and roads. For example, roads or other infrastructure associated with energy development 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.

The presence of energy infrastructure, mining and silviculture operations, and roads near the project site can be determined in the field or using available aerial imagery or other spatial data. Spatial data are available from the Colorado Division of Reclamation Mining and Safety[10] and the Colorado Oil and Gas Conservation Commission.[11] The most recent State Transportation Improvement Program[12] is available from the Colorado Department of Transportation to determine what projects are expected to receive funding during a 4-year time span. Landscape-scale information is also available through EPA's 2017 Preliminary Healthy Watersheds Assessment for each HUC 12 watershed in Colorado[4] and the Colorado Watershed Planning Toolbox.[5]

### *CDPS Permits*

The Colorado Discharge Permit System (CDPS) program regulates water quality and monitoring procedures for point source discharges to water bodies. While the program ensures discharged water meets minimum water quality standards, standards may not exist for all relevant parameters (e.g., nutrients), or effluent limits may be technology-based rather than water quality-based (e.g., dissolved solids, conductivity, oil and grease), thus discharges may limit full restoration potential. A catchment in good condition would have no major and few minor CDPS facilities upstream of the project reach while a poor catchment in this category would have CDPS permitted facilities comprising a high percentage of the baseflow in the project reach or one or more facilities present within two miles upstream of the project reach. CDPS stormwater and temporary discharge permits are excluded from consideration; a change in condition must be attributable to project actions rather than CDPS permit conditions. The Colorado Water Quality Control Division lists the minor and major CDPS permitted facilities.[13]

### *Riparian Vegetation*

This category considers the extent and connectivity of riparian areas within and upstream of the project area. Riparian areas serve as wildlife habitat corridors, protect and buffer the stream channel from erosive runoff velocities, and provide nutrient and pollutant removal benefits. Catchments in good condition will have natural riparian plant communities extending across the majority (e.g., more than 2/3) of the 100-year floodplain, and riparian corridors that are largely (e.g., over 80%) contiguous along the contributing catchment stream length. Catchments in poor condition will have limited natural plant communities (e.g., extending across less than 1/3 of the 100-year floodplain), and/or substantial gaps in the riparian corridor (e.g., that exceed 30% or more of the contributing catchment stream length).

The 100-year floodplain can be estimated using available spatial data or Federal Emergency Management Agency delineated floodplains (Note: floodplain maps may not be reflective of the historic floodplain in urban or developed areas). FEMA floodplain data is available in the Colorado Watershed Planning Toolbox.[5] The prevalence of riparian vegetation on streams draining to the project reach can be determined using recent aerial imagery and/or by field observations within the catchment. Landscape-scale information is also available through EPA's

[10] https://mining.state.co.us
[11] https://cogccmap.state.co.us
[12] https://www.codot.gov/programs/planning/transportation-plans-and-studies/stip
[4] https://www.epa.gov/hwp/download-2017-preliminary-healthy-watersheds-assessments
[5] https://cnhp.colostate.edu/cwic/tools/toolbox/
[13] https://www.colorado.gov/pacific/cdphe/water-division-permit-public-actions

2017 Preliminary Healthy Watersheds Assessment for each HUC 12 watershed in Colorado.[4] Relevant data from this assessment could include population density within the riparian zone, road density within the riparian zone, natural cover within the hydrologically active zone, and high intensity land cover in the riparian zone.

***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 change a transport system into a response system and create a challenging design problem. Sediment regime is considered in determining reach-scale process drivers (Section 2.2) and selecting a reference stream type. For transport systems, the restoration project could aggrade if the design does not adequately address alterations in the sediment load. 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.

Users should review recent aerial imagery of the catchment and walk as much of the upstream channel as possible looking for evidence of altered sediment loads, including extensive bank erosion, mid-channel bars, lateral bars, sediment fans at mouths of tributaries, and other evidence of excess human sources of sediment (Example 6). If there are multiple lines of evidence indicating moderate or high levels of excess sediment, and this is not a naturally occurring condition, then the catchment condition would be considered fair or poor, respectively. If there are only a few sources of sediment or sediment sources are naturally occurring, then the catchment condition is good.

***Example 6: Indicators of Human-Altered Sediment Regimes***

*For the transport system pictured below, the alternating point bars lacking vegetation indicate sediment storage in the channel that can be mobilized during high flows. Sediment is also being supplied to the channel from bank erosion.*

There are many tools available to estimate the sediment load from surrounding land use, including the: Spreadsheet Tool for Estimating Pollutant Loads (STEPL v4.1; Tetra Tech, Inc. 2011), Watershed Assessment of River Stability and Sediment Supply (WARSSS; Rosgen 2006), and Bedload Assessment for Gravel-bed Streams (BAGS; Pitlick et al. 2009). WARSSS is an intensive level of effort that is not necessary for this assessment but could be used to inform this category if WARSSS was applied for other reasons on the project.

***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 hydrologic functioning of the project reach.

## 2.4 Data Collection for Site Information and Reference Selection

The condition assessment in the Quantification Tool worksheet of the CSQT workbook and the Existing and Proposed Conditions worksheets in the Debit Calculator workbook use reference curves to translate measured field values into index scores. For some metrics, these curves are stratified by physical stream characteristics like stream type, temperature, and ecoregion. The Site Information and Reference Selection section of these worksheets consists of general site information and classifications to determine which reference curves are used to calculate index values for relevant metrics. Information on each and guidance on how to select values is described below. It may not be necessary to complete all fields, depending on parameter selection. Metrics will not be scored or may be scored incorrectly if required data are not provided in this section. Note that incorrect information in the Site Information and Reference Selection section may result in applying reference curves that are not suitable for the project.

For fields with drop-down menus, if a certain variable is not included in the drop-down menus, then data to inform index values for that variable are not yet available for Colorado. Additional information on how reference curves are stratified is included in the Scientific Support for the CSQT (CSQT SC 2020).

Project Name (CSQT workbook only) – Enter the name of the project. This information is also in the Project Assessment worksheet of the Debit Calculator workbook, if debits are calculated as part of the project.

Reach ID – Each project reach within a project area should be assigned a unique identifier (Section 2.1).

Restoration Potential (CSQT workbook only) – Restoration potential should be determined for the project reach using the stepwise process described in Section 3.2. **This cell is automatically populated from the Project Assessment worksheet** and requires completion of the Catchment Assessment.

Project Reach Stream Length – Existing (ft) (CSQT workbook only) – Project reach stream length is the centerline distance extending 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. Stream length is not used for reference curve stratification but is used to calculate functional feet. This information is also in the Debit Calculator worksheet of the Debit Calculator workbook, if debits are calculated as part of the project.

Project Reach Stream Length – Proposed (ft) (CSQT workbook only) – Project reach stream length is the centerline distance extending from the upstream to the downstream end of the project reach. The proposed length can be estimated from project design documents, and later verified using as-built conditions using the approaches described in Existing Project Reach Stream Length above. Where stream length does not change post-project, the same value can be entered for the Existing and Proposed Project Stream Length. Stream length is not used for reference curve stratification but is used to calculate functional feet. This information is also in the Debit Calculator worksheet of the Debit Calculator workbook, if debits are calculated as part of the project.

Drainage Area (sq.mi.) (CSQT workbook only) – 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., StreamStats, USGS maps, LiDAR or other digital terrain data). The drainage area is not used to stratify any reference curves but is important information to consider for bankfull verification (Section 2.6).

Flow Permanence – Select whether the stream reach is Perennial, Intermittent, or Ephemeral. Flow permanence is not used for reference curve stratification but can be used to inform parameter selection and to provide context to the change in functional feet in the Mitigation Summary Table. Consult with the Corps regarding the current definition of these terms.

Strahler Stream Order – Stream order as defined by Strahler (1957) is a classification based on stream/tributary relationships. Headwater streams are first order; a stream is second order downstream of the confluence of two first order streams; a stream is third order downstream of the confluence of two second order streams; and so on. Stream order is not used for reference curve stratification but is used to provide context to the change in functional feet in the Mitigation Summary Table.

Outstanding Water (Debit Calculator workbook only) – Outstanding Waters relies on the CDPHE designation; maps can be found on the CDPHE website or the CNHP Watershed Planning Toolbox.[14] In the Debit Calculator workbook this cell is automatically populated from the Project Assessment worksheet.

Ecoregion – The CSQT uses the project's ecoregion to stratify reference curves for the woody vegetation cover metric. EPA Level III ecoregion data from Colorado were grouped into broader classifications, as shown in Table 6. The ecoregions of Colorado are depicted in Figure 16.[15]

***Table 6: EPA Level III Ecoregion Groupings for Colorado***

| Mountains | Basins | Plains |
|---|---|---|
| Southern Rockies | Wyoming Basin | High Plains |
| - | Colorado Plateau | Southwestern Tablelands |
| - | Arizona/New Mexico Plateau | - |

[14] https://cnhp.colostate.edu/cwic/tools/toolbox/
[15] https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states

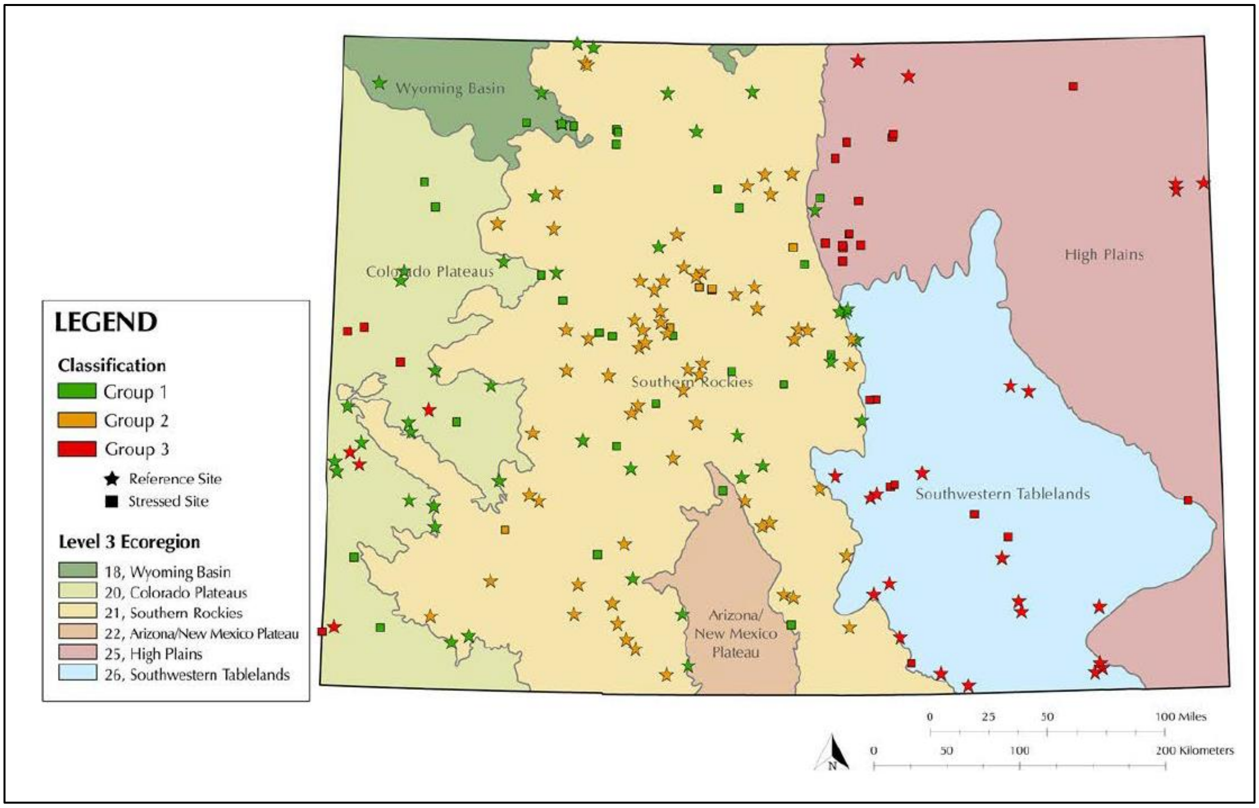



*Figure 16: Colorado Biotypes and EPA Level III Ecoregions (reproduced from Appendix A of CDPHE 2017)*

Biotype – Biotype is used to determine the correct reference curves for the chlorophyll α and macroinvertebrate metrics. Biotype is similar to, but distinct from, the ecoregions described above. Biotypes are defined by CDPHE to classify groups of streams with similar physical and biological traits (CDPHE 2017; "groups" as shown in Figure 16). Biotype is determined based on EPA Level IV ecoregion[16], elevation, and stream slope as shown in Table 7.

*Table 7: Site Biotype Classification Rules (reproduced from Appendix A of CDPHE 2017)*

| Criteria | Biotype 1 | Biotype 2 | Biotype 3 |
|---|---|---|---|
| EPA Level IV Ecoregions: | 21d, 21h, 21i, 21j, 25l, 26i | 21a, 21b, 21e, or 21g | All 25 and 26 Level IV Ecoregions except 25l and 26i |
| Slope: | 21c and slope < 0.04 ft/ft | 21c and slope > 0.04 ft/ft | - |
| Elevation: | 21f and elevation < 8,202 ft | 21f and elevation > 8,202 ft | Any ecoregion, elevation < 5,085 ft |

[16] https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states

Proposed Bankfull Width (ft) – Bankfull width is used for stratification of the baseflow depth metric and also serves as the denominator for the pool spacing ratio metric. The bankfull width is the width of a representative riffle (Section 2.6).

Stream Slope (%) – The CSQT uses stream slope to select the correct reference curves for percent riffle. The stream slope is a reach average and not the slope of an individual bed feature, e.g., a riffle. Field methods to determine stream slope are outlined in Appendix A.

River Basin – River Basin is used to select an appropriate fish species list for the number of native fish species metric. Colorado is subdivided into thirteen major river basins (Figure 17): Arkansas River, Colorado River, Republican River, Rio Grande River, South Platte River, North Platte River, Gunnison River, Cimarron River, Yampa River, Dolores River, Green River, San Juan River, and White River. Select the river basin that the project reach falls within.

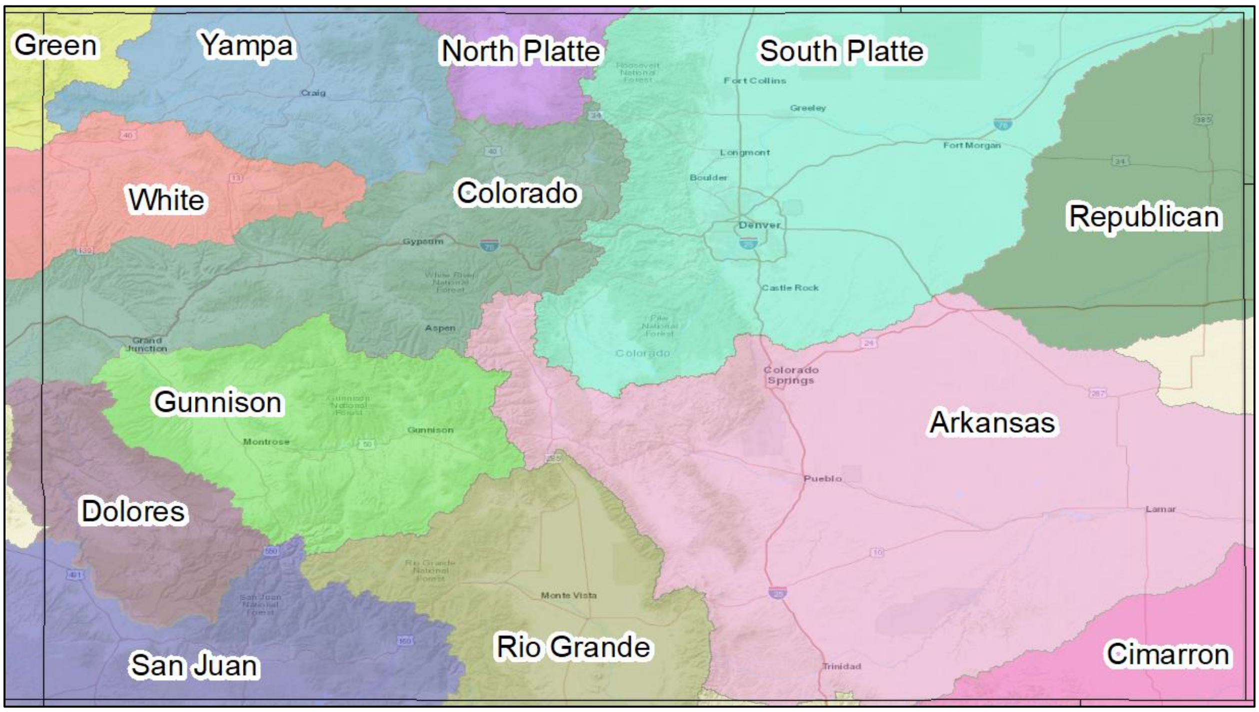



*Figure 17: Major River Basins in Colorado*

Stream Temperature – The stream temperature tier is used to determine the correct reference curve for the temperature parameter and the baseflow depth metric. Streams in Colorado are identified as cold streams (CS) or warm streams (WS) and classified by thermal tiers based on the most thermally sensitive species expected to occupy the reach in summer (Table 8). Within each river basin, streams are divided into segments and assigned temperature tiers. This information can be found in the "Stream Classifications and Water Quality Standards Tables" in the basin regulations (see Regulations 32 – 38).[17] These tables identify what temperature tier the segment is in. If the applicable temperature tier is not appropriate for the reach, a

[17] https://www.colorado.gov/pacific/cdphe/water-quality-control-commission-regulations

temperature tier should be selected based on the most thermally sensitive species that occupies the reach and justification provided for the alternate tier.

**Table 8: Stream Temperature Tiers based on Expected Species**

| Tier | Species Expected to be Present |
|---|---|
| CS-I MWF | Mountain whitefish early life stages (applied to spawning grounds only).<br>*Note: The early life stages include the pre-hatch embryonic period (egg), the post-hatch yolk-sac fry, and the larval period during which the organism first begins to feed. CPW aquatic biologists can help users identify mountain whitefish spawning grounds if this is the appropriate temperature tier.* |
| CS-I | Brook trout and cutthroat trout |
| CS-II | Brown trout, rainbow trout, mottled sculpin, mountain whitefish, and longnose sucker |
| WS-I | Common shiner, johnny darter, orangethroat darter, and stonecat |
| WS-II | Brook stickleback, central stoneroller, creek chub, longnose dace, northern redbelly dace, finescale dace, razorback sucker, white sucker, and mountain sucker. |
| WS-III | Arkansas darter, bigmouth shiner, black bullhead, bluegill, bluehead sucker, bonytail, brassy minnow, brown bullhead, channel catfish, Colorado pikeminnow, common carp, fathead minnow, flannelmouth sucker, flathead catfish, freshwater drum, green sunfish, horneyhead chub, Iowa darter, plains killifish, plains minnow, plains topminnow, orangespotted sunfish, pumpkinseed sunfish, quillback, red shiner, Rio Grande chub, Rio Grande sucker, river carpsucker, roundtail chub, sand shiner, smallmouth bass, smallmouth buffalo, southern redbelly dace, speckled dace, spottail shiner, western mosquitofish, and yellow bullhead |

Reference Vegetation Cover – Reference vegetation cover is used to determine whether to apply the woody or herbaceous cover metric. Reference vegetation cover represents the community that would occur naturally at the site if the reach were free of anthropogenic alteration and impacts. The following classifications are based on the community types described in Carsey et al. (2003):

- Woody sites are those whose reference standard condition is greater than or equal to 20% absolute cover of woody vegetation.
- Herbaceous sites are those whose reference standard condition would be less than 20% absolute woody cover.

A common reference vegetation cover is a scrub/shrub or forested system with greater than 20% woody vegetation cover, while some plains systems and other E channels may have an herbaceous reference condition with less than 20% woody vegetation cover. The appropriate reference community type can be determined by locating a similar pristine or minimally altered reference site within the catchment area or watershed, researching historical and ecological descriptions of mature and undisturbed vegetation communities in the vicinity, or deduced through understanding the effects of land use practices and management on vegetation communities. For example, many of the unconfined or partially confined alluvial mountain valleys in Colorado were likely dominated by woody riparian vegetation across the valley floor prior to anthropogenic human activities. Many of these systems are currently dominated by upland grasses.

Stream Productivity Class – The CSQT uses the stream productivity class to select the correct reference curves for the wild trout biomass metric. Baseline pre-project biomass data should be used to determine the productivity class. The high productivity class includes streams where current biomass is equal to or greater than 60 pounds per acre, which is the biomass criteria for a Gold Medal fishery in Colorado. The moderate productivity class ranges from 30-60 pounds per acre and the low productivity class includes streams that currently have less than 30 pounds per acre.

Valley Type – Valley type is used to stratify reference curves for riparian width. The valley type options are unconfined alluvial, confined alluvial, colluvial/v-shaped, or bedrock. Refer to glossary for definitions. In the CSQT workbook this cell is automatically populated from the Project Assessment worksheet.

Reference Stream Type – Reference stream type is used to stratify reference curves for entrenchment ratio and pool spacing ratio metrics. Refer to Section 2.2 for further instruction. In the CSQT workbook this cell is automatically populated from the Project Assessment worksheet.

Sediment Regime – Sediment regime is used to stratify reference curves for the bank height ratio metric. The sediment regime options are source, transport, and response. Refer to glossary for definitions. In the CSQT workbook this cell is automatically populated from the Project Assessment worksheet.

## 2.5 Parameter Selection

The CSQT workbook and Debit Calculator workbook include 29 metrics used to quantify 12 parameters. They also include a Flow Alteration Module that adds (or subtracts) functional feet to the reach score based on the magnitude of flow alteration within a larger, hydrologically affected reach.

Not all metrics and parameters will need to be evaluated at each site. The user should consider landscape setting, process drivers, function-based goals/objectives, and restoration potential when selecting parameters.

**A basic suite of metrics within 5 parameters are required at all project sites evaluated for CWA 404 purposes** to provide consistency between impacts and compensatory mitigation and allow for more consistent accounting of functional change. The basic suite of metrics includes metrics within the reach runoff, floodplain connectivity, lateral migration, riparian vegetation, and bed form diversity parameters. Note, for ephemeral and/or multi-thread sites, the bed form diversity parameter should not be evaluated. Application of the basic suite of metrics is considered rapid, as field data can be collected by a team of 2 in less than a day. Additional metrics may require more time in the field.

A parameter selection checklist is provided in Appendix B and should be completed for each project reach using the guidance in this section.

***Important Considerations:***

- For CWA 404 projects, the Corps has discretion over which field methods, metrics, and parameters are used for a project. Users should complete the Parameter Selection Checklist and consult with the Corps prior to data collection on a project.
- The same parameters must be used in the existing condition and all subsequent condition assessments (i.e., proposed, as-built, and monitoring) within a project reach, otherwise the relative weighting between metrics and parameters changes and the CSQT output is not comparable over time.
- For metrics that are not selected, the metric is not included in the scoring. **Users should not enter field values for metrics that were not selected or evaluated.**
- The overall scores should not be compared or contrasted between sites when parameters and metric selection varies between project sites. To evaluate multiple sites, the same suite of parameters and metrics would need to be collected at all sites.
- Field methods in Appendix A are focused on single-thread, wadeable streams. Some metrics may be difficult to sample in non-wadeable or multi-thread systems and may require alternate field methodologies. For CWA 404 projects, sampling plans in these systems should be discussed with the Corps prior to data collection efforts.
- Reference curves to assign index values have been primarily derived from data within perennial, wadeable, single-thread stream systems. When applying metrics in other stream situations, the user should note this and select only applicable parameters and metrics (Table 9). While a parameter and associated metrics may be applicable to ephemeral and multi-thread channels, reference curves were not developed specifically for these systems. Therefore, more focus should be placed on the difference in pre- and post-project scores rather than the absolute value.

***Table 9: Applicability of metrics across flow permanence and in multi-thread systems. An 'x' denotes that one or more metrics within a parameter is applicable within these stream types.***

<table>
<tr><th>Applicable Parameters</th><th>Perennial</th><th>Intermittent</th><th>Ephemeral</th><th>Multi-thread Channels</th></tr>
<tr><td>Reach Runoff</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Flow Alteration</td><td>x</td><td>x</td><td></td><td>x</td></tr>
<tr><td>Baseflow Dynamics</td><td>x</td><td></td><td></td><td></td></tr>
<tr><td>Floodplain Connectivity</td><td>x</td><td>x</td><td>x</td><td>x (BHR only)</td></tr>
<tr><td>Large Wood*</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Lateral Migration</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Bed Form Diversity</td><td>x</td><td>x</td><td></td><td></td></tr>
<tr><td>Riparian Vegetation</td><td>x</td><td>x</td><td>x</td><td>x</td></tr>
<tr><td>Temperature</td><td>x</td><td rowspan="4">Where baseflows extend through sampling period</td><td></td><td>x</td></tr>
<tr><td>Dissolved Oxygen</td><td>x</td><td></td><td>x</td></tr>
<tr><td>Nutrients</td><td>x</td><td></td><td>x</td></tr>
<tr><td>Macroinvertebrates</td><td>x</td><td></td><td>x (perennial only)</td></tr>
<tr><td>Fish</td><td>x</td><td>x</td><td></td><td>x</td></tr>
<tr><td colspan="5">* May not be applicable if large wood is not naturally present in the system.</td></tr>
</table>

***Specific guidance on parameter selection:***

Reach Runoff Parameter – This parameter should be evaluated at all project sites. Both metrics should be evaluated together.

Baseflow Dynamics Parameter – This parameter is optional and is only applicable in single-thread, intermittent or perennial cold streams (CS; see Stream Temperature in Section 2.4) that have or are proposed to have regulated flow (see catchment assessment Section 2.3). This parameter is recommended where hydraulic conditions during summer/fall baseflow periods may not support trout assemblages under existing or proposed conditions due to flow or channel alteration. Both metrics should be evaluated together.

Floodplain Connectivity Parameter – This parameter should be evaluated at all project sites. Users should evaluate both the bank height ratio (BHR) and entrenchment ratio (ER) metrics, except in multi-thread systems, where the BHR should be applied alone. Entrenchment ratio characterizes the horizontal extent of the floodplain while BHR characterize the frequency of floodplain inundation.

The percent side channels metric is optional and is only applicable in alluvial valleys where side channels could be supported. This metric should not be applied in multi-thread systems. Colluvial, confined, and steeper systems tend to be unable to support side channels. This metric would be applied in addition to BHR and ER as noted above.

Large Woody Debris (LWD) Parameter – This parameter is optional and is recommended where the upstream watershed or adjacent land area naturally support, or historically supported, trees large enough to produce LWD. This parameter is not applicable to streams that lack forested catchments or riparian gallery forests, or otherwise naturally have a limited supply of LWD. Users can evaluate either the Large Woody Debris Index (LWDI) or large wood piece count metric, but not both. The LWDI metric better characterizes the complexity of large wood in streams but takes more time to assess. For willow-dominated sites, the LWDI may be preferable, as it includes willow debris jams in the index, while the large wood piece count does not.

Lateral Migration Parameter – This parameter should be evaluated at all project sites. Users should evaluate either the Greenline Stability Rating (GSR) metric or the dominant BEHI/NBS and percent erosion metrics together. The percent armoring metric should be applied in addition to the other metric(s) when armoring techniques are present or proposed in the project reach. Refer to Figure 18.

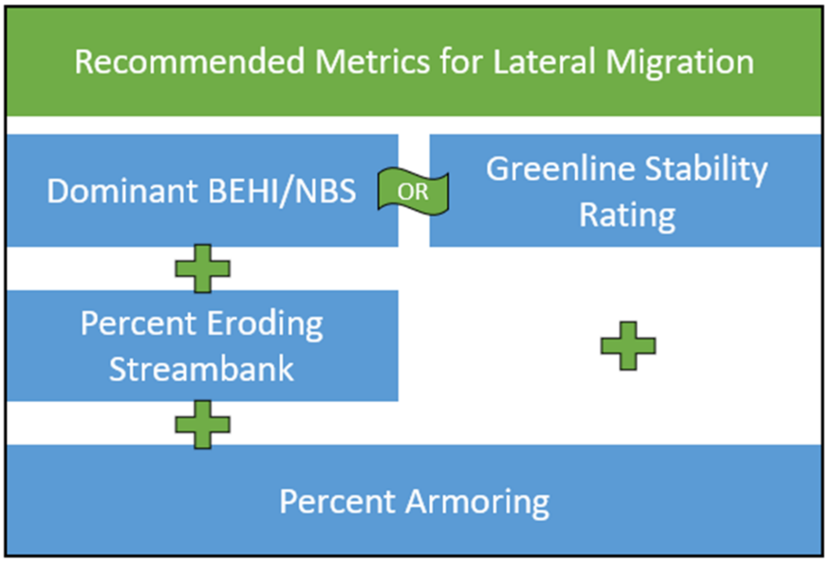



*Figure 18: Metric Selection Guidance for Lateral Migration Parameter*

The GSR metric is applicable in all streams with less than 4% slope and is an alternative to dominant BEHI/NBS and percent erosion, including streams that are naturally in disequilibrium, like some systems with naturally high rates of bank erosion or response systems (e.g. braided streams, ephemeral channels, or alluvial fans). GSR is not applicable in highly modified streams where natural and artificially hardened banks are less susceptible to vegetation influences; or in large rivers where landform features play the dominant role in regulating hydrologic influences.

The dominant BEHI/NBS and percent erosion metrics are applicable in single-thread channels. The dominant BEHI/NBS characterizes the magnitude of bank erosion, while percent erosion characterizes the extent of bank erosion within a reach. These metrics are not recommended in systems with naturally high rates of bank erosion or response systems (e.g. braided streams, ephemeral channels, or alluvial fans).

The percent armoring metric should be applied whenever man-made armoring is present or proposed in a project reach. Note that for project reaches where armoring exceeds 50% of the total bank length, the parameter will score a 0.00 and other metrics may not need to be assessed.

Bed Form Diversity Parameter – This parameter should be evaluated at all single-thread perennial and intermittent project sites. Users should evaluate pool spacing ratio, pool depth ratio, and percent riffle metrics together, except natural bedrock systems where the pool spacing ratio would not apply. The aggradation ratio metric is optional.

The aggradation ratio metric is recommended for meandering single-thread stream types in transport settings where the riffles are exhibiting signs of aggradation. The metric is not recommended in source or response reaches.

Riparian Vegetation Parameter – This parameter should be evaluated at all project sites. Users should determine whether the reference community type is herbaceous or woody and evaluate either herbaceous vegetation cover or woody vegetation cover, respectively. Riparian extent and relative native cover should be evaluated at all sites. Refer to Figure 19.

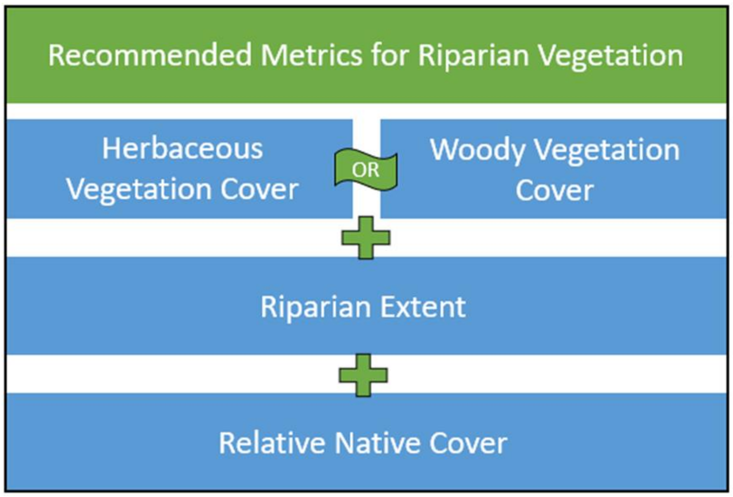



***Figure 19: Metric Selection Guidance for Riparian Vegetation Parameter***

Temperature, Dissolved Oxygen, and Nutrients Parameters[18] – These parameters are optional and are recommended for projects with goals and objectives related to water quality improvements or projects where improvements to these parameters are anticipated based on restoration potential. One or more parameters can be applied at a project site. These parameters are applicable in perennial and intermittent streams (including multi-thread) where baseflows extend through August.

The metric for the nutrients parameter is applicable in most streams where baseflow extends through August except those with consistently turbid water.

Macroinvertebrates Parameter[13] – This parameter is optional and is recommended for projects in perennial and intermittent streams (including multi-thread) that have goals and objectives related to biological improvements or projects where improvements in biological condition are anticipated based on restoration potential.

[18] Without evaluating the physicochemical and biological parameters, the maximum overall score in the CSQT will be 0.60. Selecting and assessing parameters in both physicochemical and biological functional categories will increase the maximum overall score to 1.0 in the CSQT.

Fish Parameter[19] – This parameter is optional and is recommended for projects in perennial and intermittent streams (including multi-thread) that have goals and objectives related to fisheries improvements. These metrics could also be required for development projects that are likely to result in functional loss in priority conservation areas or other valuable fish habitats. Consultation with an area fish biologist at CPW is highly recommended prior to selecting this parameter. Selection and sampling of a control/reference reach is required for the wild trout biomass metric. Users can either apply the native species and SGCN metrics together or the wild trout biomass metric; refer to Figure 20. Additional guidance on metric selection follows:

1. The native species richness and SGCN metrics should be applied together at sites where project goals and CPW management objectives relate to native fish species restoration.
2. The wild trout biomass metric should be applied at sites where project goals and CPW management objectives relate to game fish species enhancement.

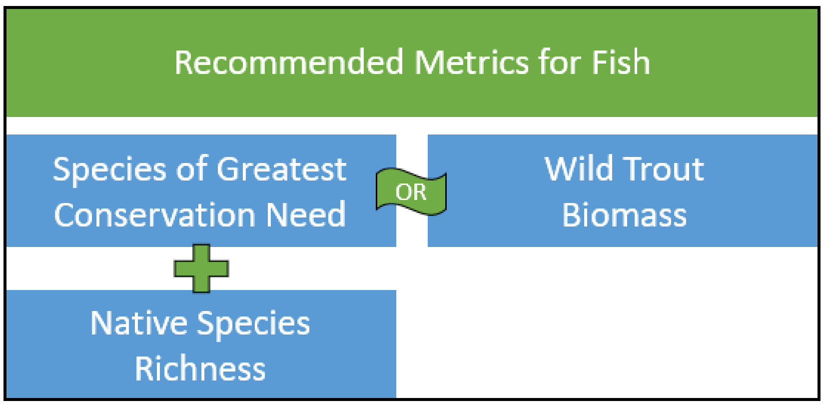



*Figure 20: Metric Selection Guidance for Fish Parameter*

Flow Alteration Module: This module is optional and provisional. The module can be used to calculate change in hydrologic condition where there are available flow records and the project entails changes in operational commitments, acquisition/ change of existing water rights, or new facilities that enable the proposed hydrology to occur within a specific length of stream. Metric selection within the module is discussed in Section 2.11.

[19] Without evaluating the Physicochemical and Biological Parameters, the maximum overall score in the CSQT will be 0.60. Selecting and assessing parameters in both functional categories will increase the maximum overall score to 1.0 in the CSQT.

## 2.6 Bankfull Identification and Verification

Bankfull discharge 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). Correctly identifying bankfull stage is crucial, and the user should identify and verify bankfull using multiple lines of evidence. Bankfull stage and bankfull dimensions are needed to calculate field values for several metrics, including bank height ratio, entrenchment ratio, large woody debris index, dominant BEHI/NBS, pool spacing ratio, pool depth ratio, and aggradation ratio. Additionally, the CSQT uses bankfull in the definition of side channels; in identifying the length of the representative sub-reach; and delineating the expected riparian width.[20]

Bankfull identification should be performed by professionals with a background in geomorphology and the necessary experience to accurately complete the methods described here. Bankfull discharge modeling and return interval calculations should be performed by engineers or hydrologists with experience with hydrologic and hydraulic modeling in Colorado, including the modeling of water diversions and withdrawals.

Users should apply the following hierarchical method to verify bankfull indicators and to calculate bankfull dimensions and discharge. A flow chart is provided to guide users through the decision-making process (Figure 21). The flow chart and methods described below are not exhaustive and other methods may be presented to the Corps for approval. **Method 1** is used when field indicators are present and bankfull is not affected by flow alteration; it includes a combination of field indicators and regional curves. **Method 2** is used when bankfull indicators are present, but flow alteration is suspected; it includes a combination of field indicators and return interval analysis. **Method 3** is used when indicators are not present; it includes stream surveys, bankfull regional curves if available, and modeling.

**Bankfull verification should be documented on the Bankfull Verification Form provided in Appendix B.**

[20] Depending on the valley setting, there are alternative methods that do not rely on bankfull for determining the assessment sub-reach length and expected riparian width.

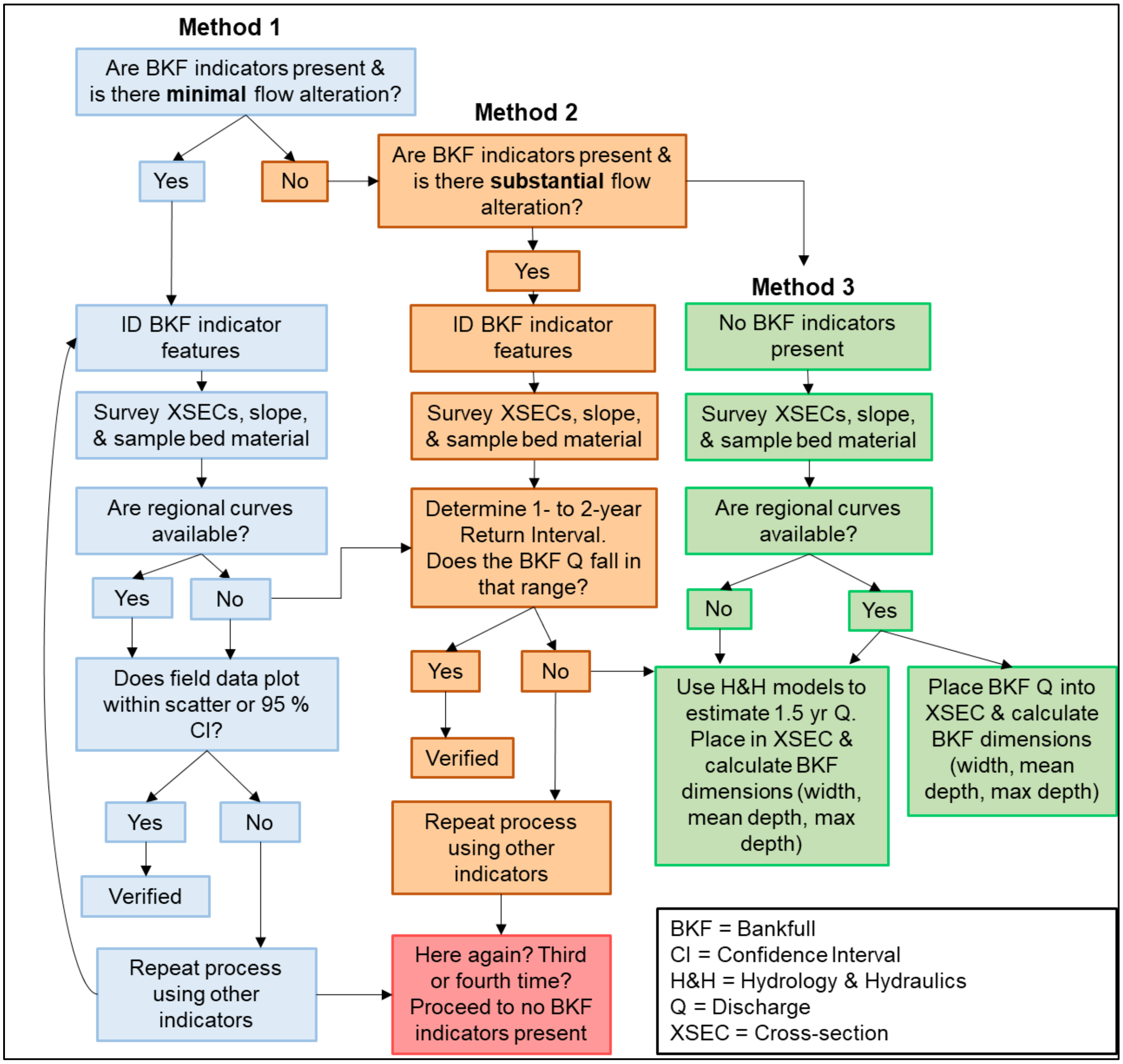



*Figure 21: Bankfull Verification Flow Chart depicted three methods for bankfull verification.*

### *Method 1*

Note that this method cannot be used without an applicable regional curve. If none exist and the practitioner will not develop one for the site/watershed, proceed to Method 2.

