The Montana Department of Environmental Quality Western Montana Sediment Assessment Method: Considerations, Physical and Biological Parameters, and Decision Making

DRAFT

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ACRONYMS

Acronym	Definition
DEQ	Department of Environmental Quality (Montana)
EPA	Environmental Protection Agency (US)
GPS	Global Positioning System
MCA	Montana Codes Annotated
MFISH	Montana Fish Wildlife and Parks Montana Fisheries Information
PIBO	PACFISH/INFISH Biological Opinion
QAPP	Quality Assurance Project Plan
RPD	Residual pool depth
RSI	Riffle Stability Index
SRS	Site Response Section
TMDL	Total Maximum Daily Load
USDA	United States Department of Agriculture

SEDIMENT ASSESSMENT METHOD SUMMARY

This summary describes the techniques to be used for assessing a waterbody for sediment impairment in western Montana. The assessment method applies to perennial or intermittent streams with a Strahler order ≤ 4 contained within the Northern Rockies, Middle Rockies, Canadian Rockies, or Idaho Batholith Level III Ecoregions. This assessment method will only be used on Strahler order 1 streams when deemed appropriate.

The assessment process considers effects of sediment on the most sensitive beneficial use (i.e., aquatic life), thereby protecting all uses against sediment impairment. Using narrative water quality standards for sediment, a defined process determines whether beneficial uses are being supported. The primary monitoring parameters that are evaluated for the assessment include:

- percent riffle fines (< 6 mm and < 2 mm)
- percent pool tail fines (< 6 mm)
- residual pool depth
- pool frequency
- width/depth ratio
- riffle stability index

Fine sediment parameters (riffle and pool tail fines) are evaluated to determine whether streams are impaired by “sedimentation/siltation.” Coarse sediment and habitat parameters (pool depth and frequency, width/depth ratio, and riffle stability index) are evaluated separately to determine whether streams are impaired from “solids (bedload)” or “aquatic habitat conditions.” Data will be evaluated against a reference dataset or literature/target values to determine attainment of water quality standards for sediment. The preferred option is to compare stream physical data to reference data sets.

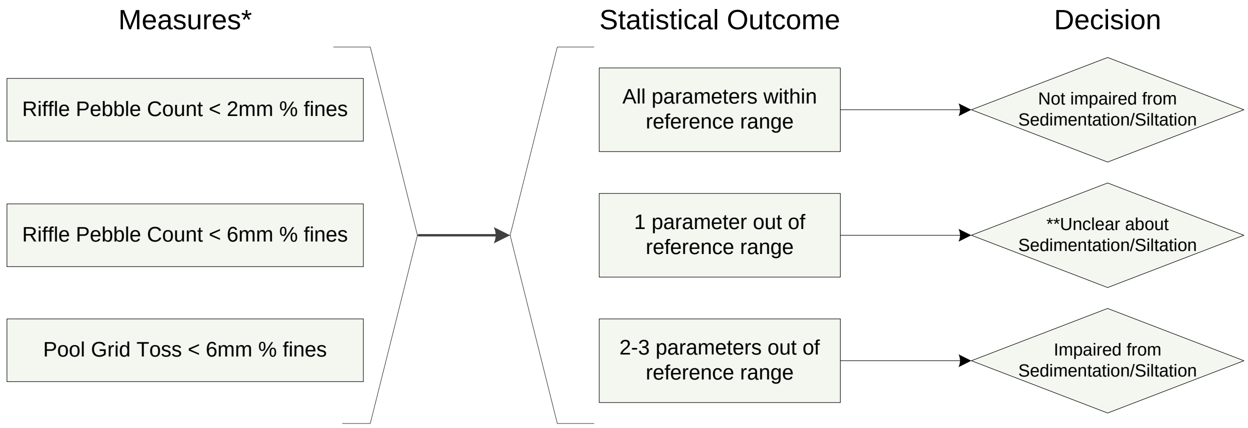
FINE SEDIMENT ASSESSMENT

Riffle and pool fines are evaluated by comparing riffle pebble counts (<2mm and <6mm) and pool tail grid toss data (<6mm) to reference data or literature/target values. First, the data are grouped (by ecoregion, Strahler order, Rosgen channel type, etc., based on the judgment of the assessor) so that like streams and/or stream types are being compared. Second, specific non-parametric statistical tests are used to determine whether physical parameter values from assessed streams are within those defined by the reference data or literature/target values. A minimum of 1 sample must be collected when using reference data sets. The statistical methods used to test for differences for reference data sets are based on the number of samples collected:

- When < 4 samples are collected use the 1-Sample Wilcoxon Signed Rank Test.
- When ≥ 4 samples are collected use the Mann-Whitney U test

At least 3 samples must be collected when using literature/target values. The 1-Sample Wilcoxon Signed Rank Test is the statistical method used to test for differences in literature values or targets.

The impairment decision is based on the statistical outcomes as shown in **Figures 1**. If all parameters are within the acceptable range of reference, the waterbody is considered “not impaired”. The waterbody is considered “impaired” from Sedimentation/Siltation when 2 to 3 parameters are out of reference range. Human-caused sediment sources must be present for any sediment listing.



* Additional fine sediment measurements may include McNeil core, V*, or a second year of data collection. If McNeil cores are readily available, they should be included with the above measures and the same decision criteria used. In addition, biology may be used.
**If decision outcome is unclear, additional data may be pursued or a collective decision will be made by experienced WQPB staff and the WQPB QA Officer.

Figure 1. Decision flow chart for determining sedimentation/siltation impairment.

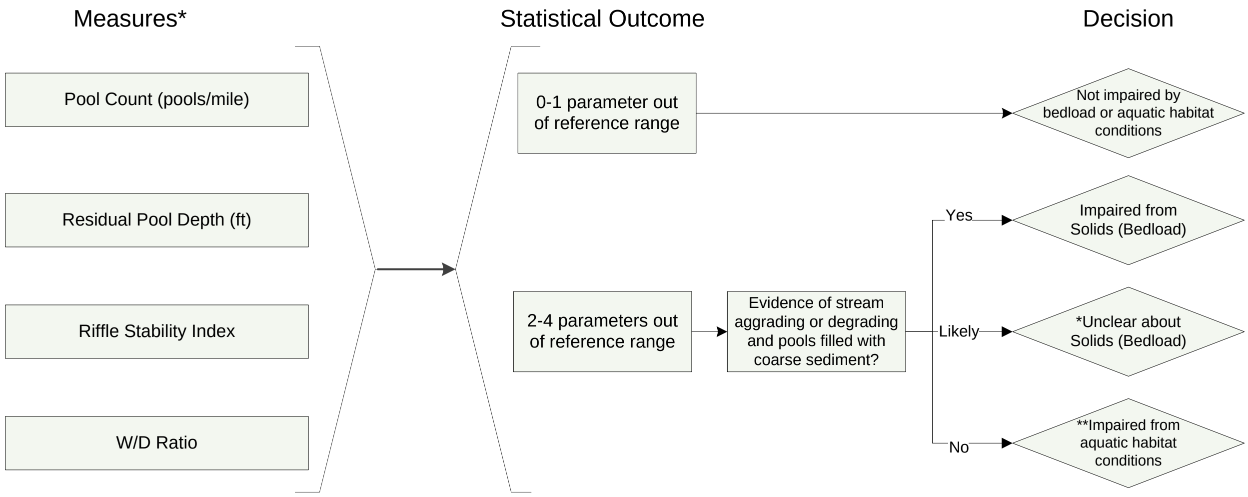
Coarse Sediment and Habitat Assessment

Pool filling parameters (pool depth and frequency) as well as width/depth ratio, and riffle stability index are compared to reference data or literature/target values. First, the data are grouped (by ecoregion, Strahler order, Rosgen channel type, etc., based on the judgment of the assessor) so that like streams and/or stream types are being compared. Second, specific non-parametric statistical tests are used to determine whether assessed stream physical parameter values are within those defined by the reference data or literature/target values. A minimum of 1 sample must be collected when using reference data sets. The statistical methods used to test for differences for reference data sets are based on the number of samples collected:

- When < 4 samples are collected use the 1-Sample Wilcoxon Signed Rank Test.
- When ≥ 4 samples are collected use the Mann-Whitney U test

At least 3 samples must be collected when using literature/target values. The 1-Sample Wilcoxon Signed Rank Test is the statistical method used to test for differences in literature values or targets.

The impairment decision is based on the statistical outcomes as shown in **Figure 2**. If 0 or 1 parameter is out of reference range, the waterbody will be considered “not impaired”. The waterbody is considered “impaired” from solids (bedload) when 2 or more parameters are out of reference range and there is evidence of the stream aggrading or degrading and pools are filled with coarse sediment. The waterbody is considered “impaired” from aquatic habitat conditions when 2 or more parameters are out of reference range and there is no evidence of the stream aggrading or degrading and no pool filling. Human-caused sediment sources must be present for any solids (bedload) listing and human influences to habitat must be present for any habitat listing.