Users should first determine if bankfull indicators are present along the project reach. If bankfull indicators are present, the user will also need to determine if flow alteration within the watershed is significant enough to alter the return interval associated with the feature. The user should look for signs of flow alteration, e.g., diversion dams, water storage reservoirs, hydroelectric power operations or trans-basin diversions (refer to Section 2.3 Flow Alteration sub-heading). If bankfull indicators are present and the bankfull discharge is not affected by flow alteration, the following steps should be followed:

1. **Identify Field Indicators:** Bankfull stage or elevation data should be collected in the field. Field methods are included in Section 3 of Appendix A, which includes quality control for field identification of bankfull features, descriptions of primary and secondary field indicators, and methods to be followed for the entire reach.

2. **Survey Riffle Cross-sections, Slope, & Sample Bed Material:** The cross-section(s) should be representative of the channel width and depth for the reach. The user is encouraged to find a representative riffle to survey for bankfull verification where possible (refer to Section 3 of Appendix A). Field data collection includes:

    - Surveying cross-sections at riffles or crossover features, preferably where the thalweg is in the center of the channel. The cross-section should extend across the bankfull channel.
    - Surveying average channel slope, and
    - Bed material samples collected from the same riffle that includes the cross-section survey; these values are used to estimate bed roughness and the bankfull discharge calculation.[21]

3. **Process data from Step 3:** Using the data collected above, calculate bankfull discharge and bankfull dimensions of area, width, and mean depth. The CSQT does not require or promote a single software to analyze cross-sections. 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 (DNR) is a free, user-friendly tool that will calculate discharge, entrenchment ratio, and several other hydraulic variables.[22] Note that a hydraulic model can also be used to determine the discharge that fills the channel throughout a project reach. The Hydrologic Engineering Center River Analysis System (HEC-RAS) is a free hydraulic modeling software but is best used by experienced hydrologists and engineers.[23]

4. **Regional Curves:** Compare the measured bankfull dimensions from surveyed riffles to regional curve(s). The field data for the site, particularly the cross-sectional area, should fall within the range of scatter or 95% confidence limits of the regional curve for bankfull to be verified.

    Due to the range of climatic conditions and underlying geology, regional curves can vary significantly throughout the state. Regional curves should only be used when they are applicable to the project site. Ideally, users may develop site-specific regional curves representative of the project catchment. Resources for regional curves within Colorado include Torizzo and Pitlick (2004), Blackburn-Lynch et al. (2017), and UDFCD (2016).

If the bankfull cross-sectional area from the surveyed cross-section plots outside the range of scatter on the regional curve, the user should look for other potential bankfull indicators and repeat the process.

[21] Bed material samples can be used to calculate a Manning's 'n' roughness value. Field measurements of velocity taken during a flow at or near bankfull can be used instead of bed material samples.
[22] The spreadsheet is available at https://stream-mechanics.com/stream-functions-pyramid-framework/ under spreadsheet tools.
[23] https://www.hec.usace.army.mil/software/hec-ras/

- 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.
- If no indicators fall within the range of scatter, the user should move to the Method 3.

If regional curves are not available for the project watershed, the user should move to Method 2, step 3 in the flow chart.

***Method 2***

If bankfull indicators are present along the project reach but flow alteration in the watershed has changed the return interval associated with the feature, then Method 2 should be used. Method 2 should also be used if the user did not find or develop regional curves that represent the project watershed. Without regional curves bankfull cannot be verified using Method 1.

1. **Identify Field Indicators:** See above (Method 1, step 1)

2. **Survey Riffle Cross-sections and Estimate Bankfull Discharge:** See above (Method 1, steps 2 and 3).

3. **Return Interval Determination:** The user should determine discharges associated with the 1.01- to 25-year return interval. Users should apply the standard procedure for estimating flood frequency, a log Pearson frequency analysis as described in Bulletin 17B (Interagency Advisory Committee on Water Data 1982).

   The program PeakFQ implements the Bulletin 17C procedures for flood-frequency analysis of streamflow records.[24] One of the simplest methods to determine return intervals, or flood frequency, for unregulated streams in Colorado is StreamStats.[25] The minimum return interval reported by StreamStats is the 2-year discharge so the user will need to develop a return interval versus discharge curve and extrapolate down to determine the lower return intervals. Projects that have altered or otherwise complicated hydrology cannot use StreamStats and should include more robust hydrologic analyses, such as hydrologic models to estimate peak flow discharges and return intervals or developing empirical relationships from a nearby gage station. Refer to UDFCD (2016) for considerations in estimating return interval (return period) in urban settings.

The common range of bankfull return intervals for perennial streams 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 can be verified. If not, proceed to Method 3. Note, in Method 2, the user can verify a bankfull feature with a return interval slightly above 2.0 if sufficient justification is presented to and accepted by the Corps.

***Method 3***

Method 3 should be used if bankfull indicators are not present in the project reach due to reach-wide instability or the calculated return interval in the Method 2 was greater than 2.0 years (and justification for the higher return interval is not provided). It should be noted that Method 3

[24] https://water.usgs.gov/software/PeakFQ/
[25] https://streamstats.usgs.gov/ss/

estimates bankfull discharge and dimensions from watershed hydrology and reach hydraulics and the method does not 'verify' a bankfull feature, e.g., floodplain elevation.

**Method 3 does not include field identification of bankfull and an explanation should be provided on the Bankfull Verification Form provided in Appendix B.**

1. **Survey Riffle Cross-sections, Slope, & Sample Bed Material:** See above (Method 1, step 2). A representative riffle cross-section must be surveyed whether there are bankfull indicators or not. The only difference between this survey and the other methods is there may be few or no bankfull features identified in the cross-section.

2. **Bankfull Discharge from Regional Curves:** If regional curves representing the project watershed are available, the bankfull discharge from the regional curve can be used to calculate bankfull dimensions in the project reach. The bankfull discharge estimated from the regional curve is placed in the cross-section from step 1 using a single-section analyzer or other tool to estimate the bankfull dimensions, i.e. bankfull area, width, and mean depth (see Method 1, Step 3).

   Due to the range of climatic conditions and underlying geology, regional curves can vary significantly throughout the state. Regional curves should only be used when they are applicable to the project site. Ideally, users could develop site-specific regional curves representative of the project catchment. Resources for regional curves within Colorado include Torizzo and Pitlick (2004), Blackburn-Lynch et al. (2017), and UDFCD (2016).

3. **Bankfull Discharge from Hydrologic Models:** If bankfull regional curves are not available, use hydrologic models to estimate the 1.5-year discharge to use as a surrogate for the bankfull discharge. Apply the 1.5-year discharge to the surveyed riffle cross-section(s) and calculate bankfull dimensions (area, width, mean depth). Refer to UDFCD (2016) for considerations relevant to hydrologic modeling in urban settings.

When regional curves are available, the bankfull dimensions calculated from steps 2 and 3 can be compared. Otherwise, the results from step 3 should be used to calculate field values, identify side channels, determine the assessment sub-reach length, and expected riparian area as needed based on parameter selection.

## 2.7 Reach Hydrology and Hydraulics Functional Category Metrics

There is one function-based parameter to assess reach-scale hydrology functions: reach runoff. There are two function-based parameters to assess hydraulic functions: baseflow dynamics and floodplain connectivity. Not all parameters will be evaluated for all projects. Refer to Section 2.5 of this manual for recommendations on when to apply each parameter and metric.

### 2.7.1 Reach Runoff

**Definition:** The reach runoff parameter evaluates the infiltration and runoff processes of the land that drains laterally into the stream reach. The lateral drainage area (Figure 22) is the portion of the reach catchment that drains directly to the reach from adjacent land uses.

The reach runoff parameter consists of two metrics: land use coefficient and concentrated flow points.

**Experience Requirements:** Data collection for reach runoff metrics should be performed by professionals with experience in GIS or other spatial analysis software.

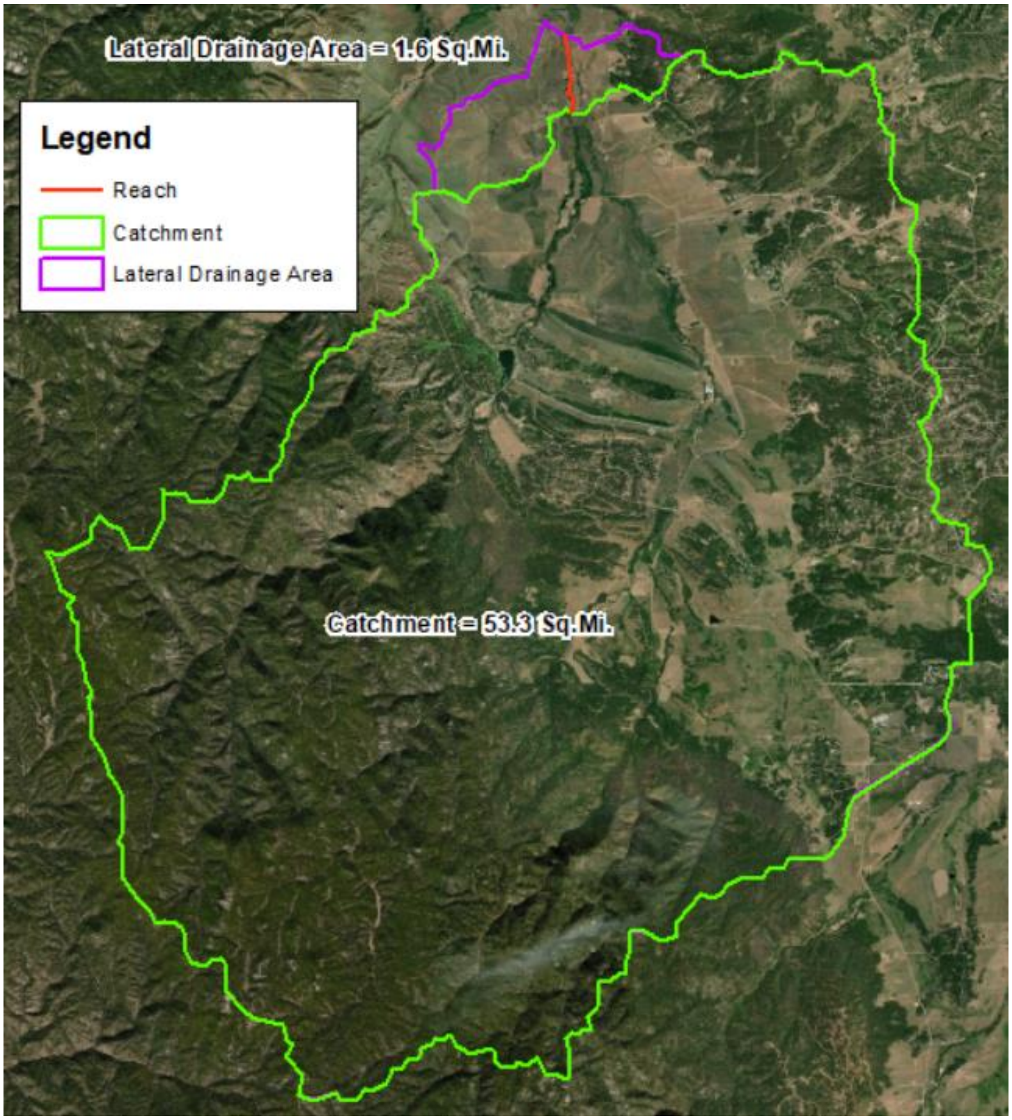



***Figure 22:*** ***Lateral Drainage Area for Reach Runoff.*** *The purple line delineates the upgradient extent of the land draining to the project reach (i.e., 1.6 mi$^2$).*

## *Land Use Coefficient*

Land use data can serve as a surrogate for runoff potential and infiltration. Vegetation removal and land cover change alters evapotranspiration, infiltration, and interception volumes, snowpack distribution, and runoff processes.

**Definition:** An area weighted land use coefficient serves as an indicator of runoff potential from land uses draining into the project reach between the upstream and downstream end points. Higher values, nearer 100, indicate more runoff potential while lower values, nearer 0, indicate less runoff. Land use coefficients are shown in Table 10.

***Table 10: Land Use Coefficients. Adapted from NRCS (1986).***

| 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* [26] | |
| Open space (for example lawns, golf courses, parks, etc.) | 61 |
| Impervious surfaces (roofs, driveways, streets, parking lots, etc.) | 98 |
| *Agricultural Lands* | |
| Pasture, grassland, or range | 61 |
| Cropland | 74 |

**Method:**

1. Delineate the lateral drainage area adjacent to the project reach and calculate the total lateral drainage area (Figure 22). Record the lateral drainage area on the Field Value Documentation Form in Appendix B.
2. Using the USGS National Land Cover Database (NLCD) or recent aerial imagery, delineate the different land use types within the lateral drainage area and calculate the area occupied by each type listed in Table 10. Record these areas on the Field Value Documentation Form in Appendix B along with a note describing the source of the land cover data.
3. Using Table 10, assign each land use type a land use coefficient value.
4. 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 (see 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.

[26] UDFCD (2016) provides percent imperviousness values for typical urban land uses, if needed.

### *Concentrated Flow Points*

Anthropogenic impacts can lead to concentrated flows that accelerate storm runoff routing, erode soils, and transport sediment into receiving stream channels. Anthropogenic causes of concentrated flow may include agricultural drainage ditches, impervious surfaces, storm drains, and others (Example 7).

**Definition:** Concentrated flow points are defined as storm drains, outfalls or erosional features, such as swales, gullies or other channels that are created by anthropogenic impacts.

***Example 7: Concentrated Flow Points***

*An agricultural ditch draining water from an adjacent field into a project reach.*

Natural ephemeral tributaries and outlets of stormwater best management practices (BMPs) are not considered concentrated flow points in this method.

**Method:** This metric assesses the number of concentrated flow points (CFP) that enter the project reach per 1,000 linear feet of stream.

$$\text{CFP / 1000 ft} = \frac{\#\ CFPs}{Proposed\ Reach\ length\ (ft)} * \ 1000\ ft$$

1. Review terrain and aerial imagery of the lateral drainage area to identify natural drainages and potential concentrated flow points before going in the field.
2. Walk the **entire project reach**, including both sides of the stream channel, and record any observed concentrated flow points on the Project Reach form (Appendix B).
3. Normalize the number counted using the equation above.

**Estimating proposed condition field values:** Proposed field values for this metric can be calculated based on anticipated changes to concentrated flow points in the project area associated with the proposed project. Stream restoration projects may reduce concentrated flow entering the channel by dispersing flow in the floodplain, increasing ground cover near the channel, or by installing stormwater best management practices within the project area. *Combining multiple concentrated flow points 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 constructed wetlands, and other stormwater control measures.

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

### 2.7.2 Baseflow Dynamics

**Definition:** This parameter characterizes habitat conditions within the reach during baseflow. Baseflow ($Q_{baseflow}$), measured in cubic feet per second (cfs), is defined as the average of the mean daily flow values during the low flow period occurring in the late summer and early fall of the monitoring year.

There are two metrics to assess baseflow dynamics: average velocity and average depth. Terms used to derive field values for these metrics are shown in Figure 23.

**Experience Requirements:** Data collection and analysis for baseflow dynamics metrics should be performed by professionals that have experience with standard survey techniques, at-a-station hydraulic analysis, gage installation and water level monitoring, and measuring velocity in-situ.

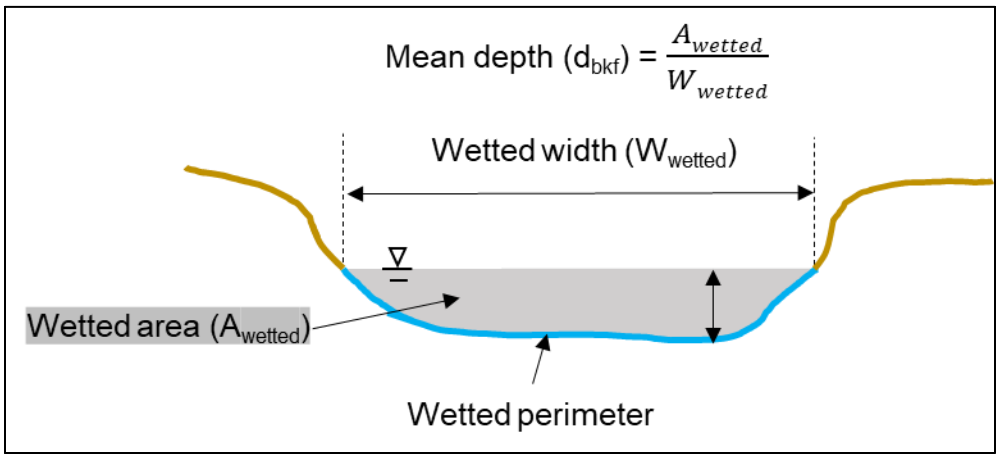



*Figure 23: Wetted Dimensions for Baseflow Dynamics*

#### *Average Velocity*

**Definition:** Average velocity is the baseflow discharge divided by the area wetted at the baseflow discharge for a cross-section. Velocity measurements may be collected in order to develop a stage-discharge relationship and can serve as a quality check for the calculated values within the reach.

This metric uses the continuity equation to determine the average cross-section velocity (V) from three riffles within the reach for the baseflow discharge ($Q_{baseflow}$).

$$Velocity = {Q_{baseflow}}/{A_{wetted}}$$

Where $A_{wetted}$ (sf) is the wetted cross-sectional area of the cross-section at $Q_{baseflow}$ (cfs).

**Method:** To determine the field value for velocity (measured in feet per second; ft/s):

1. Determine baseflow discharge using existing stream gage data or monitoring stream flow gages during the late summer and early fall of the monitoring year. Appendix A provides

information on gage installation to measure flow, and best practices for developing stage-discharge relationships.

Record the baseflow discharge on the Field Value Documentation Form in Appendix B and describe in the note the data used to calculate this value (i.e. period or record and whether onsite gage was installed).

2. Survey a minimum of three riffle cross-sections within the reach using standard survey protocols. Appendix A provides rapid survey instructions using hand or laser-levels, but other survey protocols are acceptable (e.g., survey grade GPS). Station and elevation data must be collected to accurately plot cross-sections and calculate baseflow dimensions.
3. Process survey data to determine the cross-sectional area wetted at baseflow at each riffle cross-section. Record the wetted area for each cross section and note the survey method and any post-processing tools used on the Field Value Documentation Form in Appendix B.
4. Calculate the average velocity for each cross-section using the equation above. Average the values from the three cross-sections to calculate the field value for the velocity metric in the CSQT. Record the average velocity for each cross section on the Field Value Documentation Form in Appendix B.

**Estimating proposed condition field values:** This metric is intended to capture changes in velocity associated with changes to channel cross-section dimensions. Therefore, proposed conditions can be determined by analyzing baseflow data within the proposed channel cross-section. Alterations to the bankfull channel dimensions can improve baseflow depth and velocity where existing channels are overly wide. Alternatively, proposed channels that remove an inner berm feature or widen the channel can reduce velocity.

Note that it is also possible to apply this metric where there are changes in the baseflow discharge ($Q_{baseflow}$). In this case, users should estimate the anticipated baseflow in the channel using hydrologic and hydraulic assessments. Since annual variations in climate may alter the $Q_{baseflow}$, care should be taken to determine whether increases in $Q_{baseflow}$ are a result of the project (e.g. increased return flows or decreased groundwater pumping agreement with land owner) rather than variations in climate.

### Average Depth

**Definition:** Average depth is the area wetted at the baseflow discharge divided by the wetted width of the cross-section (Figure 23). The average depth is calculated from three surveyed cross-sections. This metric uses cross-section geometry to determine the average cross-section depth (d) at riffles within the reach for the baseflow discharge ($Q_{baseflow}$).

$$\text{Mean depth } (d_{bkf}) = {}^{A_{wetted}}/_{W_{wetted}}$$

Where $A_{wetted}$ (sf) is the wetted cross-sectional area of the cross-section at $Q_{baseflow}$ (cfs) and $W_{wetted}$ (ft) is the top width of the cross-section at $Q_{baseflow}$.

**Method:** To determine the field value for average depth (ft):

1. Follow Steps 1-3 for the average velocity metric (see above section).

2. Calculate the average depth for each cross-section using the equation above. Average the values from the three cross-sections to calculate the field value for the average depth metric in the CSQT. Record the wetted width and average depth for each cross section and note the survey method and any post-processing tools used on the Field Value Documentation Form in Appendix B.

**Estimating proposed condition field values:** This metric is intended to capture changes in depth associated with changes to channel cross-section dimensions. Estimating proposed condition field values for this metric are the same as for the average velocity metric in the section above.

### 2.7.3 Floodplain Connectivity

**Definition:** The floodplain is the area adjacent to the channel that is inundated during overbank flow events. This parameter includes metrics that evaluate whether flows can access, and the extent to which they access the floodplain, and the occurrence of side channels within the floodplain.

There are three metrics to assess floodplain connectivity: bank height ratio (BHR), entrenchment ratio (ER), and percent side channels.

**Experience Requirements:** Data collection for floodplain connectivity metrics should be performed by professionals that have experience with standard survey techniques and experience with identification and verification of bankfull.

#### *Bank Height Ratio (BHR)*

**Definition:** The bank height ratio (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 at riffles and calculated as the low bank height (LBH) divided by the bankfull riffle maximum depth (also referred to as bankfull maximum 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.

Typically, bank height ratios will be 1.0 or greater, meaning that bankfull is equal to or higher than the top of the streambank. In systems experiencing aggradation, either due to natural processes or because of changes in sediment supply or transport, it is possible for the bank height ratio to be less than 1.0 (Example 8).

> ***Example 8: Transport systems with BHR less than 1.0***
>
> In transport gravel/cobble systems, severe aggradation can occur when sediment supply exceeds transport capacity. Visual evidence is typically gravel deposits on the floodplain, and sometimes channel formation (erosion) on the floodplain. For the ratio to be below 1.0, bankfull maximum depth is greater than the low bank height, so the bankfull discharge is not contained within the channel. In this case, the bankfull feature may be located at the edge of the valley bottom.

**Method:** Prior to calculating this metric, users need to complete the bankfull verification process (Section 2.6).

At every riffle within the representative sub-reach:

1. Measure the length of the riffle (refer to glossary for the definition of a riffle). Record the length of each riffle and note the survey method and any post-processing tools used on the Field Value Documentation Form in Appendix B.

2. Identify the bankfull elevation and low bank feature. The bankfull verification process (Section 2.6) should be used to identify the bankfull elevation. For low bank height, identify the break between the channel and a floodplain or terrace on both sides of the stream and identify the bank with the lower elevation.

In incised channels with a bankfull bench, determining when bankfull and the top of bank are equal to each other can be challenging. Two common scenarios are detailed below (following Example 9) to aid users in low bank identification.

3. At the approximate mid-point of the riffle, record the difference between the low bank elevation and the thalweg elevation (low bank height). Note, when the low bank elevation and the bankfull elevation are the same, the BHR equals 1.0.
4. Record the difference between the bankfull elevation and the thalweg elevation (bankfull maximum depth).
5. Calculate the BHR for that riffle by dividing the low bank height (step 3) by the bankfull maximum depth (step 4). Record the BHR at each riffle and note the survey method and any post-processing tools used on the Field Value Documentation Form in Appendix B.

Standard survey protocols are required to collect accurate elevation data for steps 2 and 3 above. Appendix A provides rapid survey instructions using a tape and hand or laser-levels. Other survey protocols are acceptable (e.g. survey grade GPS) provided that accurate elevation data can be obtained to calculate bank height ratio.

6. Using the BHR and riffle length for every riffle feature within the representative sub-reach, calculate the weighted BHR using the equation below and Example 9. The weighted BHR should then be entered in the CSQT.

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

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

***Example 9: 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 | | | |

Scenario 1 – If the bankfull elevation is identified as the back of the bench as shown in Figure 24, then the low bank feature is the top of the left bank in the cross section shown.

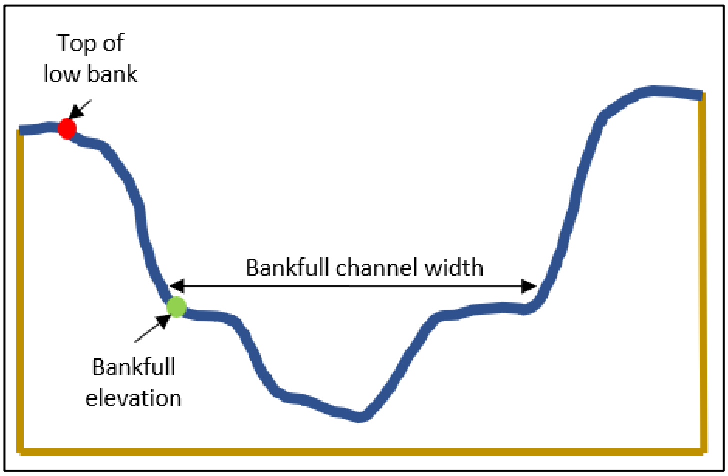



***Figure 24: Incised Stream Scenario 1, where bankfull elevation and low bank elevation are not equal.***

Scenario 2 – If the bankfull elevation is identified as the front of the bench as shown in Figure 25, then the width of the bankfull bench(es) must be considered before the low bank feature can be determined.

- For C/E reference stream types, if the total width (left bench + bankfull channel + right bench) is greater than 2.2 times the bankfull channel width, then the low bank feature is equal to bankfull (shown as the green dots in Figure 25).
- For B reference stream types, if the total width is greater than 1.4 times the bankfull channel width, then the low bank feature is equal to bankfull (shown as the green dots in Figure 25).
- If total width is lower than the 2.2 for C/E reference stream types or 1.4 for B reference stream types, then the low bank feature is top of the left bank (shown as the red dot in the cross section shown in Figure 25).

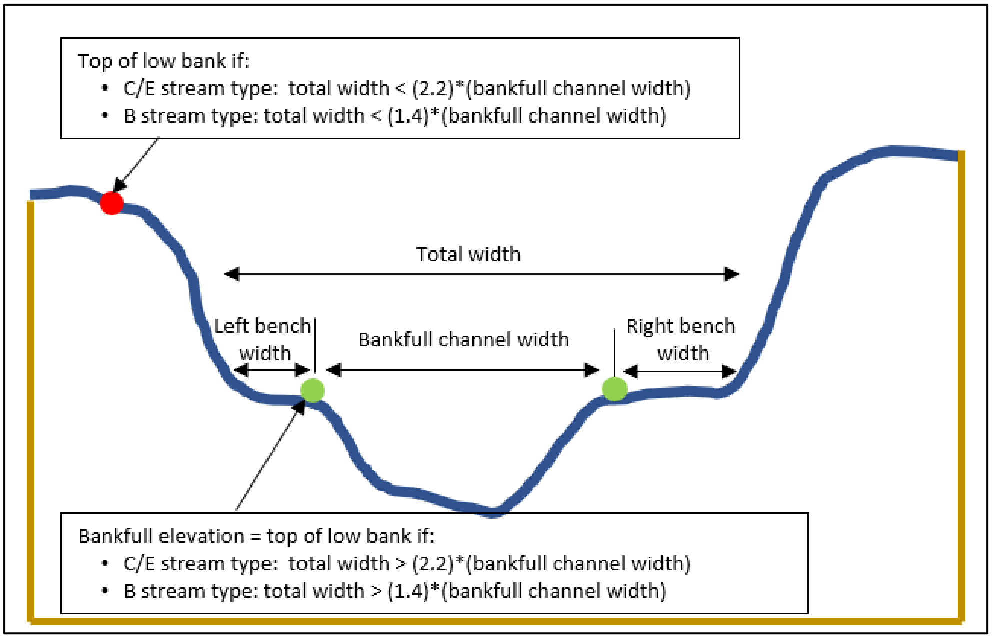



*Figure 25: Incised Stream Scenario 2, where the width of bankfull benches determine low bank elevation. The green or the red dot can indicate the top of low bank.*

**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 consider any proposed activities that may alter the cross-section or longitudinal profile, including floodplain excavation and construction of berms or levees.

### *Entrenchment Ratio (ER)*

**Definition:** An entrenchment ratio characterizes the vertical containment of the river by evaluating the ratio of the flood-prone width to the bankfull channel width measured at a riffle cross-section (Rosgen 1996). This metric is described in detail 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 riffle maximum depth.

$$ER = \frac{Flood - Prone\ Width}{Bankfull\ Channel\ Width}$$

**Method:** Prior to calculating this metric, users need to complete the bankfull verification process (Section 2.6).

The ER should be calculated for each riffle within the representative sub-reach to calculate the weighted ER (see equation below and Example 10). At each study riffle:

1. Measure the length of the riffle (refer to glossary for the definition of a riffle). Record the length of each riffle and note the survey method and any post-processing tools used on the Field Value Documentation Form in Appendix B.

2. At the approximate mid-point of the riffle, record the bankfull channel width and flood-prone width. The bankfull verification process (Section 2.6) should be used to identify the bankfull elevation where the width is measured. If the flood-prone width is uniform (as verified using topographic data), it is unnecessary to measure at every riffle.
3. Calculate the ER for that riffle. Record the ER at each riffle and note the survey method and any post-processing tools used on the Field Value Documentation Form in Appendix B.

Standard survey protocols are required to collect accurate dimensions and elevation data for step 2 above. Appendix A provides rapid survey instructions using a tape and hand or laser-levels. Other survey protocols (e.g. survey grade GPS) are acceptable provided that accurate width measurements can be obtained.

4. Using the ER and riffle lengths for every riffle feature within the representative sub-reach, calculate the weighted ER using the equation below and Example 10. The weighted ER should then be entered in the CSQT.

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

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

***Example 10: 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 riffle length, flood-prone area width, and channel width for every riffle in a representative sub-reach of the proposed channel. Calculations should consider any proposed activities that may alter the flood-prone area, cross-section, or longitudinal profile, including floodplain excavation and construction of berms or levees.

### *Percent Side Channels*

**Definition:** Side channels are small open water channels that are connected to the main channel at one or both ends. Floodplain channels can be included in this metric when one or both ends are connected to the main channel and the **depth is at least one-half the bankfull riffle maximum depth**. For example, if the bankfull riffle maximum depth is two feet, the floodplain side channel depth must be within one foot of the bankfull elevation where the side channel intersects the main channel. Floodplain channels that have filled with sediment to the bankfull depth at both ends are not counted as side channels. Where multiple channels are created by islands and mid channel bars, these are not considered side channels (Figure 26).

Identifying side channels may require bankfull verification (Section 2.6).

**Method:** The percent side channels metric is calculated by measuring the total length of all side channels within the valley bottom of the project reach area and dividing by the total length of the main channel. It is reported in percent as the field value.

$$Field\ Value = 100 * \frac{\sum Side\ channel\ length\ (ft)}{Reach\ length\ (ft)}$$

Side channels can be assessed from aerial photos **and** field reconnaissance. The lengths can be measured on aerials if they are visible or measured in the field with a tape measure or range finder. Walk the **entire project reach**, including both sides of the stream channel, identify and verify any side channels meet the definition outlined above, and record side channel lengths on the Project Reach field form (Appendix B).

**Estimating proposed condition field values:** The proposed condition field value is calculated using the length of side-channels proposed to be added or removed as part of the project and the proposed stream length.

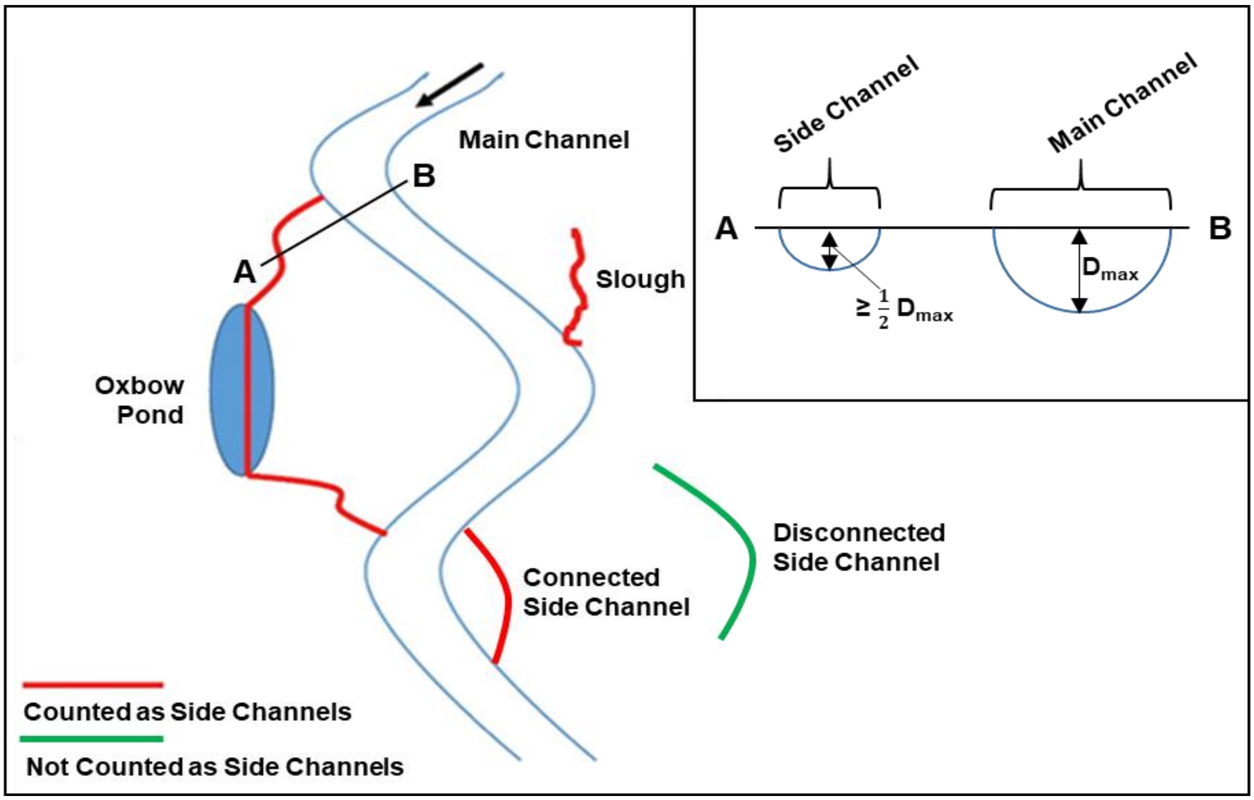



*Figure 26: Examples of Side Channels*

## 2.8 Geomorphology Functional Category Metrics

The CSQT contains the following function-based parameters to assess the geomorphology functional category: large woody debris, lateral migration, bed form diversity, and riparian vegetation. Not all geomorphic parameters will be evaluated for all projects. Refer to Section 2.5 of this manual for recommendations on when to apply each parameter and metric.

### 2.8.1 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.[27] 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 metrics used to assess large woody debris (LWD): large woody debris index (LWDI) and LWD piece count.

**Experience Requirements:** Data collection for large woody debris metrics should be performed by the same team performing floodplain connectivity and bed form diversity assessments, or individuals with experience in large wood assessments.

### *LWDI*

**Definition:** The Large Woody Debris Index (LWDI) is a dimensionless value based on rating the geomorphic significance of LWD pieces and dams within a 328-foot (100 meters) section of stream. This index was developed by the USDA Forest Service Rocky Mountain Research Station (Davis et al. 2001).

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

1. 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 to calculate the reach LWDI. The LWDI is entered as the field value in the CSQT. Record the field value on the Field Value Documentation Form in Appendix B.

**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 feet. See Harman et al. (2017) for examples 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.

### *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 stream.

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

Count all pieces of dead and fallen wood wholly or partially within the active channel that are over 3.28 feet (1 m) in length and at least 3.9 inches (10 cm) in diameter at the largest end within the 328-foot reach. Data is recorded on the Project Reach form (Appendix B). For debris

[27] Note: Standing dead material is not included as LWD. In willow-dominated systems, willow branches that form debris jams are included in the LWDI assessment even if they do not meet the minimum piece size. Additional discussion is provided in the LWDI manual.

dams, to the extent possible, count each piece within the dam that qualifies as LWD. The number of pieces observed is the field value input for the CSQT. No additional calculation is required. Record the field value on the Field Value Documentation Form in Appendix B.

**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 feet. The proposed value should consider the removal of any existing LWD or installation of new LWD that would occur during project construction.

### 2.8.2 Lateral Migration

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

There are four metrics for this parameter: dominant bank erosion hazard index (BEHI)/near-bank stress (NBS), percent streambank erosion, percent armoring, and greenline stability rating (GSR).

**Experience Requirements:** Data collection for lateral migration metrics should be performed by professionals with training and experience in applying either the BEHI/NBS or Greenline Stability Rating methods.

#### *Dominant Bank Erosion Hazard Index/Near-bank Stress (BEHI/NBS)*

**Definition:** The Bank Erosion Hazard Index (BEHI) is a method used to estimate the tendency of a given stream bank to erode based on:

1. Bank angle,
2. Riparian vegetation,
3. Rooting depth and density,
4. Surface protection, and
5. Bank height relative to bankfull height.

Near-bank Stress (NBS) is an estimate of shear stress exerted by flowing water on the stream banks. Together, BEHI and NBS are used to populate the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model and produce cumulative estimates of stream bank erosion rates for surveyed reaches (Rosgen 2014).

In the CSQT, the BEHI/NBS assessment is used to determine the dominant BEHI/NBS category for eroding banks within the representative sub-reach.

**Method:** BEHI/NBS should be evaluated throughout the representative sub-reach.

Follow the guidance 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 included in Appendix A for convenience.

Prior to calculating this metric, users need to complete the bankfull verification process (Section 2.6).

1. Measure the bank length of **every** outside meander bend and determine its BEHI/NBS category. The outside of the meander bend is always assessed, even when it is not eroding.

2. Measure the bank length of **any other bank that is actively contributing sediment** and determine its BEHI/NBS category.

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** from the CSQT BEHI/NBS survey.

**Banks that are armored should not be assessed with the dominant BEHI/NBS metric.** See Percent Armoring metric for armored banks.

3. Add up the length of all assessed banks in the representative sub-reach. Record the total length on the Field Value Documentation Form in Appendix B and note the survey method and any post-processing tools used.
4. Divide the length of each bank by the total assessed bank length.
5. The total percent is calculated for each category by summing the percent for each assessed bank length within that category (Example 11). 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.

To enter the field value in the CSQT, a drop-down list of BEHI/NBS categories is provided in the Quantification Tool worksheet. Record up to six BEHI/NBS categories and assessed bank lengths associated with that category on the Field Value Documentation Form in Appendix B and note the survey method and any post-processing tools used.

***Example 11: Calculation of Dominant BEHI/NBS***

In this example, data were collected in the field along the left and right banks of a 550-foot representative sub-reach. Within this reach, actively eroding banks and those with a strong potential to erode were assessed using the BEHI/NBS methods.

| Bank ID (Left and Right) | BEHI/NBS | Length (Feet) | Percent of Total (%) |
|---|---|---|---|
| L1 | Low/Low | 50 | 50 / 155 = 32% |
| **L2** | **High/High** | **12** | **8%** |
| R1 | Mod/High | 22 | 14% |
| **R2** | **High/High** | **31** | **20%** |
| L3 | Low/Mod | 9 | 6% |
| **R4** | **High/High** | **31** | **20%** |
| **Total Length** | | **155** | |

BEHI/NBS assessments were done on 155 feet of stream bank, out of the total 1,100 feet of streambank within the representative sub-reach. There are four BEHI/NBS categories present. The length of each bank was summed and divided by the total assessed bank length; the total percent is then calculated for each category (e.g., High/High: 8+20+20 = 48). The dominant BEHI/NBS category is High/High since that score is highest and describes 48% of the assessed banks.

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

### *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 11). Record this length on the Field Value Documentation Form in Appendix B.

***Table 11: BEHI/NBS Stability Ratings that Represent Actively Eroding and Non-eroding Banks***

| *Non-eroding Banks* | *Actively Eroding Banks* |
|---|---|
| L/VL, L/L, L/M, L/H, L/VH, L/Ex, M/VL, M/L | M/M, M/H, M/VH, M/Ex, H/L, H/M, H/H, H/Ex, VH/VL, Ex/VL, Ex/L Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex |
| *VL = Very Low, L=Low, M = Moderate, H = High, VH = Very High, Ex = Extreme* | |

3. Divide the total length of actively eroding bank by the total length of streambank within the sub-reach (Example 12). The total length of streambank is the sum of the left and right bank lengths within the representative sub-reach (approximately twice the channel length). Note, this value is different from the assessed bank length used to calculate the dominant BEHI/NBS metric (Table 11). Record the field value on the Field Value Documentation Form in Appendix B.

$$Percent\ Streambank\ Erosion = \frac{Length\ of\ eroding\ bank}{Total\ length\ of\ streambank_{sub-reach}} * 100$$

**Estimating proposed condition field values:** The proposed condition field value should be based on any anticipated changes to channel bank or hydraulic conditions associated with the proposed project within the representative sub-reach. 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. For impact sites, the user must estimate the extent of bank erosion that is likely, considering hydraulic expansion/contraction effects associated with stream crossings. Removing vegetation along the bank (greenline) is also likely to lead to bank erosion.

**Example 12: Calculation of Percent Erosion**

This example uses the same BEHI/NBS results as above. In the table below, actively eroding banks are identified in bold per Table 11. These bank lengths are summed (12+22+31+31 = 96 feet) and divided by the total bank length (representative sub-reach length of 550 feet * 2 = 1,100). The total percent streambank erosion is 96 / 1,100 (feet) = 8.7%.

| Bank ID (Left and Right) | BEHI/NBS | Length (Feet) |
|---|---|---|
| L1 | Low/Low | 50 |
| **L2** | **High/High** | **12** |
| **R1** | **Mod/High** | **22** |
| **R2** | **High/High** | **31** |
| L3 | Low/Mod | 9 |
| **R4** | **High/High** | **31** |

## *Greenline Stability Rating (GSR)*

**Definition:** The greenline is a linear grouping of live perennial vascular plants on or near the water's edge. Greenline stability ratings (GSR) are calculated by multiplying the percent composition of each community type along the greenline by the stability class rating assigned to that type (per methods referenced below).

**Method:** Follow the guidance in either of two methods to measure the GSR:

- The original greenline data collection procedures described in *Monitoring the Vegetation Resources in Riparian Areas* (Winward 2000).
- The Modified Winward Greenline Stability Rating procedures described in *Riparian Area Management: Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation* (USDOI 2011).

The Modified Winward Greenline Stability Rating integrates a more systematic approach to collecting data by using plots instead of paces and calculating stability ratings by key species rather than community types to improve precision. It also includes additional species stability ratings not identified in Winward (2000). Regardless of the GSR collection method selected, Table H1 of the USDOI (2011) MIM document outlines procedures for developing a relative stability value for other plant species.

Data collection should occur throughout the representative sub-reach. Record the total percent composition for each stability rating observed at the site and note the species on Field Value Documentation Form in Appendix B. Record the final field value on this form as well.

**Estimating proposed condition field values:** The proposed condition field value should be based on any anticipated changes to channel bank conditions or bank vegetation associated with the proposed project within the representative sub-reach. Note that because the method is based on establishment of riparian vegetation, the proposed GSR field value should be estimated based on anticipated conditions and community composition at project closeout.

### *Percent Armoring*

**Definition:** Bank armoring is defined as any rigid human-made stabilization practice that permanently prevents lateral migration processes. Examples of bank armoring include rip rap, gabion baskets, concrete, and other engineered materials.

Percent armoring is calculated by measuring the total length of all armored banks within the **entire project reach** and dividing by the total length of streambank. 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.

$$Percent\ Armoring = \frac{Length\ of\ armored\ bank}{Total\ length\ of\ streambank_{reach}} * 100$$

**Method:** Walk the **entire reach**, including both sides of the stream channel, and measure the lengths of armored banks. Lengths should be recorded on the Project Reach field form (Appendix B).

**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).

### 2.8.3 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 create important channel patterns and habitats for aquatic life. Riffles and pool types described below are defined in the glossary.

There are four metrics for this parameter: pool spacing ratio, pool depth ratio, percent riffle, and aggradation ratio.

**Experience Requirements:** Data collection for bed form diversity metrics should be performed by professionals that have experience with standard survey techniques, prior field experience identifying fluvial bed forms in Colorado, and experience with identification and verification of bankfull. Users should have prior field experience in identifying bedform features sequences in different stream types, including experience differentiating between geomorphic pools, significant pools, and micro-pools as defined by the CSQT (see Appendix A for additional information on these features).

### *Pool Spacing Ratio*

**Definition:** The pool spacing ratio compares the stream length distance between sequential geomorphic pools to the bankfull width at a riffle (Rosgen 2014).

**Method:** Prior to calculating this metric, users need to complete the bankfull verification process (Section 2.6). The bankfull channel width of the representative riffle also needs to be determined prior to calculating this metric (Section 2.6). Note this value is equal to the proposed bankfull width described in Section 2.4. The bankfull channel width from the representative riffle should be recorded on the Field Value Documentation Form in Appendix B. The user should note the survey method and any post-processing tools used on this form as well.

1. Record the location along the longitudinal profile of the **maximum pool depth** of every **geomorphic pool** in the representative sub-reach. Measure and record the spacing between the maximum depths of the sequential pools.

Standard survey protocols are required to collect accurate location data of the stream centerline.[28] Appendix A provides rapid survey instructions using tape; other survey protocols (e.g., survey grade GPS) are also acceptable.

2. The pool spacing ratio is calculated for each pair of sequential geomorphic pools in the representative sub-reach using the equation below. Note that the bankfull channel width to calculate this metric is from a representative riffle (Section 2.6) and is the value recorded in the Site Information and Reference Selection section of the Quantification Tool worksheet.

$$Pool\ Spacing\ Ratio = \frac{Distance\ between\ sequential\ geomorphic\ pools}{Bankfull\ channel\ width}$$

3. The pool spacing ratio, using the median of at least three pool spacing measurements, should be entered as the field value.
4. Record the median pool spacing value, the number of geomorphic pools, and the bankfull channel width and note the survey method and any post-processing tools used on the Field Value Documentation Form in Appendix B.

When working in streams that have been straightened (channelized), a bed form sequence may not be present. This typically occurs because pool forming processes (meandering and scour processes) have been removed. **In this case, the reach will likely be mostly riffle habitat and the user should enter a field value of 0.0 for this metric.** This result indicates that a bed form sequence should be present based on the reference stream type, but it is absent due to channelization. This situation is most common in channelized streams where the meander width ratio (belt width / bankfull width) is less than 3.5 and the sinuosity is less than 1.2.

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

### *Pool Depth Ratio*

**Definition:** The pool depth ratio is a measure of pool quality, where deeper pools score higher than shallow pools. Pool depth ratio is calculated as the bankfull pool maximum depth divided by the bankfull mean depth. Pool depth represents the difference in elevation between the deepest point of each pool and the bankfull elevation.

[28] Appendix A field methods instruct users to stretch the tape along the stream bank. Channel centerline and streambank are considered equivalent.

**Method:** Prior to calculating this metric, users need to complete bankfull verification, evaluate the representative riffle, and calculate the bankfull mean depth (Section 2.6).

At every **geomorphic and significant pool** within the representative sub-reach:

1. Identify the bankfull elevation and pool maximum depth. The bankfull verification process (Section 2.6) should be used to identify the bankfull elevation.
2. Measure and record the **difference** between the bankfull elevation and the thalweg elevation (bankfull pool maximum depth).

Standard survey protocols are required to collect accurate location data of the stream centerline and elevation data. Appendix A provides rapid survey instructions using a tape and hand or laser-levels, though other survey protocols (e.g. survey grade GPS) are also acceptable.

3. Pool depth ratio is calculated by dividing the bankfull pool maximum depth by the bankfull mean depth from the representative riffle survey.

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

If a longitudinal profile is generated, the best-fit-line through the bankfull points should be used to calculate the bankfull elevation associated with each pool maximum depth.

For the rapid survey, the difference in bankfull and water surface (established during the bankfull verification process) should be used at each bankfull pool maximum depth location.

4. Average the pool depth ratio values from all geomorphic and significant pools in the representative sub-reach and enter it as the field value into the CSQT. Record the average pool depth, number of pools measured, mean riffle depth, and field value on the Field Value Documentation Form in Appendix B. Note the survey method and any post-processing tools used.

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

### *Percent Riffle*

**Definition:** The percent riffle is the proportion of the representative sub-reach containing riffle and run features, as distinct from pool features. Riffle is defined in detail in the glossary, and generally refers to the plan form crossover section in between lateral scour pools in meandering channels and the cascade section of a mountain stream.

**Method:**

1. Measure the length of each riffle in the representative sub-reach from the channel centerline. Riffle length is measured from the head (beginning) of the riffle downstream to the head of a geomorphic or significant pool. **Run features are included within the riffle**

**length**.[29] Riffle length may include riffles with micro-pools. Glide features are classified as pools.

Standard survey protocols are required to collect accurate location data of the stream centerline and bed form features. Appendix A provides rapid survey instructions using a tape and hand or laser-levels, though other survey protocols (e.g., survey grade GPS) are also acceptable.

2. Add the length of all riffles within the representative sub-reach. Percent riffle is calculated by dividing the total length of riffles within the representative sub-reach by the total representative sub-reach length.

$$\%\,Riffle = \frac{\sum(Riffle\ length_{sub-reach})}{Total\ length_{sub-reach}}$$

3. Record the reach length, bankfull channel width, representative sub-reach length, total riffle length within the sub-reach, and the field value on the Field Value Documentation Form in Appendix B. Note the survey method and any post-processing tools used.

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

### *Aggradation Ratio*

**Definition:** 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, and the deposition of gravel on the floodplain.

The aggradation ratio is measured as the bankfull channel width at the **widest riffle** within the representative sub-reach divided by the bankfull mean depth (width/depth ratio [W/D]). This ratio is then divided by a reference W/D. This metric is described as W/D ratio state by Rosgen (2014).

$$Aggradation\ Ratio = \left.\frac{W_{riffle}}{D_{mean\ riffle}}\right/ Reference\ WDR$$

**Method:** Prior to calculating this metric, users need to complete the bankfull verification process (Section 2.6).

1. Survey multiple riffle cross-sections in the representative sub-reach with signs of aggradation. It is recommended to measure this metric at multiple riffle cross-sections with aggradation features to ensure that the widest value for the representative sub-reach is obtained and to document the extent of aggradation throughout the representative sub-reach.

[29] A run is a transitional feature from the riffle to the pool and the glide transitions from the pool to the riffle (Rosgen 2014).

Standard survey protocols are required to collect accurate elevation data; Appendix A provides rapid survey instructions using a tape and hand or laser-levels. Other survey protocols (e.g., survey grade GPS) are also acceptable.

2. Determine the cross-section with the widest bankfull channel width and calculate the W/D.
3. 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 representative riffle cross-section (Section 2.6), a riffle cross-section adjacent to the project reach, or through the design process. Hydraulic and sediment transport models, such as Torizzo and Pitlick (2004), may be used to select a channel dimension and slope that yields a stable W/D. Justification for the selected W/D should be provided in the Field Value Documentation form.
4. Calculate the field value for aggradation ratio by dividing the results of step 2 by the reference W/D (step 3).
5. Record the bankfull width at the widest riffle, bankfull mean depth, reference W/D, and the field value on the Field Value Documentation Form in Appendix B. Note the survey method and any post-processing tools used.

**Estimating proposed condition field values:** The maximum W/D for the proposed condition should be selected after evaluating the proposed cross-section at every riffle in the representative sub-reach. The expected (or reference) value should remain the same for both the existing and proposed calculations.

### 2.8.4 Riparian Vegetation

Riparian vegetation plays a critical role in supporting channel stability and physicochemical and biological processes. Data collection methods have been selected to provide repeatability and consistency and to allow for extrapolation of species information to draw inferences on vegetation composition and/or to apply additional regulatory performance standards at mitigation sites.

**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.

There are four metrics for riparian vegetation: riparian extent (%), woody vegetation cover (%), herbaceous vegetation cover (%), and percent native cover.

**Experience Requirements:** Data collection for riparian vegetation metrics should be performed by professionals with experience identifying plant species and estimating absolute cover by species. Users will need to be able to key native and nonnative plants commonly found in riparian zones within the region and should be able to **identify at least 80% of the species within a plot**.

#### *Riparian Extent*

**Definition:** The riparian extent metric describes the portion of the expected riparian area that currently contains riparian vegetation and is free from utility-related, urban, or otherwise soil disturbing land uses, fill, and development.

This metric characterizes the current, observed extent of the riparian area, as compared with the reference expectation for that site. The reference expectation, or expected riparian area, is an estimate of the natural or potential extent of the riparian area. Each of these values should first be estimated using aerial imagery interpretation and then validated in the field.

The riparian extent metric is the percentage of the expected riparian area that currently contains riparian vegetation and is free from development, as described above. Riparian area (%) is the field value entered into the CSQT and is calculated using the following equation:

$$Riparian\ Extent = \frac{Observed\ Riparian\ Area}{Expected\ Riparian\ Area} * 100$$

**Method:** The riparian extent metric relies on a combination of desktop methods and field verification methods (see below and also Appendix A).

Expected Riparian Area:

Whenever possible, the expected riparian area should be determined using aerial imagery and other spatial data to identify hydrologic, topographic, and geomorphic indicators of expected riparian extent, which are then validated in the field. However, in areas of extensive floodplain development, these indicators may no longer be directly observable. In these circumstances, the expected riparian area should be estimated using 1) a reference meander width ratio for that valley type, or 2) by comparing present day topographic images to reconstructed topographic images (see Step 4 of procedure).

The procedure is described below:

1. Using aerial imagery and other spatial data such as topographic layers or digital elevation models, identify the edge of the (expected) riparian area within the project reach. The expected riparian area includes the extent of the riparian corridor in each direction, landward from the stream to the extent of geomorphic, and hydrologic indicators of the floodplain. Substrate indicators are found within the portion of the valley bottom influenced by fluvial processes under the current climatic regime, while hydrologic indicators are found where the valley bottom would be flooded at the stage of the 100-year recurrence interval.[30] Hydrologic and substrate indicators may include a fluvially formed break in slope between bank edge and valley edge, a change in sediment from fluvial sediments (rounded) to hillslope sediment (angular), or evidence of flood events (e.g., bar deposition, staining, water marks, or floodplain mapping).

2. Using desktop measurement tools, delineate the extent of the expected riparian area using appropriate indicators, as identified in Step 1 above, and calculate the area within this extent (Example 13). This area should include the stream channel itself. The expected riparian area value and indicators should be noted on the Riparian Area field form prior to going out in the field. If natural indicators are no longer present due to anthropogenic modification, see Step 4 below.

3. During riparian data collection, expected riparian area indicators and extent should be verified in the field using the procedure outlined in Appendix A.

[30] The floodplain extent may be tied to recurrence intervals less than the 100-year, depending on the process domain at the project site (see Merritt et al. 2017 and Polvi et al. 2011).

4. Where significant anthropogenic modification of the riparian area has occurred (e.g., development, grading, incision) and aerial imagery, spatial data, and/or field indicators cannot be used to delineate the expected riparian extent, two options can be employed:

    a. The meander width ratio (MWR) may be used to calculate expected riparian extent. The MWR is the belt width of a meandering stream in its valley divided by the bankfull width (Rosgen 2014). This option does not require the MWR to be measured but instead applies a typical MWR based on the valley type (Table 12). To determine the expected riparian area using this method, multiply the bankfull channel width of the channel by a selected MWR for the given valley type and add an additional width for outside meander bends (see equation below and Figure 27). The expected riparian area should then be multiplied by valley length to calculate expected riparian area. Valley length should be calculated along the centerline of the valley.

$$Expected\ Riparian\ Area = Valley\ Length * (W_{Bankfull} * MWR + 2 * W_{additional})$$

    b. Historic topographic images may be reconstructed from geomorphic maps or riverine deposits may be reconstructed from geologic and soils maps and compared to current topographic images. Hydrologic and substrate indicators should be identified per step 1.

***Table 12: MWR by Valley Type adapted from Harman et al. (2012) and Rosgen (2014)***

| Valley Type | MWR | Additional Width (ft) $W_{additional}$ |
|---|---|---|
| Alluvial Valley | 7 | 25 |
| Confined Alluvial | 3 | 15 |
| Colluvial | 2 | 10 |

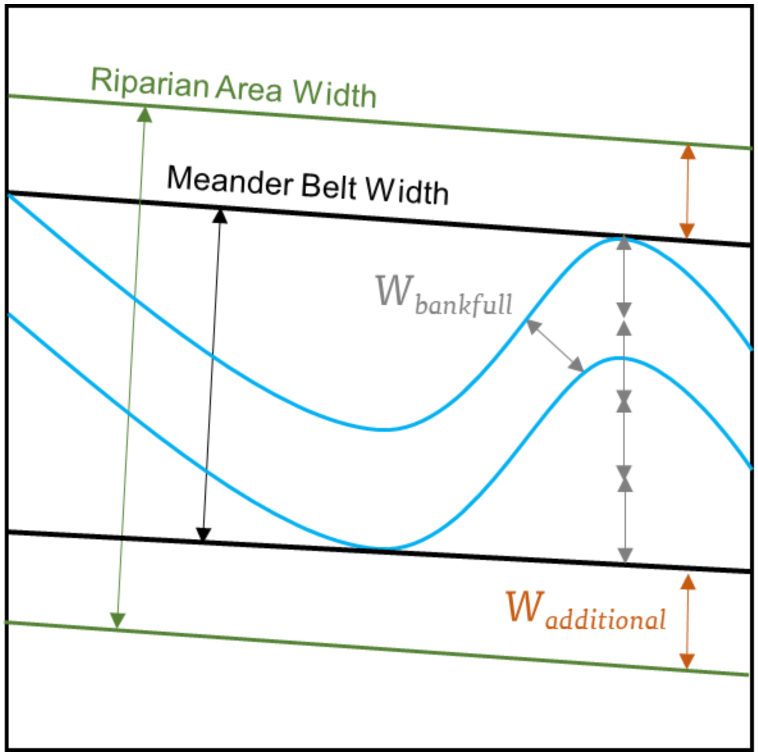



*Figure 27: Expected Riparian Width Calculation Relying on Meander Width Ratio*

Observed Riparian Area:

The observed riparian area can also be determined using aerial imagery and other spatial data via desktop methods and then verified in the field. The observed riparian area is the current extent, moving landward from the stream channel, of riparian vegetation indicators on the landscape.

The procedure is described below:

1. Using aerial imagery, identify the edge of the observed riparian area within the project reach using biotic indicators, which include riparian vegetation characteristic of the region and plants known to be adapted to shallow water tables and fluvial disturbance (Merritt et al. 2017). The observed riparian area is the area that currently contains riparian vegetation and is free from urban, utility-related, or agricultural land uses and development. Riparian areas have one or both of the following characteristics: 1) distinctly different vegetation species than adjacent areas, and 2) species like adjacent areas but exhibiting more vigorous or robust growth forms (USFWS 2009).
2. Using desktop measurement tools, delineate the extent of the observed riparian area using appropriate indicators, as identified in Step 1 above, and calculate the area within this extent (Example 13), including the stream channel itself. Observed riparian area values and indicators should be noted on the Riparian Area field form prior to going out in the field.

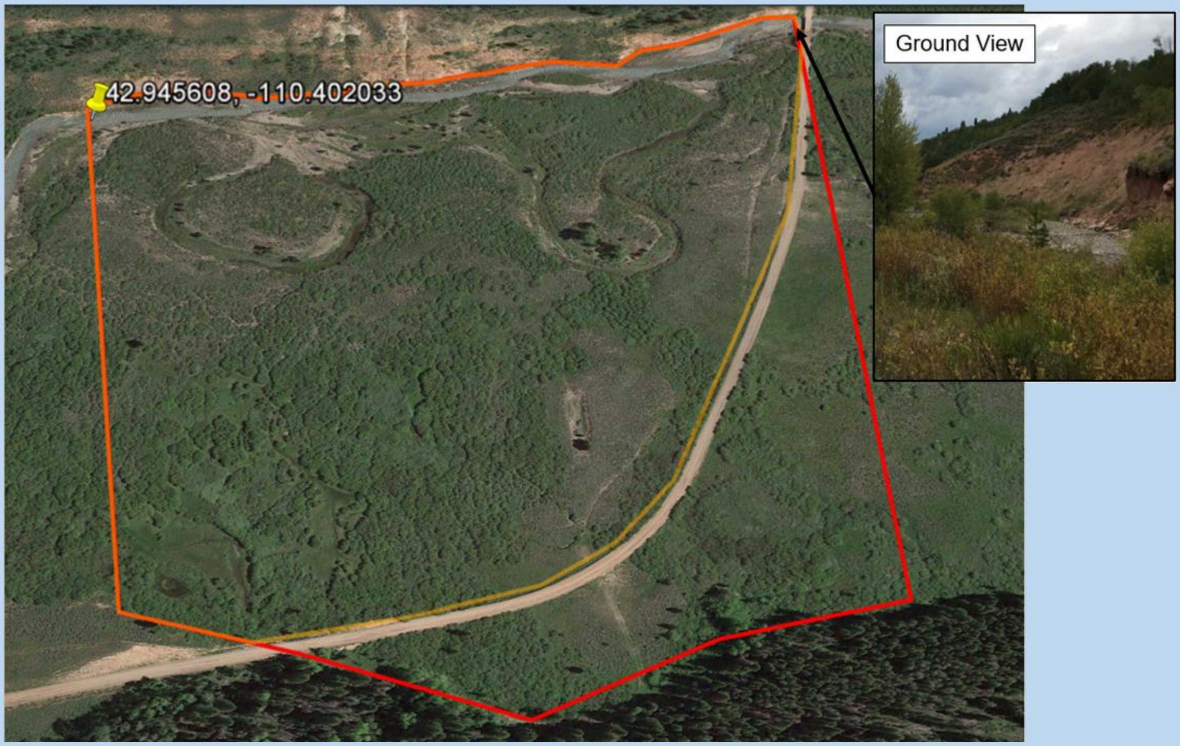
3. During riparian data collection, observed riparian area indicators and extent should be verified in the field using the procedure outlined in Appendix A.
4. Apply the field-verified expected riparian area and observed riparian area measurements to the equation identified at the beginning of this section to calculate the CSQT value for riparian area (%). Record the field value on the Field Value Documentation Form in Appendix B.

See Example 13 for an example of riparian area delineation and calculation.

**Estimating proposed condition field values:** The field value for this metric is an observed value divided by an expected value; the expected value should remain the same for both the existing and proposed calculations. The observed value for the proposed condition can be calculated based on anticipated areas of riparian vegetation planting or removal in the expected riparian area associated with the proposed project.

**Example 13: Riparian Extent**

The following is an example showing how the riparian extent metric can be calculated by delineating the observed (yellow) and expected (red) riparian area within a project reach. The riparian area boundaries were delineated using aerial photographs and indicators of the extent were verified in the field. Review of aerial imagery included identification of any observable topographic and valley edge indicators, including valley edge, slope break/terrace, change in sediment, and change in vegetation. Existing riparian extent was delineated by also considering indicators of anthropogenic modification, in this case, the presence of a road. In this example, the observed riparian area (yellow) was 39.7 acres, the expected riparian area (red) was 48.6 acres and the O/E calculation was 81.7%.




## Woody Vegetation Cover

This metric characterizes abundance and type of woody vegetation, which can affect channel stability, floodplain roughness, and provide habitat for riparian dependent wildlife.

**Definition:** The woody vegetation cover field value for the CSQT is the sum of absolute percent woody plant cover from shrub and tree species, averaged across all plots within the representative sub-reach.

$$Woody\ vegetation\ cover = \ Woody_{Shrub\ Species\ Cover} + Woody_{Tree\ Species\ Cover}$$

Note that estimates among different species are independent of each other, so the sum of the woody cover for overlapping species combined could add up to more than 100%.

**Method:** Riparian vegetation should be assessed during the growing season within sampling plots located along the edge of bank (where bed-meets- bank) of the representative sub-reach (Figure 28). Data from riparian sampling plots should be collected according to the instructions provided in Appendix A. Record the average field value on the Field Value Documentation Form in Appendix B.

Within each riparian plot for the **representative sub-reach**, visually estimate the percent absolute cover of each plant species within the nested plot types to determine abundance, structure, composition, and complexity. **Users will need to identify at least 80% of the species within a plot.**

These methods represent a combination of techniques adapted from the Corps of Engineers' Wetland Delineation Manual (USACE 1987) and regional supplements for the Arid West (USACE 2008b), Great Plains (USACE 2010a), and Western Mountains, Valleys, and Coast (USACE 2010b); the Hydrogeomorphic (HGM) Approach (Hauer et al. 2002); and the Bureau of Land Management Assessment, Inventory, and Monitoring projects (BLM 2017). Instructions for setting up and monitoring riparian plots is described in Appendix A and a data form is provided in Appendix B.

**Estimating proposed condition field values:** The proposed condition field value should be an estimate of woody cover for conditions at project closeout. Users should consider the extent of preserved vegetation, vegetation removal, and the growth rates and expected cover for planted vegetation over the monitoring period.

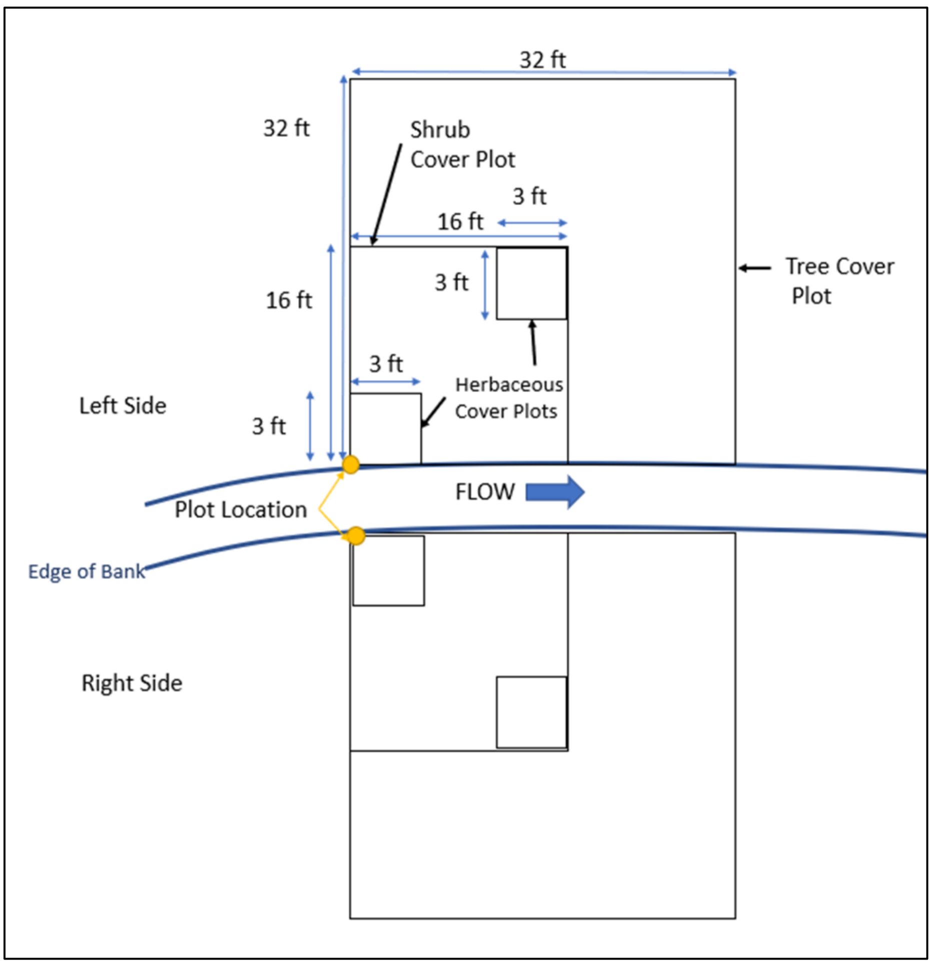



*Figure 28: Riparian Vegetation Sample Plot Layout*

### Herbaceous Vegetation Cover

This metric characterizes herbaceous vegetation cover, which is important for bank stability, water quality, and habitat, particularly in systems where woody vegetation is not prevalent.

**Definition:** The herbaceous vegetation cover field value for the CSQT is the sum of absolute percent herbaceous plant cover from herbaceous species averaged across all plots within the representative sub-reach.

$$Herbaceous\ vegetation\ cover = \ Herbaceous\ _{Ground\ Cover}$$

Note that estimates among different species are independent of each other, so the sum of the herbaceous cover for overlapping species combined could add up to more than 100%.

**Method:** See method for Woody Vegetation Cover above. Data should be collected from the riparian sampling plots according to the instructions provided in Appendix A. Record the average field value on the Field Value Documentation Form in Appendix B.

**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.

### Percent Native Cover

This metric characterizes the proportion of native species at a project site, compared with total vegetation cover, and serves as an indicator of the composition and condition of the riparian communities.

**Definition:** Percent native cover metric is the relative cover of native species averaged across all plots within the representative sub-reach. Relative cover is the absolute cover of a species, or group of species, divided by the total coverage of all species, expressed as a percent. The percent native cover field value is calculated at each plot using the equation below. The values from all plots are averaged and this value is entered into the CSQT.

$$Percent\ Native\ Cover = \frac{Native\ Vegetation\ Cover}{Herb\ Vegetation\ Cover + Woody\ Vegetation\ Cover} * 100$$

Note that this metric calculates relative cover; therefore, the metric value **cannot** exceed 100%.

**Method:** See method for Woody Vegetation Cover above. Data should be collected from the riparian sampling plots according to the instructions provided in Appendix A. Record the field value on the Field Value Documentation Form in Appendix B.

**Estimating proposed condition field values:** The field value for the proposed condition is an estimate of conditions at the end of monitoring or project closeout. The value can be estimated based on proposed invasive species removal and any associated monitoring and management plan (or lack thereof). Invasive species can often take over a recently disturbed site and, for restoration projects, require active management to ensure success of planted native species. Where there is a seed source for invasive non-native species, an impacted site will likely see an increase in non-native cover unless a vegetation management plan is implemented.

## 2.9 Physicochemical Functional Category Metrics

The CSQT contains three function-based parameters to assess the physicochemical functional category: temperature, dissolved oxygen (DO), and nutrients. Not all parameters will be evaluated for all projects. Refer to Section 2.5 of this manual for recommendations on when to apply each parameter and metric.

### 2.9.1 Temperature

**Definition:** Temperature in the CSQT characterizes the in-stream summer temperatures within a reach.

There are two metrics included in the CSQT for the temperature parameter: (1) the daily maximum temperature, and (2) the maximum weekly average temperature (MWAT).

**Experience Requirements:** Data collection for temperature metrics should be performed by personnel with experience calibrating and installing stream temperature gages and processing data in accordance with State regulation 31 (5 CCR 1002-31).

#### *Daily Maximum Temperature*

**Definition:** The daily maximum (DM) temperature is the highest two-hour average water temperature recorded during a given 24-hour period (5 CCR 1002-31).

**Method:** Install continuous temperature gages following *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams* (USEPA 2014) or USFS's *Measuring Stream Temperature with Digital Data Loggers: A Field Guide* (Dunham et al. 2005). Record data and perform any necessary maintenance throughout the summer season.

To determine the field value for the daily maximum temperature (measured in degrees Celsius):

1. Using the individual temperature readings, calculate the 2-hour average temperatures on a rolling basis for the sampling period.

Therefore, for a sampling interval of 30-minutes, the average of 4 consecutive measurements is used. Similarly, for a sampling interval of 15-minutes, the average of 8 consecutive measurements is used.

2. Identify the maximum of the rolling 2-hour average temperatures and enter as the field value in the CSQT.
3. Record the period of record, sampling interval, field value, and date of time of the field value on the Field Value Documentation form in Appendix B.

**Only one year of data is required** to characterize the existing condition. As water temperature is strongly influenced by meteorological conditions, it is **recommended** that multiple years of data are collected and averaged to inform the existing condition field value. Monitoring a reference site, unaffected by the project, during existing and post-construction monitoring is also recommended where possible.

**Estimating proposed condition field values:** The proposed condition field value should estimate/predict the expected change in the daily maximum field value resulting from the project. Reference reach monitoring near the project can inform proposed condition field values. 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).

### *MWAT*

**Definition:** The Maximum Weekly Average Temperature (MWAT) is the largest weekly average stream temperature in the period of interest (5 CCR 1002-31).

**Method:** Install continuous temperature gages following *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams* (USEPA 2014) or USFS's *Measuring Stream Temperature with Digital Data Loggers: A Field Guide* (Dunham et al. 2005). Record data and perform any necessary maintenance throughout the summer season.

To determine the field value for the MWAT (measured in degrees Celsius):

1. Calculate the average temperature recorded for each day in the sample period (July to August; minimum 62 days). These are the mean daily temperatures.
2. Using the mean daily temperatures, calculate the weekly average temperatures on a rolling seven-day basis for the sampling period.
3. Identify the maximum of the rolling weekly average temperatures and enter as the field value in the CSQT.
4. Record the period of record, sampling interval, field value, and the date range of the field value on the Field Value Documentation form in Appendix B.

**Only one year of data is required** to characterize the existing condition. As water temperature is strongly influenced by meteorological conditions, it is **recommended** that multiple years of data are collected and averaged to inform the existing condition field value.

**Estimating proposed condition field values:** The proposed condition field value should estimate/predict the expected change in the MWAT field value resulting from the project. Reference reach monitoring near the project can inform proposed condition field values. 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).

## 2.9.2 Dissolved Oxygen

**Definition:** The DO parameter assesses in-stream DO to determine suitable water quality during summer.

There is one metric included in the CSQT for this parameter, the DO concentration, measured in milligrams per liter (mg/L).

**Experience Requirements:** Field values for the DO metric should be calculated by professionals with experience calibrating, installing, and maintaining DO loggers and processing data in accordance with WDEQ Standard Operating Procedure (WDEQ/WQD 2018).[31]

[31] The CSQT SC reviewed the WDEQ/WQD methods and compared them to the CO SOPs (CDPHE 2016) and found the Wyoming methods were comparable and provided more detail.

### *Dissolved Oxygen Concentration*

**Definition:** DO is the amount (mg) of oxygen dissolved in one liter of water and available for aquatic use.

**Method:** Measure DO concentration in accordance with the WDEQ Standard Operating Procedure (WDEQ/WQD 2018). Deploy continuous recording DO loggers. Refer to sensor instructions for deployment, calibration, and instrument cleaning instructions.

Loggers should be located in comparable habitats for pre- and post-project data collection and collect daily readings at a time **when minimum values are expected** in the months of July or August for at least 7 consecutive days. Minimum DO levels typically occur in the early morning before sunrise when respiration has been occurring throughout the night.

To determine the field value for the DO concentration (measured in mg/L) from daily measurements, calculate the minimum of the DO readings from the sample period (7 data points) and enter as the field value in the CSQT.

Record the period of record, sampling interval, field value, and date and time of the field value on the Field Value Documentation form in Appendix B.

**Only one year of data is required** to characterize the existing condition. As DO can be strongly influenced by meteorological conditions, it is **recommended** that multiple years of data are collected and averaged to inform the existing condition field value.

**Estimating proposed condition field values:** The proposed condition field value should estimate/predict the expected change in DO concentration resulting from the project. Reference reach monitoring near the project can inform proposed condition field values. Practices that could impact DO include, but are not limited to, altering the amount of turbulent water habitats (i.e. riffles), riparian buffers such that nutrient loads and algae growth are affected, and practices that alter stream temperature (see above).