* Additional coarse sediment and habitat measurements may include large woody debris, riparian greenline transects and other appropriate measures approved by WQPB management.
**These decisions will be reviewed by experienced WQPB staff and the WQPB QA Officer.

Figure 2. Decision flow chart for determining Solids (bedload) or aquatic habitat conditions impairment.

1.0 INTRODUCTION

Sediment is a leading cause of waterbody impairment in Western Montana. This pollutant can have a variety of adverse effects on many different aquatic organisms. Past listings for sediment were often based on best professional judgment with few standardized data quality objectives. This document provides a sediment assessment method that is both standardized and defendable. The parameters collected and the way in which they are measured are supported by the current peer-reviewed literature. The process we have developed to make an impairment decision helps account for natural variability and specifies when data is insufficient for a determination. The method described should lead to consistent and reproducible sediment impairment decisions.

1.1 BACKGROUND

Erosion and sediment are naturally occurring components of healthy and stable stream ecosystems. Deposited fine sediment from weathering, bank erosion, and instream fluvial processes is naturally transported and regular flooding allows sediment deposition to build floodplain soils and point bars, and prevents excess scour of the stream channel. Riparian vegetation and natural instream barriers such as large woody debris, beaver dams, or overhanging vegetation help trap sediment and build channel and floodplain features.

Stream health can be affected by human activities when excessive sediment loading enters the system from increased bank erosion or other sources. The increased load may alter channel form and function as well as affect fish and other aquatic life by increasing turbidity and causing excess sediment to accumulate in critical aquatic habitat areas not naturally characterized by high levels of fine sediment.

When developing an assessment method, it is important to understand the linkage between the parameter of concern and the potential impacts to the use of concern, in this case the aquatic life beneficial use. This assessment method applies a weight of evidence approach using physical parameters recognized to cause harm (e.g., reduced survival, community shift, use of suboptimal habitat) at a certain level. The biological aspect relied upon to infer physical measures that can relate harm to the aquatic life beneficial use relative to sediment is fish. This decision was made due to the large number of peer-reviewed studies (laboratory and field-based) linking fine sediment to reduced spawning and rearing and habitat loss to aggradation and deposition. In addition, we found that studies for other biological communities that quantified sediment concentrations to harm generally used similar physical measurements as in those for fish.

Excess sediment can be detrimental to the biotic communities within a waterbody. Increasing sediment levels can lead to a decrease in periphyton biomass (Yamada and Nakamura, 2002) as well as a decrease in macroinvertebrate density and diversity (Waters, 1995) and a shift in macroinvertebrate community toward burrowing taxa (Suttle et al., 2004). More specifically, sediment may block light and cause a decline in primary production, and it may also interfere with fish and macroinvertebrate survival and reproduction. Fine sediment deposition reduces availability of suitable spawning habitat for salmonid fishes and can smother eggs or fry. Effects from excess sediment are not limited to suspended or fine sediment; an accumulation of larger sediment (e.g., cobbles) can fill pools, reduce the percentage of desirable particle sizes for fish spawning, and cause channel overwidening (which may lead to additional sediment loading and/or increased temperatures). Effects on salmonids include impaired growth and survival of juveniles (Suttle et al., 2004), reduced redd escapement by fry (Fudge et al., 2008), and decreased spawning success (Fraley and Weaver, 1993; Tappel and Bjornn, 1983; Reiser and White, 1988). In addition to causing a reduction in habitat quality, excess sediment (fine or coarse) filling riffles and pools can reduce the quantity of habitat available for organisms during part or all of their life cycle.

Although fish and aquatic life are typically the most sensitive beneficial uses regarding sediment, excess sediment may also affect other uses. For instance, high concentrations of suspended sediment in streams can cause water to appear murky and discolored, negatively impacting recreational use, and excessive sediment can increase filtration costs for water treatment facilities that provide safe drinking water.

The Montana narrative standard for sediment states: “No increases are allowed above naturally occurring concentrations of sediment or suspended sediment (except as permitted in 75-5-318, MCA), settleable solids, oils, or floating solids, which will or are likely to create a nuisance or render the waters harmful, detrimental, or injurious to public health, recreation, safety, welfare, livestock, wild animals, birds, fish, or other wildlife” (17.30.623 (f)). Determining whether or not a waterbody is impaired by sediment entails defining natural sediment conditions within a system and demonstrating that the human influenced sediment load harms aquatic life. Sediment can cause harm through multiple routes of exposure, and although high percent fines can limit salmonid embryo survival, this could be the natural condition for a waterbody. Many studies show increased percent fines in spawning areas reduce a fish’s ability to reproduce. Thus, direct measure of fine sediment compared to reference conditions is used to determine sediments affect upon fish.

In addition, if a stream is effected by high sediment loads, different locations within the stream may respond differently (Lisle, 1989). Identifying the natural sediment condition within a waterbody as well as demonstrating that increases in sediment are harmful to aquatic life is not a simple task. Despite this challenge, the development of well-planned sampling schemes and collection of biologically relevant and statistically rigorous data can help streamline and simplify this process. The process provided in this document provides an approach to assess the most sensitive use affected by sediment in streams of Western Montana.

2.0 PURPOSE

The purpose of this paper is to describe techniques to be used when assessing a waterbody for sediment impairment in western Montana. The method will be performed to assess the effects of “sedimentation/siltation,” and “bedload solids,” and “aquatic habitat conditions” on mountain and transitional streams in western Montana. In this document, sediment is referred to as the particles that are deposited on the streambed. When this method demonstrates that streams are not meeting the standard for sedimentation/siltation, bedload solids, and/or aquatic habitat conditions they will be placed on the 303(d) list.

This assessment process will streamline Montana’s decision making with regards to sediment condition. The process considers effects of sediment on the most sensitive beneficial use (i.e., aquatic life), thereby protecting all uses against sediment impairment. This method will require specific data be collected and analyzed for the Montana Department of Environmental Quality (DEQ) to make consistent sediment impairment decisions. The methods described are supported by peer-reviewed literature and represent what we believe to be the best currently available options for collecting reproducible and statistically rigorous data. The following methods are designed to answer specific questions related to the instream sediment condition. Although this paper represents our best efforts to address sediment impairment in most western Montana streams, it is by no means an end-all approach to making such determinations.

This method will likely address most nonpoint source related turbidity and suspended solids problems in smaller western Montana streams because sediment transport and deposition are often closely related in these watersheds. If turbidity is elevated from human caused sources during low flow periods when streams are usually low in turbidity, these discrete sources of turbidity and suspended solids may affect fishes. In these situations turbidity and suspended solids related listings may be pursued using an approach different than those covered in this document.

2.1 METHOD APPLICABILITY

The streams (or the segments) being assessed with this assessment method must be contained within the Northern Rockies, Middle Rockies, Canadian Rockies, or Idaho Batholith level III ecoregions (**Figure 3**). Additional constraints to this protocol include that streams must be perennial or intermittent, and Strahler order ≤ 4 (Strahler, 1957b; Strahler, 1957a). In addition, this assessment method will only be used on Strahler order 1 streams when deemed appropriate. These conditions have been applied to the method recognizing that the sediment regimes of mountain streams in western Montana are vastly different from those of larger rivers and eastern Montana prairie streams. These other situations present their own unique challenges when it comes to identifying routes of harm such as turbidity, sediment transport, and in some cases a sediment tolerant ichthyofauna. The protocols in this method do not address suspended sediment, sediment quality, non-wadeable, or lentic waterbodies. Sediment assessment protocols that address medium and large rivers and also eastern Montana prairie streams may be developed by DEQ in the future.

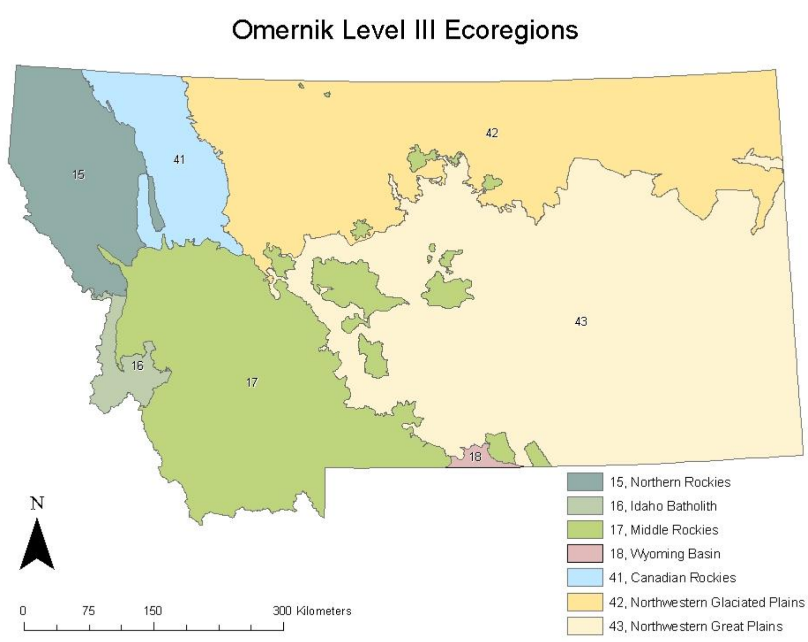


Figure 3. Level III ecoregions in Montana (Woods et al., 2002).
The assessment method within this document will be applied only to waterbodies within ecoregions 15, 16, 17, and 41.