## 2.9.3 Nutrients

**Definition:** Excessive nitrogen and/or phosphorus can lead to excessive plant and algal growth, which in turn can degrade stream microhabitats, cause periodic low oxygen concentrations, and blooms of toxin producing algae.

There is one metric included in the CSQT for this parameter, chlorophyll α, measured in milligrams per square meter ($mg/m^2$).

**Experience Requirements:** Field values for the nutrient metric should be calculated by professionals with training and experience collecting periphyton samples in accordance with the Standard Operating Procedures for the Collection of Periphyton Samples (CDPHE 2015).

### *Chlorophyll α*

**Definition:** Chlorophyll α is the pigment that allows plants (including algae) to use sunlight to convert simple molecules into organic compounds via the process of photosynthesis. Chlorophyll α concentration is directly affected by the amount of nitrogen and phosphorus in the stream. Chlorophyll α data should be expressed as milligrams of chlorophyll α per square meter of sampled rock substrate ($mg/m^2$).

**Method:** Methods for collecting chlorophyll α are included in Appendix A. Chlorophyll α sample collection and processing should be conducted according to the CDPHE Standard Operating Procedure procedures outlined in CDPHE (2015).

Record the field value and the sample collection date on the Field Value Documentation Form in Appendix B.

**Only one sample is required** to characterize the existing condition. It is **recommended** that multiple samples be collected if feasible to capture intra-annual variability. Refer to the monitoring section in Section 3.4 for more detail.

**Estimating proposed condition field values:** The proposed condition field value should estimate/predict the expected change in chlorophyll α resulting from the project. Practices that could impact chlorophyll α include, but are not limited to, altering nutrient loads entering the stream channel from the lateral drainage area (through management agreements or buffer planting). Altering flow volumes could also lead to measurable changes in measured chlorophyll α concentration.

## 2.10 Biology Functional Category Metrics

The function-based parameters included in the CSQT for the biology functional category are macroinvertebrates and fish. Refer to Section 2.5 of this manual for recommendations on when to apply each parameter and metric.

### 2.10.1 Macroinvertebrates

**Definition:** Benthic macroinvertebrates, also called aquatic macroinvertebrates, are an integral part of the food web and are commonly used as indicators of stream ecosystem condition.

One metric is included in this parameter, the Colorado Multi-Metric Index (CO MMI) of macroinvertebrate communities, which was developed by CDPHE to assess the biological condition of Colorado streams.

**Experience Requirements:** Field values for macroinvertebrate metrics should be calculated by professionals with training and experience sampling and processing samples in accordance with Policy Statement 10-1 (CDPHE 2017). Samples require laboratory identification and enumeration.

#### *CO MMI*

**Definition:** The CO MMI is a statewide regionally calibrated macroinvertebrate-based multi-metric index. According to CDPHE (2017), "[w]ithin the benthic macroinvertebrate assemblage, metrics are selected that represent some measurable aspect of the community structure and function. These measurements are grouped into five metric categories: taxa richness, composition, pollution tolerance, functional feeding groups, and habit (mode of locomotion). Combining metrics from these categories into a multi-metric index transforms taxonomic identifications and individual counts into a unitless score that ranges from 0-100."

**Method:** Methods for collecting, processing, and identifying macroinvertebrates are included in Appendix A and are consistent with the benthic macroinvertebrate sampling, processing, and identification procedures outlined in Policy Statement 10-1 and its appendices (CDPHE 2017).

The CO MMI score is entered as the field value for the CSQT. Record the field value and the sample collection date on the Field Value Documentation Form in Appendix B.

**Only one sample is required** to characterize the existing condition. It is **recommended** that multiple samples be collected if feasible to capture intra-annual variability. Refer to the monitoring section in Section 3.4 for more detail.

**Estimating proposed condition field values:** The proposed condition field value should estimate/predict the expected change in CO MMI score resulting from the project. Practices that could impact macroinvertebrate communities include, but are not limited to, altering in-stream water quality (refer to Section 2.9), presence and extent of macroinvertebrate habitat, and landscape and aquatic connectivity. Altering flow volumes could also lead to measurable changes in measured macroinvertebrate communities.

### 2.10.2 Fish

**Definition:** Fish are an integral part of many functioning stream systems and are an important management priority within Colorado.

Three metrics for fish are included in the CSQT: native fish species richness (%); absence of Species of Greatest Conservation Need (SGCN); and wild trout biomass.

**Experience Requirements:** Users should have experience performing standard fish sampling techniques to capture the full array of potential species at a site. Electrofishing, species identification, and population estimates should be performed by trained fisheries biologists or aquatic biologists. Fisheries biologists or aquatic biologists performing species identification should be able to identify 100% of the fish species present, including species that hybridize.

**A CPW scientific collection permit is required to collect fish samples.**[32]

**Note:** Project specific consultation with an area fish biologist from CPW is recommended, as they can provide local information on potential limiting factors to improving fish communities or indicate whether project goals should center on native fish species restoration or game fish species restoration based on the identified management objectives for the project site.

#### *Native Fish Species Richness (% of expected)*

**Definition:** This metric documents the diversity of the native fish community in comparison to reference expectations. The deviation of the observed from the expected taxa, a ratio known as the O/E value, is a measure of compositional similarity expressed in units of taxa richness.

The percent of the expected native fish assemblage observed in the stream is the field value entered into the CSQT and is calculated using the following equation:

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32 https://cpw.state.co.us/learn/Pages/ResearchAquaticData.aspx#Aquatic%20Scientific%20Collection%20Permits

$$Native\ Fish\ Species\ Richness = \frac{Observed\ Native\ Fish\ Assemblage}{Expected\ Native\ Fish\ Assemblage} * 100$$

**Method:**

Expected Fish Community – Users should first review the species assemblage list included in Appendix C for a preliminary estimate of the expected native fish assemblage at a site. Recognizing that each fish species' distribution varies naturally within any basin due to underlying factors such as geology, flow regime and duration, water temperatures, or natural barriers, the expected species in a project area will likely be a subset of the assemblage list for the entire basin, and may require further refinements based upon local knowledge. There may also be anthropogenic factors outside of a restoration user's control that influence the number of species present, including flow alteration, barriers to movement, etc. While these anthropogenic factors may limit the restoration potential at a site, they should not be considered in estimating the "expected" fish community. Therefore, the "expected" community consists of the fish that should be naturally present in the absence of anthropogenic influence. Once a preliminary estimate of the number of native fish species is made, the user should coordinate with an area fish biologist at CPW to further refine the expected species assemblage. The area fish biologist will also be able to advise the user whether improvements to the native fish community at a given site are possible or whether native fish species restoration is an appropriate project goal.

Record the number of native fish species on the Field Value Documentation form in Appendix B. Include the list of species and names of any aquatic biologists consulted in developing the list in the reference column.

Observed Fish Community – Fish community data may be requested from CPW, and where proximate and representative data have been collected within the previous 3 years, these data may serve as a preliminary estimate of the number of native species present. Detailed fish surveys should be conducted prior to the initiation of a project to refine this preliminary estimate.

- Detailed fish surveys should be conducted within the project reach using standard methods (e.g., Bonar et al. 2009). Record the date of each sampling event on the Field Value Documentation form in Appendix B.
- To verify fish identification, users should collect and preserve voucher specimens of fish species not readily identified in the field. This recommendation does not apply for federally listed threatened and endangered species.
- Because of inter- and intra-annual variability in native fish communities, **at least two sampling events occurring in different seasons (at least 60 days between sampling occurrences) or ideally in two consecutive years** are needed to establish the observed fish community. If a native species is present in one of the two sampling events, the species should be considered present.

The field value for the CSQT is calculated as the percent of species from the expected native fish assemblage that were observed during **at least one of the two sampling events**. For instance, if:

- The expected native fish assemblage at the project site includes 8 species,
- The first sampling event found 4 of those species, and

- The second sampling event found the same 4 and 1 more species, then
- The field value is 100 * 5/8 = 62.5%

Record the number of observed native fish and the field value on the Field Value Documentation Form in Appendix B. Include the list of species identified in the reference column.

**Estimating proposed condition field values:** The proposed condition field value should estimate/predict the number of native species anticipated to be present following the proposed project. Consultation with an area aquatic biologist to determine the expected species assemblage will inform the anthropogenic causes of impairment and whether the proposed actions could improve the observed assemblage.

### *Absence of Species of Greatest Conservation (SGCN)*

**Definition:** Species of Greatest Conservation Need (SGCN) are identified in the SWAP (2015) as those species whose conservation status warrants increased management attention and funding. SGCN are also considered in conservation, land use, and development planning in Colorado. SGCN species are classified into tiers; tier 1 species have the highest conservation need while tier 2 species have less of a conservation need than tier 1.

**Method:** Prior to calculating this metric, users need to determine the expected fish community and observed fish community following the methods outlined in the previous section for Native Fish Species Richness.

1. Identify which species, if any, in the expected fish community are listed as tier 1 and tier 2.
2. Count how many tier 1 species **were not** in the observed fish community.
3. Count how many tier 2 species **were not** in the observed fish community.
4. Use Table 13 to calculate the field value for this metric. See Example 14.

*Table 13: How to Calculate the Field Value for SGCN Metric*

| SGCN Species *(A)* | Multiplier *(B)* | Equation |
|---|---|---|
| # Tier 1 Species Absent | 2 | $C_1 = A_1 * B_1$ |
| # Tier 2 Species Absent | 1 | $C_2 = A_2 * B_2$ |
| Field Value for the CSQT = | | $C_1 + C_2$ |

The field value for the CSQT is calculated using the number of tier 1 and tier 2 species from the expected native fish assemblage that were **not observed during either of the two sampling events.** Record the number of SGCN species absent in tier 1 and tier 2, and the field value on the Field Value Documentation Form in Appendix B.

**Estimating proposed condition field values:** The proposed condition field value should estimate/predict the number of SGCN anticipated to be present following the proposed project. Consultation with an area aquatic biologist to determine the expected species assemblage will inform the anthropogenic causes of impairment and whether the proposed actions could improve the observed assemblage.

***Example 14: Calculation of the SGCN metric***

A project is proposed in a warm stream in the Arkansas River Basin. According to Appendix C, seven tier 1 SGCN species (Arkansas Darter, Flathead Chub, Northern Plains Killifish, Orangespotted Sunfish, Plains Minnow, Southern Redbelly Dace, and Suckermouth Minnow) may be expected in the stream under pristine conditions. Upon coordination with the regional fish biologist, it is determined that only six have the natural potential to occupy that catchment. The user then determines whether those species are present by sampling using standard methods over at least two sampling events. Only one species is detected. The field value in the CSQT would be 10 since there were 5 Tier 1 SGCN species expected but absent.

### *Wild Trout Biomass (% Change)*

This metric characterizes the biomass of native or introduced wild trout species. See Section 2.5 for guidance on when this metric should be applied.

**Definition:** This metric measures the increase in wild trout biomass following a restoration project relative to the change observed at a **control site.**

Fish baseline data from a nearby control reach is required to account for variability. The control reach should have a similar elevation and geomorphic setting as the project reach and should be of reference quality (to the extent practicable). The control reach should be geographically proximate to the project reach but outside the influence of the project actions. A control reach can be located upstream or downstream from the project reach, or in a separate catchment within the same river basin as the project reach.

**Note:** Consultation with the area fish biologist is important to determine whether certain species or age classes should be excluded from biomass estimates because of stocking efforts within the watershed or poor capture probability due to small fish sizes (for young age classes).

**Method:** The metric field value for the existing condition assessment is 0.0.

The proposed condition field value and field values for all subsequent monitoring events are calculated as the percent increase in biomass compared with pre-project biomass data, after correcting for natural variability using control site data. To calculate the Wild Trout Biomass metric:

1. Conduct at least two sampling events (Bonar et al. 2009) at both the project reach and a control reach to establish baseline **pre-project** biomass estimates and determine the productivity class input into the Site Information and Reference Stratification section. Record the date of each sampling event on the Field Value Documentation form in Appendix B and note the sampling methodology.

   a. A sampling methodology acceptable to CPW is required, such as multi-pass depletion or mark-recapture techniques. Whichever sampling methods are used to assess fish populations at the start of the project must be continued throughout all subsequent monitoring events.
   b. The high productivity class includes streams where current biomass is equal to or greater than 60 pounds per acre, which is the biomass criteria for a Gold Medal fishery in Colorado. The moderate productivity class ranges from 30-60 pounds per acre and the low productivity class includes streams that currently have less than 30 pounds per acre.
2. Conduct at least two sampling events in consecutive years at both the project reach and the control reach **post-construction**. **Sampling events should occur at a similar time of year and should avoid spawning seasons**. Record the date of each sampling event on the Field Value Documentation form in Appendix B and note the sampling methodology.
3. For each post-construction sampling event, calculate the percent change in biomass for the project site and the percent change in biomass at the control site.
4. Subtract the percent change in biomass at the control site from the percent change in biomass at the project site. Subtracting the change in biomass at the control site helps account for inter and intra-annual variability inherent in fish populations and reduces the influence of climatic or other external factors in determining increases in biomass associated with a restoration project.
5. Average two years of sampling data; this average percentage difference is the field value to be entered into the CSQT. Record the field value on the Field Value Documentation Form in Appendix B.

**Estimating proposed condition field values:** The proposed condition field value should estimate/predict the change in biomass likely to occur following the project. Users should consider the current productivity class, recognizing that streams with an already productive fishery may be less likely to see large additional increases in productivity following a restoration project.

***Example 15: Calculation of Wild Trout Biomass***

Example data and calculations are provided for a high productivity trout stream where data are collected across multiple years.

*Baseline data for wild trout biomass in a high productivity trout stream:*

| Monitoring Event | Sampling Event Yield (lbs/acre) | |
|---|---|---|
| | Project Site | Control Site |
| Baseline Year 1 | 65 | 90 |
| Baseline Year 2 | 85 | 110 |
| Pre-Project Average | 75 | 100 |

*Monitoring data for wild trout biomass in a high productivity trout stream:*

| Monitoring Event | Sampling Event Yield (lbs/acre) | | Percent Increase | | Difference |
|---|---|---|---|---|---|
| | Project Site | Control Site | Project Site | Control Site | |
| Baseline | 75 | 100 | | | |
| Post Construction Year 1 | 100 | 115 | $\frac{100-75}{75} = 33\%$ | 15% | 18% |
| Post Construction Year 2 | 90 | 105 | 20% | 5% | 15% |
| Post Construction Year 3 | 100 | 95 | 33% | -5% | 38% |
| Post Construction Year 4 | 105 | 105 | 40% | 5% | 35% |
| **Average Year 1 and 2** | | | | | **16.5%** |
| **Average Year 3 and 4** | | | | | **36.5%** |

*Field Values for Wild Trout Biomass in a High Productivity Trout Stream:*

| Condition Assessment | Biomass Field Value |
|---|---|
| Existing | 0 |
| Proposed | 30 |
| As-built (ASB) | 0<br>(value same as existing condition) |
| Monitoring Year 1 | 0<br>(value same as ASB) |
| Monitoring Year 2 | 16.5 |
| Monitoring Year 3 | 16.5<br>(value same as previous year) |
| Monitoring Year 4 | 36.5 |

## 2.11 Flow Alteration Module

**Definition:** Flow alteration in the CSQT refers to changes in operational commitments, acquisition/change of existing water rights, or new facilities that enable the proposed hydrology to occur.

**The module and metrics are provisional** and subject to testing and revision. For restoration projects, users should ensure that:

- Water is available in the reach to restore one or more aspects of the flow regime,
- Flow protections can be applied within a specified length of stream, and
- The restoration of flow in the reach will not have adverse effects elsewhere.

**Experience Required:** Field values for metrics within the flow alteration module (FAM) should be calculated by engineers or hydrologists with experience developing hydrologic models in Colorado, including models that account for water diversions and reservoir operations.

### 2.11.1 Affected Stream Length

Where flow alteration will occur, the reach affected by the flow altering activities may be shorter or longer than the reach assessed using the Quantification Tool worksheet. The affected stream length in the FAM is defined at the upstream end where impacts or flow protection would initiate, and at the downstream end by the location of the next water rights user, tributary junction, or terminus beyond which the flow modification has no material effect on SQT parameters. When used for CWA 404 compensatory mitigation projects and impact sites, the FAM is applicable where impacts from flow alteration or improvements associated with flow protection can be evaluated within the affected stream length.

### 2.11.2 Metric Selection

The FAM includes six metrics (Table 14). Metric selection will vary based on ecological relevance and data availability.

**Ecological Relevance:** Metrics characterize different aspects of hydrologic alteration and may vary depending on the flow regime in the affected stream length (Table 15). Where these six metrics may not be representative of a critical aspect of the flow regime within a specific reach or watershed, **substitution of flow metrics may be considered** where enough information is available to demonstrate a metric's importance to the local native flow regime. **Note:** any alternate metric should be based on flow or water level field values, otherwise the reference curves are not applicable.

**Data Availability:** Flow records for hydrologic analyses must be sufficiently long (e.g., 20 years of data) to account for inter-annual variability (TNC 2009). Daily flow data should be used for all metrics if it is available. Where daily flow data is unavailable, the annual peak daily flow and 7-day minimum metrics cannot be calculated. Monthly flow data is the minimum time step requirement.

Flow records for hydrologic analyses can be obtained from sources such as USGS gages, state-operated streamflow gages, or the State of Colorado's Stream Simulation Model (StateMod). Each of these data sources are discussed below. All datasets should be checked for data gaps prior to analysis to determine if sufficient data are available to calculate each flow metric. All extrapolated data should be reviewed as well.

*Table 14: Flow Alteration Module Metrics*

| Metric | Description | Aspect of Hydrologic Alteration Characterized | Data Requirements |
|---|---|---|---|
| Mean Annual Q (O/E) | The average of mean monthly flows (cfs) for each water year in the period of record. | Changes in annual flow volume | Daily or Monthly Average Flow Data |
| Mean Aug Q (O/E) | The average flow rate (cfs) for the calendar month of August in each water year in the period of record. | Summer/Fall baseflow alteration | Daily or Monthly Average Flow Data |
| Mean Sept Q (O/E) | The average flow rate (cfs) for the calendar month of September in each water year in the period of record. | Summer/Fall baseflow alteration | Daily or Monthly Average Flow Data |
| Mean Jan Q (O/E) | The average flow rate (cfs) for the calendar month of January in each water year in the period of record. | Winter baseflow alteration | Daily or Monthly Average Flow Data |
| Mean Annual Peak Daily Q (O/E) | The average of the peak daily discharge (cfs) for each water year in the period of record. | High flow pulses | Daily Flow Data |
| 7-Day Minimum (O/E) | The minimum of the 7-day moving average mean for each water year in the period of record. | Extreme low flows | Daily Flow Data |

*Table 15: FAM Metric Selection Based on Ecological Relevance*

<table>
<tr><th>Flow Regime</th><th>Annual Flow Volume</th><th>Summer Baseflow**</th><th>Winter Baseflow</th><th>Extreme Low Flows</th><th>High Flow Pulses</th></tr>
<tr><td>Intermittent</td><td rowspan="2">Mean Annual Q (O/E)</td><td colspan="2">Select a month (or months) critical to spawning instead of a baseflow.*</td><td># Zero flow days*</td><td rowspan="2">Mean Annual Peak Daily Q (O/E)</td></tr>
<tr><td>Perennial</td><td>Mean Aug Q (O/E)<br>AND/OR<br>Mean Sept Q (O/E)</td><td>Mean Jan Q (O/E)</td><td>7-Day Minimum (O/E)</td></tr>
<tr><td colspan="6">* Metric not included in the FAM but may qualify as an acceptable substitution.</td></tr>
<tr><td colspan="6">** August and September should not be used where climatic variations preclude these months from representing baseflow. Alternative months or a single month should be selected.</td></tr>
</table>

**Gages:** When stream gages are present within or near the project site, these data are invaluable. Empirical relationships from a nearby gage station can be developed to produce flow records for the affected stream reach (TNC 2009; Archfield and Vogel 2010; Gianfagna et al. 2015). Any flow datasets should be evaluated to identify data gaps, data quality outliers, or other anomalies, and then compared to historic documentation to establish whether the native flow condition can be determined.

The most common source of continuous stream flow data is the USGS gage network.[33] There are also State operated stream gage networks.[34,35] Note that the State of Colorado Division of Water Resources network of stream gages is operated for administration purposes which generally exclude non-irrigation season data (Nov - March).[17] Thus the January mean Q may not be an available metric for sites without these data unless flow can be modeled for the missing values. Similarly, the dataset for the mean annual Q value may need to be truncated to the same period for each year.

**StateMod:** StateMod is a surface water allocation and accounting model that can be used to simulate various water management approaches in Colorado (StateMod 2016[36]), including simulation of flows after accounting for flow alteration within the river system. The user would need to apply the Base Flow[37] module and the simulation module to generate data characterizing the native flow, i.e. expected values. StateMod generally estimates average monthly flows but an advanced StateMod user can generate daily time step data. Users should consult the StateMod User Manual for instructions and limitations (StateMod 2016).

**Other Hydrologic Models:** Where streamflow data are not available or sufficient in length, the user can create a hydrologic model of the reach catchment to generate stream flows. Note that watershed hydrologic models can be very inaccurate due to their need to parameterize entire watersheds. Records such as daily diversion records and reservoir volumes may be required for modeling existing, pre-project conditions and are available through HydroBase.[38] Precipitation datasets used in hydrologic modeling, similar to flow datasets mentioned above, should be evaluated to identify data gaps, data quality outliers, or other anomalies.

Note, the **CSQT does not require the use of a specific software for performing these analyses.** Existing hydrologic analyses performed in Colorado that may be useful can be found in Barlow et al. (2014) and Sanderson et al. (2012). The Urban Storm Drainage Criteria Manual (UDFCD 2016) promotes the use of the EPA Stormwater Management Model (EPA SWMM) for performing hydrologic assessments associated with major drainageways or outfall systems. The USACE Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS; USACE 2020) can also be used to generate flow records.

### 2.11.3 Methods

All metrics in this module are calculated from hydrologic analyses of flow records. While several approaches are available to perform the necessary analyses, these procedures are beyond the scope of this manual.

For each metric, the value of interest (e.g. mean annual Q) is calculated for each water year in the flow record. Then **the median value for the flow record is calculated** (non-parametric

33 https://nwis.waterdata.usgs.gov/nwis/sw
34 http://www.dwr.state.co.us/Surfacewater/default.aspx
35 https://dnrweb.state.co.us/cdss/
36 https://www.colorado.gov/pacific/cdss/statemod
37 Base Flow is defined in StateMod as representing "…basin streamflows absent man's influence including diversions, return flows, reservoir operations and pumping. If 100% of man's influence is removed, baseflows are often called virgin flows or natural flows." (StateMod 2016)
38 https://www.colorado.gov/cdss

analysis). For most analyses, the distribution of the value of interest within the flow record will be non-normal and the median value should be used (TNC 2009). Justification will need to be provided to use the mean value (parametric analysis).

The field value input to the CSQT is the ratio of the observed value to the expected value (O/E). For each metric, field values are calculated as the deviation from a reference condition (refer to Table 1 on page 17). Therefore, the user needs to calculate the value of interest for three scenarios:

1. Native Flow – For the purposes of the CSQT, native flows are estimates of the stream flows that would result from natural hydrologic processes such as rainfall-runoff and snowmelt-runoff without anthropogenic influence at a given location. This is the expected (E) condition in the O/E calculations.
2. Pre-project condition – The amount of flow seen by the system prior to project implementation. This is the observed (O) condition in the O/E calculations for the existing condition assessment.
3. Post-project condition – The amount of flow seen by the system as a result of project implementation. The post-project condition reflects changes to the operating rules or modeling parameters that reflect the implementation of the project. Ideally, this value is determined through modeling that uses the same period of record as the pre-project condition. This is the observed (O) condition in the O/E calculations for the proposed condition assessment and post-project monitoring assessments.

The pre-project condition is compared to the native flow to calculate the **existing** condition O/E field value for all six metrics and quantifies the flow alteration within the system **before** the project (impact or restoration) is implemented.

The post-project condition is compared to the native flow to calculate the proposed condition O/E field values and quantifies the flow alteration within the system **after** the project is implemented.

The Indicators of Hydrologic Alteration (IHA; Richter et al. 1996) is a commonly applied approach for evaluating flow alteration in rivers (Richter et al. 1997; Mathews and Richter 2007; Poff et al. 2010). IHA is a standalone software application that can be used to evaluate hydrologic alteration and develop environmental flow targets using daily stream gage records or modeled daily flows. Users should refer to the IHA Version 7.1 User's Manual for more detail (TNC 2009). IHA requires daily streamflow data and the software performs linear interpolation over any gaps in the datasets loaded into the software (TNC 2009). Example 16 shows how IHA can be used to generate field values for the CSQT.

Note, the **CSQT does not require the use of IHA**. Other software or tools can be used to calculate streamflow statistics and generate field values, for example, there is also an R package called EFlowstats.[39] Where USGS stream gages are at or near the project site, some of the metrics may be calculated directly on the USGS NWIS webpage.[40]

[39] http://adsabs.harvard.edu/abs/2013AGUFM.H43E1508T
[40] https://maps.waterdata.usgs.gov/mapper/index.html

**Data Collection:** Field data collection needs will vary depending on the data source for flow records. Individual flow measurements may be sufficient to validate empirical relationships that convert flow values from a nearby gage to the affected stream length. Ultimately, the data requirements and study design should be developed based on project specific needs.

Field data collection may include surveying cross-section(s), measuring discharge in the field using a current meter, installing stream gages, calculating the average channel slope, and sampling the bed material. Field data collection procedures are provided in Appendix A. Placement and use of stream gages should follow Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams (USEPA 2014).

**Proposed Condition:** The existing condition field values are derived from data collection and analysis methods outlined above. The proposed condition field values are generated through altering the pre-project condition flow record to reflect the proposed hydrology according to operational commitments, acquisition/ change of existing water rights, or new facilities that enable the proposed hydrology to occur.

**Monitoring:** The Flow Alteration Module contains ten condition assessments for monitoring to verify that the proposed hydrology has been achieved. Installing stream gage(s) and developing a stage-discharge rating curve for the gage is recommended to monitor hydrology throughout the monitoring period. At project closeout, the average observed values from the monitoring period measured at the project site could be used to calculate the final field values. However, flow is highly dependent on annual variations in weather (precipitation, temperature, etc.). Flow can also be impacted by catchment stressors and activities such as clear cutting in the watershed and annual variations in the utilization of upstream water rights. Care should be taken to determine whether measured changes are a result of the project activity.

***Example 16: Flow Alteration in the Fraser River***

Average daily flows for the Fraser River near the Winter Park stream gage were used to develop this example. Flow alteration began in 1936 when the Moffat Tunnel began diverting water from the Fraser basin to the Colorado Front Range. Historical data from 1911-1935 were used to represent native hydrology. Native flows were compared to current hydrology using data from 1988-2017. The comparison of native vs. current flows was used to create an existing condition score for the flow alteration reach, which extends 10.5 miles (55,213 ft) from the Fraser River near Winter Park stream gage to the confluence of the Fraser and Colorado rivers.

Sample IHA output are shown on the following page with the values used to calculate field values for the Flow Alteration Module highlighted in yellow. Example field value calculations are provided below for the mean January Q and mean annual Q metrics. The flow record was evaluated, and a parametric analysis was found to be more appropriate; therefore, means are reported below. Typically, a non-parametric analysis is preferred.

*The existing condition field value for the mean January Q metric = O/E = 5.496 cfs /7.772 cfs = 0.71*

*The existing condition field value for the mean annual Q metric = O/E = 20.04 cfs /44.28 cfs = 0.45*

The existing condition assessment in the Flow Alteration Module is shown below. The existing condition score of 0.61 indicates that the affected reach is functioning-at-risk with respect to flow alteration.

| Metric | Field Value | Index Value | Module |
|---|---|---|---|
| Mean Annual Q (O/E) | 0.45 | 0.50 | 0.61 |
| Mean Aug Q (O/E) | 0.39 | 0.43 | |
| Mean Sept Q (O/E) | 0.46 | 0.51 | |
| Mean Jan Q (O/E) | 0.71 | 0.79 | |
| Mean Annual Peak Daily Q (O/E) | 0.55 | 0.62 | |
| 7-Day Minimum (O/E) | 0.74 | 0.83 | |

A hypothetical flow augmentation scenario that added 10 cfs to each daily value from August to November comprised the proposed condition. The mean annual Q, mean annual peak daily Q, 7-day minimum, and mean Jan Q were unchanged; however, the mean Aug Q and mean Sept Q were affected upwards by this scenario, with associated increases in index value.

| Metric | Field Value | Index Value | Module |
|---|---|---|---|
| Mean Annual Q (O/E) | 0.45 | 0.50 | 0.73 |
| Mean Aug Q (O/E) | 0.64 | 0.71 | |
| Mean Sept Q (O/E) | 0.85 | 0.95 | |
| Mean Jan Q (O/E) | 0.71 | 0.79 | |
| Mean Annual Peak Daily Q (O/E) | 0.56 | 0.62 | |
| 7-Day Minimum (O/E) | 0.74 | 0.83 | |

The Functional Feet value is calculated by multiplying the affected stream length (55,213 LF) by the change in condition scores (0.73-0.61 = 0.12) and applying a 20% weight factor, for a gain of 1,325 FF. This Functional Feet value is added to the Functional Feet value calculated in the Quantification Tool worksheet.

***Example 16 Continued: Sample IHA Output from the Fraser River***

| IHA Parametric Scorecard | | |
|---|---|---|
| | | |
| Fraser River at Winter Park Two-Period Parametric Analysis | | |
| | | |
| | Pre-impact period: 1911-1935 ( 25 years) | Post-impact period: 1988-2017 ( 30 years) |
| NormalizationFactor | 1 | 1 |
| Mean annual flow | 44.28 | 20.04 |
| Non-Normalized Mean Flow | 44.28 | 20.04 |
| Annual C. V. | 1.52 | 1.97 |
| Flow predictability | 0.68 | 0.6 |
| Constancy/predictability | 0.44 | 0.63 |
| % of floods in 60d period | 0.88 | 0.89 |
| Flood-free season | 272 | 242 |

| | MEANS | |
|---|---|---|
| | Pre | Post |
| Parameter Group #1 | | |
| October | 18.170 | 8.647 |
| November | 13.920 | 6.344 |
| December | 9.708 | 5.730 |
| January | 7.772 | 5.496 |
| February | 6.967 | 5.449 |
| March | 7.422 | 6.108 |
| April | 16.480 | 9.682 |
| May | 90.670 | 29.210 |
| June | 204.500 | 96.520 |
| July | 89.490 | 39.950 |
| August | 40.250 | 15.810 |
| September | 25.360 | 11.650 |
| Parameter Group #2 | | |
| 1-day minimum | 5.388 | 4.086 |
| 3-day minimum | 5.601 | 4.187 |
| 7-day minimum | 5.787 | 4.302 |
| 30-day minimum | 6.229 | 4.722 |
| 90-day minimum | 7.030 | 5.224 |
| 1-day maximum | 316.600 | 175.500 |
| 3-day maximum | 299.200 | 167.500 |
| 7-day maximum | 280.800 | 152.400 |
| 30-day maximum | 217.900 | 108.200 |
| 90-day maximum | 131.900 | 56.760 |
| Number of zero days | 0.000 | 0.000 |
| Base flow index | 0.137 | 0.262 |

# Chapter 3. Applying the CSQT in Mitigation Projects

This chapter outlines the process and concepts that should be considered for projects providing mitigation under CWA 404 (i.e., mitigation banks, in-lieu fee projects, or on-site/off-site permittee responsible mitigation projects). The sections of the CSQT workbook that should be completed for restoration and mitigation projects are summarized in Table 16. See Section 1.2.3 for information on how the CSQT calculates functional lift.

*Table 16: CSQT Worksheets Used for Restoration Projects*

| Worksheets | Relevant Sections |
|---|---|
| Project Assessment (Section 1.2.1) | • Programmatic Goals<br>• Reach Description<br>• Aerial Photograph of Project Reach<br>• Restoration Approach |
| Catchment Assessment (Section 1.2.2) | • Complete entire form<br>• Determine restoration potential |
| Quantification Tool (Section 1.2.3) | • Site Information and Reference Selection<br>• Existing Condition field values*<br>• Proposed Condition field values* |
| Flow Alteration Module* (Section 1.2.6) | • Site Information<br>• Existing Condition field values*<br>• Proposed Condition field values*<br>• Field values for up to 10 monitoring events* |
| Monitoring Data (Section 1.2.4) | • As-Built Condition field values*<br>• Field values for up to 10 monitoring events** |
| Data Summary | No data entry in this worksheet |
| Reference Curves | No data entry in this worksheet |
| ** Guidance on parameter selection is provided in Section 2.5 and detailed instructions for collecting and analyzing field values for all metrics are provided in Chapter 2.* | |
| *** Guidance on collecting and entering data for monitoring events is provided in Section 3.4.* | |

## 3.1 Site Selection

The CSQT can be used to assist with selecting or ranking the priority of a potential stream restoration or mitigation site. While there are many other elements to include in a thorough site-selection process (ELI 2016; Starr and Harman 2016), this section only illustrates the role of the CSQT.

In the CSQT, functional lift is estimated from the difference in pre- and post-project condition scores, expressed as an overall change in functional feet. Therefore, if the user is deciding between multiple sites, the CSQT can be used to rank sites based on the amount of functional lift available. If there are time or budget constraints, the user may want to evaluate potential mitigation or restoration project sites using rapid methods where available (see Chapter 2 and

Appendix A). At this stage, a user will likely have to estimate post-project condition scores using best professional judgement. The user could model a variety of design approaches to see how much lift is reasonable for each parameter. While evaluating different sites, it is generally recommended to select a mitigation site that can achieve the following post-project condition scores:

1. An index score of 0.70 or higher for floodplain connectivity, bed form diversity, and lateral migration; and
2. An index score of 0.60 or higher for riparian vegetation (recognizing that riparian vegetation may take multiple years to reach full potential and therefore may not reach the functioning range of 0.7 or higher).

If the purpose of the project is to provide mitigation under CWA 404, the user should also refer to the COMP (USACE 2020) or consult with the Corps for further guidance on site selection.

## 3.2 Restoration or Mitigation Project Planning

### 3.2.1 Restoration Potential

Restoration potential is selected after following the steps outlined below and is then entered in the Project Assessment Worksheet. Results are automatically copied to the Site Information and Reference Selection section of the Quantification Tool worksheet.

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). Restoration potential is determined by the degree to which physical, chemical, and biological processes at the reach scale are maintained or restored given the stressors in the watershed or even downstream of the reach. The “highest level” refers to the functional categories in the Stream Functions Pyramid, and whether a project can restore functional capacity within each of the categories to a reference standard. A project with full restoration potential may restore the functional capacity within all categories to a reference standard. Partial restoration may improve some, but not all functions to reference standard. For example, partial restoration might mean restoring floodplain connectivity, lateral migration, and aquatic habitat to a reference standard by implementing activities that affect functional capacity in the Reach Hydrology & Hydraulics and Geomorphology categories, but not restoring temperature or fish communities to a reference standard due to watershed stressors (Beechie et al. 2010; Harman et al. 2012).

- Full Restoration Potential – The project has the potential to restore functions within all categories, including biology, to a reference standard (see Table 1 on page 17). This is consistent with the ‘full-restoration’ concept identified by Beechie et al. (2010), where actions restore habitat-forming processes and return the site to its natural range of biological conditions and dynamics.
- Partial Restoration Potential – The project has the potential to improve some functions compared with pre-project or baseline conditions. One or more functional categories may be restored to conditions typical of, or approaching reference standard, but some catchment stressors or reach-scale constraints are preventing the site from reaching full potential.

Partial restoration is the most common for stream restoration projects. Watershed processes and reach-scale constraints influencing a project site may allow for some functions, such as floodplain connectivity and in-stream habitat, to be restored but may limit the restoration of physicochemical or biological functions to reference standard. For partial restoration projects, improvements in all functional categories may be observed, but these improvements may not reflect a reference standard.

There are likely situations where even partial restoration is not possible due to the severity of catchment stressors and project constraints that may be outside the control of the practitioner. For example, flow alteration (a catchment-scale stressor) may modify the hydrologic and sediment transport processes to such a degree that partial-restoration is not feasible. Some stressors and constraints limit restoration potential to such a degree that the site may not be suitable for restoration activities.

**Procedure for Determining Restoration Potential:**

1. Determine the project reach limits and delineate the catchment area to the downstream end of the project reach (Section 2.1).
2. Complete the Catchment Assessment worksheet (Section 1.2.2 and 2.3). Review the scores for each category to determine if an identified stressor can be overcome by proposed activities or whether it will limit restoration potential in the project reach. A stressor that prohibits even partial restoration may constitute a "deal breaker", meaning the reach is not a good candidate for stream restoration activities unless catchment-scale stressors can be improved.
    a. Upon completing the Catchment Assessment worksheet, the user should determine if restoration activities can overcome any or all the catchment perturbations. Refer to the individual category ratings in the Catchment Assessment. Can the fair or poor ratings for each individual category be overcome by the scale of the project or by doing additional work in the catchment? If individual category ratings can change from fair or poor to good, then full restoration may be possible.
    b. Compare the reach size to the catchment size (length and/or area). Can the scale and type of restoration overcome the catchment stressors? At the reach scale, users should consider several factors, including the scale of the restoration project in relation to the watershed. For small catchments where the length or area of the restoration project is large compared to the total stream length or catchment area, reach-scale activities may be able to overcome the stressors and perturbations.
    c. Consider whether catchment-scale efforts, in combination with a restoration project, are feasible and could overcome catchment perturbations/stressors. For example, if discontinuous flow is occurring upstream of the project reach, restoration may not be successful unless the user can restore important aspects of the flow regime. Broader-scale efforts could also include managing sources of sediment imbalances within the contributing watershed, improving stormwater management practices, restoring more natural hydrology, removing connectivity barriers, etc. Note: evaluating and addressing stressors to underlying hydrologic or sediment transport processes will require additional design and/or modeling analyses that are outside the scope of this tool.

3. Identify reach-scale human-caused constraints. Explain how they could limit restoration potential. Constraints are human-caused conditions, structures, and land uses that inhibit restoration activities at the reach scale and are outside the user's control. A constraint is different than a stressor, which occurs at the catchment-scale outside of the project reach. In some cases, a stressor can be considered a constraint if it is located within the reach and will not be removed as part of the restoration plan. Constraints can negatively affect processes needed to support full restoration potential (and in extreme cases can even limit partial restoration).