3.0 DATA COLLECTION

When performing a sediment assessment, water quality data should be collected consistently to allow for comparisons between data sets (Roper et al., 2010). Collecting data in a repeatable manner will benefit DEQ when examining the status of a waterbody over time. Comparability of data collected by the various groups internal to the Water Quality Planning Bureau as well as external entities (e.g. United States Forest Service, Montana Fish Wildlife and Parks, watershed groups) will result in more robust data sets and prevent unnecessary sampling. Compiling a western Montana sediment dataset with consistent collection methods will promote a more robust and organized regional reference system. The assessment method described herein has been developed with this in mind.

The data collected from a given stream will be compared to that of expected "reference condition" (Suplee et al., 2005; Stoddard et al., 2006) for that particular stream in the weight of evidence approach. Reference data used may include data collected from an internal reference site within a stream, external reference sites from other streams, or literature values for a particular stream type. This method has been used by Kershner et al. (2004b) and Kershner and Roper (2010) to distinguish between reference and managed watersheds in the western United States. Although there is literature supporting the development of thresholds for fine sediment impacts to aquatic organisms (Kaller and Hartman, 2004; Bryce et al., 2010; Bryce et al., 2008; Paul et al., 2008), DEQ has opted to not take the threshold approach at this time. The inherent variability within watersheds can create problems when thresholds are applied to habitat metrics (Al-Chokhachy et al., 2010; Kershner and Roper, 2010). This could lead to placing streams on the 303(d) list that do not belong there or vice versa. Collection of data for both reference and assessed streams using this method will create a robust dataset that can facilitate the development of fine sediment thresholds if deemed appropriate by DEQ in the future (see Cormier et al. (2008) and USEPA (2006) for examples of how this may be done).

When making impairment determinations, there is a chance of making the following two types of errors:

Type 1: Identifying a stream segment as impaired for sediment when in reality, it is fully supporting the aquatic life beneficial use.

Type 2: Identifying a stream segment as fully supporting when in actuality, sediment is harming the aquatic life beneficial use.

No single sediment tool exists to fully describe all types of harm to aquatic life in all surface water systems in Montana. In an effort to reduce incidence of type 1 and type 2 errors, we have incorporated the following concepts into our assessment method:

- Use of a multiple reference approach for a given parameter when possible to help evaluate a stream's use support capabilities relative to a given parameter;
- Evaluation of multiple parameters to determine impairment so that an error in evaluating one parameter is less likely to result in an error in making an impairment determination;
- Identification of linkage between instream condition and identified sources, either existing or historical;
- Appropriate planning to ensure collection of sufficient data to detect differences between assessed and reference populations;
- The opportunity to improve upon data collection and analysis methods to help ensure program consistency and overall quality assurance.

Because we recognize that no single parameter may accurately indicate impairment due to fine or coarse sediment, or aquatic habitat conditions, seven primary monitoring parameters will be collected that will aid in describing routes of harm caused by sediment:

- Percent fine sediment in riffles less than 2 mm
- Percent fine sediment in riffles less than 6 mm
- Percent fine sediment in pool tails less than 6 mm
- Residual pool depth
- Number of pools per mile
- Width/depth ratio
- Riffle Stability Index

In addition, this assessment method considers reference condition and uses stratification to make comparisons between assessed streams and similar reference sites. When physical parameters do not provide a clear decision of impairment or non-impairment, biological parameters may be analyzed to determine if the physical deviation from reference is manifesting in biological disturbance. Finally, in situations where the measurement of physical parameters is severely limited (e.g., there are no pools or riffles), analysis of those that are collected will occur and the assessment decision will be supplemented by the best professional judgment of the assessor, DEQ management, and when possible, the input of a local fish biologist.

To determine fine sediment impairment, riffle and pool-tail percent fines will be measured. These parameters both address surface fines within a stream. Percent fines are defined as the percentage of sampled substrate material that is less than 6 mm as measured in pool tails, and less than 6 mm and less than 2 mm in riffles, as these are values supported throughout the literature as having effects on aquatic biota (Edwards et al., 2007; Fraley and Weaver, 1993; Phillips et al., 1975; Shepard et al., 1984; Suttle et al., 2004; Yamada and Nakamura, 2002). If deemed necessary by the assessor, larger or finer size fractions (e.g., 9.5 mm, 0.85 mm (Tappel and Bjornn, 1983)) may also be examined. The goal of measuring percent fines is to evaluate the quality of available spawning habitat within a stream.

A robust variation of the Wolman pebble count (Wolman, 1954) will be used to sample percent surface fines. This method is designed to reduce sampling bias, improve representation of the substrate present, and improve data comparability and reproducibility both within and between streams. A second means of measuring percent surface fines, the grid toss, will be used in pool tails exclusively (Archer et al., 2012; Kershner et al., 2004a). Although not a standard measurement for this protocol, subsurface fine sediment data (e.g., McNeil cores) may be used with equivalent confidence as surface fines if both assessed stream conditions and reference conditions are known.

To further address fine sediment issues as well as consider possible aggradation and coarse sediment supply, residual pool depth (Lisle, 1987), pool frequency, width/depth ratio, riffle stability index will be measured. Measuring pool structure is important as pools serve as habitat for a variety of aquatic organisms (Bisson et al., 1982; Lewis, 1969; Muhlfeld and Bennett, 2001; Roni, 2002; Sullivan et al., 1987). Pools are especially important for fish as winter habitat (Harper and Farag, 2004; Heifetz et al., 1986; Jakober et al., 2000) and refuge from thermal stress (Baird and Krueger, 2003; Matthews et al., 1994; Nielsen et al., 1994) and water velocity (Bonneau, 1998; Bunt et al., 1999). Increased sediment in a system can cause a reduction in pool size, depth, and number (Lisle, 1982; Buffington et al., 2002). Aggradation due to coarse sediment supply, whether natural or from human-caused sources, can lead to streams becoming intermittent with stranded pools that provide limited fish habitat (May and Lee, 2004). These resulting changes have ramifications for aquatic populations' stability, persistence, and ability to recover from disturbance (Lonzarich et al., 2004). Measuring pool parameters will help DEQ determine the amount of habitat available for juvenile rearing and adult fishes.

Width/depth ratio can be used for assessing departure from reference condition due to aggradation and sediment deposition. Channel width is often linked to excess streambank erosion and/or sediment inputs from sources upstream of the study site. Channels that are overwidened are often associated with excess sediment deposition and streambank erosion, contain shallower and warmer water, and provide fewer deepwater habitat refugia for fish (Montana Department of Environmental Quality, 2011).

If it is deemed that a single season of sampling is insufficient to make an impairment determination with regards to sediment, data collection of the primary monitoring parameters during a second season may take place and the collection of supplementary sediment parameters may be necessary. Methods for measuring Instability Index (ISI) (Cobb and Flannagan, 1990), subsurface fines (Young et al., 1991; McNeil and Ahnell, 1964) intragravel dissolved oxygen (which may be affected by the percent fines (Maret et al., 1993; Kondolf, 2000)), and residual pool volume (V*) (the fraction of pool volume filled with fine sediment (Lisle and Hilton, 1992; Lisle and Hilton, 1991)) are discussed in **Appendix A**.

The following considerations and parameters apply when sediment sources are identified during a risk assessment, impairment needs to be reassessed, and/or when describing the natural condition of reference waterbodies.

3.1 Data Collection Requirements

All physical parameters should be collected under base flow conditions to limit the likelihood of misidentifying a feature due to flow conditions (e.g., identifying a feature as a run at high or moderate flows when it would be considered a pool at base flow) and because during high flows instream assessments are difficult due to suspension of fine sediment, as well as unsafe.

After a map based assessment that breaks streams into similar reaches based upon valley confinement, valley gradient, ecoregion and stream order, monitoring sites are selected with the goal of being representative of various reach characteristics, land use category, and anthropogenic influence. Sampling sites should be selected to maximize the likelihood of observing anthropogenic source effects. Thus, it is not a random sampling design intended to sample stream reaches representing all potential impairment and non-impairment conditions. Instead, it is a focused sampling design that aims to assess a representative subset of reach types while ensuring that reaches that are most likely influenced by sources are incorporated into the overall evaluation. Typically, the effects of excess sediment are most apparent in mid-low gradient, unconfined streams larger than 1st order (i.e., having at least one tributary); therefore, this stream type will be the focus of most field efforts. Not all streams have areas with these characteristics and sample site selection may necessitate a shift to other stream channel types with higher or lower gradients.

Another component of the focused sampling approach will be to sample areas that can be used for reference conditions. Reference site selection should consider similar sites and watersheds where land, soil, and water conservation practices are in place. Regional reference data may be available via prior monitoring efforts from DEQ and other agencies, yet if reference conditions are presumed to be present based on map and aerial photo assessment during stream segmentation, reference condition sites should be considered for sampling.

The sampling process is labor intensive and thus costly. Therefore, a limited number of sites are feasible for sediment assessment on each stream segment. This focused approach provides a higher likelihood of detecting sediment problems when a limited number of sample sites are monitored. Physical data must be collected from a minimum of one representative site per stream segment for an assessment to take place, with ideally at least two sites per segment.

While biological data is not needed for all assessments, it may be useful in situations where physical data is inconclusive. Biological monitoring should target macroinvertebrate and periphyton communities. It is DEQ's goal to collect biological data during the same visit as the sediment monitoring, yet if assessment deadlines are not pressing, biology data may be collected the second year if needed to save costs. These samples must be collected during the time period for which metrics were developed. The samples do not need to be collected from the same location as the physical data as long as all data being examined was collected from a location with the same type of stream attributes as the physical data. Macroinvertebrates and periphyton may be evaluated when the primary monitoring parameters do not provide a clear impairment decision. When biological data is needed, two samples from different locations are recommended.

3.2 Site Selection

A key component to the determination of sediment impairment is that sediment levels must be above natural. For this to occur in a waterbody, there must be anthropogenic sources. This assessment method is based upon risk analysis and reach segregation. When a study stream is identified for study, similar reaches are identified using USGS maps and aerial photos. Ecoregion, valley slope and valley confinement are used to estimate likely stream channel types using ArcMap software. Aerial photos are then used to further refine the assessors' understanding about potential sediment sources. This should lead the assessor to appropriate channel types and select sites downstream of human sources and also select a limited number of reference sites where land management appears to deter sediment movement with land, soil, and water conservation practices to track instream conditions across land use changes. When collecting and analyzing data related to the sediment condition of a waterbody, the question, "Does this measure show a linkage between the source and the impact the source is creating?" must continuously be considered. This is an important concept because a waterbody could naturally have high levels of coarse or fine sediment due to inherent characteristics and have potential anthropogenic sources that do not actually contribute to the sediment load above the natural variability. Linking anthropogenic sources of sediment to measureable physical parameters is an important step in determining the natural condition of a waterbody. Sites will be selected to address potential effects of anthropogenic sediment sources.

Monitoring sites should be selected so that they allow for comparisons to those with the same characteristics, land uses, and anthropogenic influences. There is a preference toward sampling those reaches where anthropogenic influences would most likely lead to impairment conditions. The risk analysis will include an evaluation of human-induced and natural sediment sources, along with field observations and watershed scale source assessment information from aerial imagery and GIS data layers. Initially, streams of interest should be segmented into reaches with the same characteristics that influence sediment transport and deposition (i.e., stream order, ecoregion, valley slope, and valley confinement) and are not affected by human activity. The next step is to identify land uses and land management practices that have a significant influence on stream morphology and sediment characteristics (e.g., upland grazing, unpaved roads, bank/channel erosion) and stratify based on the land use category and anthropogenic influence.

Sampling locations will be chosen prior to the beginning of fieldwork. Selection of sites will be based on the results of a risk-based analysis for the waterbody (the methods for which are currently in development) and the best professional judgment of the assessor. Site locations may be adjusted in the field if the assessor determines the preselected site to be unsuitable or less appropriate for the assessment than another location. Each time a site is sampled, one sample (n = 1) will be collected for each of the parameters discussed in **Sections 3.3.1 – 3.3.6**.

Although most sites will not be physically monumented, each sampling site will be georeferenced (downstream and upstream extent) to allow for future sampling of the same features within a site (Olsen et al., 2005; Roper et al., 2002b; Roper et al., 2003). Georeferenced sampling sites will allow for analysis of change at given locations over time, allow for a site to be revisited for quality assurance review, and provide a starting point for other groups to conduct sampling (TMDL data collection, annual monitoring by conservation districts, etc.). In addition to helping provide rigorous data for assessing impairment, using permanent sites will facilitate the development of trends through time and for evaluating differing land or water management techniques. Collection of data at permanent sites will be an asset when performing TMDL five-year reviews and reassessments of 303(d) listed waterbodies. When georeferencing sampling sites, GPS coordinates of both the lower and upper extents of the site, photos, and a written description of the location will be documented.

Collaboration between multiple programs within DEQ should take place to determine sampling locations that will be useful to involved groups. Agreement on site locations will help create a database for a waterbody, watershed, or ecoregion that can be used and built upon by DEQ and others.

3.2.1 Site Length

The goal in defining the sample frame from which data will be collected is to gain a representation of the stream segment being considered in the assessment in areas most likely to be influenced by human activities. To ensure data representativeness, sampled reaches must be relatively homogenous (i.e., the reach is not a transition between two channel types). The length of a stream site (within a reach) that will be sufficient to effectively describe habitats can vary depending on the heterogeneity of the stream. Although different programs use different distances for their site length (e.g., U.S. Environmental Protection Agency's EMAP uses 40 times wetted width (Kaufmann et al., 1999), Rosgen (1996) uses 20 times bankfull width)), 20 times the wetted width is generally the minimum distance used (Fitzpatrick et al., 1998; Simonson et al., 1994). Leopold et al. (1964) determined that riffle/pool sequences are typically 5-7 bankfull widths in length and Keller and Melhorn (1973) reported riffle/pool sequences to be 3-9 bankfull widths. Using site lengths at least 20 times bankfull means that sampling will likely take place over multiple meander wave-lengths and riffle-pool units, and will aid in determining averaged values for specific populations (e.g., riffles) that account for local effects (Bunte et al., 2009). As a result, site length for sediment sampling will be a minimum of 20 times the bankfull width. This site length will be appropriate for a greater range of stream widths, can provide more rigor in statistical analysis (Simonson et al., 1994), and will allow for a more reliable representation of residual pool parameters (Keim and Skaugset, 2002) than using a shorter site length. Using a site length 20 times the bankfull width equates well with the site length systems used by DEQ Total Maximum Daily Load planners when verifying sediment impairment (Montana Department of Environmental Quality, 2006b)and the U.S. Forest Service in the PacFish/InFish Biological Opinion program (Archer et al., 2012). Site length will be determined by the bankfull width categories shown in **Table 1**. All sites will begin and end at the downstream extent of a pool.

Table 1. Width categories for determining minimum site length (adapted from Heitke et al., (2008)).

Average bankfull width (ft)	Width Category	Minimum site length (ft)
0 to 26	26	520
26.1 to 33	33	660
33.1 to 39	39	780
39.1 to 46	46	920
46.1 to 53	53	1060
53.1 to 59	59	1180
59.1 to 66	66	1320
66.1 to 72	72	1440
>72	79*	1580

* If a stream's average bankfull width is greater than 79 ft, the minimum site length will be 20 times the measured value.

3.3 Primary Monitoring Parameters

A detailed description of the field methods for collecting the primary monitoring parameters is described in **Appendix B**.

3.3.1 Riffle Pebble Count

The sensitivity of riffles to increased sediment supply makes them a suitable location to sample for changes in substrate size distribution (Cover et al., 2008; Dietrich et al., 1989; Kappesser, 2002; Parker and Klingeman, 1982; Price and Leigh, 2006). In addition, riffles serve as a winter refuge for juvenile salmonids. Excess fine sediment can fill interstices and reduce the availability of this crucial habitat (Bjornn et al., 1974). To sample the surface fines within riffles, a variation of the Wolman pebble count will be used (Wolman, 1954). The Wolman method is considered accurate and reproducible when sampling a single, homogeneous, population (e.g., one riffle; (Brush, 1961; Kondolf and Wolman, 1993; Mosley and Tindale, 1985; Wolman, 1954); riffle pebble counts will consist of at least 100 pebbles per sampled riffle. The pebble count shall be performed within the bankfull channel (Archer et al., 2012). Although collecting particles in this way might skew results toward the size of sediments outside of the actual aquatic habitat at the time of sampling, Mebane (2001) demonstrated strong correlation between percent fines collected within the bankfull width and macroinvertebrate health. To help address this potential bias, particles measured between the water's edge and the bankfull will be recorded as either fluvial (i.e., deposited by the relatively recent action of flowing water) or non-fluvial (i.e., older, established bank soil or substrate).

To reduce sampling bias, a gravelometer will be used to measure the combined b, c -axis of each particle, as this helps to reduce operator error in measuring the particles and is more compatible with sieve data than using a ruler (Bunte and Abt, 2001a; Hey and Thorne, 1983; Roper et al., 2010; Bunte et al., 2009; Kondolf, 1997; Bunte and Abt, 2001b). Four individual riffles will be sampled per site, each with a 100 pebble count to yield a combined 400 particle riffle count, which according to Fripp and Diplas (1993) and Rice and Church (1996) yields the most efficient sampling results. If more than four riffles are present in a sampling site, the first four should be sampled. If fewer than four riffles are present, a total of 400 particles will still be counted. The count will be evenly spread out among the riffles that are present using the same four-transect setup (e.g., if two riffles are present, each will have a 200 particle count). Multiple transects will be used to capture longitudinal variability present within a riffle. If the entire site is one riffle, then 16 transects will be evenly distributed throughout the site for sampling. If no riffles are present within the site (e.g., the site is all pool due to beaver activity, etc.) the site will be moved to an alternate location. The determination of individual riffle populations to be sampled can be performed visually (Roper and Scarnecchia, 1995).