   Common constraints include land uses within the floodplain or valley bottom that minimize stream-corridor width (e.g., roads, utility easements, levees/berms, etc.); dams or diversions that affect natural timing, magnitude, duration, frequency or rate of change of flows; and existing dams or culverts that function as migration barriers for fish and prevent streambed elevation changes during design. Note that natural conditions are not constraints. For example, while hillslopes constrain the lateral extent of meandering streams, that is not a constraint, as defined here. Hillslopes are a natural condition of the catchment. The presence of bedrock can limit changes to bed elevation and even prevent some aquatic species from migrating upstream. However, these are natural conditions that create habitat diversity. They are not considered constraints in this methodology and would therefore not limit the restoration potential.

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

   Selecting the reference stream type is a qualitative process and therefore requires considerable experience in fluvial geomorphology by the user. The user making the selection should have experience and knowledge about channel evolution, process drivers, and the Rosgen Stream Classification system.

   a. Identify the dominant process drivers for geology, hydrology, and biology at the project reach and record this information using the drop-down menus on the Project Assessment Worksheet (Section 2.2). Using the Stream Evolution Triangle (SET) and Figures 6a and 6b from Castro and Thorne (2019), determine the typical Rosgen stream type(s) that might be expected given the process drivers. Note that the existing stream type may be different than the reference stream type identified. Geologic process drivers include valley type and sediment regime, which will play an important role in selecting reference stream type.

   b. Characterize the current condition of the stream and determine the current and future potential Stream Evolution Model (SEM; Cluer and Thorne 2013) and/or Rosgen Channel Succession Stage (Rosgen 2006). Is the stream trending towards greater or lesser functionality? What is the realistic final SEM stage or Rosgen stream type as compared to the previously undisturbed SEM Stage or stream type?

   c. Users should then consider whether the proposed project has the potential to restore the reach to the reference stream type identified (Refer to 2a, b, and c above).

The SEM (Cluer and Thorne 2013), SET (Castro and Thorne 2019), and Rosgen Channel Succession Stages (Rosgen 2006) are not described in detail in this manual and users should consult the source material in applying these methods. The SEM provides more detail for systems that historically existed as stream/wetland complexes or anastomosed systems ($D_A$ stream type). These systems are typically in low gradient alluvial valleys with a response sediment regime. Table 17 provides guidance for determining existing and reference Rosgen stream types based on the SEM stage that relates to the current condition and proposed end point.

*Table 17: Crosswalk Linking Stream Evolution Model Stages to Rosgen Stream Type Succession*

| Stream Evolution Model Stages (Cluer and Thorne 2013) | Corresponding Rosgen Stream Types |
|---|---|
| Stage 0 – Anastomosing | $D_A$ |
| Stage 1 – Sinuous Single Thread | C, E |
| Stage 2 – Channelized | C, E, Gc |
| Stage 3 – Degradation | Gc |
| Stage 3s – Arrested Degradation | Gc, F, Bc |
| Stage 4 – Degradation and Widening | Gc, F |
| Stage 5 – Aggradation and Widening | F, C |
| Stage 6 – Quasi Equilibrium | C, E |
| Stage 7 – Laterally Active | C, E, F |
| Stage 8 – Anastomosing | DA |

5. Use the Quantification Tool worksheet to determine the baseline condition of the reach. The Quantification Tool worksheet will characterize existing functional capacity by parameter and functional category.

Based on Steps 1-5, describe the restoration potential as Full or Partial. Explain the reasons for your selection. Identify which parameters/functions could be restored to a reference standard and which may not. The restoration potential of the project reach is recorded on the Project Assessment worksheet. Results are also automatically populated in the Site Information and Reference selection Section of the Quantification Tool worksheet.

### 3.2.2 Function-Based Design Goals and Objectives

After the restoration potential has been determined, users should develop function-based goals and objectives. This information is also entered into the CSQT Workbook on the Project Assessment worksheet. Guidance on developing function-based goals and objectives is adapted from Harman et al. (2012).

Design goals are statements about *why* the project is needed at the specific project site and outline a general intention for the restoration project. These goals communicate the reasons behind the project's development. Design objectives explain *how* the project will be completed. Objectives are specific, tangible, and can be validated with monitoring and performance standards. Objectives, in combination with the stated goals, describe what the user will do to address the functional impairment. Typically, objectives will explain how key function-based parameters like floodplain connectivity, bed form diversity, lateral migration, and riparian vegetation will be changed to meet the goals. Design goals and objectives can be used to inform parameter selection within the CSQT (see Example 17).

The design goals should be cross referenced with the restoration potential of the project site to ensure that the goals do not exceed the restoration potential. For example, increasing native fish species richness to a reference standard is not feasible if the restoration potential is "partial" due to limitations identified in the catchment assessment. In this example, the design goal could be revised to restore physical habitat for native species, a restoration goal that matches the partial restoration potential result. If native fish populations in the project reach are to be monitored, increasing the native species richness could be possible even with partial restoration potential; however, returning native species richness to reference standard would not be expected or possible. If catchment-level improvements are implemented to address the stressors, full restoration could be possible. This outcome would require reach-scale *and* catchment-scale restoration efforts.

***Example 17: Project with Partial Restoration Potential***

Partial Restoration Potential: The catchment draining to the project is mostly rangelands or irrigated pasture. The overall catchment health is fair and biological improvements are limited by flow alteration.

Goals: Improve aquatic habitat for native fish communities and reduce sediment supply from bank erosion.

Objectives: Fence out cattle and re-plant riparian vegetation to stabilize banks, reconstruct portions of channel to improve bed form diversity (habitat).

Possible Parameter List:

- Reach Runoff
- Floodplain Connectivity
- Lateral Migration
- Bed Form Diversity
- Riparian Vegetation
- Nutrients
- Macroinvertebrates
- Fish

Monitoring is included for metrics within all categories because the project is expected to show some improvement. However, the project is not expected to restore nutrients, macroinvertebrates, and fish parameters to a reference standard.

## 3.3 Passive Versus Active Restoration Approach Examples

The CSQT evaluates the functional lift of restoration activities through changes in function-based parameter scores, not by the scale of restoration activities, e.g., the amount of heavy equipment used in a project or the number of in-stream structures installed. Therefore, the CSQT can evaluate lift across a range of restoration approaches that require varying amounts of effort.

Hypothetical examples of three unique restoration approaches and the potential lift that can be captured using the CSQT are detailed below. The three example approaches include: Passive, Moderately Active, and Active. Active restoration approaches typically include significant earthwork (e.g., Priority 1 or 2) and more passive approaches typically avoid heavy machinery and may include management actions (e.g., cattle exclusion). All three examples evaluate the following parameters:

- Reach Runoff
- Floodplain Connectivity
- Large Woody Debris
- Lateral Migration
- Bed Form Diversity
- Riparian Vegetation
- Temperature
- Nutrients
- Macroinvertebrates
- Fish

To illustrate the benefit of monitoring physicochemical and biological condition, ΔFF is reported at the end of this section for two monitoring scenarios, where 1) Reach Hydrology & Hydraulics and Geomorphology are monitored, and 2) all functional categories are monitored. Thus, it was assumed that all example projects could show modest improvements in temperature, nutrients, macroinvertebrate, and fish parameters.[41]

**Passive Restoration Approach:**

In this hypothetical example, 1,000 linear feet of stream is flowing through open rangeland. An existing conditions assessment showed that the stream had not been channelized in the past and meanders within a confined alluvial valley. The process drivers for this system indicate that erosion resistance, stream power, and biological interaction are all moderate. The existing stream is a Rosgen C stream type with a single-thread sinuous channel. Due to the meanders and corresponding lateral-scour pools, bed form diversity was characterized as functioning, despite the absence of in-stream large woody debris. However, cattle have full access to the stream so most riparian vegetation has been removed by grazing, which has led to moderate erosion on several outside meander bends. Erosion is also evident where cattle have accessed or crossed the stream. Channel widening is likely to continue so long as cattle have access to the stream. Bank heights are low, and energy continues to be dissipated by spreading flood waters across the floodplain.

[41] Without evaluating the physicochemical and biological parameters, the maximum overall score in the CSQT will be 0.60. Selecting and assessing parameters in both functional categories will increase the maximum overall score to 1.0 in the CSQT and will increase the amount of functional feet generated.

Due to upstream agricultural land use practices, the project received a partial restoration potential determination. The nutrients parameter score is expected to improve the existing condition slightly; however, it will remain not functioning and limit biological lift as well.

The stream will likely stay a Rosgen C type but could evolve into a $D_A$ (anastomosed system) if biotic interaction increases substantially and erosion resistance increases moderately. The mitigation approach is to remove intensive grazing pressure by fencing out the cattle, incorporating water gaps, and re-planting the riparian area. This passive approach is feasible because reach runoff, floodplain connectivity, and bed form diversity are already within the reference standard range of condition (it often takes significant channel modification to fix these parameters). With these functions in place, a newly planted riparian area will improve lateral migration and support limited improvement to physicochemical and biology functions within the mitigation monitoring period of 5 years (Figure 29).

| Functional Category | Function-Based Parameters | Existing Parameter | Proposed Parameter |
|---|---|---|---|
| Reach Hydrology & Hydraulics | Reach Runoff | 0.89 | 0.92 |
| | Baseflow Dynamics | | |
| | Floodplain Connectivity | 0.71 | 0.71 |
| Geomorphology | Large Woody Debris | 0.00 | 0.00 |
| | Lateral Migration | 0.59 | 0.97 |
| | Bed Form Diversity | 0.81 | 0.82 |
| | Riparian Vegetation | 0.24 | 0.66 |
| Physicochemical | Temperature | 0.71 | 0.78 |
| | Dissolved Oxygen | | |
| | Nutrients | 0.13 | 0.19 |
| Biology | Macroinvertebrates | 0.20 | 0.26 |
| | Fish | 0.60 | 0.64 |

***Figure 29:*** ***Passive Restoration Approach CSQT Example. Red equals not-functioning, yellow equals functioning-at-risk, and green equals functioning.***

**Moderate Restoration Approach:**

In this hypothetical example, the stream reach is in a similar rangeland setting as the passive example with one major change—the stream reach has been channelized and is currently 800 linear feet in length. Although slope and stream power have increased due to channelization, the presence of underlying bedrock has prevented incision. However, the removal of meander bends and large wood have prevented pool-forming processes. Thus, bed form diversity is not-functioning compared to reference standard. The riparian vegetation has been substantially grazed, which has led to moderate bank erosion; however, floodplain connectivity has been largely maintained. In this scenario, the existing stream channel is a Rosgen Cb type. Again, it is moderately influenced by biology, hydrology, and geology. The channel will likely stay a Cb because bedrock is preventing incision.

The mitigation approach involves fencing out the cattle, planting riparian vegetation, and adding large wood and in-stream structures to create pools in the straightened channel. The addition of large wood will improve the large woody debris score and the in-stream structures will improve the bed form diversity and lateral migration scores (Figure 30).

| Functional Category | Function-Based Parameters | Existing Parameter | Proposed Parameter |
|---|---|---|---|
| Reach Hydrology & Hydraulics | Reach Runoff | 0.89 | 0.92 |
| | Baseflow Dynamics | | |
| | Floodplain Connectivity | 0.71 | 0.71 |
| Geomorphology | Large Woody Debris | 0.00 | 0.57 |
| | Lateral Migration | 0.52 | 0.97 |
| | Bed Form Diversity | 0.39 | 0.82 |
| | Riparian Vegetation | 0.24 | 0.66 |
| Physicochemical | Temperature | 0.71 | 0.78 |
| | Dissolved Oxygen | | |
| | Nutrients | 0.13 | 0.19 |
| Biology | Macroinvertebrates | 0.20 | 0.26 |
| | Fish | 0.60 | 0.64 |

*Figure 30: Moderately Restoration Approach CSQT Example. Red equals not-functioning, yellow equals functioning-at-risk, and green equals functioning.*

**Active Restoration Approach:**

In this hypothetical example, the stream reach is in a rangeland setting like the previous two examples, but the stream has been channelized (800 linear feet in length) and is also incised (i.e., no floodplain connectivity). Riparian vegetation and bed form diversity are not functioning for reasons explained in the previous examples. Lateral migration is also not-functioning because the bank heights are high due to floodplain disconnection and channel incision, which is exacerbated by the lack of riparian vegetation.

This scenario is an example of active restoration because floodplain reconnection is necessary to prevent flood flows from continuing to further erode and widen the channel. The current stream type is a Rosgen Gc, which may evolve into an F through bank erosion and aggradation. The channel will likely evolve back into a C channel after decades of channel evolution. The current stage in the stream evolution model (SEM; Cluer and Thorne 2013) for this incised stream is stage 3 or stage 4, degradation or degradation and widening. Eventually the combination of decreased stream power resulting from channel widening and the increased sediment supply from the bank will lead to aggradation and, after decades of channel evolution, the channel will likely evolve to quasi-equilibrium (stage 6).

Significant modification is needed to establish a new meandering channel geometry (1,000 linear feet in length) and reconnect the stream to a floodplain, either by raising the bed and remeandering the channel or excavating a floodplain. Improvements in parameter scores are shown in Figure 31.

| Functional Category | Function-Based Parameters | Existing Parameter | Proposed Parameter |
|---|---|---|---|
| Reach Hydrology & Hydraulics | Reach Runoff | 0.89 | 0.92 |
| | Baseflow Dynamics | | |
| | Floodplain Connectivity | 0.00 | 0.71 |
| Geomorphology | Large Woody Debris | 0.00 | 0.57 |
| | Lateral Migration | 0.27 | 0.97 |
| | Bed Form Diversity | 0.39 | 0.82 |
| | Riparian Vegetation | 0.18 | 0.66 |
| Physicochemical | Temperature | 0.71 | 0.78 |
| | Dissolved Oxygen | | |
| | Nutrients | 0.13 | 0.19 |
| Biology | Macroinvertebrates | 0.18 | 0.26 |
| | Fish | 0.41 | 0.64 |

*Figure 31: Active Restoration Approach CSQT Example. Red equals not-functioning, yellow equals functioning-at-risk, and green equals functioning.*

Functional lift for each scenario is summarized in Table 18. For the passive and active restoration approaches, the proposed stream length is 1,000 linear feet but for the moderate approach, the channelized stream length remains at 800 linear feet. Even though the proposed condition scores are similar across all three scenarios, the most functional lift was achieved by the active approach because the existing channel in this scenario was in the worst condition. Additionally, greater lift was achieved when all functional categories were monitored instead of only Reach Hydrology & Hydraulics and Geomorphology, demonstrating the value in monitoring Physicochemical and Biology even if they do not achieve a reference standard.

*Table 18: Summary of Restoration Approach Scenarios for two monitoring scenarios, where ∆FF is change in functional feet and RH&H is Reach Hydrology & Hydraulics.*

| Restoration Approach | ∆FF for RH&H and Geomorphology | ∆FF for RH&H, Geomorphology, Physicochemical and Biology |
|---|---|---|
| Passive | 63 | 85 |
| Moderate | 115 | 133 |
| Active | 313 | 385 |

## 3.4 Monitoring

Functional change is predicted using the Quantification Tool worksheet and then verified through monitoring. Monitoring data are entered in the Monitoring Data worksheet (Section 1.2.4). For any field value entered into the CSQT workbook, a completed Field Value Documentation form (Appendix B) must be provided to document values and references for field value entries.

Monitoring requirements may vary between projects, and thus **the monitoring period length, performance standards, and number of monitoring events will be specified by the Corps on a project-specific basis**. Below are general guidelines for applying the CSQT.

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

- Note: If a field value is entered for a metric in the Existing Condition Assessment, a value **must also be entered** for the same metric in all subsequent condition assessments (proposed, as-built, and every monitoring event).
- For some metrics multiple years of data are required (i.e. fish metrics).
- For other metrics, where only a single sampling event is required, multiple sampling events will improve the accuracy of the field value used to calculate lift by quantifying inter- or intra-annual variability (e.g. macroinvertebrates and physicochemical metrics).

<u>Proposed Condition</u> – Proposed condition field values are estimated/predicted using available project data. For mitigation projects, proposed conditions are based on the **expected condition at the end of the project monitoring period** or at mitigation closeout (e.g., year 5, 7 or 10). Bankfull verification and proposed condition field values should be outlined in the restoration or mitigation plan and documented using the forms in Appendix B.

<u>As-built</u> – As-built condition should verify proposed field values following construction for some metrics (listed below). The as-built field values should highlight any changes from the proposed condition.

- Channel plan form should verify pool spacing ratio in meandering streams and the proposed stream length.
- Concentrated flow points, large woody debris index or piece count, percent armoring, and percent side channels metric field values should be measured post-construction or documented in record drawings.
- Floodplain grading should verify flood-prone width for the entrenchment ratio and riparian extent metrics.
- Channel dimensions should verify bankfull elevations and metric field values for bank height, entrenchment ratio, aggradation ratio, and for both baseflow dynamics metrics.
- Channel profile should verify bankfull elevations and pool spacing ratio, pool depth ratio, and percent riffle metric field values.
- The proposed condition field values for the remaining metrics (land use coefficient, other lateral migration metrics, riparian vegetation cover metrics, and all metrics in the physicochemical and biology functional categories) may not be achieved immediately post-construction and the existing condition field value should be entered for the as-built

condition and subsequent monitoring events until post-project data are collected for a particular metric.

Monitoring Events – Monitoring field values are measured at any given point after restoration activities have been completed and data collection should be sufficient to **document potential problems in achieving the proposed condition** during the monitoring period. The frequency of monitoring different metrics can vary based on the level of effort and expense of the data collection.

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

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

Note that where stressors and changes to catchment scale processes are suspected to affect either the existing or proposed condition scores the user should consult with the Corps.

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# APPENDIX A:

# Field Data Collection Methods for the Colorado Stream Quantification Tool v1.0

# Table of Contents

# 1. Introduction and Purpose

The purpose of this document is to provide field methods that can be used to collect data for entry into the Colorado Stream Quantification Tool and Debit Calculator (CSQT). Teams collecting and analyzing these data should have experience and expertise in botany, aquatic ecology, hydrology, and geomorphology as well as experience and expertise applying the assessment methods used to calculate the metrics included in the SQT. **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 these methods and the Stream Functions Pyramid Framework are recommended to ensure that the methods are executed consistently.

This appendix serves as a compliment to Chapter 2 of the User Manual, which provides information on how to select parameters, calculate metric field values from field data, and input these values into the CSQT and Debit Calculator workbooks. Few measurements are unique to the CSQT, and data collection methods are often detailed in other instruction manuals or literature. This document is modified from the Field Data Collection Methods for the WSQT v1.0 (USACE 2018 Appendix A) and has been edited for Colorado with input from the Colorado Stream Quantification Tool Steering (Advisory) Committee (CSQT SC). The WSQT v1.0 served as the basis for the CSQT Beta Version and many Chapters in this document are reproduced with minor edits from USACE (2018) Appendix A.

The forms necessary for data collection and completion of the CSQT are provided in Appendix B. Other field forms that may be useful for data collection, but are not required, are included in Section 12. Prior to going into the field, the user should complete the Parameter Selection Checklist (Appendix B). Guidance on filling out the checklist is provided in Section 2.5 of the User Manual.

| Required Forms (User Manual Appendix B): | Other Field Forms (Section 12): |
|---|---|
| Parameter Selection Checklist | Longitudinal Profile Form |
| Project Reach Form | Standard Cross-Section Form |
| Bankfull Verification | Rapid Survey Form |
| Field Value Documentation | Lateral Migration Form |
| Riparian Extent Form(s) | Physicochemical and Biology Form |
| Vegetation Plot Form(s) | Pebble Count Form |

Survey methods described in this appendix are provided for convenience, recognizing that other standard survey techniques that collect accurate location and elevation data are acceptable and can be used to calculate metric field values. Field forms provided in Section 12 of this appendix are similarly optional and provided for convenience. Required forms are provided as Appendix B of the User Manual. Several of the data forms are also available as Microsoft Excel Workbooks where data can be entered upon returning from the field.[1] There is a shading key on some of the field forms that indicates which cells are to be filled out in the office versus the field, and which cells perform calculations. The calculation cells will automatically calculate values from provided field data in the workbook versions. These cells can also be filled out on a printed field

[1] Microsoft Excel version of the field forms are available from: https://ribits.usace.army.mil/

form. Other data processing tools, such as Mecklenberg (2004) can be used to process field data and calculate metric values.

For evaluating the following parameters and metrics, **users should be familiar with the following methods and should review the following references prior to field sampling.**

*Table A.1: Field methods not included in this document*

| Metric or Method | References |
|---|---|
| Pebble count for characterizing bed materials (Site Information and Stratification) | • River Stability Field Guide, Second Edition (Rosgen 2014)<br>• Standard Operating Procedure for the Collection of Pebble Counts (CDPHE 2015a) |
| Large Woody Debris Index (LWDI) | • Pages 73 – 77 of Monitoring Wilderness Stream Ecosystems (Davis et al. 2001)<br>• Application of the Large Woody Debris Index: A Field User Manual Version 1 (Harman et al. 2017) |
| Large Woody Debris Piece Counts | • CSQT v1 User Manual |
| Bank Erosion Hazard Index/Near Bank Stress (BEHI/NBS) | • Appendix D of Function-Based Rapid Field Stream Assessment Methodology (Starr et al. 2015), or<br>• River Stability Field Guide, Second Edition (Rosgen 2014) |
| Greenline Stability Rating | • Monitoring the Vegetation Resources in Riparian Areas (Winward 2000), or<br>• Riparian Area Management: Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation (USDOI 2011) |
| Temperature Parameter | • Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams (USEPA 2014), or<br>• Measuring Stream Temperatures with Digital Data Loggers: A User's Field Guide (Dunham et al. 2005) |
| Measuring Flow for Baseflow Dynamics and Flow Alteration Module | • Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams (USEPA 2014). |
| Fish Parameter | • Standard Methods for Sampling North American Freshwater Fishes (Bonar et al. 2009) |

# 2. Field Preparation Information

Parameter selection will dictate how many visits to the project may be necessary to accomplish data collection for all metrics. At a minimum, users should assess reach hydrology & hydraulics and geomorphology using the basic suite of parameters. Rapid options for field data collection are available for some metrics, including large woody debris and the metrics derived from longitudinal profile and cross-section survey data. Team members require experience with bankfull identification, surveying methods, BEHI/NBS (or Greenline Stability Rating; GSR), and vegetation identification (see User Manual, Chapter 2 for specific experience requirements).

## Equipment List

At a minimum, the following field gear will be needed:

- Field forms and maps
- Waders
- Camera
- Metric ruler
- Clinometer
- GPS unit (helpful with lateral migration, riparian extent, and sinuosity field measurements)
- Calipers large enough to measure 50 cm diameter logs (not required, but helpful for the LWDI assessment. Not needed for Rapid assessment)
- Survey equipment – The field methods in this manual are for differential-leveling survey methods using a laser level, hand level, or line level. **Other surveying methods that collect accurate location and elevation data are acceptable.** Methods are provided for convenience and not as a requirement. For the methods in this manual, the following gear will be needed:
    - Laser level (hand or line level sufficient for rapid methods described below)
    - 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

## Metric Sampling Periods & Restrictions

Sampling periods for metrics vary. Most metrics in the CSQT can be assessed in a single day or visit, but multiple days or visits may be required, depending on the complexity and size of the site and which metrics were selected for analysis. Table A.2. shows sampling restrictions and considerations by parameter. Parameters that are not listed do not have sampling restrictions.

*Table A.2: Sampling Restrictions*

| Parameter | Sampling Periods and Restrictions |
|---|---|
| Baseflow Dynamics – Both metrics | Gages recording during summer low flows. |
| Lateral Migration – GSR | GSR – Field data should be collected during the growing season at the same time of year for pre- and post-project evaluations. |
| Riparian Vegetation – Vegetation cover metrics | Field data should be collected during the growing season at the same time of year for pre- and post-project evaluations. |
| Temperature – Both metrics | Gages recording during summer months. |
| DO – Concentration | Logger recording during summer months. |
| Nutrients – Chlorophyll α | Mid-summer to early fall |
| Macroinvertebrates | Biotype 1 & 2: late June to early November<br>Biotype 3: May 1 to November 30 |
| Fish – Native species richness and SGCN | Two sampling periods a minimum of 60 days apart |
| Fish – Wild trout biomass | Consecutive year sampling events during the same season; avoid spawning season. |

**Reference Control Reaches**

The Wild Trout Biomass metric requires data collection at a reference site *in addition* to data collection within the project area. Specific guidance is provided in the Fish Sampling section of this Appendix.

## 3. Reach and Representative Sub-Reach Assessments

The following sequence of steps is recommended. Based on parameter selection, not all steps will need to be completed for all projects.

Prior to field work, the user should determine whether the project area should be delineated into multiple project reaches (see Section 2.1 of the User Manual). When multiple project reaches exist on the same stream, data collection typically proceeds from upstream to downstream. However, if biological sampling is being performed, evaluate the most downstream reach first and work upstream or collect biological samples prior to other instream work.

Procedure:

1. Conduct necessary pre-field desktop activities (see Chapter 2 of the User Manual). Complete the **Parameter Selection Checklist** and the Site Information and Reference Stratification section of the **Project Reach form**. All values in these sections should be filled in prior to completing fieldwork. Users should also complete the desktop evaluation for **Riparian Extent**.

2. Walk along the stream throughout the project area to verify the delineation of project reaches. Determine whether additional segmentation is needed based on field conditions. Record the GPS location at the downstream end of the reach in Section I of the **Project Reach form**.

3. Within each project reach, walk along the stream length to view locations and character of riffles, the number of concentrated flow points, length of armoring, presence of side channels, beaver dams or other impoundments, and bankfull indicators.

    a. Measure difference between bankfull stage and water surface elevation at multiple points along the project reach (See Bankfull Elevation – Field Identification). This data can be recorded in the **Project Reach form**. Use this 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 II of the **Project Reach form**. If the channel does not have water, use the edge of channel in riffles as a surrogate for water, but avoid scour areas and bars. Note, this method will create more variability in the measurement.

    b. Consider possible locations for the representative riffle cross-section (see Representative Riffle Survey). The preference is for the riffle to be located within the representative sub-reach. However, in disturbed settings, this cross-section may be located upstream or downstream of the sub-reach.

    c. Record number of concentrated flow points, length of any armored sections of bank, and length of any side channels on the **Project Reach form.** Instructions for these metrics are provided in Chapter 2 of the User Manual.

    d. Measure slope and sinuosity (See Rosgen Stream Classification and Sinuosity, respectively).

4. If the project reach is long, determine the location of the representative sub-reach. The sub-reach is at least two meander cycles or 20 bankfull widths in length. The sub-reach should be representative of the typical bed form diversity in the project reach and should include the

stretch of channel with the greatest amount of large woody debris. Record the length of the representative sub-reach on the **Project Reach form**.

5. Record the GPS location at the downstream end of the representative sub-reach in Section III of the **Project Reach form**.
6. Select the location within the sub-reach for biological sampling (if applicable). Refer to Section 12 of Policy Statement 10-1 (CDPHE 2017) for information on selecting a sample location.
7. Sample macroinvertebrates (see Macroinvertebrate Sampling in Section 9). Processed samples should be immediately preserved with ethanol or other appropriate preservative, and stored in a cool, shaded area for the remainder of data collection.
8. Sample chlorophyll α (see Chlorophyll α Sampling in Section 8). Chlorophyll α sampling can be done simultaneously during macroinvertebrate sample collection. Processed samples should be immediately transferred to a cooler with dry ice, and stored in a cool, shaded area for the remainder of data collection.
9. Survey the representative riffle cross-section (see Representative Riffle Survey methods below). If located within the sub-reach, the same riffle used for biological sampling may be used for the cross-section survey, or an alternative representative riffle can be selected. If the same riffle is used, locate the cross-section in a portion of the riffle not substantially disturbed from biological sampling. Locate bankfull indicators using the Bankfull Elevation - Field Identification methods.
   a. Survey additional riffle cross-sections as needed to quantify baseflow dynamics, entrenchment ratio, and aggradation ratio.
10. Conduct a longitudinal profile (see Section 3 for generalized method) or Rapid Survey (Section 4) for bed form diversity and floodplain connectivity data.
11. Conduct a large woody debris assessment, lateral migration evaluations, and riparian vegetation survey (Section 7), as applicable based on parameter selection.
12. Install stream gages, temperature sensors, and dissolved oxygen sensors as applicable based on parameter selection.
    - Note: Users will need to survey cross-sections and measure flow at any stream gages that will be used to determine stream flow (applicable to the baseflow dynamics and metrics in the flow alteration module).

## Bankfull Elevation – Field Identification

Several parameters in the CSQT require bankfull dimensions to calculate metrics and determine the Rosgen stream type. Prior to making field measurements for these parameters and determining stream type, the user should identify and verify the bankfull stage and associated dimensions. Section 2.6 of the User Manual describes a hierarchical method to verify a bankfull indicator and calculate bankfull dimensions and discharge. This section outlines methods to follow when field indicators are present. Users should complete the **Bankfull Verification form.**

Methods to establish and verify bankfull elevation in the field can be found in the Bankfull Elevation – Field Identification section of the Manual of Standard Operating Procedures for Sample Collection and Analysis (WDEQ/WQD 2018). The text is duplicated here with minor modifications; photographs from the original reference are not included.

*Quality Control:*

Appropriate use of bankfull elevation indicators requires adherence to the following principles:

1. Seek indicators appropriate for specific Rosgen stream types.
2. Know the recent flood and drought history of the area to avoid being misled by spurious indicators. This includes conducting site reconnaissance during bankfull discharge events.
3. Use multiple indicators wherever possible as reinforcement of a common stage or elevation.
4. Exercise caution when identifying bankfull elevation in reaches of the stream that are subject to frequent inundation caused by beaver dams, diversion structures, etc.
5. Bankfull elevation above and below hydrologic anomalies that influence the entire active channel such as natural controls (boulders, bedrock), headcuts, dams, and similar features will likely be different. These breaks in bankfull elevation should be accounted for at all site visits.
6. Except in cases noted above, bankfull indicators should be at a consistent elevation relative to the water surface along an individual stream reach.
7. Reach-wide bankfull slope should be similar to the reach-wide water surface slope, assuming both variables were measured on the same day and rapid aggradation or degradation is not occurring. This can be determined from the longitudinal profile and difference in measurements between the bankfull indicator and water surface.
8. Bankfull indicators along pools, particularly along the outside of meander bends, may be at a higher elevation than indicators at riffles. However, there should still be consistency in elevation of bankfull indicators along the entire reach.
9. Where possible, calibrate field-determined bankfull stage elevation and corresponding bankfull channel dimensions to known recurrence interval discharges at gage stations and/or applicable regional curves. [Refer to Section 2.6 of the User Manual]
10. Persistent long-term drought conditions may create a false “bankfull” elevation that does not correspond to the actual bankfull elevation under the current climatic regime. See step 9.

*Introduction:*

Bankfull discharge is a frequently occurring peak flow whose corresponding stage or elevation often represents the incipient point of flooding associated with a return period of 1-2 years. Bankfull elevation (and its associated discharge) serves as a consistent reference point which can be related to the formation, maintenance, and dimensions of the channel as it exists under the current climatic regime. Bankfull elevation often represents the break point between processes of channel and floodplain formation. Correctly identifying bankfull elevation is crucial and serves as the foundation for all subsequent geomorphic methods used in the determination of channel classification, dimension, pattern, and profile.

In the intermountain west, bankfull discharge generally occurs in the late spring or early summer, which coincides with snow-melt or the period of frequent and/or intense precipitation events. However, bankfull discharge can conceptually occur at any time during the year. Because site visits are often not conducted during a bankfull event, bankfull indicators must be relied on to correctly identify bankfull elevation. There are several bankfull indicators, though no one indicator is suitable in all circumstances. Use the following common bankfull indicators to identify bankfull elevation, many of which have been adapted from Rosgen (2008). In all cases, multiple bankfull indicators should be used to identify bankfull elevation. Primary indicators should always be sought out at the site; secondary indicators should be used only as supplemental information to support primary indicators. Illustrated examples of bankfull elevation and associated bankfull indicators from Wyoming streams are provided in WDEQ/WQD (2018).

*Primary Field Indicators:*

1. Floodplains – Bankfull elevation is often associated with the point at which water begins to spread out onto the floodplain. This may or may not be the top of the bank. This is one of the best indicators of bankfull elevation for use on Rosgen C, D, $D_A$, and E stream types which often have well-developed floodplains. Floodplain indicators do not apply to entrenched Rosgen A, B, F and G stream types which generally do not have floodplains. Most streams in alluvial/colluvial valleys have three distinct terraces. Do not confuse the low terrace with the floodplain, which may be close in elevation. The low terrace is an abandoned floodplain often characterized by upland or a mixture of upland and facultative riparian vegetation.
2. Breaks in Slope – A change in slope from a near vertical bank to a more horizontal bank is often the best indicator of the incipient point of flooding, or the transition from the bankfull channel to a floodplain. Such changes in slope often correspond to the “bankfull bench”. However, streams that have undergone physical alterations in the past or are actively degrading or aggrading can have multiple slope breaks that represent abandoned floodplains or terraces, rather than the bankfull elevation. For incised channels with near vertical banks, the first substantial break in slope (example: transitioning from 90° to 45°) at the bottom of the near vertical bank can be the bankfull elevation.
3. Scour Lines – A scour line at a consistent elevation along a reach that lies below an intact soil layer can represent bankfull elevation. Scour lines may or may not have exposed root hairs.
4. Undercuts – On bank sections where the perennial vegetation forms a dense root mat, the upper extent or top of the undercut is normally slightly below bankfull elevation. Undercuts are best used as indicators in channels lacking obvious floodplains.
5. Depositional Features – The elevation on top of the highest depositional feature (point bar or mid-channel bar) within the active channel is often associated with the bankfull elevation. However, in streams that have experienced recent record flood events, the tops of the highest depositional features may be above bankfull elevation. In streams that are rapidly degrading (downcutting), the tops of the highest depositional features may also be above the bankfull elevation.

6. Particle Size Demarcation – The point at which there is a distinct change in particle size of the active channel bed at a consistent elevation along a reach is often associated with bankfull elevation. Changes in particle size can be from coarse to fine or from fine to coarse and may also correspond to a break in slope or the top of a depositional feature.

*Secondary Field Indicators:*

1. Vegetation - Using vegetation to identify bankfull elevation must be done cautiously. When vegetation is used as a sole indicator, bankfull is frequently underestimated. Common riparian species such as alder (*Alnus* spp.), dogwood (*Cornus* spp.) and redtop (*Agrostis* spp.) can be used as supplemental indicators of bankfull elevation in Colorado streams. Generally, bankfull elevation is located at or just under the base of riparian vegetation often associated with a scour line. Willow (*Salix* spp.) and cottonwood (*Populus* spp.) should not be used as indicators as they can colonize within the bankfull channel. Mature woody species are generally found above the bankfull elevation and should not be used. Vegetation generally is not an appropriate indicator in streams where active degradation such as bank sloughing is occurring.
2. Lichens or Mosses – A noticeable change in color, pattern, and/or species of lichens or mosses on boulders or bedrock at a consistent elevation along a reach may represent bankfull elevation.
3. Debris Lines - The top of a debris line consisting of leaf and woody litter, dead algae, fecal material, trash, or other floating debris at a consistent elevation along a reach may represent bankfull elevation. However, do not confuse debris deposited by flow events larger than bankfull to represent bankfull elevation.

*Procedures:*

1. Determine whether hydrologic anomalies such as natural controls (boulders, bedrock), headcuts, dams, and similar features exist in the reach and account for their influence on bankfull elevation accordingly.
2. Using the bankfull indicators described above, walk the entire length of the reach, multiple times if needed, and identify primary and secondary bankfull indicators where applicable. Care should be taken to use only the best bankfull indicators that provide the strongest evidence of the breakpoint between channel formation (transport) processes and floodplain (depositional) processes.
3. Mark the locations of both primary and secondary bankfull indicators with pin flags.
4. Use a pocket rod or stadia rod to measure the distance from the current water surface to the estimated bankfull elevation at each indicator. Bankfull indicators should follow a generally consistent elevation relative to the water surface throughout the reach. As such, distances from the current water surface to the estimated bankfull elevation should be similar among all measurements. Outlying distances will be evident and should be removed or revisited and verified.
5. Use a weighted (primary indicators have greater weight than secondary indicators) average distance between water surface and bankfull elevation as a reference point when

conducting subsequent geomorphic survey procedures such as cross-sections and longitudinal profiles on the same day the average value was measured.

6. If desired for future reference, photo document the location of the bankfull elevation using the pin flags as reference points, making sure the entire bankfull channel is visible in the photograph. If a measurement tape has been stretched longitudinally along the entire reach, record the distance along the tape where the bankfull indicator in the photograph is located.

## Sinuosity

The sinuosity of a stream is calculated by dividing the channel distance by the straight- line valley length between the upstream and downstream extent of the project reach (measure the full project reach length rather than the sub-reach). Sinuosity can be calculated from recent aerial imagery, if available (see Section 2.2.1 of the User Manual). **If recent aerial imagery is not available or the stream channel is not visible in the imagery, then sinuosity should be measured in the field.**

*Method:*

1. Measure the stream length for the entire project reach using a tape along the edge of channel, GPS, or aerial imagery.
2. Measure a straight line following the fall-line of the valley using a tape, range finder, GPS, or aerial imagery.
3. The stream length divided by the valley length equals sinuosity. Enter this value in the space provided on the **Project Reach form**.

## Representative Riffle Survey

A representative riffle should be surveyed to calculate the bankfull dimensions of area, width, and mean depth, and to determine the Rosgen Stream Classification type (see following section). These are the primary reasons for surveying the representative riffle and the selection of the representative riffle should keep these objectives in mind. The ideal riffle is free to form (no rip rap or other controlling features), has a bank height ratio near 1.0, a bankfull width/depth ratio that is on the low end of the range for the reach, and has a stable bed and bank.

Two representative riffle cross-sections may be required in severely degraded systems where the first cross-section is a different stream type than the assessment reach. In this case, the two cross-sections should be measured following the procedures below. The first is used for bankfull verification and to calculate dimensionless ratios for the bed form diversity parameter. The second riffle is measured within the assessment reach to characterize the existing Rosgen stream type.[2]

The representative riffle survey can be completed using a survey-grade GPS, standard survey equipment, or a stadia rod and level tape for rapid surveys. Methods to set up and measure the representative riffle cross-section using standard surveying equipment are derived from the

[2] Cross-sections surveyed within the project reach can also be used to characterize reach conditions for metrics if applicable.

Channel Cross-section Survey methods outlined in the Manual of Standard Operating Procedures for Sample Collection and Analysis (WDEQ/WQD 2018). The text is duplicated here with minor modifications; information on quality control and photographs from the original reference are not included. A rapid method using a tape and stadia rod follow.