Within each riffle, four transects set perpendicular to flow, will be evenly distributed (from downstream to upstream) at 20, 40, 60, and 80% of the riffle length. Along each transect, 25 sampling locations will be evenly spaced within the bankfull width so that the distance between each is a maximum of 1/25 of the bankfull width. Bankfull width will be recorded for each pebble count transect. **Figure 4** provides a schematic of the riffle pebble count setup. Percent fine sediment < 6 mm and < 2 mm will be measured using this technique. If the same particle is selected more than once (i.e., because it is large enough that it covers more than one sampling location), it will be recorded as many times as it is selected. One pebble count sample equals 400 measured pebbles. Two metrics are derived from each pebble count. These metrics include one value (n = 1) for percent fines < 2 mm and one value (n = 1) for percent fines < 6 mm.

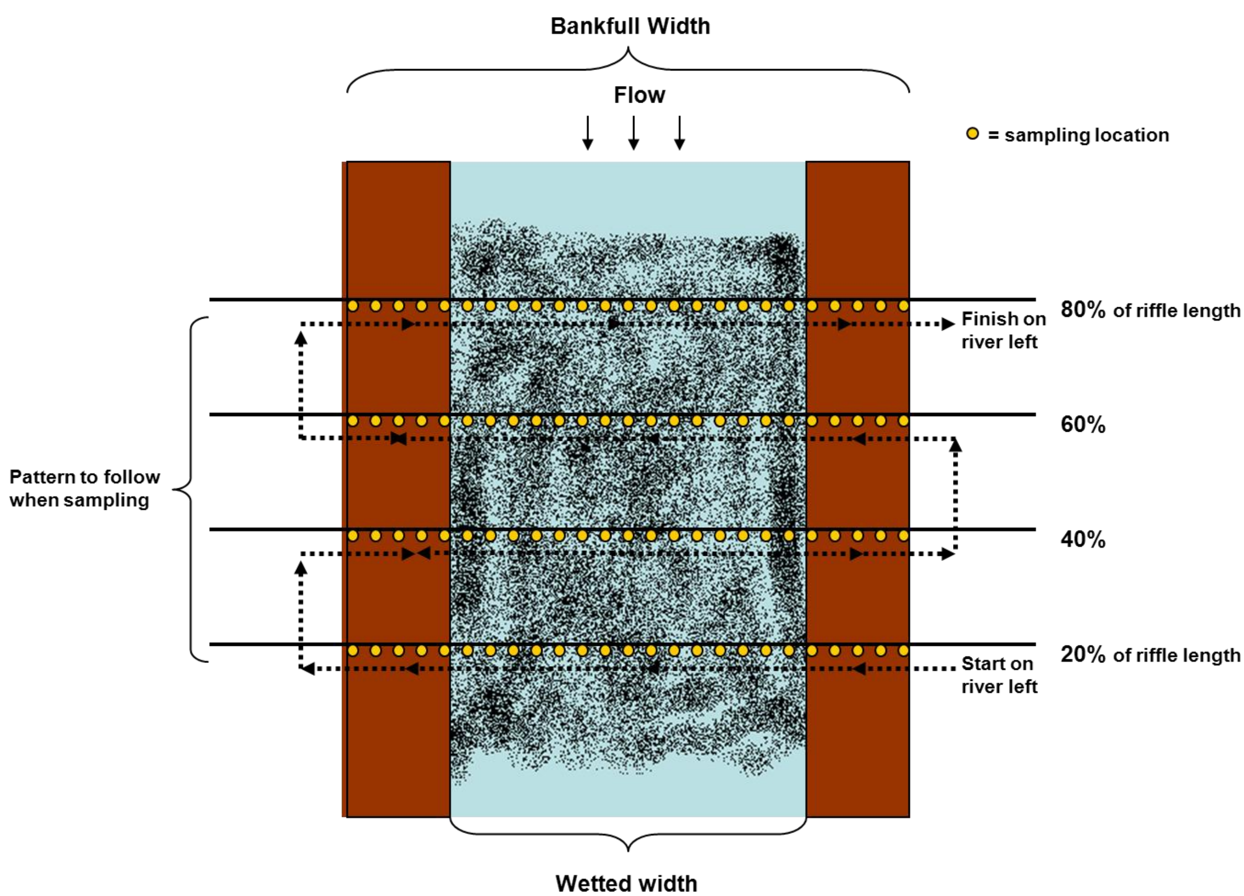


Figure 4. Setup for performing a riffle pebble count.

3.3.2. Grid toss

The grid toss will be performed to describe the substrate quality in the areas most likely used by salmonids for spawning. Salmonids generally can spawn in gravels with a D_{50} up to about 10% of their body length and tend to spawn in areas of streams where either downwelling or upwelling is present (Kondolf, 2000; Kondolf and Wolman, 1993). As a result, pool tails are a likely salmonid spawning location (Keller et al., 1990) especially for rainbow trout (Muhlfeld, 2002). In addition, pools are likely locations to observe the effects of excess fine sediment within a system (Cover et al., 2008; Kappesser, 2002; Lisle, 1982). Grid toss counts of fine sediments will be performed in the tail of all scour pools (not formed by logs or some other debris completely damming the downstream end of the pool) within the sampling site. To be considered a pool, a feature must have a maximum depth ≥ 1.5 times the pool-tail depth (Archer et al., 2012). Three grid tosses will be performed in each of the pool tails (Archer et al., 2012); **Figure 5**). The intersections of the grid are approximately 6 mm and as a result, percent fines values for sediment < 6 mm will be measured. The median size (D_{50}) of all particles observed under each grid toss will be recorded. One grid toss (n = 1) equals the percentage derived from the sum of all of the tosses in all of the pool tails sampled. For example, there are four pool tails and three tosses in each pool yields counts of 2/147, 10/147, 16/147, and 11/147. The percent fines < 6 mm are then 39/588 or 7%.

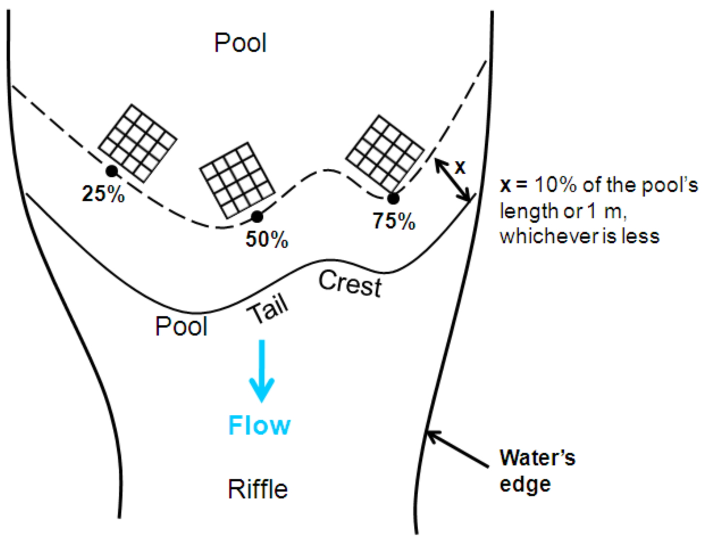


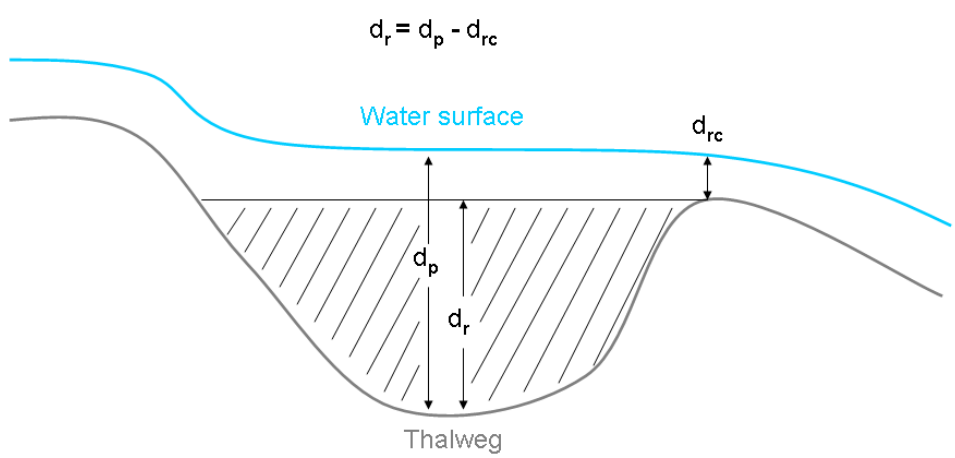
Figure 5. Locations within a pool tail to be sampled with the grid toss (adapted from Archer et al., (2012)).