NOTE: The flood-prone width should be recorded for all riffle cross-sections and measured perpendicular to the fall line of the valley. Entrenchment ratio is necessary to determine the stream type. Independent of whether the representative riffle is surveyed following the WDEQ/WQD procedure or rapid survey methods, the cross-section flood-prone width is required. This means that either the cross-section should extend far enough into the floodplain to capture the flood prone width OR the distance from the channel bank to the elevation that is twice the max bankfull depth should be recorded for each side of the channel. Where it is not feasible to survey the entire flood prone width, the cross-section should span a width that is at least 3 times the width of the channel. Figure A.1 demonstrates how to measure the flood prone width with a hand level.

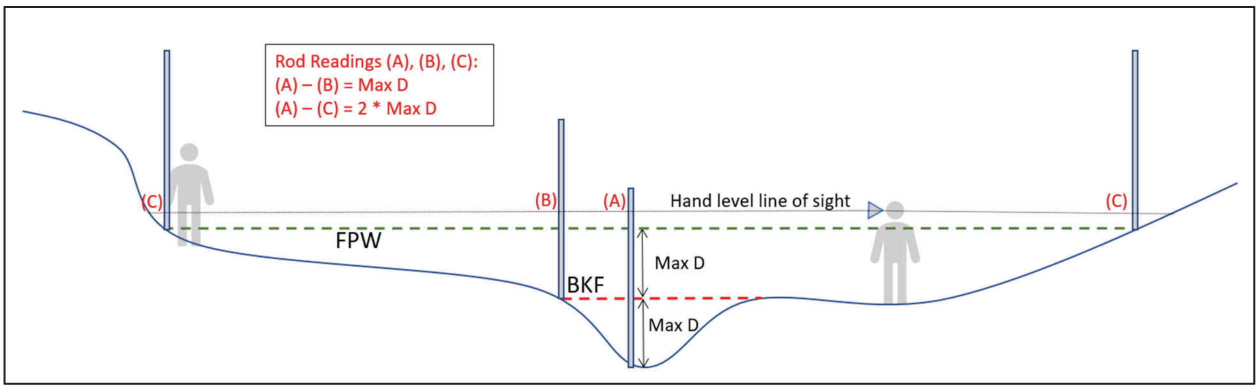


**Figure A.1: Surveying Flood Prone Width**

*Detailed Method –Cross-section Survey (WDEQ/WQD 2018):*

1. Identify the riffle within the project area that will be used as the representative riffle. Where possible, the representative riffle should be located within the representative sub-reach. However, in a highly degraded reach, a stable riffle cross-section from an adjoining upstream or downstream sub-reach may be used.

2. Following the procedure in Bankfull Elevation–Field Identification, identify bankfull elevation in the reach.

3. Determine the location of the cross-section within the representative riffle. Cross-sections should not be placed over riffles or other features that have been substantially disturbed by biological sampling, animal or human activity or similar causes. Avoid placement of the cross-section at the top or bottom of a riffle feature. In streams with active physical degradation and/or aggradation, features may migrate longitudinally within the reach from one year to another. Place the cross-section across the mid-point of the feature to increase the likelihood that the facet type you measure will be the same type you measure in subsequent years. Make sure that the cross-section is perpendicular to the direction of flow at bankfull. Where possible, cross-section endpoints should be located above the bankfull

elevation and preferably above the flood prone elevation (twice the maximum bankfull depth, see Figure A.1).

4. If possible, establish permanent markers at the cross-section endpoint locations by driving rebar vertically in the ground. Attach either plastic or metal end caps on the tops of rebar for identification. This step is only needed if repeat surveys are anticipated.
5. Stretch the measurement tape or tag line (tape) across the channel with zero always beginning on the left bank as you are facing downstream. The zero mark on the tape should be placed over the left cross-section endpoint. The tape can be secured to the ground with range pins. Make sure to stretch and secure the tape tight between both endpoints; sagging tapes are unacceptable. During windy conditions, flagging ribbon can be attached at regular intervals on the cross-section tape to minimize tape “waving”.
6. Record the station ID of the cross-section using the tape stretched along the length of the representative sub-reach (see Longitudinal Profile and Rapid Bed Form Survey Method) and sketch the cross-section location as part of the site map with associated landmarks. Document as much information as possible about the cross-section location on the datasheet so it can be relocated for future surveys or site visits.
7. Starting with the top of the left endpoint at 0, begin the cross-section survey. Proceed with rod readings at breaks in slope; record important features such as terraces, top of bank, low bank, bankfull, edge of water, inner berm, and thalweg. If undercuts are present, use a combination of the stadia rod and pocket rod to accurately characterize the undercut. Otherwise, take survey readings at regular intervals of generally one to five feet, with wider intervals used for wider channels. Record any features along the cross-section tape in the notes section of the datasheet. Complete the survey by taking rod readings at the right endpoint. Record all features on the datasheet next to their corresponding rod readings.

*Rapid Method – Stadia Rod & Level Tape Cross-section Survey:*

1. Follow steps 1-3 in the above procedure.
2. Stretch a tape from the left bankfull indicator to the right bankfull indicator. Use the primary bankfull indicator or the difference between water surface elevation and bankfull that has been recorded on the Project Reach form as the control.
3. Record the bankfull width. Space is provided on the Project Reach form.
4. Level the tape by attaching a line level or by 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.
5. Working from left to right, record the station from the tape and the depth from the tape to the ground using a stadia rod. Include bankfull, major breaks in slope, the thalweg, and other points along the channel bottom. Record this data on the Project Reach form.
6. Space is provided on the Project Field form to calculate the bankfull mean depth and area. These calculations are automatically performed in the Microsoft Excel Workbook version of the Project Reach form. A rough estimate of the mean depth can be calculated by adding all

the depth measurements (except for zeros at bankfull) and dividing by the number of observations.

7. Compare the bankfull width, mean depth, and area to the regional curve values on the field form.

8. Measure the flood prone width on either side of the bankfull channel as shown in Figure A.1. The flood prone width should be measured perpendicular to the fall line of the valley.

**Rosgen Stream Classification**

The Project Assessment worksheet of CSQT requires an assessment of process domains and stream or channel evolution to assist in determining the restoration target for the stream reach. While the CSQT does not require the application of natural channel design, it requires that the reference stream type be determined according to the Rosgen classification system (Rosgen 1996) since the available datasets that determined the reference curves for entrenchment ratio and pool spacing ratio used this classification system. Stream classification is based on entrenchment ratio, width depth ratio, sinuosity, slope, and channel material.

Methods to determine Rosgen Stream Classification are derived from the Rosgen Stream Classification section in the Manual of Standard Operating Procedures for Sample Collection and Analysis (WDEQ/WQD 2018). The text below is modified from this reference. This section is included in the field data collection methods to ensure that sufficient data is collected to classify the existing stream type. As shown in the procedures below, determining the stream type is based on values derived from data collected as described elsewhere in this appendix. As such, determining the stream type can be done in the office after the data is collected and processed.

*Field Measurements:*

1. Entrenchment Ratio (ER): Measure of flood-prone area width ($W_{fpa}$) divided by bankfull width ($W_{bkf}$). Parameter is unitless.
   a. Values are measured or calculated from the Representative Riffle Survey.
2. Width to Depth Ratio ($W_{bkf}$ / $d_{bkf}$): Measure of bankfull width ($W_{bkf}$) divided by bankfull mean depth ($d_{bkf}$). Parameter is unitless.
   a. Values are measured or calculated from the Representative Riffle Survey.
3. Channel Sinuosity. Parameter is unitless.
   a. Measurement procedures are provided in the Sinuosity section above.
4. Channel Materials (Particle Size Index) ($D_{50}$): Measure the mean diameter of channel materials ($D_{50}$) sampled within a reach at least twenty bankfull widths in length between the bankfull and thalweg elevations. Measure in millimeters.
   a. 105-Count Procedure section of the Standard Operating Procedure for the Collection of Pebble Counts (CDPHE 2015a).
5. Water Surface Slope (S): Measure of water surface slope from the top of a riffle to the top of another riffle at least twenty bankfull widths in length. A laser level is likely needed for this

measurement. This measurement is a surrogate for the water surface slope at bankfull stage. Measure in ft/ft.

a. See Longitudinal Profile and Rapid Bed Form Survey Methods.

b. Note if baseflow is not present, the bottom of the channel should be used. However, care must be taken to not create large elevation changes due to localized scour or fill. One method to avoid localized scour or fill is to use the edge of channel rather than the thalweg. In both cases (with and without baseflow), the measurements should be made at the top of a feature, e.g., the top or beginning of a riffle.

# 4. Standard Survey (Longitudinal Profile)

This method will provide data to inform the floodplain connectivity and bed form diversity parameters within the CSQT. Additionally, data from the longitudinal profile can be used to calculate average reach slope and riffle slopes. Average reach slope is part of stream classification and metric stratification, while riffle slopes are necessary to calculate discharge from stage data at riffle cross-sections where stream gages are installed.

This manual describes two methods that **can be used** to collect bed form diversity and floodplain connectivity data for the CSQT, the Longitudinal Profile (described in this section) and the Rapid Survey (described in Section 4). For CWA Section 404 projects, it is recommended the user coordinate with the Corps prior to selecting between these methods. The rapid survey techniques for collecting the bed form diversity and floodplain connectivity data are considered more rapid than surveying the longitudinal profile and require little post-processing of the field data.

Field forms for the survey include the longitudinal profile form and the cross-section form. They are provided in Section 12. Data collected using these forms will require post-processing to calculate CSQT metric field values for pool spacing ratio, pool depth ratio, percent riffle, and bank height ratio. Data analysis should follow the methods described in Chapter 2 of the User Manual. The Reference Reach Spreadsheet version 4.3 developed by Dan Mecklenburg with the Ohio Department of Natural Resources (DNR) is a free, user-friendly tool for entering survey and pebble count data and can be used to calculate these metrics.[3] Users should provide the raw survey data, longitudinal profile plots at legible scales, and bed form identification callouts that indicate where measurements were taken to calculate field values.

<u>Quality Control:</u> Following the process described in Harrelson et al. (1994), no longitudinal profile is complete without checking the accuracy of the survey with a survey closure. To close the survey, take a foresight reading at the benchmark, compute the elevation, and compare the difference to the original benchmark elevation at the start of the survey. Typically, a closure of no more than 0.05 feet is acceptable when conducting stream surveys. The survey closure error shall be documented on the longitudinal profile datasheet.

<u>Introduction:</u> The longitudinal profile documents the existing water surface, bankfull, low bank, terrace, and thalweg elevations of a stream reach. Longitudinal profile data is used to calculate average bankfull and water surface slopes of a reach, along with maximum, minimum, and average slopes of features such as riffles, runs, pools, and glides (also known as facet slopes). Maximum, minimum, and average bankfull depths and spacing measures are obtained from longitudinal profile data. These data are useful in geomorphic assessments of streambed stability and sediment supply and may be useful for design objectives. Longitudinal profiles require basic surveying skills and equipment. Survey basics such as establishing benchmarks, foresights, positioning the level, turning points, and others are not covered here. For more information on survey basics consult Harrelson et al. (1994).

[3] The spreadsheet is no longer available from the DNR web page, but is available at https://stream-mechanics.com/resources/spreadsheet tools.

*Method:*

1. Establish a representative sub-reach within the project reach, generally at least two meander cycles or 20 bankfull widths in length. The sub-reach should be representative of the typical bed form diversity in the project reach and should include the stretch of channel with the greatest amount of large woody debris.
2. Beginning at the upstream end of the sub-reach, stretch the tape(s) along either the left or right bank as close to the edge of the channel as possible, threading them through riparian vegetation or other obstructions if necessary. Tape(s) can be secured to the ground with range pins, vegetation, or rocks. Stationing of features will be obtained from the tape.
3. If desired, establish permanent markers at the beginning and end of the longitudinal profile tape by driving rebar vertically in the ground. Attach either plastic or metal end caps on top of the rebar for identification.
4. The position of the longitudinal profile tape should be included on the site map along with associated landmarks, stream channel cross-sections, and other relevant features. If desired, triangulate the top and bottom of the longitudinal profile between the benchmark and another permanent feature and record on the datasheet. GPS locations of the top and bottom of the longitudinal profile can be used in place of triangulation. Document as much information as possible about the longitudinal profile tape location on the datasheet so it can be relocated for future surveys.
5. Follow the procedure in Bankfull Elevation – Field Identification to identify bankfull elevation in the reach.
6. Follow the process described by Harrelson et al. (1994) to establish a benchmark and height-of-instrument.
7. Begin the longitudinal profile survey with a thalweg measurement at station 0 on the longitudinal profile tape. Obtain the rod reading and record the value as a foresight on the datasheet. Record (at a minimum) rod readings of water surface, bankfull and low bank (if greater than bankfull) perpendicular to the longitudinal profile tape at station 0. Only take rod readings of bankfull and low bank where indicators are present.
8. Continue the same sequence as in step 7, working downstream, collecting readings at the top, mid-point and bottom of each feature (riffle, run, pool, and glide), along with any other major bed features (dams, weirs, etc.). For pools, take a reading at the maximum depth location and note whether the pool is a geomorphic pool (refer to Pool Identification below). For streams with long features or a homogeneous bed, take rod readings at regular intervals, generally spaced no more than one bankfull width.
9. Note the stationing of all cross-section locations (if present) on the longitudinal profile tape and record on the datasheet. Take rod readings at the tops of all cross-section endpoints located along the bank with the longitudinal profile tape and record on the datasheet.
10. Close the survey according to the process described in the Quality Control section of this document.

**Pool Identification Definitions**

The SQT requires identification of three pool types: **geomorphic pools, significant pools,** and **micro-pools**. Guidance for identifying pools in different valley types is provided below. **Note: Pool identification is slightly different for pool spacing than it is for pool depth and percent riffle metrics.** Guidance on pool identification for each 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 flow conditions. These pools are associated with the outside of a meander bend (streams in alluvial valleys) and downstream of a large cascade or step (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 have a width that is at least one-half the channel bottom width, a concave profile, and a water surface slope that is flatter than the riffle. The depth of these pools is measured for the pool depth ratio metric, and the length is not included in the percent riffle metric.

**Micro-pools** are small, typically less than half the width of the channel, and may not last for a long period of time or after a large flow event. Micro-pools can be found in riffles and cascades. An example is a scour pool downstream of a single piece of large woody debris. **Micro-pools are never counted as pools in the SQT.**

*Identifying Geomorphic Pools in Alluvial-Valley Streams:*

Geomorphic pools in alluvial valleys are located along the outside of the meander bend. Figure A.2 provides an illustration of what is and is not counted as a pool (pools counted are marked with an 'X'). The figure illustrates a meandering stream, where the 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. The pools associated with the large woody debris and boulder clusters in this figure are not counted because they are micro-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.

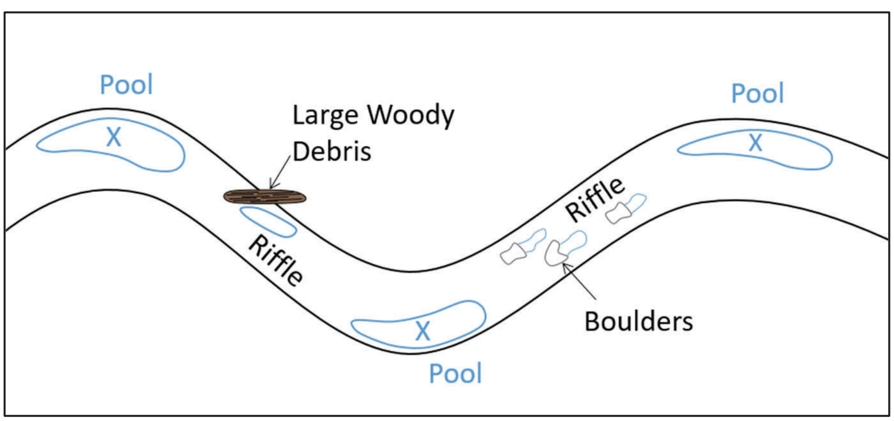


*Figure A.2: Pool Spacing in Alluvial Valley Streams*

*Identifying Geomorphic Pools in Colluvial and V-Shaped Valleys:*

Pools in colluvial or v-shaped valleys should only be counted if they are downstream of a step, riffle, or cascade. Micro-pools within a riffle or cascade are not counted, just like pools within a riffle of a meandering stream are not counted. An example of pool spacing in a colluvial or v-shaped valley is shown in Figure A.3. For these bed forms, pools are only counted at the downstream end of the riffle or cascade; micro-pools within the feature are not included.

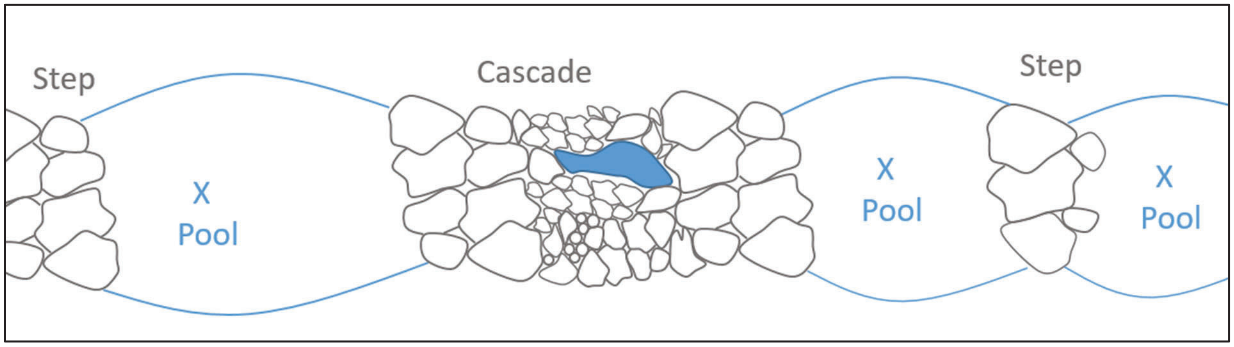


*Figure A.3: Pool Spacing in Colluvial and V-Shaped Valleys*

## Cross-section Surveys

Data should be collected from cross-sections at multiple riffles within the representative sub-reach to inform the baseflow dynamics metrics (average velocity and average depth), entrenchment ratio, and aggradation ratio metrics. The flow alteration module requires the collection of continuous flow data and cross-section surveys are required to convert recorded stage data to flow values.

A Cross-section form is provided in Section 12 to collect these data. Data collected using these forms will require post-processing to calculate CSQT metric field values. Cross-sections should be collected following the procedures described in the Representative Riffle Survey section. The WDEQ or rapid cross-section survey method, or a combination of the two, can be used based on best professional judgement.

- For the entrenchment ratio, it is recommended that the entrenchment ratio be measured at each riffle unless the valley width is consistent throughout the representative sub-reach. The flood prone width should be measured perpendicular to the fall line of the valley.
- For the aggradation ratio, it is recommended to measure this metric at multiple riffle cross-sections with aggradation features to ensure that the widest value for the sub-reach is obtained and to document the extent of aggradation throughout the project reach. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections.

For cross-sections where the data will be used to calculate discharge (as applicable for the average velocity, average depth, return interval, and the metrics in the flow alteration module), follow the procedures outlined in Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams (USEPA 2014) for developing stage-discharge rating curves. Users should provide the raw survey data, cross-section plots at legible scales, and callouts for features that indicate where measurements were taken to calculate field values.

# 5. Rapid Survey

This section outlines rapid survey methods to collect data to inform floodplain connectivity and bed form diversity parameters. There are two methods that can be used to collect bed form diversity and floodplain connectivity data for the CSQT, the Longitudinal Profile (described in Section 3) and the Rapid Survey (described in this section). For CWA Section 404 projects, it is recommended the user coordinate with the Corps prior to selecting between these methods. The rapid survey techniques for collecting the bed form diversity and floodplain connectivity data are considered more rapid than surveying the longitudinal profile and require little post-processing of the field data.

The Rapid Survey form is provided in Section 12. There is a shading key on the field form that indicates which cells are intended to be filled out in the office versus the field, and which sections are for performing field calculations. The calculation cells can be filled out on a printed field form. In the workbook version, these cells will automatically calculate values from provided field data. Field values that can be entered directly into the Quantification Tool worksheet from this field form are bolded. These include: weighted BHR, weighted ER, maximum WDR, percent riffle, average pool depth ration, and median pool spacing ratio.

*Method:*

1. Establish a representative sub-reach within the project reach, generally at least two meander cycles or 20 bankfull widths in length, whichever is longer. The sub-reach should be representative of the typical bed form diversity in the project reach and should include the stretch of channel with the greatest amount of large woody debris.
2. Beginning at the upstream end of the sub-reach, stretch tape(s) along either the left or right bank as close to the edge of the channel as possible, threading them through riparian vegetation or other obstructions if necessary. Tape(s) can be secured to the ground with range pins, vegetation, or rocks. Stationing of features will be obtained from the tape. Begin and end the representative sub-reach at the head of a riffle feature.
3. Record sub-reach length in Rapid Survey form.
4. Measure the slope of the sub-reach (see Reach Slope section below).
5. Working from upstream to downstream, take measurements at every riffle and pool within the sub-reach using a stadia rod and a hand level. A line level can be used instead of a hand level for small streams. NOTE: Review pool identification instructions provided below and in Section 2.6.d of the User Manual.
    a. Measure the following at every riffle within the sub-reach and record values in the Rapid Survey form. These data are used to calculate the bank height ratio, entrenchment ratio, aggradation ratio, and percent riffle metrics.
        i. Measure the length of the riffle, including runs, if present. Riffle length is measured by taking a station reading from the tape at the head (beginning) of the riffle and another station reading downstream at the head of the pool.

    Field calculation: Percent riffle can be calculated by adding the length of all riffles within the sub-reach (total riffle length) and dividing by the total sub-reach length. Total riffle length is also used to calculate weighted entrenchment ratio and weighted bank height ratio below.

ii. Identify the middle of the riffle feature and bankfull elevation (see Bankfull Elevation – Field Identification).

iii. From mid-riffle, measure the difference in stadia rod readings from the thalweg to the top of the lower of the two streambanks. Record this value as the Low Bank Height on the rapid survey form. The low bank height is the lower of the left and right streambanks, indicating the minimum water depth necessary to inundate the floodplain.

iv. From mid-riffle, measure the difference in stadia rod readings from the thalweg to the bankfull indicator, and record this value as the bankfull maximum depth on the Rapid Survey form. Alternatively, 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 II on the Project Reach form).

Field calculation: bank height ratio can be calculated by dividing the low bank height by the bankfull maximum depth. Space is also provided to calculate the weighted bank height ratio: multiply the bank height ratio by the riffle length at each riffle and divide by the total length for the sub-reach.

v. From mid-riffle, measure the bankfull width and record this on the form.

vi. Flood prone width should also be measured at each riffle in sub-reaches with changes in valley width or a bank height ratio near, or greater than, 2.0. At mid-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 that of the bankfull maximum depth (see Figure A.1 for illustration). Record flood prone width on the rapid survey form.

Field calculation: entrenchment ratio can be calculated by dividing the flood prone width by the bankfull maximum depth. Space is also provided to calculate the weighted entrenchment ratio: multiply the entrenchment ratio by the riffle length at each riffle and divide by the total riffle length for the sub-reach.

vii. If evaluating the aggradation ratio, at the widest riffle in the sub-reach (or any riffle with aggradation features) the bankfull mean depth should also be measured and recorded. Visual indicators of aggradation include mid-channel bars and bank erosion within riffle sections. At candidate riffle features, estimate the mean depth as the difference between the edge of channel and the bankfull stage. This is measured by placing a stadia rod at the edge of channel, which is the breakpoint between the streambed and streambank. Measure the stadia rod height at the bankfull elevation and record as the mean depth. Note: It is recommended to collect data from multiple riffle cross-sections with aggradation features to ensure that the widest value for the sub-reach is obtained and to document the extent of aggradation throughout the project reach.

Field calculation: width depth ratio can be calculated by dividing bankfull width by bankfull mean depth. The largest width depth ratio within the sub-reach is considered the maximum width depth ratio.

b. Identify pools within the sub-reach. Refer to pool definitions in Section 3 of this appendix for geomorphic and significant pools.

c. Measure the following at every pool within the sub-reach and record values in the Rapid Survey form. These data are used to calculate the pool spacing and pool depth ratio metrics.

   i. Determine the deepest point of the pool and record the station number from the tape on the form.

   Field calculation: The pool spacing ratio can be calculated by determining the distance between each pair of geomorphic pools and dividing this distance by the bankfull riffle width from the representative cross-section. Space is provided to record the median pool spacing ratio on the Rapid Survey form.

   ii. Measure the maximum bankfull pool depth of all significant pools by placing the stadia rod at the deepest point in the pool and recording the depth **to bankfull elevation**. Alternatively, measure the difference in stadia rod readings from the deepest point in the pool to the water surface and then add the value recorded for the difference between bankfull stage and water surface recorded in Section II of the Project Reach form.

   Field calculation: The pool depth ratio can be calculated by dividing the bankfull pool depth by the mean bankfull riffle depth (from Section IV of the Project Reach form). Space is provided to record the average pool depth ratio on the Rapid Survey form.

**Reach Slope**

Average reach slope is part of stream classification and metric stratification. It is not used as a function-based parameter or metric; however it does inform the calculation of discharge. If a longitudinal profile is performed, slope can be calculated from that data and does not also need to be collected using the procedure below. If the rapid method is used, data should be collected using the following field procedure.

*Method:*

1. Take a stadia rod reading of the water surface elevation at the head of the first riffle and the head of the last riffle in the representative sub-reach. If limited by the line of sight and/or magnification of the hand level being used, take a stadia rod reading of the water surface elevation at the head of the first riffle and the head of the last riffle within a line of sight. Repeat as needed throughout the project reach making sure that the total drop in elevation is recorded. Note, for streams with a uniform slope, a relatively short length of channel can be measured. For streams with large slope changes between riffles and pools, the entire sub-reach should be measured. Using a hand level to calculate slope is prone to large errors. It is preferable to use a laser level to calculate slope if one is available.

Field calculation: Calculate the difference in stadia rod readings, divide the difference in stadia rod readings by the channel length between these two points. Where multiple readings were taken, the sum of the elevation changes should be used in the numerator (total fall over the measured length). The denominator is the total stream length between the first and last measurement point. Space is available for calculations in the Project Reach form.

# 6. Lateral Migration

**BEHI/NBS and Percent Streambank Erosion**

The dominant BEHI/NBS and percent streambank erosion metrics within the lateral migration parameter are informed by an assessment of bank erosion hazard index (BEHI)/near bank stress (NBS). Data forms are provided in Section 12. **Detailed field methods are not provided below**, but can be found in the following references:

- Appendix D of Function-Based Rapid Field Stream Assessment Methodology (Starr et al. 2015)
- River Stability Field Guide, Second Edition (Rosgen 2014)

*Additional notes on the method:*

1. Evaluate the outside bank of every meander bend whether or not it is eroding. In addition, assess all other areas of active erosion regardless of their location. Depositional zones and riffle sections that are not eroding should not be evaluated.
2. Give each study bank an ID, e.g. L1 for left side, bank number 1. Determine the BEHI/NBS rating for each study bank. Record data on the Lateral Migration form. Show bank ID's on aerial photograph or basemap.
3. Measure and record the length of each bank assessed using the station numbers from the tape(s) stretched along the sub-reach for the Longitudinal Profile or Rapid Survey. A GPS unit can also be used to map the length of assessed banks.
4. Photograph each bank and label with bank ID.

Note: If a bank is armored, do not apply the dominant BEHI/NBS metric.

Data can be recorded on the Lateral Migration form found in Section 12. These data can be used to determine the field values following the instructions in Chapter 2 of the User Manual for the following metrics: dominant BEHI/NBS and percent streambank erosion.

# 7. Riparian Vegetation

Field data should be collected during the growing season at the same time of year for pre- and post-project evaluations.

A Riparian Vegetation form and a Riparian Extent form are provided to record data (Appendix B). The calculation cells can be filled out on a printed field form. In the workbook version, these cells will automatically calculate values from provided field data. Field values will need to be averaged across plots before entering field values into the Existing Condition or Quantification Tool spreadsheets (see Section 2.8.4 in Chapter 2 of the User Manual).

All riparian vegetation metrics are assessed at plots located at equally spaced intervals along the assessment sub-reach. To begin, the location of the first plot must be determined as follows:

1. Determine the number of riparian plots using the representative sub-reach length as shown in Table A.3. Plots should be systematically distributed along each bank 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.
2. Calculate the spacing interval of the plots by dividing the sub-reach length by the number of plots per side.
3. Select a random starting point within the first 20 feet of the sub-reach length.

*Table A.3. Recommended Number of Sampling Plots Per Sub-Reach*

| Sub-Reach Length | Number of Plots per Side | Number of Plots per Sub-Reach |
|---|---|---|
| 300-400 ft | 3 plots | 6 plots |
| 400-600 ft | 4 plots | 8 plots |
| 600-900 ft | 6 plots | 12 plots |
| 900 -1300 ft | 8 plots | 16 plots |

**Riparian Extent – Field Verification**

*Method:*

1. Observed and Expected riparian area measurements should be collected from four locations within the reach using aerial imagery prior to going out into the field and entered on the Riparian Extent field form (see Section 2.8.4 in Chapter 2 of the User Manual).
2. Field data can be used to verify the indicators used to determine the extent of the expected and observed riparian area obtained from aerial imagery. Examine the reach and landscape. Where practicable or possible, verify the expected riparian extent from the station ID recorded for each sampling plot location using tape or a range finder or record the GPS location of the expected riparian extent. On the Riparian Extent form, indicate which field

indicators were used to verify this extent. If needed, the riparian extent measurements and mapping can be revised in the office later.

Expected riparian extent includes the width across the stream in each direction, landward to the extent of substrate and hydrologic indicators. Field indicators such as a fluvially formed break in slope between bank edge and valley edge, a change in sediment from fluvial sediments (rounded) to hillslope sediment (angular), or evidence of flood events (e.g., bar deposition, staining, water marks, etc.) can be used to delineate the expected riparian area. Where significant incision or anthropogenic modification of the riparian area has occurred (e.g., development, grading, etc.) and aerial imagery and/or field indicators cannot be used to delineate the expected riparian extent, the meander width ratio may be used to calculate expected riparian area (See Chapter 2 of the User Manual).

3. At the station ID recorded for each plot location, measure the riparian area extent from the edge of the bank landward to the edge of the observed riparian area using tape or a range finder, or record the GPS location of the observed riparian extent to map later in the office.

   The observed riparian area should extend from the edge of the bank landward to the current extent of riparian vegetation. This area should be free from urban, utility-related, or intensive agricultural land uses and development. The edge of the observed riparian area should be determined using vegetation attributes, including the presence of riparian vegetation, distinctly different vegetation species than adjacent upland areas (e.g., species with wetland indicator ratings of OBL, FACW, FAC and some FACU; Lichvar et al. 2016), and species similar to adjacent upland areas but exhibiting more vigorous or robust growth forms (USFWS 2009).  On the Riparian Extent form, record the observed riparian measurements and indicators used to determine the extent.

4. Measure the channel width at the location of riparian area measurements and record on the Riparian Extent form. Where plots have been relocated, measurements for riparian extent should be taken on both sides of the channel at the station ID of the left side plots.

## Herbaceous, Woody, and Percent Native Vegetation Cover

*Setting up Riparian Plot Locations:*

1. Set up the first plot at a random starting point on the left-hand side of the stream (looking downstream). The plot should begin at the edge of bank (where bed-meets-bank; BLM 2017) and extend landward and downstream from this point. All vegetation sampling is conducted within the reach's **expected** riparian area extent, and thus may extend into developed or modified upland areas (see Riparian Extent - Field Verification). In narrower or colluvial valleys, square plots may need to be reshaped (to a rectangular plot of the same area) to keep the plots within the expected riparian area extent of the reach. This could affect the location of subsequent plots, and subsequent plots may need to be relocated to avoid overlap.  Plots should be located adjacent to the primary channel if high-flow secondary channels exist, and outside intricately braided active channels, mid-channel bars, and ponded beaver areas.

2. Subsequent sampling plot locations should be identified using the spacing interval identified in step 2 above. Locations should be determined using the station reading from the tapes set up for the Longitudinal Profile or Rapid Survey. Plot locations on the right side of the

stream should use the same station locations as identified on the left unless they need to be relocated. Consecutively number the plots down the left bank and up the right bank.

3. 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 or reshaped plots; inaccessible locations; or at the confluence of a large secondary channel or tributary, etc.). If necessary, vegetation plots may be removed or be extended beyond the downstream end of the representative sub-reach but should not extend outside the project reach. Relocation of a plot on the left side of the channel does not necessarily require relocation on the right side as well. Record the new station location and note the reason for relocation.

4. It is recommended that riparian data sampling start at the most upstream plot on the left side of the stream and move downstream. After data from the last plot is collected on the left side, cross the stream and place the first plot on the right side and move upstream collecting data on the remaining number of evenly spaced plots. However, plots may be sampled in any order once plot locations are identified.

*Riparian Plot Establishment:*

1. On the left side of the stream (looking downstream), for each plot, place a corner of the plot at the appropriate station reading where it intersects the edge of the bank; this is the starting point in Figure A.4. The plot should extend landward and downstream from this point and contain the nested sub-plot configuration according to the diagram provided in Figure A.4. When sampling the right side of the stream place the first corner of the plot at the same station reading where it intersects the edge of the bank. The plot should extend landward and downstream from this point such that the plots are mirror images across the channel at each designated station (Figure A.4).

   From the starting point, measure or pace out the bounds of a 32-ft x 32-ft (10m$^2$) tree (canopy) plot and a 16-ft x 16-ft (5 m$^2$) shrub (understory) nested plot and mark corners with pin flags as depicted in Figure A.4. Then mark two 3-ft x 3-ft (1 m$^2$) herbaceous ground cover nested plots at the starting point and in the diagonally opposite corner of the shrub plot.

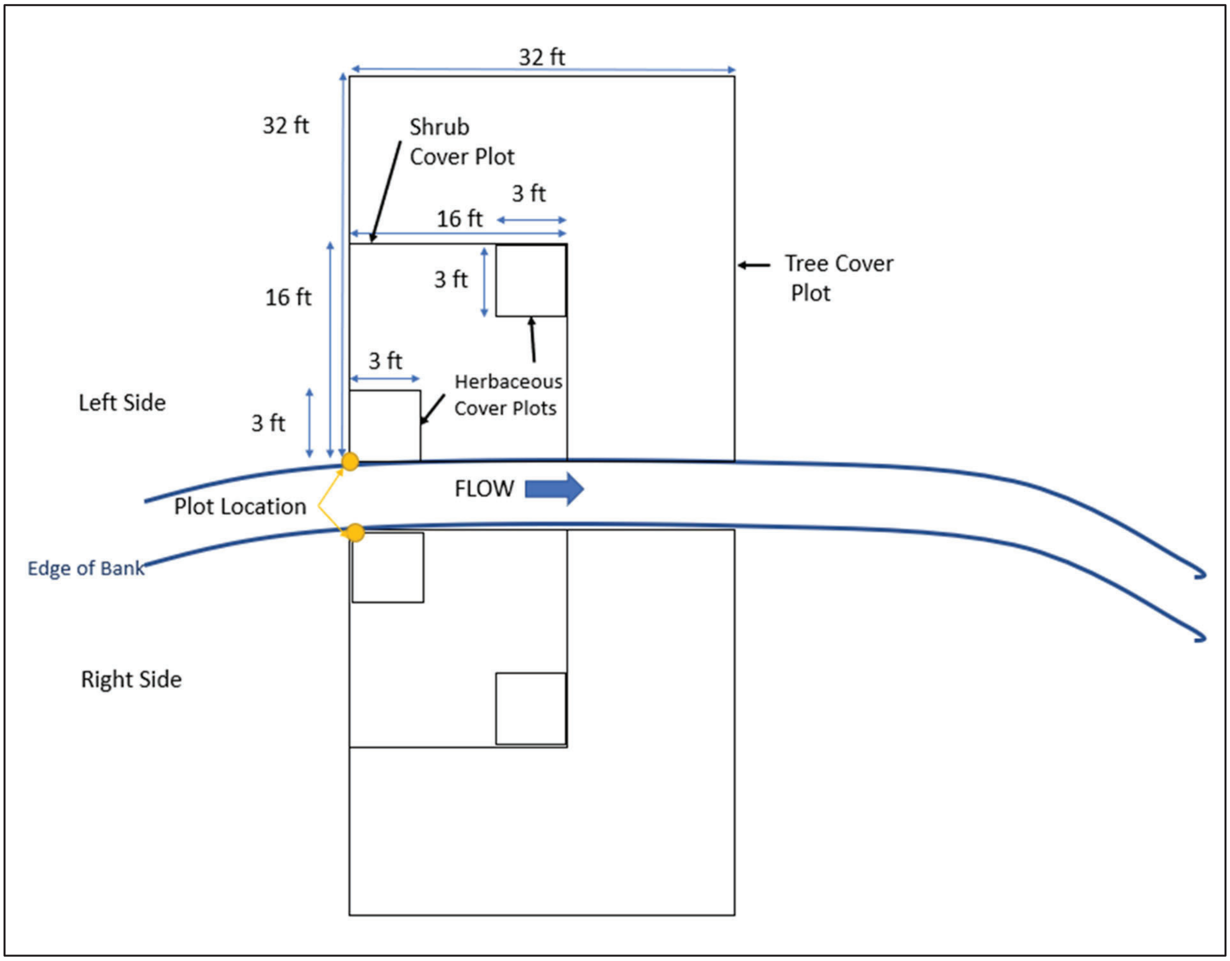


*Figure A.4: Standard Riparian Plot Layout for Riparian Vegetation Cover*

_Detailed Method: Data Collection_

1. All data should be recorded on the Riparian Vegetation field form.
2. Take a photo of the riparian plot so that the near-stream herbaceous plot is visible in the foreground and a good portion of the remaining riparian plot is in the background. Note the photo number on the data form or include the plot number in the photograph.
3. Note the geomorphic location of the 32-ft x 32-ft plot as inside meander, outside meander, or straight/riffle. If this changes over the length of the plot, record the geomorphic location of the majority of the plot.
4. Within each riparian plot for the representative sub-reach, visually estimate the percent absolute cover of each plant species within the nested plot types to determine vegetation abundance, structure, composition, and complexity (USACE 2008, 2010a, 2010b; Kittel et al. 1999). Practitioners should be able to identify at least 80% of the species within a plot. Absolute cover is the percentage of the ground surface that is covered by the aerial portions (leaves and stems) of a plant species when viewed from above. It can also be described as an estimate of the amount of shadow that would be cast by a particular plant species if the sun were directly over the plot area.

a. Absolute herbaceous (herb) cover by species should be measured at every riparian plot location within each of two nested 3-ft by 3-ft herb plots (see Figure A.4), then averaged. This technique is helpful to sample variable understories and smaller sized species over a larger area. Alternatively, herb cover data may be collected in the 16-ft x 16-ft plot, but this method requires additional survey effort for plant species within a larger area and may be less precise and more time consuming. Consistent plot size should be used for all aspects of the project.

   i. Identify and record the herbaceous plant species that occur within the plot and visually estimate the portion of the plot each species covers.

   ii. Record total bare ground/litter and total embedded rock (> 15 cm diameter) as separate absolute values (out of 100 percent) to document uncovered or partially exposed substrate. Note that high flow or minor secondary channels are counted as bare ground.

   iii. If using nested herb plots, repeat the procedure for the second herb plot and average species values across herb plots for a combined list within each riparian plot.

   iv. Record the sum of all herbaceous species cover.

b. Absolute shrub cover by species includes woody plants less than 3 inches DBH and less than 16 ft (5 m) tall and is measured within a single 16-ft by 16-ft nested plot (see Figure A.4).

   i. Identify and record shrub plant species and visually estimate the portion of the plot each species covers.

   ii. Record the sum of shrub species cover.

c. Absolute tree cover by species includes woody plants greater than 3 inches DBH and greater than 16 ft (5 m) tall and is measured within a 32-ft by 32-ft plot.

   i. Identify and record tree species and visually estimate the portion of the plot each species covers.

   ii. Record the sum of tree species cover.

d. Record the sum of shrub and tree species cover as woody vegetation cover and record the sum of all plant species cover as total vegetation cover for the riparian plot.

e. Identify and record which species are native or introduced (i.e., non-native or naturalized). Use USDA PLANTS Database http://plants.usda.gov to verify. Record the sum of all native species cover.