3.3.3 Pool Frequency

Pool frequency is simply a count of the number of pools encountered within a sampling site. For a feature to be considered a pool, it must have a maximum depth ≥ 1.5 times the pool-tail depth (Archer et al., 2012). Pools that occupy at least 50% of the wetted channel width at any will be called large pools; those that never span more than 50% of the wetted channel width at any point, will be called small pools. When conducting a pool count, it will be noted whether or not the pool is being influenced by woody debris (wood is acting as a dam or causing scour that forms a pool). Average pool spacing (and thus frequency) can be quite variable, from one channel width to nine or more, depending on the stream type, local setting, and amount of large woody debris present (Beschta and Platts, 1986; Bilby, 1984; Keller and Melhorn, 1973; Montgomery et al., 1995). In addition, the narrower the stream, the more variable pool spacing becomes (Montgomery et al., 1995). Despite the variability in this parameter and the need to carefully consider all possible factors that can affect it, Woodsmith and Buffington (1996) were able to correctly classify disturbed and undisturbed watersheds with at least 90% accuracy when using this parameter and the ratio of mean residual pool depth to mean bankfull depth in discriminant function analysis. Because of the natural high variability of this parameter, it will be applied carefully in sediment impairment determination and will be tested through time. One (n = 1) pool frequency sample equals the sum of the number of pools within the site.

3.3.4 Residual Pool Depth

Residual pool depth (RPD) has been linked to land management practices (Kershner et al., 2004b; Lisle and Hilton, 1992); **Figure 6**). As a result, RPD measurements will be collected at all pools within each sampling site that meet the following criteria: (a) pools must be formed by the scouring action of water (not formed by logs or some other debris completely damming the downstream end of the pool), and (b) pools must be at least 50% of the wetted channel width at any location within the pool and have a maximum depth ≥ 1.5 times the pool-tail depth (Archer et al., 2012). The benefit of using residual parameters over those measured based on wetted perimeter is that they are flow/stage independent (no discharge relationship needs to be determined), and give an indication of the minimum amount of available pool habitat (Lisle, 1987). To reduce error, the goal will be to collect RPD from every pool within the site as Keim and Skaugset (2002) demonstrated that collecting residual pool volume data over a long sampling site may provide a better representation than looking at individual pools. Instructions on how to collect residual pool depth can be found in **Appendix B**. One (n = 1) residual pool depth sample equals the average of all measured pools within the site.



d_r = residual pool depth; d_p = total pool depth at the deepest point along the thalweg; d_{rc} = depth of the riffle crest at the thalweg.

Figure 6. Profile of a pool and locations to measure when determining residual pool depth (adapted from Lisle(1987)).

3.3.5 Width/Depth Ratio

The channel width/depth ratio is defined as the channel bankfull width divided by the mean bankfull depth. The channel width/depth ratio is one of several standard measurements used to classify stream channels, making it a useful variable for comparing conditions between reaches with the same stream type (Rosgen, 1996). A comparison of observed and expected width/depth ratios is a useful indicator of channel overwidening and aggradation, which are often linked to excess streambank erosion and/or sediment inputs from sources upstream of the study reach. As channels widen, there is usually increased local erosion from nearby banks, which supplies the channel with a higher course sediment load which fills nearby pool habitat. As specified in **Appendix B**, one width/depth measurement will be collected at the most well defined area of each riffle where pebble counts occur. A width/depth ratio sample (n = 1) consists of the average of all calculated ratios.

3.3.6 Riffle Stability Index

Riffle stability index (RSI) is an estimate of the mobile fraction of particles within a riffle. To calculate this index, the size distribution of particles collected from a riffle is compared to the mean size of dominant large particles collected from an adjacent depositional area (see **Appendix B** for the data collection methods). High RSI has been shown to correlate with reduced pool volume and be significantly different between reference and managed sites (Cross and Everest, 1995; Kappesser, 2002). In addition, Cross and Everest (1995) found bull trout (*Salvelinus confluentus*) redds nearly exclusively in reference streams with RSI less than 65.

3.4 Additional Monitoring Data

The following data may be collected during any sediment assessment. It will typically be used to facilitate appropriate stratification of streams and supplement the primary monitoring parameter data.

3.4.1 Rosgen Channel Type

At each site, measurements will be made to determine Rosgen channel type (A, B, C, etc.; (Rosgen, 1994; 1996); see Figure 1 in Rosgen (1994) for a diagram of stream channel types). This method considers variables such as valley type, stream slope, sinuosity, bankfull width, width/depth ratio, entrenchment and flood-prone area and will help ensure that similar streams are being compared. Because stream channels can transition from one type to another due to disturbances, a designated classification of a stream only indicates the existing condition and does not necessarily indicate that it is stable or at its potential. The stage of channel evolution and the stream potential should be considered before stratifying streams based on Rosgen channel type. The current and potentially stable channel form will be determined. The potential stream type should be estimated based upon stream stratification process and what was seen in the field. Reference data will be combined based on channel type when appropriate so that comparisons between reference and assessed sites are meaningful. Rosgen channel type is not used as an impairment indicator, and is only used to characterize the stream channel at the site for reference comparison purposes.

3.4.2 Biological Data

Macroinvertebrates and periphyton may be collected when the primary monitoring parameters do not yield a straight forward determination with regards to sediment impairment. These parameters should be collected from at least two sampling sites along the stream segment. It is best if the biological samples are collected from the same location as the physical data to be used in analysis, although not required (see: ***Data Collection Requirements***). These samples will be collected via DEQ protocol for the specific biological parameters that will be used in analysis of biological condition. The biological data may be examined in cases where physical data does not provide clear evidence of use support or impairment.

Macroinvertebrates will be collected using the Environmental Monitoring and Assessment Protocol's "reachwide" method (Montana Department of Environmental Quality, 2006a). Periphyton will be collected following the "Peri-1" method (Montana Department of Environmental Quality, 2005a).

Currently, DEQ has Observed/Expected (O/E) metrics that will be used for sediment assessment (Feldman, 2006). These metrics are not a specific diagnostic tool for sediment, but DEQ is in the process of developing and refining macroinvertebrate indices that will be sediment specific. Diatom indicators similar to those found in Bahls et al. (2008) that are diagnostic for sediment impairment at the Level III Ecoregion scale are now available for use.

Fish indices may be useful but are not currently being developed by DEQ. Testing of those already developed for other States' aquatic systems (Hughes et al., 1998; Hughes et al., 2004; McCormick et al., 2001; Mebane et al., 2003) may prove useful in the decision making process. If DEQ does develop fish indicators or concludes already developed indices to be useful in the future, they could be easily added to the assessment process. Until DEQ has its own fish metrics, it is strongly recommended that data available on the Montana Fish Wildlife and Parks Montana Fisheries Information (MFISH) website (http://fwp.mt.gov/fishing/mFish/) be used in consultation with a trained fisheries biologist to determine if fish in the assessed waterbody are demonstrating impairment due to the sediment condition.

3.4.3 Additional Parameters

Additional parameters may be collected when the primary monitoring parameters do not yield a straight forward determination with regards to sediment impairment. These additional parameters are described in **Appendix A**.

4.0 Evaluating Data for Assessment Decisions

DEQ will compare sediment data to data collected from reference sites of streams using specific non-parametric statistical tests. The analysis will determine whether assessed stream primary monitoring parameter values are within those defined by the reference data. Fine sediment parameters will be evaluated to determine whether streams are impaired by sedimentation/siltation, while coarse sediment and habitat parameters will be evaluated to determine whether streams are impaired from solids (bedload) or aquatic habitat conditions. The approaches for determining reference sites, how the data is analyzed, and the decision matrix are described in this section.

4.1 Reference Condition

DEQ defines reference condition as the condition of a waterbody capable of supporting its present and future beneficial uses when all reasonable land, soil, and water conservation practices have been applied. For a waterbody to be reference, it does not need to be pristine. Instead, reference waterbodies are those that demonstrate few to no effects from anthropogenic sources on the applicable beneficial uses. Reference condition also does not necessarily reflect conditions that existed before human settlement, but is intended to represent conditions where wise land use planning under human control protects aquatic ecosystems. Reference conditions are measured to estimate natural variations in biological communities, water chemistry, etc. due to climate, bedrock, soils, hydrology, and other natural physiochemical differences. The intention is to differentiate between natural conditions and widespread or significant human caused alterations of biology, chemistry, or hydrogeomorphology. Therefore, reference conditions should reflect minimum impacts from human activities. Reference waterbodies are either Tier 1 (Natural Condition) or Tier 2 (Minimally Impacted Condition) as determined by criteria that have been considered with intensive, onsite inspection and best professional judgment (Suplee et al., 2005).

Comparison of conditions in a waterbody to reference waterbody conditions must be made during similar season and/or hydrologic conditions for both waters. The following methods may be used to determine reference conditions:

Primary Approaches

- Comparing conditions in a waterbody to baseline data from minimally impaired waterbodies that are in a nearby watershed or in the same region having similar valley type, geology, hydrology, morphology, and/or riparian habitat
- Evaluating historical data relating to condition of the waterbody in the past (e.g., if there has been documented changes in land or water use)
- Comparing conditions in a waterbody to conditions in another portion of the same waterbody, such as an unimpaired portion of the same stream (e.g., upstream/downstream of significant sources comparison)
- Reviewing literature (e.g., a review of studies about sediment effects that reduce fish survival, etc.). Because this is the least certain approach, it should always be used in conjunction with other primary approaches

Secondary Approaches

- Seeking expert opinion (e.g., expert opinion from a regional fisheries biologist who has a good understanding of the waterbody's fisheries health or potential)
- Applying quantitative modeling (e.g., applying sediment transport models to determine how much sediment is entering a stream based on land use information, etc.)

DEQ uses the primary approach for determining reference condition if adequate regional or other primary reference data is available, and uses the secondary approach to estimate reference condition when primary approach data is limited or unavailable. DEQ often uses more than one approach to determine reference condition, especially when regional reference condition data are sparse or nonexistent.

4.2 Analysis

Data analysis will occur after one season of collecting primary monitoring parameter data. To compare sediment data collected from reference sites, the data will first be grouped (by ecoregion, Strahler order, Rosgen channel type, etc., based on the judgment of the assessor) so that like streams and/or stream types are being compared. Next, specific non-parametric statistical tests will be used to determine whether assessed stream primary monitoring parameter values are within those defined by the reference data (**Table 2**). These tests are appropriate because they have no distribution requirements and are suitable for situations that involve low sample numbers (Helsel and Hirsch, 1995). An alpha value of 0.25 will be used in statistical analysis of physical parameter data. This will help balance the likelihood of committing either a type I or type II error when comparing assessed stream data to reference data and is the same value used when assessing for nutrient impairment (Suplee and Sada de Suplee, 2011). When performing the analysis, data will be examined in the order defined by the following reference priority: 1) Combination of internal and external, 2) Only external, and 3) Literature. Reference data used in the analysis will depend on what is currently available and/or what may be collected. Literature values should primarily be used to support the results of reference data collected in the field. If the assessor does not deem literature values appropriate for a given waterbody, then this will be explained in the assessment.

Data analysis may involve examining biological data. Biology for a discrete reach may be considered indicative of impairment when >25% or more metrics suggest biological limitation. Best professional judgment may override this decision based on the data analysis when biological metrics may be confounded by other pollutants/pollution.

Table 2. Metrics to be collected and the statistical methods used to test for physical differences between assessed streams and reference data and to determine harm to use.
The preferred option is to compare assessed stream physical values to reference data sets.

Metric	Minimum n[1]	Analysis
Percent Fines: < 2 mm < 6 mm Pool Tail Fines: < 6 mm Residual Pool Depth Pool Count Width/Depth Ratio Riffle Stability Index	n = 1	<u>Using Reference Data Sets</u>[2]: When < 4 samples are collected use the 1-Sample Wilcoxon Signed Rank Test: - The 'Variables' entered will be the values from the reference data. - The 'Test Median' will be the values determined from the 400 pebble count, total percent of all grid tosses, mean residual pool depth, or pool count from the assessed stream sample site (or average of all applicable sites). - α = 0.25 When ≥ 4 samples are collected use the Mann-Whitney U test - α = 0.25
	n = 3	<u>Using Literature Values or Targets</u>: Use the 1-Sample Wilcoxon Signed Rank Test: - The 'Variables' entered will be the values determined from the 400 pebble count, total percent of all grid tosses, mean residual pool depth, or pool count from each assessed stream site. - The 'Test Median' will be the literature or TMDL target value. - α = 0.25
Periphyton Increaser O/E	n = 2 (for each metric)	If > 25% of all biological metrics suggest biological limitation, then a reach may be indicative of impairment.

[1] Refers to the number of samples collected from the stream to be assessed. There is no minimum n specified for use in the reference dataset.
[2] Preferred approach

4.2 Assessment Decisions

Fine sediment parameters (riffle and pool fines) are evaluated to determine whether streams are impaired by "Sedimentation/Siltation." Coarse sediment and habitat parameters (pool depth and frequency, width/depth ratio, riffle stability index, and instability index) are evaluated separately to determine whether streams are impaired from "Solids (bedload)" or "Aquatic habitat conditions." Data will be evaluated against a reference dataset or literature/target values to determine attainment of water quality standards for sediment. Additional data including biological measures (i.e., diatoms and macroinvertebrates) may be evaluated.

The impairment decision is based on the statistical outcomes as shown in **Figure 7**. For fine sediment assessments, if all parameters are within the acceptable range of reference, the waterbody is considered "not impaired". The waterbody is considered "impaired" from Sedimentation/Siltation when 2 to 3 parameters are out of reference range. Human-caused sediment sources must be present for any sediment listing. For coarse sediment and habitat assessments, if 0 to 1 parameter is out of the acceptable range of reference, the waterbody will be considered “not impaired”. The waterbody is considered “impaired” from Solids (bedload) when 2 or more parameters are out of reference range and there is evidence of the stream aggrading or degrading and pools are filled with coarse sediment. The waterbody is considered “impaired” from aquatic habitat conditions when 2 or more parameters are out of reference range and there is no evidence of the stream aggrading or degrading and no pool filling. Human-caused sediment sources must be present for any solids (bedload) listing and human influences to habitat must be present for any aquatic habitat conditions listing.

If any physical parameter from either the fine sediment deposition or coarse sediment/habitat assessments are not within the acceptable range of reference, yet a clear impairment decision cannot be made, a sediment team consisting of technical experts will meet. The team will look at further data types if available and provide an evaluation of impairment pathways and consider the magnitude of controllable human induced sediment sources. The sediment team will determine whether a use assessment decision can be made with the data presented or whether additional sampling should occur. If a second season of sampling takes place, the same parameters will be sampled again and additional parameters described in **Appendix A** may be added. In addition, biology sampling will be considered.

When additional data has been collected, all data will be combined for analysis unless there is reason to believe conditions have changed sufficiently since the first year of data collection to make this action inappropriate. A decision shall be made based on the data collected and the best professional judgment of the assessor, sediment team, and DEQ management. The decision process accepts that variability is inherent within streams, special situations arise that a method cannot always anticipate, and that cases may arise where components of the physical composition may seem degraded but without adverse impacts to the biology.