5. Based on the data collected, determine the general vegetation cover type for the riparian plot area as herbaceous, scrub-shrub, or forested and record at the top of the form. The cover type is distinguished by the plant life form that constitutes the uppermost layer of vegetation and that possesses an aerial coverage of 30 percent or greater (Cowardin et al. 1979). For example, an area with 50% aerial coverage of trees over a shrub layer with a 60% aerial coverage would be classified as forested; an area with 20% aerial coverage of

trees over the same (60%) shrub layer would be classified as scrub-shrub. When trees or shrubs alone cover less than 30% of an area but in combination cover 30% or more, the area is assigned to the scrub-shrub cover type.

Additional notes on sampling procedure:

- Individual species aerial cover estimates cannot exceed 100% but can be less than 100%.
- Due to overlapping plant canopies, the sum of absolute cover values for all species in a community or stratum may exceed 100 percent. (In contrast, "relative cover" is the absolute cover of a species divided by the total coverage of all species in that stratum, expressed as a percent. This is how the percent native vegetation metric is determined.)
- Naturalized species are not considered native.
- Absolute cover for riparian and non-riparian (upland) species should be estimated.
- Plants over-hanging the plot do not need to be rooted in the plot to be counted as absolute aerial cover; however, species rooted outside of the expected riparian area that are overhanging the riparian plot would not be counted.
- Standing dead shrubs/trees should be included in aerial cover estimates but eliminated from percent native cover calculations.
- Additional data collected and not reported in the CSQT provides context for riparian area reporting.

*Rapid Method: Data Collection*

Less intensive methods of collecting riparian cover data will result in similar but less accurate data and would only be suitable for cursory characterization or planning estimates. These methods would not be appropriate for determination of functional lift or monitoring efforts.

1. Abundance-only data could be collected using the methods outlined above with the following exception. Abundance-only data for herbaceous and woody vegetation cover metrics would involve estimating absolute cover by species without taxonomic identification and summarizing information by life form (e.g., herbaceous species A, B, C and D; shrub species A, B, and C). Native cover could not be accurately determined using this method.

   or

2. Data could be collected from a reduced number of plots, e.g., one or two representative plots per bank. Plot locations would be selected using best professional judgment of representativeness based on the overall abundance and composition of riparian communities throughout the reach. Sampling methods would be the same as outlined above.

# 8. Periphyton

Sample collection and processing should be conducted according to the Standard Operating Procedures for the Collection of Periphyton Samples (CDPHE 2015b). A Physicochemical and Biological data form is provided in Section 12.

Data collection methods are duplicated below with minor modification. See CDPHE (2015b) for additional information on quality control methods and an equipment list. Chlorophyll a data should be expressed as milligrams per square meter of sampled substrate (mg/m$^2$).

*Sampling Period & Restrictions:*

Periphyton samples will be sampled at times of normal, stable flows and when the benthic algal community has peaked for the season. The optimal sampling season is mid-summer to early fall. Earlier sampling may be performed at lower elevations, but only to the extent that normal flow conditions are present, and algae is in a state of growing or has already matured.

In the event of light flooding or scouring, sampling shall be delayed for a minimum of one week to allow recolonization. Studies have shown recovery after high discharge can be as rapid as seven days if the scouring event was less severe (Stevenson 1990).

Sampling shall be delayed for three weeks following severe, bottom-scouring flows to allow for recolonization and succession to a mature periphyton community. This is based on a recommendation by Peterson and Stevenson (1990).

*Method:*

1. Five transects will be setup within the overall reach.
   a. Determine a representative stream length of 50 to 100 meters that contains at least one riffle or run habitat. This may not always be achievable, so as an alternative, choose 3 to 5 riffles and/or runs, so that 5 transects or cross-sections can be established.
   b. Beginning at the most downstream position, extend a tape measure from one wetted edge to the other being careful not to disturb the substrate beneath or immediately downstream of the tape measure. Fasten the tape measure to each bank edge so the measuring tape is taut and does not dip into the stream.
   c. Moving in an upstream direction, establish the remaining four transects at equidistant locations within the selected stream length or at each chosen riffle/run. Note: periphyton is typically collected in concert with a pebble counting method. Transects may be shared between the two methods but caution must be taken to prevent agitation to the substrate immediately below the tape measure. Also avoid establishing transects that overlap with macroinvertebrate sampling areas.
   d. Illustrate the area between the first and fifth transects on the site sketch section of the Project Reach field form.

   This method has been adapted to two different types of substrate common to Colorado. The first method (Step 2) is best applied to streams with pre-dominantly hard-bottomed substrate, such as cobble, pebble, and gravel (herein referred to as “rocks”). The second type (Step 3) is applied to sandy, shifty bottom streams, as found in lower elevations of the Plains ecoregion or the far western Xerics ecoregion of Colorado.

2. The following method applies to hard-bottomed streams:

    a. Note the distance from one wetted edge to the other along the tape measure at the first transect. Collect three rocks from the first transect at the ¼, ½ and ¾ points along the tape measure.

    b. Place the cobble facing upwards in the plastic pan. Cover the rocks with a moist medium-sized hand towel to prevent exposure to sunlight.

    c. Continue to collect three rocks from the remaining four transects, as described in Step 1, carefully pulling rocks from the ¼, ½ and ¾ points along the tape measure and covering them with the hand towel as you proceed from transect to transect.

    d. Proceed to a shaded location on the stream bank to begin scraping periphyton from the rocks. See Step 4.

3. The following methods apply to soft-bottomed streams:

    Collecting periphyton in soft-bottomed streams allows periphyton from all available substrates and habitats to be sampled as long as they are representative of the overall reach. The purpose of this section is to collect 15 subsamples, each with an area of 0.785 $in^2$, from submerged, removable habitats or loose sediment depositional zones present along or near each transect.

    a. Sampling Method for Rocks (Cobble), Woody Snags or Submerged Vegetation

        i. If rocks are not available or are limited at the ¼, ½ and ¾ points along the tape measure, then select the nearest woody snag (debris) or submerged vegetation (mosses, microalgae, vascular plants, and root masses). If submerged woody snags or other vegetation are large or flexible enough, can be lifted above the water line, and have a relatively smooth surface then use the bottle cap method described in Step 4 making certain that scrapings and rinse water are flushed directly into the 1-liter Nalgene bottle. Otherwise, identify the part of the submerged woody snag or vegetation to be scraped later and carefully remove a 4-8 in. section with pruning shears or a small saw. Place the removed section into the plastic pan.

    b. Suction Method for Loose Sediments (Loose sediment may be defined as sand, silt, clay, or fine particulate organic matter)

        i. At sampling points with low depth/velocity and a depositional zone consisting of any of the loose sediments listed above, place a PVC ring on top of the sediment. Press the ring into the sediment to a depth of one-half inch.

        ii. Use a suction bulb to remove the entire top layer of periphyton. It is acceptable to suction up some sediment in the process.

        iii. Squirt this medium of material into the 1-liter Nalgene bottle.

c. Cover the rocks or other removable substrates and the 1-liter Nalgene bottle with the hand towel to prevent exposure to sunlight as you move from habitat to habitat in the stream channel.

d. Once completed, proceed to a shaded location on the stream bank to begin scraping periphyton from the remaining rocks or other removable substrates placed in the plastic pan. See Step 4.

   Example: If 10 sub-samples are collected via siphoning or by instream bottle cap method, then the remaining 5 sub-samples must be removable substrate that are scraped on the stream bank later. All forms of sub-samples must add up to 15.

4. Scraping and rinsing. This method applies to all objects that were removed from the stream and need to be scraped but will be simply referred to as “rocks” in this section.

   a. Sit in a shaded location on the stream bank, within an arm’s reach of the water’s surface.

   b. Rinse twice and then fill the spray bottle with stream water. Ensure that the spray head mechanisms are thoroughly rinsed by pumping water through the spray head several times.

   c. Carefully pull back an edge of the hand towel and remove the first rock. Place the bottle cap (“cap”) on any section of the upside aspect (e.g. where algae are attached) of the rock. With the rock in hand, hold the cap firm with your thumb. With your free hand, vigorously scrape algae from the area not under but around the cap with the toothbrush. Rinse the rock, with the cap still firmly in place, and toothbrush bristles in the stream. Repeat the scrape and rinse process one more time.

   d. Note: Based on the density of periphyton on the rock, you may have to use a spoon or putty knife to remove macroalgae from the area not under the cap.

   e. Remove the cap and place to the side. Hold the rock directly above the 1-liter Nalgene bottle. Gently scrape the area that was under the cap with the toothbrush.

   f. Use the spray bottle to rinse the dislodged scrapings directly into the 1-liter Nalgene bottle. Ensure that the slurry of algal material and rinse water runs off or drips into the 1-liter Nalgene bottle. Keep the rinse water to a minimum, just enough to rinse off the scrapings.

   g. Scrape and rinse the area that was under the lid a second time.

   h. Discard the rock back into the stream and rinse the toothbrush (or applicable scraping device) in the stream.

   i. Repeat the scraping and rinse process for the remaining 14 rocks at sites with hard-bottomed substrate or the remaining number of rocks or removable objects pulled from soft-bottomed streams.

   j. At this point, approximately 75-150 ml of scrapings and rinse water will be in the 1- liter Nalgene bottle. Remove the spray head from the spray bottle. Pour stream water from the spray bottle into the 1-liter Nalgene bottle until the mixture reaches the 500 ml graduated increment.

k. If applicable, discard the remaining stream water from the spray bottle.

l. Cap the 1-liter Nalgene bottle and invert several times to homogenize the composite of scrapings and rinse water.

m. Record the composite material volume on the Physicochemical and Biology field form.

5. Sample preparation (Chlorophyll α)

a. Rinse the filter funnel and holder in the stream. Using tweezers, center a single 47 mm Whatman glass microfiber filter directly on the filter funnel base. Then screw and tighten the filter funnel to the base.

b. Using a cap-less 50 ml conical centrifuge tube, measure 20-50 ml of composite material.

c. Pump the measured composite material through the filter using the hand-operated PVC vacuum pump. Do not let the vacuum pressure rise above 20 psi to prevent cell damage.

d. Note the volume filtered on the Physicochemical and Biology field form.

e. Remove the cap from a pre-labeled 50 ml conical centrifuge tube. Use the tweezers to remove and gently fold in half the glass microfiber filter. Slide the folded filter into the centrifuge tube. Screw the cap back on.

f. Wrap the centrifuge vial in a 6” x 6” sheet of aluminum foil. Fold close the ends in such a fashion to ensure the aluminum foil does not rip or come undone during transport to the laboratory. Note: It is okay to cover the label. This process ensures that the label will remain fixed to the centrifuge vial rather than on top of the aluminum foil and will prevent loss of the label during transport.

g. Place the wrapped centrifuge tube(s) in an ice chest containing blocks of dry ice. For proper preservation, immediately place the tubes in direct proximity to the dry ice.

h. Discard the filtered extract from the filter funnel holder. Rinse the entire filtering apparatus.

# 9. Macroinvertebrate Sampling

Methods to collect macroinvertebrate data can be found in Appendix B of Policy Statement 10-1 (CDPHE 2017). The methods outlined in Policy Statement 10-1 represent semi-quantitative methods for collecting a single sample from perennial, wadeable streams. Quantitative sample collection methods via a Hess Sampler may also be used (Rees and Kotalik 2018; CDPHE 2019). Information on these methods is also available on the CDPHE website.

While the CDPHE (2017) approach is intended for use in perennial streams, macroinvertebrate sample collection could also be completed in non-perennial streams when standing or flowing water is present during the index period. However, it is important to note that spatial and interannual variability may be greater within these systems, and sampling may have more limited repeatability.

Record information related to macroinvertebrate sampling on Physicochemical and Biology field form in Section 12.

*Sampling Period:*

Samples should be collected during designated sampling periods to minimize seasonal variation (Table A.5). Whatever date is selected for the preliminary sampling, a similar time frame (within a week or two) should be selected for subsequent sampling to further minimize seasonal variability.

***Table A.5. Sampling period restrictions for macroinvertebrate sampling.***

| Project Location | Sampling Period |
|---|---|
| Biotype 1 & 2 | Late June to November 30 |
| Biotype 3 | May 1 to November 30 |

*Method:*

An equipment list is included in CDPHE (2017) Appendix B, Section 6.1. Sampling methods for riffle and multi-habitat approaches are provided in CDPHE (2017) Appendix B and are duplicated with minor edits below. Please see the original reference for additional information, including information on site selection, quality control methods, and invasive species management.

The riffle habitat method (CDPHE 2017 Appendix B, Sections 6.0 and 7.1), which focuses on sampling riffle habitats, should be applied in hard-bottomed streams (i.e., moderate to high gradient streams with a dominate substrate of particles gravel size or larger).

The multi-habitat method (CDPHE 2017 Appendix B, Sections 6.0 and 7.2), which focuses on sampling non-riffle habitats, such as vegetated bank margins, submerged woody debris or snags and aquatic macrophytes, should be applied in soft-bottomed streams (e.g., low gradient streams with a dominant substrate of sand, silt, clay or mud, often found in the Eastern Plains and in the far western xeric plateaus of Colorado, and dominated by glide/pool habitats).

*Riffle Habitat Method Methods (from CDPHE 2017):*

1. Ensure that the sampling net and sieve bucket are clean prior to usage.
2. Select the dominant riffle habitat within the study reach according to Section 5.0 of CDPHE (2017).
3. Place the net frame flush to the streambed with the frame open to the upstream flow. Check that the nylon bag and sieve bucket are freely floating immediately downstream of the net frame. This will ensure that once the substrate is disturbed that specimens will be directed through the nylon bag and into the capture sieve bucket.
4. Carefully lower the handle forward in an upstream direction until the sampling net is nearly horizontal to the water surface but the net frame is still flush to the streambed. The point at which the tip of the handle extends along the streambed is the point at which the kicking activity will cease. This distance multiplied by the width of the net frame equals one square meter. Return the handle to its vertical position.
5. Position yourself next to sampling net and begin to disturb the substrate immediately upstream of the net. Disturb the substrate using the heel of your boot or entire foot by kicking to dislodge the upper layer of cobbles or gravel and to scrape the underlying bed. The area disturbed should extend no further than the point delineated and not exceed 1 minute. Approximately 0.25 meters should be disturbed for every 15 seconds.
6. Larger cobble may be scraped by hand, if necessary, to remove specimens. Cobble should be scraped clean quickly and efficiently as the scraping is counted within the one-minute time frame.
7. Transfer material (matrix of specimens and insubstantial amount of stream substrate/detritus) from the interior of the net and sieve bucket into the sample jar and wash or pick all specimens off the net interior. Specimens that cling to the exterior of the net are not considered part of the sample. They may be removed and placed back into the stream.
8. Release back into the stream any fish, amphibians, reptiles, or crayfish caught in the net.
9. If excessive or large debris items are present refer to Sample Processing Procedures below. The kick-net should be rinsed clean by backwashing with site water before collecting additional samples.
10. Continue to Sample Processing.

*Multi-Habitat Method Methods:*

1. Ensure that the sampling net and sieve bucket are clean prior to usage.
2. Sample multiple habitats, as defined below, using the following methods. The design is to sample an equivalent of a one-meter sweep across multiple non-riffle habitats. Avoid dredging the kick net through mud or silt and clumps of leafy detritus or algal material. Also avoid hard-bottomed substrates as those habitats will be sampled separately according to the Riffle Habitat Method
   a. Woody Debris or Snag: Jab the kick net into an area of submerged and partially decayed woody debris to dislodge specimens, followed by 1-2 “cleaning” sweeps through the

water column to capture specimens in the water column. Scrub larger debris by hand over the opening of the kick net. The area of the larger debris should be included in the one-meter unit effort.

b. Bank Margins: Locate an area of bank within the study reach. Jab the kick net vigorously into the bank for a distance of 1 meter to dislodge specimens, followed by 1 to 2 "cleaning" sweeps to collect specimens in the water column.

c. Aquatic Macrophytes: Sweep the kick net through submerged or emergent vegetation for a distance of 1 meter to loosen and capture specimens, followed by 1 to 2 "cleaning" sweeps to collect specimens in the water column.

3. Transfer material (matrix of specimens and insubstantial amount of stream substrate/detritus) from the interior of the net and sieve bucket into the sample jar and wash or pick all specimens off the net interior. Specimens that cling to the exterior of the net are not considered part of the sample. They may be removed and placed back into the stream.
4. Release back into the stream any fish, amphibians, reptiles, or crayfish caught in the net.
5. If excessive or large debris items are present refer to Sample Processing Procedures below.
6. The kick-net should be rinsed clean by backwashing with site water before collecting additional samples.
7. Continue to Sample Processing.

*Sample Processing Procedure (On-site):*

Sample processing is characteristically conducted in the field. Sample processing consists of excessive material or large debris item removal and rinsing, elutriation (if necessary), preservation, and storage.

1. Remove Excessive and Large Debris Items: Picking and rinsing should be performed in a Number 30 (600 μm) or 35 (500 μm) standard sieve. Rinse off and remove any excessive debris such as algal clumps or large debris items such as leaves, sticks, or rocks that will not fit into a 1-liter sample jar or will lessen the effectiveness of the preservative. Calmly rinse the debris with stream water over the sieve opening using care not to cause unnecessary splattering of material. Examine larger debris to ensure that all specimens have been thoroughly rinsed or scraped into the sieve. Discard the material. Transfer the remaining sample matrix in the sieve to a 1-liter wide-mouth polyethylene sample jar. Each sample jar should be no more than half full of sample material. Consequently, splitting the sample into two or more sample jars is acceptable. If splitting the sample among several containers, label appropriately to indicate that the sample has been split (e.g., Sample 1 of 2 and Sample 2 of 2).
2. Elutriation: Elutriation is a technique used to extract specimens from excessive substrate that has been captured during the sample collection process. This technique works best when the substrate is comprised of fines, sands and pebbles and should be used in circumstances when the amount of substrate is disproportionate to the amount of the detritus/specimen matrix. Keeping the sample in the 5-gallon bucket, add stream water to the bucket. Gently swish the sample around in the bottom of the bucket to liberate organic

material and macroinvertebrates from the substrate. Pour the water and all floating material and specimens into a Number 30 (600 µm) or 35 (500 µm) standard sieve. This process may not work for heavy invertebrates such as snails, larger annelids or case-building caddis flies that use sand. Continue rinsing in a similar fashion 2-3 more times to maximize retention of specimens collected. If it appears that the heavy invertebrates are not being separated from the substrate, pour the remaining sample in the bucket into a tray and spread the sample homogenously across the bottom of the tray. Use forceps to remove remaining specimens and place them into the sieve. Transfer the remaining sample matrix in the sieve to a 1-liter wide-mouth polyethylene sample jar. Each sample jar should be no more than 1/2 full of sample material. Consequently, splitting the sample into two or more sample jars is acceptable. If splitting the sample among several containers, label appropriately to indicate that the sample has been split (e.g., Sample 1 of 2 and Sample 2 of 2).

3. Sample Preservation: Sample preservation is very important to ensure the integrity of the benthic organisms collected from the site. The sample is preserved by decanting as much remaining water as possible and then filling the jar with 95% ethanol (ETOH) so the ETOH is 1” above the detritus/specimen matrix. Gently invert the sample jar several times to thoroughly homogenize the sample and preservative. This will make certain that the entire sample is preserved. Poorly preserved specimens can impede the identification and enumeration process. Any liquid leaking from the jar lid with the bottle inverted indicates an incomplete seal. Allowing for dilution with water remaining in the sample container, the minimum ethanol concentration should always be greater than 70%. If in doubt, or with samples containing a large amount of organic material, the ethanol should be decanted after initial preservation and replaced with fresh 95% ethanol. In general, the volume of the container should contain no more than 50% of the sample.
4. Labeling: Add moisture resistant labels to both the inside and outside of the sample container. Affix the label to the outside using transparent packaging tape. Pull back a corner of the packaging tape prior to affixing the label so the tape/label can be easily removed later once the taxonomist returns the 1-liter jars. The following information should be recorded with a pencil on each label and placed in each sample container:
   a. Reach ID
   b. Stream name
   c. Date
   d. Collector’s initials
   e. Indicate if sample is split
5. Storage: Place the sample jars in a hard-cased ice chest or equivalent container for transport to the laboratory. Ensure that jar lids are thoroughly tightened to eliminate leakage and fumes from developing inside vehicle cargo holds or truck beds.

*Sample Processing:*

Standard operating procedures for laboratory identification and enumeration are outlined in CDPHE (2017) Appendix C.

Once taxa are identified from the sample following standard operating procedures outlined in Appendix C of CDHPE (2017), CO MMI values can be calculated by inputting data into the EDAS database (see Appendix D of CDPHE (2017)). Laboratories providing taxonomic identification services may also calculate CO MMI scores upon request. Note that midges (family Chironomidae) must have sufficient taxonomic resolution to calculate an MMI score. Some labs charge a separate fee for higher taxonomic resolution for this group. A public version of EDAS and EDAS User Manual is available for use; contact the Environmental Data Unit at CDPHE for a copy. Contact CDPHE for questions on macroinvertebrate sampling and assistance with calculating CO MMI scores, if needed.

# 10. Measuring Flow

Implementing the Flow Alteration Module and the Baseflow Dynamics parameter may require continuous monitoring of stream flow, or discharge measured in cubic feet per second (cfs) within the reach. Detailed instructions for deploying stream gages, establishing a rating curve, and analyzing flow records are provided in EPA's *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams* (2014). **Detailed methods are not provided in this section.** These measurements will require current meters in addition to the surveying equipment listed in Section 1.

Multiple field measurements of discharge will be required for the Flow Alteration Module, where extremes and baseflow discharge values are calculated from the gage record. For baseflow dynamics, where the discharge of interest is a single stage in the cross-section, multiple flow measurements are preferred but one measurement is sufficient provided that baseflow is within a range of 0.4 to 2.5 times the measured flow (Espegren 1996).

Record the time and date of sensor deployment on the Field Value Documentation form(s) in Appendix B.

*General Methods:*

Before deploying stream gages to monitor discharge in the reach, the user should review *Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams* (USEPA 2014). Existing stream gage data can be used where the gage is nearby and where no change in the baseflow Q is expected between the existing and proposed condition. When using data from a nearby gage, perform steps 2, 5, 6 and 7.

1. Deploy stream gage(s) to collect data throughout the late summer and early fall of the monitoring year. The sensors should be set to record point stage measurements at intervals that do not exceed one hour.
2. Measure discharge at or near baseflow and relate the discharge measurements to the measured stage at the stream gage as described by EPA (2014). Due to turbulent flow, these measurements are not required to be recorded in riffle features, refer to section 3.8.3 of EPA (2014) for site selection considerations in measuring discharge.
3. Create a stage-discharge rating curve for the gage and convert recorded stage values to flow values.
4. Use the monitored stream stage data to calculate the mean daily flow for each day in the period of record.

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# 12. Field Forms

## Colorado Stream Quantification Tool
## Longitudinal Profile Form

| | |
|---|---|
| Date: | Rod Team: |
| Stream Name: | Instrument Team: |
| Reach I.D. | Notes Team: |
| Team Number: | |

**Longitudinal Profile Field Form**

**Key Codes:**

| | | | | | |
|---|---|---|---|---|---|
| Head of Riffle | R | Bankfull | BKF | Benchmark | TBM |
| Head of Run | N | Top of Bank | TOB | Turning Point | TP |
| Head of Pool | P | Edge of Channel | EC | Backsight | BS |
| Head of Glide | G | Inner Berm | IB | Foresight | FS |
| Thalweg | TW | | | Height of Instrument | HI |

| **Survey:** | | | **Thalweg** | | **Water Surface** | | **Bankfull** | | **Top of Low Bank** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Station** | **BS (+)** | **HI** | **FS (-)** | **Elevation** | **FS (-)** | **Elevation** | **FS (-)** | **Elevation** | **FS (-)** | **Elevation** | **FS (-)** | **Elevation** |
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**Colorado Stream Quantification Tool**
**Longitudinal Profile Form**

| Survey: | | | Thalweg | | Water Surface | | Bankfull | | Top of Low Bank | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | BS (+) | HI | FS (-) | Elevation | FS (-) | Elevation | FS (-) | Elevation | FS (-) | Elevation | FS (-) | Elevation |
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**Colorado Stream Quantification Tool**
**Cross Section Form**

| | |
|---|---|
| Date: | Rod Team: |
| Stream Name: | Instrument Team: |
| Reach I.D. | Notes Team: |
| Team Number: | |

**Key Codes:**

| | | | | | |
|---|---|---|---|---|---|
| Head of Riffle | R | Bankfull | BKF | Benchmark | TBM |
| Head of Run | N | Top of Bank | TOB | Turning Point | TP |
| Head of Pool | P | Edge of Channel | EC | Backsight | BS |
| Head of Glide | G | Inner Berm | IB | Foresight | FS |
| Thalweg | TW | | | Height of Instrument | HI |

**Cross Section Field Form**

| Station | BS (+) | HI | FS (-) | Elevation | Notes |
|---|---|---|---|---|---|
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Reach ID:

## I. Riffle Data (Floodplain Connectivity & Bed Form Diversity)

| | | | | |
|---|---|---|---|---|
| A. | Representative Sub-Reach Length | | 20*Bankfull Width | |

B. Bank Height & Riffle Data: Record for each riffle in the Sub-Reach

| | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R8 |
|---|---|---|---|---|---|---|---|---|
| Begin Station | | | | | | | | |
| End Station | | | | | | | | |
| Low Bank Height (ft) | | | | | | | | |
| BKF Max Depth (ft) | | | | | | | | |
| BKF Mean Depth (ft) | | | | | | | | |
| BKF Width (ft) | | | | | | | | |
| Flood Prone Width (ft) | | | | | | | | |
| Riffle Length (ft)<br>*Including Run* | | | | | | | | |
| Bank Height Ratio (BHR)<br>Low Bank H / BKF Max D | | | | | | | | |
| BHR * Riffle Length (ft) | | | | | | | | |
| Entrenchment Ratio (ER) | | | | | | | | |
| ER * Riffle Length (ft) | | | | | | | | |
| WDR<br>BKF Width/BKF Mean Depth | | | | | | | | |

| | | |
|---|---|---|
| C. | Total Riffle Length (ft)<br>*Excludes Additional Pool Lengths* | |
| D. | **Weighted BHR**<br>$\frac{\Sigma(Bank\ Height\ Ratio_i \times \text{Riffle Length}_i)}{\Sigma Riffle\ Length}$ | |
| E. | **Weighted ER** | |
| F. | **Maximum WDR** | |
| G. | **Percent Riffle (%)** | |

| **Shading Key** |
|---|
| Field Value |
| Calculation |

## II. Pool Data (Bed Form Diversity)

A. Pool Data: Record for each pool within the Sub-Reach

| | P1 | P2 | P3 | P4 | P5 | P6 | P7 | P8 |
|---|---|---|---|---|---|---|---|---|
| Geomorphic Pool? | | | | | | | | |
| Station | | | | | | | | |
| P-P Spacing (ft) | X | | | | | | | |
| Pool Spacing Ratio<br>Pool Spacing/BKF Width | X | | | | | | | |
| Pool Depth (ft)<br>Measured from BKF | | | | | | | | |
| Pool Depth Ratio<br>Pool Depth/BKF Mean Depth | | | | | | | | |

| | | | | |
|---|---|---|---|---|
| B. | **Average Pool Depth Ratio** | | C. | **Median Pool Spacing Ratio** | |

## III. Slope

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

## IV. Notes

Date:
Investigators:

**Colorado Stream Quantification Tool**
**Lateral Migration Form**

Reach ID:
Valley Type:
Bed Material:

| | | | Bank Erosion Hazard Index | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **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** |
| | | | | | | | | | | | |
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Date:
Investigators:



**Summary Table**

| BEHI/NBS Ranking | Enter bank Length from all rows on p.1 with same ranking | | | | | | | | | Length (Feet) | of Total (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ex/Ex | | | | | | | | | | | |
| Ex/VH | | | | | | | | | | | |
| Ex/H | | | | | | | | | | | |
| Ex/M | | | | | | | | | | | |
| Ex/L | | | | | | | | | | | |
| Ex/VL | | | | | | | | | | | |
| VH/Ex | | | | | | | | | | | |
| Vh/VH | | | | | | | | | | | |
| VH/H | | | | | | | | | | | |
| VH/M | | | | | | | | | | | |
| VH/L | | | | | | | | | | | |
| VH/VL | | | | | | | | | | | |
| H/Ex | | | | | | | | | | | |
| H/VH | | | | | | | | | | | |
| H/H | | | | | | | | | | | |
| H/M | | | | | | | | | | | |
| H/L | | | | | | | | | | | |
| H/VL | | | | | | | | | | | |
| M/Ex | | | | | | | | | | | |
| M/VH | | | | | | | | | | | |
| M/H | | | | | | | | | | | |
| M/M | | | | | | | | | | | |
| M/L | | | | | | | | | | | |
| M/VL | | | | | | | | | | | |
| L/Ex | | | | | | | | | | | |
| L/VH | | | | | | | | | | | |
| L/H | | | | | | | | | | | |
| L/M | | | | | | | | | | | |
| L/L | | | | | | | | | | | |
| L/VL | | | | | | | | | | | |
| | | | | | | | | | Total Length: | | |
| | | | | | | | | | Eroding Length: | | |

Date:
Investigators:

**Colorado Stream Quantification Tool**
**Physicochemical and Biology Form**

Stream Name:
Sub-reach Name:

| Time begin: |
|---|
| Time end: |
| Describe location of sampling within reach: |

***ALSO IDENTIFY DATA COLLECTION LOCATIONS ON SUB-REACH SKETCH ON PROJECT REACH FORM***

**Benthic macroinvertebrates:** **□ Yes** **□ No**

Sample taken per habitat type:
□ Riffle Habitat □ Multi-Habitat

Gear used:
□ Kicknet □ Hess □ Other: ________

Duplicate Samples: □ Yes □ No
Total samples: ______________

Preservative used:
□ 95% ethyl alcohol □ Other: ________

**Periphyton (Chlorophyll-a):** **□ Yes** **□ No**

Five transects sampled: □ Yes □ No
Three rocks from ea. transect? □ Yes □ No

Initial volume of composite: ________ ml (500 ml target)
Chlorophyll-a ml filtered: ________

| Type of Plant Growth: | % Cover | Amount | Color | Condition |
|---|---|---|---|---|
| Microalgae | | | | |
| Macroalgae | | | | |
| Mosses | | | | |
| Macrophytes | | | | |
| Bare Substrate | | | | |
| Total | ***100%*** | | | |

Substrate Present Rank: Rock_____ Sediment_____ Wood_____

Cover: Estimate the % of wetted substrate area colonized by each of the categories listed and the percent area not colonized by any plants.

Amount: Record the relative amount of plant growth in each category as being LIGHT, MODERATE or HEAVY. Light growth barely covers the substrate surface and is not immediately evident. Heavy growth extends almost to the water surface or beyond. Moderate is intermediate between light and heavy growth.

Color: The colors of aquatic plants are clues to their identity and to the health of aquatic ecosystems. Record the predominant color of the plants in each of the categories present.

Condition: Aquatic plants go through seasonal cycles of growth, maturity, and decay. GROWING plants show new growth and bright colors. MATURE plants are larger but have more subdued colors because of age, epiphytes and sediment deposits. DECAYING plants display a loss of both pigmentation and physical integrity.

Rank: Rank the types of substrates that are available for colonization by plants (1 = substrate accounting for the most area, etc)

**Fish Data Collection:** **□ Yes** **□ No**

First sampling event? □ Yes □ No
Repeat visit? □ Yes □ No Date/time of previous event:
Reference site sampled? □ Yes □ No
Reference Site Location: Latitude: Longitude:
First ref. sampling event? □ Yes □ No Date/time of reference collection:
Repeat visit to ref. site? □ Yes □ No Date/time of previous event:

# PEBBLE COUNT DATA SHEET

| | |
|---|---|
| SITE OR PROJECT: | |
| REACH/LOCATION: | |
| DATE COLLECTED: | |
| FIELD COLLECTION BY: | |
| DATA ENTERED BY: | |

| | | | PARTICLE CLASS | | | Reach Summary | |
|---|---|---|---|---|---|---|---|
| MATERIAL | PARTICLE | SIZE (mm) | Riffle | Pool | Total | Class % | % Cum |
| | Silt / Clay | < .063 | | | | | |
| | Very Fine | .063 - .125 | | | | | |
| | Fine | .125 - .25 | | | | | |
| | Medium | .25 - .50 | | | | | |
| | Coarse | .50 - 1.0 | | | | | |
| | Very Coarse | 1.0 - 2.0 | | | | | |
| | Very Fine | 2.0 - 2.8 | | | | | |
| | Very Fine | 2.8 - 4.0 | | | | | |
| | Fine | 4.0 - 5.6 | | | | | |
| | Fine | 5.6 - 8.0 | | | | | |
| | Medium | 8.0 - 11.0 | | | | | |
| | Medium | 11.0 - 16.0 | | | | | |
| | Coarse | 16 - 22.6 | | | | | |
| | Coarse | 22.6 - 32 | | | | | |
| | Very Coarse | 32 - 45 | | | | | |
| | Very Coarse | 45 - 64 | | | | | |
| | Small | 64 - 90 | | | | | |
| | Small | 90 - 128 | | | | | |
| | Large | 128 - 180 | | | | | |
| | Large | 180 - 256 | | | | | |
| | Small | 256 - 362 | | | | | |
| | Small | 362 - 512 | | | | | |
| | Medium | 512 - 1024 | | | | | |
| | Large-Very Large | 1024 - 2048 | | | | | |
| | Bedrock | > 2048 | | | | | |

Totals

# APPENDIX B:

## Required Forms for Completing the CSQT

Project Name:
Reach ID:

**Colorado Stream Quantification Tool**
**Parameter Selection Checklist**

| | Function-Based Parameter | | Metric(s) | Applicability |
|---|---|---|---|---|
| ☒ | Reach Runoff* | ☒ | Land Use Coefficient (D) **AND** Concentrated Flow Points (F) | All streams and flow types. |
| ☐ | Baseflow Dynamics | ☐ | ***Optional:*** Velocity **AND** Average Depth (D/F) | Use where hydraulic conditions during summer/fall baseflow periods may not support trout assemblages under existing or proposed conditions due to flow or channel alteration. |
| ☒ | Floodplain Connectivity* | ☒ | Bank Height Ratio **AND** Entrenchment Ratio (F) | Omit ER in multi-thread channels. |
| | | ☐ | ***Optional:*** Percent Side Channels (F) | Metric can be used in alluvial valleys with single-thread channels that support side-channels. |
| ☐ | Large Woody Debris (LWD) | ☐ | ***Optional:*** LWD Index (F) | Use in systems with forested catchments, riparian gallery forests, or that otherwise naturally have a supply of LWD. |
| | | | ***or*** | |
| | | ☐ | ***Optional:*** No. of LWD Pieces/ 100 meters (F) | |
| ☒ | Lateral Migration* | ☒ | Dominant BEHI/NBS **AND** Percent Streambank Erosion (F) | Use in single-thread channels. |
| | | | ***or*** | |
| | | ☐ | Greenline Stability Rating (F) | Likely more applicable in streams naturally in disequilibrium. |
| | | ☐ | Percent Armoring (F) | Use in addition to the other metric(s) when man-made armoring is present or proposed in the project reach. |
| ☒ | Bed Form Diversity<br>*in perennial and intermittent single-thread channels | ☒ | Pool Spacing Ratio **AND** Pool Depth Ratio **AND** Percent Riffle* (F) | Omit pool spacing ratio in bedrock dominated systems. |
| | | ☐ | ***Optional:*** Aggradation Ratio (F) | Use in meandering single-thread stream types in transport settings where the riffles are exhibiting signs of aggradation. |
| ☒ | Riparian Vegetation* | ☐ | Riparian Extent (D/F) **AND** Woody Vegetation Cover (F) **AND** Percent Native Cover (F) | Where absolute woody vegetation cover is/should be >20%. |
| | | ☐ | Riparian Extent (D/F) **AND** Herbaceous Vegetation Cover (F) **AND** Percent Native Cover (F) | Where absolute woody vegetation cover is/should be <20%. |
| ☐ | Temperature | ☐ | ***Optional:*** Daily Maximum Temperature (F) **AND** Maximum Weekly Average Temperature (F) | Use these parameters and metrics for projects with goals related to water quality improvements. |
| ☐ | Dissolved Oxygen | ☐ | ***Optional:*** Dissolved Oxygen Concentration (F) | |
| ☐ | Nutrients | ☐ | ***Optional:*** Chlorophyll α (F) | |
| ☐ | Macroinvertebrates | ☐ | ***Optional:*** Colorado Multi-Metric Index (F) | Use for projects with goals related to biological improvements or where project may impact conservation areas or other valuable fish habitats. |
| ☐ | Fish | ☐ | ***Optional:*** Native Fish Species Richness **AND** SGCN Absent (F) | |
| | | ☐ | ***Optional:*** Wild Trout Biomass (F) | |

* Include in all assessments
(D) indicates metrics are calculated using desktop methods
(F) indicates metrics are calculated or verified using field methods

Date:
Investigators:

**Colorado Stream Quantification Tool**
**Project Reach Form**

## I. Site Information

| | |
|---|---|
| Project Name: | |
| Reach ID: | |
| Drainage Area (sq. mi.): | |
| Flow Permanence: | |
| River Basin: | |
| Valley Type: | |
| Stream Reach length (ft): | |
| Latitude: | |
| Longitude: | |

| Shading Key |
|---|
| Desktop Value |
| Field Value |
| Calculation |

## II. Reach Walk

A.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Difference between bankfull (BKF) stage and water surface (WS) (ft) | | | | | | | |
| | | | | | | | |
| Difference between BKF stage and WS (ft)<br>*Average or consensus value from reach walk.* | | | | | | | |

B.

| | |
|---|---|
| Number Concentrated Flow Points | |
| Concentrated Flow Points/ 1,000 L.F. | |

C.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Length of Armoring on banks (ft) | | | | | | | |
| Total (ft) | | | | | | | |
| Percent Armoring (%) | | | | | | | |

D.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Length of Side Channels (ft) | | | | | | | |
| Total (ft) | | | | | | | |
| Percent Side Channels (%) | | | | | | | |

E.

| | |
|---|---|
| Valley length (ft) | |
| Stream Length (ft) | |
| Sinuosity | |

## III. Identification of Representative Sub-Reach

| | |
|---|---|
| Representative Sub-Reach Length<br>At least 20 x the Bankfull Width | |
| Latitude of downstream extent: | |
| Longitude of downstream extent: | |

| | |
|---|---|
| 20*Bankfull Width | |

**Sub-Reach Survey Method**

□ Rapid Survey
□ Detailed (Laser Level, Standard Level, Total Station, Survey-grade GPS, Other)

Date:
Investigators:

**Colorado Stream Quantification Tool**
**Project Reach Form**

## Representative Sub-Reach Sketch

## Notes

Date:
Investigators:

**Colorado Stream Quantification Tool**
**Riparian Extent Form**

Project Reach Name:
Project Reach Length:

| Aerial imagery mapped extent: | Expected (area): | | Observed (area): | |
|---|---|---|---|---|

| Check Aerial Imagery indicators used to define Expected Area: | | | | Riparian Area %: | |
|---|---|---|---|---|---|
| | Valley Edge | | Slope break/Terrace | Notes: | |
| | Change in Sediment | | Meander Width Ratio | | |
| | Evidence of Flooding | | Other: | | |
| | Change in Vegetation | | | | |

If Meander Width Ratio approach was used, enter the following information:

| | | | | | |
|---|---|---|---|---|---|
| Valley Type: | | Meander Width Ratio Used: | | Additional width (ft): | |
| Valley Length (ft): | | Bankfull width (ft): | | Expected Area ($ft^2$): | |

## FIELD VERIFICATION

Date of Field visit:

| Field measured extent: | Expected (area): | | Observed (area): | |
|---|---|---|---|---|

| Check indicators observed in the field at Expected Riparian Area extent: | | | | Riparian Area %: | |
|---|---|---|---|---|---|
| | Valley Edge | | Slope break/Terrace | Notes: | |
| | Change in Sediment | | Other: | | |
| | Evidence of Flooding | | | | |
| | Change in Vegetation | | | | |

Insert Aerial Photo of Project Reach with Observed and Expected Riparian Area extents:

| **Shading Key** |
|---|
| Desktop Value |
| Field Value |
| Calculation |

Date:
Investigators:

**Colorado Stream Quantification Tool**
**Riparian Vegetation Form**

Sub-Reach Name:
Sub-Reach Length: #Plots/side: Random Start #(1-20):

| Plot Information | | Cover Type:<br>Location:<br>Station ID: | Cover Type:<br>Location:<br>Station ID: | Cover Type:<br>Location:<br>Station ID: | Cover Type:<br>Location:<br>Station ID: |
|---|---|---|---|---|---|
| Tree Plots | N/I | Left Plot __ | Right Plot __ | Left Plot __ | Right Plot __ |
| | | | | | |
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| | | | | | |
| | | | | | |
| Tree Absolute Cover Subtotal | | 0 | 0 | 0 | 0 |
| Shrub Plots | N/I | Left Plot __ | Right Plot __ | Left Plot __ | Right Plot __ |
| | | | | | |
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| | | | | | |
| Shrub Absolute Cover Subtotal | | 0 | 0 | 0 | 0 |
| Absolute Woody Cover (%) | | 0 | 0 | 0 | 0 |
| Absolute Native Woody Cover (%) | | 0 | 0 | 0 | 0 |

N= Native
I = Introduced

Cover Type: H, S, F
Herbaceous, Scrub-shrub, Forested

Location = Geomorphic Location: I, O, S
Inside meander, Outside meander, Straight/riffle

Date:

Investigators:

**Colorado Stream Quantification Tool**

**Riparian Vegetation Form**

| Herbaceous Plots | | Left Plot __ | | Right Plot __ | | Left Plot __ | | Right Plot __ | |
|---|---|---|---|---|---|---|---|---|---|
| Species | N/I | Herb Plot 1 | Herb Plot 2 | Herb Plot 1 | Herb Plot 2 | Herb Plot 1 | Herb Plot 2 | Herb Plot 1 | Herb Plot 2 |
| | | | | | | | | | |
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| | | | | | | | | | |
| Absolute Herb Cover (%) | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Absolute Native Herb Cover (%) | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

N= Native
I = Introduced

Cover Type: H, S, F
Herbaceous, Scrub-shrub, Forested

Location = Geomorphic Location: I, O, S
Inside meander, Outside meander, Straight/riffle

Project Name:
Reach ID:

**Colorado Stream Quantification Tool**
**Bankfull Verification Documentation**

**Bankfull Riffle Values used for CSQT Calculations:**

| | |
|---|---|
| Discharge (CFS): | |
| Cross-sectional area (SF): | |
| Width (FT): | |
| Maximum Depth (FT): | |
| Mean Depth (FT): | |

If field verification was not possible, explain why.

(1) Line of Evidence:

- ☐ Surveyed Profile of WSEL and Bankfull
- ☐ Return Interval Analysis
- ☐ Regional Curves
- ☐ H&H Modeling
- ☐ Other:_______________
- ☐ Other:_______________

**BKF value calculated from this method:**

**Description:**

(2) Line of Evidence:

- ☐ Surveyed Profile of WSEL and Bankfull
- ☐ Return Interval Analysis
- ☐ Regional Curves
- ☐ H&H Modeling
- ☐ Other:_______________
- ☐ Other:_______________

**BKF value calculated from this method:**

**Description**

(3) Line of Evidence:

- Surveyed Profile of WSEL and Bankfull
- Return Interval Analysis
- Regional Curves
- H&H Modeling
- Other:_______________
- Other:_______________

**BKF value calculated from this method:**

**Description**

(4) Line of Evidence:

- Surveyed Profile of WSEL and Bankfull
- Return Interval Analysis
- Regional Curves
- H&H Modeling
- Other:_______________
- Other:_______________

**BKF value calculated from this method:**

**Description**

Project Name:
Reach ID:

**EXISTING or PROPOSED or Monitoring**
**(Select one)**

**Colorado Stream Quantification Tool**
**Field Value Documentation**

| Item | Value | Value Source/Reference |
|---|---|---|
| Reach Hydrology & Hydraulics | | |
| Reach Runoff | | |
| Land Use Coefficient | | |
| Lateral Drainage Area (total; Acres) | | |
| Forested or scrub-shrub (Acres) | | |
| Herbaceous (Acres) | | |
| Open Water (Acres) | | |
| Open Space (Acres) | | |
| Impervious Surfaces (Acres) | | |
| Pasture (Acres) | | |
| Cropland (Acres) | | |
| **FIELD VALUE - Land Use Coefficient (%)** | | Calculated |
| Concentrated Flow Points (#/1000 LF) | | |
| **FIELD VALUE - Concentrated Flow Points** | | Pulls from project reach form. |
| Baseflow Dynamics | | |
| Gage Sampling Period (start, stop, and sampling interval) | | |
| Gage number (if applicable) | | |
| Q baseflow (cfs) | | |
| Area wetted (sf) - Riffle 1 | | |
| Area wetted (sf) - Riffle 2 | | |
| Area wetted (sf) - Riffle 3 | | |
| Average Velocity (fps) | | |
| Average Velocity (fps) - Riffle 1 | | |
| Average Velocity (fps) - Riffle 2 | | |
| Average Velocity (fps) - Riffle 3 | | |
| **FIELD VALUE - Average Velocity (fps)** | | Calculated |
| Average Depth (ft) | | |
| Top Width wetted (ft) - Riffle 1 | | |
| Average depth (ft) - Riffle 1 | | |
| Top Width wetted (ft) - Riffle 2 | | |
| Average depth (ft) - Riffle 2 | | |
| Top Width wetted (ft) - Riffle 3 | | |
| Average depth (ft) - Riffle 3 | | |
| **FIELD VALUE - Average Depth (ft)** | | Calculated |

Project Name:
Reach ID:

**EXISTING or PROPOSED or Monitoring**
**(Select one)**

**Colorado Stream Quantification Tool**
**Field Value Documentation**

| Item | Value | Value Source/Reference |
|---|---|---|
| Reach Hydrology & Hydraulics | | |
| Floodplain Connectivity | | |
| Riffle lengths - Riffle 1 | | |
| Riffle lengths - Riffle 2 | | |
| Riffle lengths - Riffle 3 | | |
| Riffle lengths - Riffle 4 | | |
| Bank Height Ratio | | |
| BHR - Riffle 1 | | |
| BHR - Riffle 2 | | |
| BHR - Riffle 3 | | |
| BHR - Riffle 4 | | |
| **FIELD VALUE - Weighted Bank Height Ratio (ft/ft)** | | Calculated |
| Entrenchment Ratio | | |
| ER - Riffle 1 | | |
| ER - Riffle 2 | | |
| ER - Riffle 3 | | |
| ER - Riffle 4 | | |
| **FIELD VALUE - Weighted Entrenchment Ratio (ft/ft)** | | Calculated |
| Percent Side Channels (%) | | |
| **FIELD VALUE - Percent Side Channels (%)** | | Pulls from project reach form. |

Project Name:
Reach ID:

**EXISTING** or **PROPOSED** or **Monitoring**
(Select one)

**CSQT**
**Field Value Documentation**

| Item | Value(s) | Value Source/Reference |
|---|---|---|
| Geomorphology | | |
| Large Woody Debris | | |
| LWD Index | | |
| **FIELD VALUE - LWDI** | | LWDI spreadsheet output |
| No. of LWD Pieces/ 100 meters | | |
| **FIELD VALUE - No of LWD Pieces / 100 m** | | Counted in field |
| Lateral Migration | | |
| Greenline Stability Rating | | |
| % Composition of Stability Class 1 | | |
| % Composition of Stability Class 2 | | |
| % Composition of Stability Class 3 | | |
| % Composition of Stability Class 4 | | |
| % Composition of Stability Class 5 | | |
| % Composition of Stability Class 6 | | |
| % Composition of Stability Class 7 | | |
| % Composition of Stability Class 8 | | |
| % Composition of Stability Class 9 | | |
| % Composition of Stability Class 10 | | |
| **FIELD VALUE - Greenline Stability rating** | | Calculated |
| Dominant BEHI/NBS | | |
| Total Length of Bank Assessed (ft) | | |
| BEHI/NBS Category 1 | | |
| Total Bank Length for Category 1 (ft) | | |
| BEHI/NBS Category 2 | | |
| Total Bank Length for Category 2 (ft) | | |
| BEHI/NBS Category 3 | | |
| Total Bank Length for Category 3 (ft) | | |
| BEHI/NBS Category 4 | | |
| Total Bank Length for Category 4 (ft) | | |
| BEHI/NBS Category 5 | | |
| Total Bank Length for Category 5 (ft) | | |
| BEHI/NBS Category 6 | | |
| Total Bank Length for Category 6 (ft) | | |
| **FIELD VALUE - Dominant BEHI/NBS** | | |
| Percent Streambank Erosion (%) | | |
| Length of Eroding Streambanks (sum) | | Sum from values above |
| Representative Sub-reach Length (ft) | 0 | Pulls from project reach form. |
| **FIELD VALUE - Percent Streambank Erosion (%)** | | Calculated |
| Percent Streambank Armoring (%) | | |
| **FIELD VALUE - Percent armoring (%)** | | Pulls from project reach form. |

Project Name:
Reach ID:

**EXISTING** or **PROPOSED** or **Monitoring**
(Select one)

**CSQT**
**Field Value Documentation**

| Item | Value(s) | Value Source/Reference |
|---|---|---|
| Geomorphology | | |
| Bed Form Diversity | | |
| Pool Spacing Ratio | | |
| Median of Pool Spacings | | |
| Number of Geomorphic Pools | | |
| Bankfull Riffle Width (ft) | | |
| **FIELD VALUE - Pool Spacing Ratio** | | Calculated |
| Pool Depth Ratio | | |
| Average of measured pool depth | | |
| Number of pools measured | | |
| Mean Riffle Depth | | |
| **FIELD VALUE - Pool Depth Ratio** | | Calculated |
| Percent Riffle (%) | | |
| Reach Length | | |
| Bankfull Riffle Width | | |
| Representative Sub-Reach Length | 0 | Pulls from project reach form. |
| Total Riffle Length in Representative Sub-Reach | | |
| **FIELD VALUE - Percent Riffle (%)** | | Calculated |
| Aggradation Ratio | | |
| Bankfull width at max riffle (ft) | | |
| Bankfull mean depth (ft) | | |
| Reference width/depth ratio (ft/ft) | | |
| **FIELD VALUE - Aggradation Ratio** | | Calculated |
| Riparian Vegetation - Field Forms Required, values calculated from those forms. | | |
| Riparian Extent (%) | | |
| Meander width ratio | | |
| Additional width (ft) | | per User Manual |
| **FIELD VALUE - Riparian Extent (%)** | | Calculated |
| Woody Vegetation Cover (%) | | |
| **FIELD VALUE - Average Woody Cover (%)** | | Calculated |
| Herbaceous Vegetation Cover (%) | | |
| **FIELD VALUE - Average Herbaceous Vegetation Cover (%)** | | Calculated |
| Percent Native Cover (%) | | |
| **FIELD VALUE - Native Cover (%)** | | Calculated |

Project Name:
Reach ID:

**EXISTING or PROPOSED or Monitoring**
**(Select one)**

**Colorado Stream Quantification Tool**
**Field Value Documentation**

| Item | Value | Value Source/Reference |
| --- | --- | --- |
| Physicochemical | | |
| Temperature | | |
| Date & Time First Sensor Reading | | |
| Date & Time Last Sensor Reading | | |
| Sampling Interval | | |
| Daily Maximum Temperature ($^{o}$C) | | |
| Date & Time of Daily Maximum value | | |
| **FIELD VALUE - Daily Maximum Temperature ($^{o}$C)** | | |
| MWAT ($^{o}$C) | | |
| Date range of MWAT value | | |
| **FIELD VALUE - Maximum Weekly Average Temperature ($^{o}$C)** | | |
| Dissolved Oxygen | | |
| Date & Time First Sensor Reading | | |
| Date & Time Last Sensor Reading | | |
| Sampling Interval | | |
| Dissolved Oxygen Concentration (mg/L) | | |
| Date & Time of minumum value | | |
| **FIELD VALUE - DO (mg/L)** | | |
| Nutrients | | |
| Chlorophyll α (mg/m2) | | |
| Date sample was collected | | |
| **FIELD VALUE - Average Chlorophyll α (across all samples [mg/m2])** | | |

Project Name:
Reach ID:

**EXISTING or PROPOSED or Monitoring (Select one)**

**Colorado Stream Quantification Tool**
**Field Value Documentation**

| Item | Value | Value Source/Reference |
|---|---|---|
| Biology | | |
| Macroinvertebrates | | |
| CO MMI | | |
| Date sample was collected | | |
| **FIELD VALUE - CO MMI** | | Calculated |
| Fish | | |
| Date sample 1 was collected | | |
| Date sample 2 was collected | | |
| Native Fish Species Richness (% of Expected) | | |
| Expected # native fish species (list species in comments) | | |
| Observed native fish assemblage - 1 | | |
| Observed native fish assemblage - 2 | | |
| **FIELD VALUE - Native Fish Species Richness (% of Expected)** | | Calculated |
| SGCN Absent Score | | |
| No. of SGCN species absent in Tier 1 | | |
| No. of SGCN species absent in Tier 2 | | |
| **FIELD VALUE - SGCN species Absent** | | Calculated |
| Wild Trout Biomass (% Change) | | |
| Biomass - control site - 1 | | |
| Biomass - project site - 1 | | |
| Biomass - control site - 2 | | |
| Biomass - project site - 2 | | |
| **FIELD VALUE - Wild Trout Biomass (% Change)** | | Calculated. Note field value for existing condition of this metric is always 0 |

# APPENDIX C:

# Fish Species Assemblages within Major River Basins in Colorado

| Family | Species Code | Common Name | Genus Species | Conservation Status | SGCN Tier | Arkansas | Colorado | Dolores | Republican | Cimmaron | RioGrande | Gunnison | NorthPlatte | SouthPlatte | SanJuan | Yampa | White | Green |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANGUILLIDAE | EEL | AMERICAN EEL | Anguilla rostrata | --- | --- | X | A | A | A | A | X | A | A | A | A | A | A | A |
| ANTHERINIDAE | BSS | BROOK SILVERSIDE | Labidesthes sicculus | --- | --- | A | A | A | A | A | A | A | A | X | A | A | A | A |
| CATOSTOMIDAE | BMB | BIGMOUTH BUFFALO | Ictiobus cyprinellus | --- | --- | A | A | A | A | A | A | A | A | I | A | A | A | A |
| CATOSTOMIDAE | BHS | BLUEHEAD SUCKER | Catostomus discobolus | --- | 1 | A | N | N | A | A | A | N | A | A | N | N | N | N |
| CATOSTOMIDAE | FBW | FLANNEL X BLUEHEAD X WHITE SUCKER HYBRID | --- | --- | --- | A | A | A | A | A | A | A | A | A | A | A | A | A |
| CATOSTOMIDAE | FMS | FLANNELMOUTH SUCKER | Catostomus latipinnis | --- | 1 | A | N | N | A | A | A | N | A | A | N | N | N | N |
| CATOSTOMIDAE | LGS | LONGNOSE SUCKER | Catostomus catostomus | --- | --- | I | U | I | U | A | I | I | N | N | I | I | I | I |
| CATOSTOMIDAE | MOS | MOUNTAIN SUCKER | Catostomus platyrhynchus | State Species of Concern | 1 | A | N | U | A | A | A | U | U | A | A | N | N | A |
| CATOSTOMIDAE | QUI | QUILLBACK | Carpiodes cyprinus | --- | --- | A | A | A | A | A | A | A | A | X | A | A | A | A |
| CATOSTOMIDAE | RBS | RAZORBACK SUCKER | Xyrauchen texanus | Federally Endangered, State Endangered | 1 | A | N | N | A | A | A | N | A | A | A | N | N | N |
| CATOSTOMIDAE | RGS | RIO GRANDE SUCKER | Catostomus plebeius | State Endangered | 1 | A | A | A | A | A | N | A | A | A | A | A | A | A |
| CATOSTOMIDAE | RCS | RIVER CARPSUCKER | Carpiodes carpio | --- | --- | N | A | A | N | A | A | A | A | N | A | A | A | A |
| CATOSTOMIDAE | NRH | SHORTHEAD REDHORSE | Moxostoma macrolepidotum | --- | --- | A | A | A | A | A | A | A | A | N | A | A | A | A |
| CATOSTOMIDAE | WHS | WHITE SUCKER | Catostomus commersonii | --- | --- | N | U | U | N | N | U | U | N | N | U | U | U | U |
| CENTRARCHIDAE | BCR | BLACK CRAPPIE | Pomoxis nigromaculatus | --- | --- | I | I | I | I | I | A | I | A | I | I | I | I | I |
| CENTRARCHIDAE | BGL | BLUEGILL | Lepomis macrochirus | --- | --- | I | I | I | I | N | I | I | A | I | I | I | I | I |
| CENTRARCHIDAE | SNF | GREEN SUNFISH | Lepomis cyanellus | --- | --- | N | U | I | N | N | N | I | A | N | I | I | I | I |
| CENTRARCHIDAE | LMB | LARGEMOUTH BASS | Micropterus salmoides | --- | --- | I | I | I | I | I | I | I | A | I | I | I | I | I |
| CENTRARCHIDAE | OSF | ORANGESPOTTED SUNFISH | Lepomis humilis | --- | 1 | N | I | I | N | A | A | I | A | N | A | I | I | I |
| CENTRARCHIDAE | PKS | PUMPKINSEED | Lepomis gibbosus | --- | --- | I | U | U | U | A | A | A | A | I | U | U | A | A |
| CENTRARCHIDAE | RSF | REDEAR SUNFISH | Lepomis microlophus | --- | --- | I | A | A | I | A | A | A | A | I | A | A | A | A |
| CENTRARCHIDAE | ROB | ROCK BASS | Ambloplites rupestris | --- | --- | A | A | A | A | A | A | A | A | A | A | A | A | A |
| CENTRARCHIDAE | SPE | SACRAMENTO PERCH | Archoplites interruptus | --- | --- | A | A | A | A | A | A | A | A | I | A | A | A | A |
| CENTRARCHIDAE | SMB | SMALLMOUTH BASS | Micropterus dolomieui | --- | --- | I | U | U | I | I | I | U | A | I | U | U | I | I |
| CENTRARCHIDAE | SPB | SPOTTED BASS | Micropterus punctulatus | --- | --- | I | A | A | A | A | A | A | A | A | A | A | A | A |
| CENTRARCHIDAE | WCR | WHITE CRAPPIE | Pomoxis annularis | --- | --- | I | A | A | U | I | A | A | A | I | A | A | A | A |
| CLUPEIDAE | GSD | GIZZARD SHAD | Dorosoma cepedianum | --- | --- | N | U | U | N | N | F | U | A | N | U | U | U | U |
| CLUPEIDAE | TSH | THREADFIN SHAD | Dorosoma petenense | --- | --- | A | A | A | A | A | A | A | A | I | A | A | A | A |
| COTTIDAE | MTS | MOTTLED SCULPIN | Cottus bairdii | --- | --- | I | N | N | A | A | A | N | A | I | N | N | N | N |
| COTTIDAE | PAS | PAIUTE SCULPIN | Cottus beldingii | --- | --- | A | N | N | A | A | A | N | I | I | A | N | N | N |
| CYPRINIDAE | BHC | BIGHEAD CARP | ARISTICHTHYS NOBILIS | --- | --- | A | A | A | A | A | A | A | A | I | A | A | A | A |
| CYPRINIDAE | BMS | BIGMOUTH SHINER | Notropis dorsalis | --- | --- | I | A | A | A | A | A | A | U | N | A | A | A | A |
| CYPRINIDAE | BSH | BLACKNOSE SHINER | Notropis heterolepis | --- | --- | A | A | A | A | A | A | A | A | X | A | A | A | A |
| CYPRINIDAE | BYT | BONYTAIL (CHUB) | Gila elegans | Federally Endangered, State Endangered | 1 | A | N | N | A | A | A | N | A | A | N | N | N | N |
| CYPRINIDAE | BMW | BRASSY MINNOW | Hybognathus hankinsoni | State Threatened | 1 | I | I | I | N | A | A | I | I | N | A | I | I | I |
| CYPRINIDAE | BHM | BULLHEAD MINNOW | Pimephales vigilax | --- | --- | A | A | A | A | A | I | A | A | A | A | A | A | A |
| CYPRINIDAE | STR | CENTRAL STONEROLLER | Campostoma anomalum | --- | --- | N | A | A | N | N | A | A | A | N | A | A | A | A |
| CYPRINIDAE | CPM | COLORADO PIKEMINNOW | Ptychocheilus lucius | Federally Endangered, State Threatened | 1 | A | N | X | A | A | A | N | A | A | N | N | N | N |
| CYPRINIDAE | CPP | COMMON CARP | Cyprinus carpio | --- | --- | I | U | I | U | I | I | I | A | I | I | I | I | I |
| CYPRINIDAE | CSH | COMMON SHINER | Notropis cornutus | State Threatened | 1 | I | A | A | N | A | A | A | A | N | A | A | A | A |
| CYPRINIDAE | CRC | CREEK CHUB | Semotilus atromaculatus | --- | --- | I | U | I | N | A | A | I | N | N | I | I | I | I |
| CYPRINIDAE | EMS | EMERALD SHINER | Notropis atherinoides | --- | --- | A | A | A | A | A | A | A | A | I | A | A | A | A |
| CYPRINIDAE | FMW | FATHEAD MINNOW | Pimephales promelas | --- | --- | N | U | I | N | N | N | U | N | N | U | U | U | U |
| CYPRINIDAE | FHC | FLATHEAD CHUB | Platygobio gracilis | State Species of Concern | 1 | N | A | A | A | A | N | A | A | I | A | A | A | A |
| CYPRINIDAE | GSH | GOLDEN SHINER | Notemigonus crysoleucas | --- | --- | I | I | I | U | A | A | I | A | I | A | I | I | I |
| CYPRINIDAE | GDF | GOLDFISH | Carassius auratus | --- | --- | I | I | I | U | A | A | I | A | I | I | I | I | I |
| CYPRINIDAE | HHC | HORNYHEAD CHUB | Nocomis biguttatus | --- | --- | A | A | A | A | A | A | A | A | X | A | A | A | A |
| CYPRINIDAE | HBC | HUMPBACK CHUB | Gila cypha | Federally Endangered, State Threatened | 1 | A | N | N | A | A | A | N | A | A | N | N | N | N |
| CYPRINIDAE | HGC | HYBRID GRASS CARP (TRIPLOID) | Ctenopharyngodon | --- | --- | I | I | I | I | I | I | I | A | I | I | I | I | I |
| CYPRINIDAE | KOI | KOI | CYPRINUS RUBROFUSCUS | --- | --- | A | i | A | A | A | A | A | A | A | A | A | A | A |
| CYPRINIDAE | LAC | LAKE CHUB | Couesius plumbeus | State Endangered | 2 | I | A | A | A | A | A | A | A | N | A | A | A | A |
| CYPRINIDAE | LND | LONGNOSE DACE | Rhinichthys cataractae | --- | --- | N | U | A | A | A | N | U | N | N | U | U | U | A |
| CYPRINIDAE | NRD | NORTHERN REDBELLY DACE | Phoxinus eos | State Endangered | 1 | I | A | A | A | A | A | A | A | N | A | A | A | A |

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A - Absent

| Family | Species Code | Common Name | Genus Species | Conservation Status | SGCN Tier | Arkansas | Colorado | Dolores | Republican | Cimmaron | RioGrande | Gunnison | NorthPlatte | SouthPlatte | SanJuan | Yampa | White | Green |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CYPRINIDAE | PMW | PLAINS MINNOW | Hybognathus placitus | State Endangered | 1 | N | A | A | N | A | A | A | A | N | A | A | A | A |
| CYPRINIDAE | RDS | RED SHINER | Cyprinella lutrensis | --- | --- | N | I | I | N | I | N | I | A | N | I | I | I | I |
| CYPRINIDAE | RSS | REDSIDE SHINER | Richardsonius balteatus | --- | --- | I | I | I | A | A | A | I | A | I | A | I | I | I |
| CYPRINIDAE | RCH | RIO GRANDE CHUB | Gila pandora | State Species of Concern | 1 | A | A | A | A | A | N | I | A | A | I | A | A | A |
| CYPRINIDAE | RSH | RIVER SHINER | Notropis blennius | --- | --- | A | A | A | I | A | A | A | A | A | A | A | A | A |
| CYPRINIDAE | RTC | ROUNDTAIL CHUB | Gila robusta | State Species of Concern | 1 | A | N | N | A | A | A | N | A | I | N | N | N | N |
| CYPRINIDAE | RUD | RUDD | Scardinius | --- | --- | I | A | A | U | I | A | A | A | I | A | A | A | A |
| CYPRINIDAE | SAH | SAND SHINER | Notropis stramineus | --- | --- | N | I | I | N | N | A | I | I | N | I | I | I | I |
| CYPRINIDAE | SCP | SILVER CARP | HYPOPHTHALMICHTHYS MOLITRIX | --- | --- | A | A | A | A | A | A | A | A | A | A | A | A | A |
| CYPRINIDAE | SRD | SOUTHERN REDBELLY DACE | Phoxinus erythrogaster | State Endangered | 1 | N | A | A | A | A | A | A | A | A | A | A | A | A |
| CYPRINIDAE | SPC | SPECKLED CHUB | Macrhybopsis aestivalis | --- | --- | X | A | A | A | A | A | A | A | A | A | A | A | A |
| CYPRINIDAE | SPD | SPECKLED DACE | Rhinichthys osculus | --- | --- | A | N | N | A | A | A | N | I | I | N | N | N | N |
| CYPRINIDAE | SSH | SPOTTAIL SHINER | Notropis hudsonius | --- | --- | A | A | A | A | A | A | A | A | I | U | U | A | A |
| CYPRINIDAE | SMM | SUCKERMOUTH MINNOW | Phenacobius mirabilis | State Endangered | 1 | N | A | A | N | A | A | A | I | N | A | A | A | A |
| CYPRINIDAE | TEN | TENCH | Tinca tinca | --- | --- | U | A | A | A | A | U | A | A | U | A | A | A | A |
| CYPRINIDAE | WHA | WHITE AMUR (DIPLOID GRASS CARP) | Ctenopharyngodon idella | --- | --- | I | U | U | U | I | U | U | I | I | U | U | U | U |
| ESOCIDAE | MSK | MUSKELLUNGE | Esox masquinongy | --- | --- | A | A | A | A | A | A | A | A | I | A | A | A | A |
| ESOCIDAE | NPK | NORTHERN PIKE | Esox lucius | --- | --- | U | U | U | u | A | u | U | A | u | U | U | U | U |
| ESOCIDAE | TGM | TIGER MUSKIE (NORTHERN X MUSKIE HYBRID) | Esox lucius x masquinongy | --- | --- | I | A | A | I | I | A | A | I | I | A | I | I | I |
| FUNDULIDAE | PKF | NORTHERN PLAINS KILLIFISH | Fundulus kansae | --- | --- | N | I | I | N | N | A | I | A | N | A | I | I | I |
| FUNDULIDAE | PTM | PLAINS TOPMINNOW | Fundulus sciadicus | --- | 1 | A | A | A | N | A | U | A | A | N | U | A | U | A |
| FUNDULIDAE | FKF | STRIPED KILLIFISH | Fundulus zebrinus | --- | --- | A | A | A | A | A | A | A | A | A | N | A | A | A |
| GASTEROSTEIDAE | TSS | 3-SPINE STICKLEBACK | Gasterosteus aculeatus | --- | --- | A | A | A | A | A | A | A | A | I | A | A | A | A |
| GASTEROSTEIDAE | BST | BROOK STICKLEBACK | Culaea inconstans | --- | --- | I | I | I | A | A | I | I | I | I | I | I | I | I |
| ICTALURIDAE | BBH | BLACK BULLHEAD | Ameiurus melas | --- | --- | N | U | I | N | N | I | I | A | N | I | I | I | I |
| ICTALURIDAE | BCF | BLUE CATFISH | Ictalurus furcatus | --- | --- | I | A | A | A | A | A | A | A | I | A | A | A | A |
| ICTALURIDAE | BRH | BROWN BULLHEAD | Ameiurus nebulosus | --- | --- | A | A | A | A | A | A | A | A | I | A | A | A | A |
| ICTALURIDAE | CCF | CHANNEL CATFISH | Ictalurus punctatus | --- | --- | N | I | I | N | I | I | I | A | N | I | I | I | I |
| ICTALURIDAE | FLC | FLATHEAD CATFISH | Pylodictis olivaris | --- | --- | I | A | A | A | A | A | A | A | I | A | A | A | A |
| ICTALURIDAE | STP | STONECAT | Noturus flavus | State Species of Concern | 1 | I | A | A | N | A | A | A | A | N | A | A | A | A |
| ICTALURIDAE | YBH | YELLOW BULLHEAD | Ameiurus natalis | --- | --- | U | U | A | I | A | A | U | A | U | U | A | U | A |
| LOTIDAE | BUR | BURBOT | LOTA LOTA | --- | --- | A | A | A | A | A | A | A | A | A | A | A | A | I |
| MORONIDAE | SXW | PALMETTO BASS (WIPER) | Morone saxatilis x chrysops | --- | --- | I | A | A | I | I | A | A | A | I | A | A | A | A |
| MORONIDAE | SBS | STRIPED BASS | Morone saxatilis | --- | --- | I | A | A | A | I | A | A | A | I | A | A | A | A |
| MORONIDAE | SHB | SUNSHINE BASS | Morone chrysops(f) x m. saxatilis(m) | --- | --- | I | A | A | A | A | A | A | A | I | A | A | A | A |
| MORONIDAE | WBA | WHITE BASS | Morone chrysops | --- | --- | I | A | A | I | I | A | A | A | I | A | A | A | A |
| OSMERIDAE | SMT | RAINBOW SMELT | Osmerus mordax | --- | --- | I | I | I | A | A | A | I | A | I | A | I | I | I |
| PERCIDAE | ARD | ARKANSAS DARTER | Etheostoma cragini | State Threatened | 1 | N | A | A | A | I | A | A | A | A | A | A | A | A |
| PERCIDAE | IOD | IOWA DARTER | Etheostoma exile | State Species of Concern | 2 | A | A | A | N | A | A | A | U | N | U | U | A | A |
| PERCIDAE | JOD | JOHNNY DARTER | Etheostoma nigrum | --- | --- | I | A | A | N | A | A | A | N | N | A | A | A | A |
| PERCIDAE | ORD | ORANGETHROAT DARTER | Etheostoma spectabile | State Species of Concern | 1 | A | A | A | N | A | A | A | A | A | A | A | A | A |
| PERCIDAE | SGR | SAUGER | Sander canadense | --- | --- | I | A | A | A | A | A | A | A | N | A | A | A | A |
| PERCIDAE | SAG | SAUGEYE (WALLEYE X SAUGER HYBRID) | Sander vitreum x canadense | --- | --- | I | A | A | A | I | A | A | A | I | A | A | A | A |
| PERCIDAE | WAL | WALLEYE | Sander vitreum vitreum | --- | --- | I | I | I | I | A | I | I | I | I | I | I | A | I |
| PERCIDAE | WLP | WALLEYE TRIPLOID | Sander | --- | --- | A | A | A | A | A | A | A | A | A | A | A | A | A |
| PERCIDAE | YPE | YELLOW PERCH | Perca flavescens | --- | --- | I | U | I | I | A | I | I | A | I | I | I | I | I |
| POECILIIDAE | MSQ | WESTERN MOSQUITOFISH | Gambusia affinis | --- | --- | I | I | I | U | A | I | I | A | I | I | I | I | I |
| SALMONIDAE | ARC | ARCTIC CHAR | Salvelinus alpinus | --- | --- | A | I | A | A | A | A | A | A | A | A | A | A | A |
| SALMONIDAE | GRA | ARCTIC GRAYLING | Thymallus arcticus | --- | --- | I | I | A | A | A | A | A | I | I | A | I | I | I |
| SALMONIDAE | BRK | BROOK TROUT | Salvelinus fontinalis | --- | --- | I | I | I | I | A | I | I | I | I | I | I | I | I |
| SALMONIDAE | LOC | BROWN TROUT | Salmo trutta | --- | --- | I | I | I | I | I | I | I | I | I | I | I | I | I |
| SALMONIDAE | COH | COHO (SILVER) SALMON | Oncorhynchus kisutch | --- | --- | A | F | A | A | A | A | A | A | A | A | A | A | A |
| SALMONIDAE | CRN | COLORADO RIVER CUTTHROAT | Oncorhynchus clarkii pleuriticus | State Species of Concern | 1 | I | N | N | A | A | I | N | I | I | I | N | N | N |

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| Family | Species Code | Common Name | Genus Species | Conservation Status | SGCN Tier | Arkansas | Colorado | Dolores | Republican | Cimmaron | RioGrande | Gunnison | NorthPlatte | SouthPlatte | SanJuan | Yampa | White | Green |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SALMONIDAE | NAT | CUTTHROAT TROUT (S.S.U.) | Oncorhynchus clarkii | --- | --- | N | N | N | A | A | I | N | A | N | I | N | N | N |
| SALMONIDAE | GOL | GOLDEN TROUT | Oncorhynchus aguabonita | --- | --- | A | I | A | A | A | A | I | I | I | A | I | I | I |
| SALMONIDAE | BAC | GREENBACK CUTTHROAT, BEAR CREEK | Oncorhynchus clarkii stomias | Federally Threatened, State Threatened | 1 | I | A | A | A | A | A | A | A | N | A | A | A | A |
| SALMONIDAE | KOK | KOKANEE (SOCKEYE) SALMON | Oncorhynchus nerka | --- | --- | I | I | I | A | A | I | I | I | I | I | I | I | I |
| SALMONIDAE | MAC | LAKE TROUT (MACKINAW) | Salvelinus namaycush | --- | --- | I | I | A | A | A | A | I | I | I | A | I | I | I |
| SALMONIDAE | MWF | MOUNTAIN WHITEFISH | Prosopium williamsoni | --- | --- | A | I | A | A | A | A | I | A | I | A | N | N | N |
| SALMONIDAE | NAV | NAVAJO RIVER CUTTHROAT | Oncorhynchus clarkii pleuriticus | --- | --- | A | A | A | A | A | A | A | A | A | A | A | A | A |
| SALMONIDAE | RBT | RAINBOW TROUT | Oncorhynchus mykiss | --- | --- | I | I | I | I | I | I | I | I | I | I | I | I | I |
| SALMONIDAE | RXN | RAINBOW X CUTTHROAT | Oncorhynchus mykiss | --- | --- | I | I | I | I | A | I | I | I | I | I | I | I | I |
| SALMONIDAE | RGN | RIO GRANDE CUTTHROAT | Oncorhynchus clarkii virginalis | State Species of Concern | 1 | A | A | A | A | A | N | A | A | A | I | A | A | A |
| SALMONIDAE | SRN | SNAKE RIVER CUTTHROAT | Oncorhynchus clarkii behnkei | --- | --- | I | I | I | A | A | I | I | I | I | I | I | I | I |
| SALMONIDAE | SPL | SPLAKE (BROOK X LAKE HYBRID) | Salvelinus fontinalis x namaycush | --- | --- | I | I | I | A | A | I | I | I | I | I | I | I | I |
| SALMONIDAE | LXB | TIGER TROUT | Salmo trutta x salvelinus fontinalis | --- | --- | I | I | A | A | A | I | I | A | I | I | I | I | A |
| SALMONIDAE | YSN | YELLOWSTONE CUTTHROAT | Oncorhynchus clarkii bouvieri | --- | --- | I | I | I | A | A | I | I | I | I | I | I | I | I |
| SCIAENIDAE | DRM | FRESHWATER DRUM | Aplodinotus grunniens | --- | --- | I | A | A | U | A | A | A | A | U | A | A | A | A |

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