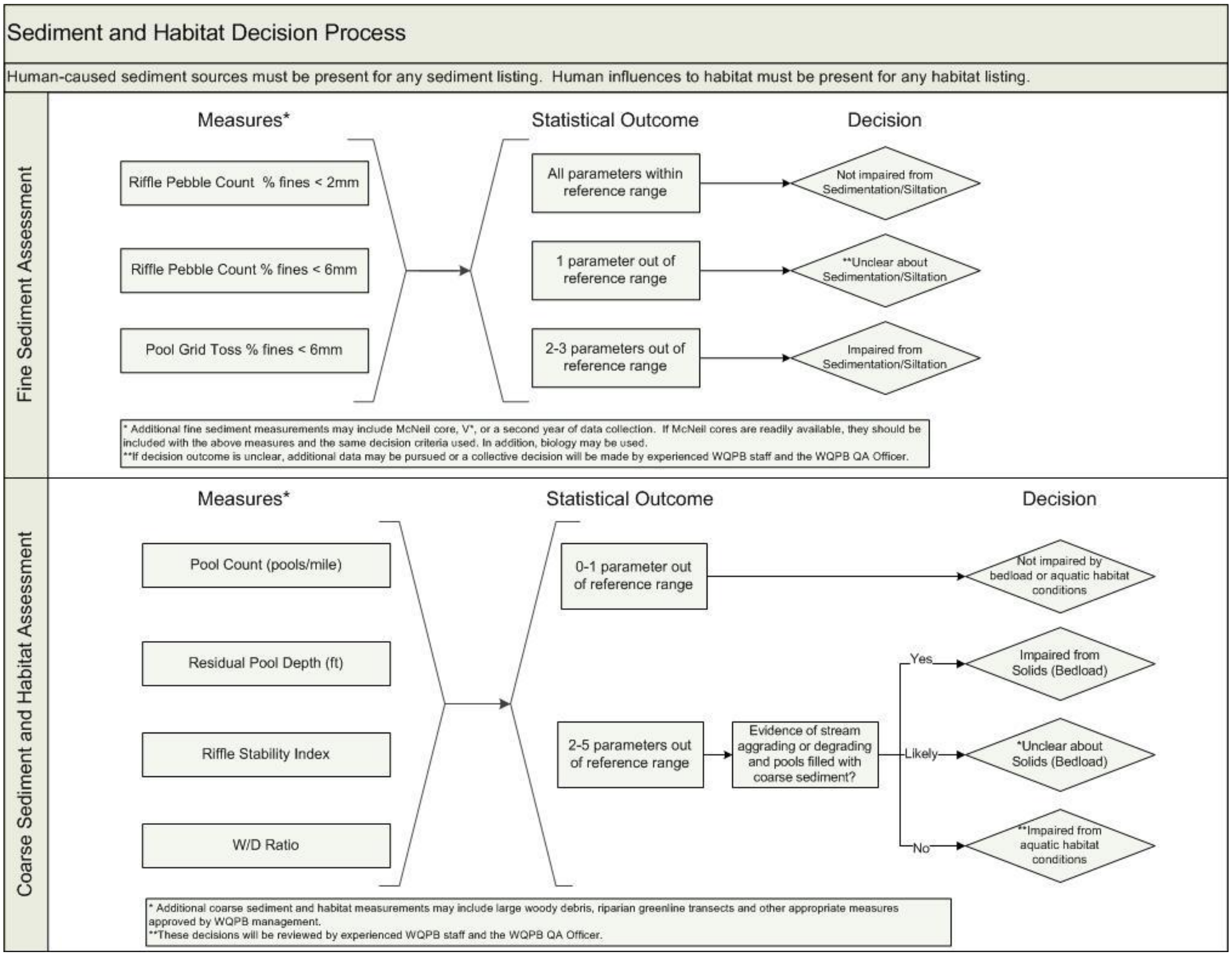


Figure 7. Decision flow chart for determining sediment impairment.

4.3 DATA FROM OTHER ENTITIES

DEQ realizes that other entities (federal and state agencies, contractors, landowners, etc.) may provide data that is relevant to the waterbody being assessed. This data will be considered in the formal assessment once it has been determined that it meets DEQ requirements for data quality. If data does not meet the requirements to be directly included in the DEQ collected dataset, it will be used to supplement the determination.

5.0 SUMMARY

This document describes a framework for making decisions on whether mountainous and transitional streams in western Montana are impaired by sediment. The aim of this document is to provide a structured and consistent approach to assess whether sediment is impairing the aquatic life beneficial use.

Using narrative water quality standards for sediment, a defined process determines whether beneficial uses are being supported. The primary monitoring parameters that are evaluated for the assessment include percent riffle fines (< 6 mm and < 2 mm), percent pool tail fines (< 6 mm), residual pool depth, width/depth ratio, pool frequency, and RSI. If all physical parameters are within the acceptable range of reference, then the waterbody will be considered “not impaired.” Fine sediment parameters (riffle and pool fines) and coarse sediment/habitat parameters (residual pool depth, pool frequency, width/depth ratio, RSI) are evaluated separately to determine beneficial-use support. Additional data including biological measures (i.e., diatoms and macroinvertebrates) may also be evaluated.

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APPENDIX A. ADDITIONAL PARAMETERS

ADDITIONAL PARAMETERS

The following additional parameters are suggested to be collected when the primary monitoring parameters discussed in the main portion of this document do not yield a straight forward determination with regards to sediment impairment. These parameters tend to require more time and resources to complete than performing those previously mentioned. As a result, they should be reserved for collection during the second season of sampling. If time and resources permit and/or a specific question needs to be answered, these parameters may be considered for integration into the initial assessment process. These parameters are to be used in addition to those previously discussed and should not be the sole determining factor in making a sediment impairment decision. To determine if these parameters are within the range of reference condition, the same approaches listed in **Table 1** of the main document shall be used.

INSTABILITY INDEX (ISI)

Instability index (ISI) is a measure of streambed stability. This index is calculated as tractive force (τ) divided by the measured median substrate size for a length of stream (Cobb and Flannagan, 1990). In this case $\tau = D_{bf}S*1000$, where D = average bankfull depth and S = average slope of the sampled stream length (Newbury 1984). Lower ISI values correspond with greater streambed stability. Higher ISI has been correlated with a reduced number of macroinvertebrate species, density, and diversity (Cobb and Flannagan, 1990; Cobb et al., 1992; Flannagan and Cobb, 1991). Moutka and Virtanen (1995) demonstrated a relationship between stream bryophyte (mosses and liverworts) communities and ISI. The demonstrated relationship between ISI and aquatic life make this index a candidate for use as a primary monitoring parameter. Although ISI is calculated with easily collected data, collecting this data is time intensive and may hinder the ability of sampling crews to visit more than one site in a day. When time permits, ISI will be collected to determine the feasibility of adding it to the suite of primary monitoring parameters. A detailed description of the field methods for collecting ISI parameters is described in **Appendix B**.

SUBSURFACE FINES

The subsurface substrate in gravel-bed rivers tends to be finer than that of the surface layer (Parker and Klingeman, 1982). Although the creation of redds by salmonids effectively reduces the amount of fines compared to non-redd substrate (MacDonald et al., 2010; McNeil and Ahnell, 1964), over time, the interstices can refill with fine sediment (Zimmerman and Lapointe, 2005). Because salmonid embryo development takes place in subsurface substrate, evaluation of these particles may provide a better link to survival than surface fine measures. In much of the literature, the combined surface and subsurface composition of the substrate is considered (Maret et al., 1993; Shepard et al., 1984; Fraley and Weaver, 1993; Tappel and Bjornn, 1983; VanDusen et al., 2005).

When sampling subsurface substrate, either McNeil cores (McNeil and Ahnell, 1964) or shovel samples may be collected (Grost et al., 1991; Hames et al., 1996; Young et al., 1991). Young et al. (1991) determined that the McNeil core method most often yielded results that were similar to the true substrate composition though differences between the McNeil and shovel methods were few. Grost et al. (1991), was able to demonstrate that the two approaches yielded similar results in the field and suggested the use of a stilling well around the shovel to improve sampling accuracy. When a stilling well and shovel method was used by Hames et al. (1996), they found that this method compared relatively well to the McNeil method though they were unable to develop a conversion that would make the results of these two techniques comparable. Hames et al. (1996) made the recommendation that regardless of the method used, the same method should always be used so that data are comparable. For use by DEQ, it is recommended that the shovel technique with a stilling well be used to collect subsurface sediment samples. This method is less costly and requires the use of lighter equipment than the McNeil method (Grost et al., 1991; Hames et al., 1996). By using this method alone, DEQ will be using the method that is most efficient and appropriate for a variety of situations with minimal monetary investment for the collection of comparable and meaningful data. Shovel samples should be collected in suspected (pool-tails and the head of riffles (Reiser and Wesche, 1977)) or known spawning locations to provide data that are biologically relevant with regards to salmonid embryo development. If data from another method, such as McNeil coring has already been collected for the assessed waterbody, it is recommended that the same method be used to ensure data comparability.

Intragravel Dissolved Oxygen and Flow

Fine sediments < 1 mm have been linked to reduced permeability in gravel (Kondolf, 2000). This reduction of permeability can reduce intragravel flow and thus, dissolved oxygen as well. Two distinct methods for sampling intragravel dissolved oxygen and flow are often used in the literature: 1) the standpipe (Barnard and McBain, 1994; Coble, 1961; Hansen, 1975; Sowden and Power, 1985; Terhune, 1958) and 2) the horizontal pipe (Hoffman, 1986; Maret et al., 1993). The standpipe method has been used by DEQ (Suplee, 2008). The method used is dependent on the questions being asked. If a long term dataset (weeks, months, etc.) with multiple or continuous measurements of dissolved oxygen at one location is desired, the horizontal pipe method is likely to be used. The standpipe method would be more appropriate when taking point measurements at multiple locations. Either of these approaches could be useful for developing a relationship between dissolved oxygen and some other variable such as percent fines or intragravel flow. The standpipe method is the method most likely to be used by DEQ, but the weight of materials required to perform it may limit its use as a supplemental indicator for sediment impairment. As a result, it is recommended that standpipes and methods to collect substrate dissolved oxygen in this way be modified (e.g., decreased pipe length and pipe pounder weight) to make its use less cumbersome for remote and difficult to access sites. As with subsurface sediment sampling, intragravel dissolved oxygen and flow should be sampled in known or suspected salmonid spawning locations.

Residual Pool Volume and V*

Residual pool volume can be measured while collecting other residual pool parameters, but because it requires many more point measurements to calculate, it may be too time consuming for initial assessment purposes. V* or the fraction of pool volume filled with fine sediment has been shown to correlate with annual sediment yield and may be used to monitor the status of sediment supply in a system (Lisle and Hilton, 1999). This method can also help capture the effects of specific sediment inputs (Lisle and Hilton, 1992; 1991). V* is also linked to biological condition based on its relationship to riffle-surface fine sediment (Cover et al., 2008). This parameter uses the residual pool volume with the addition of measuring the volume of fine sediment deposits within a pool. Lisle and Hilton (1991; 1992; 1999) provide a synopsis of how residual pool volume and V* should be collected and how each can be used to monitor sediment loading in streams.

APPENDIX B. FIELD METHODS

To collect rigorous data that has limited bias and variability, comprehensive training of those collecting data will need to occur (Marcus et al., 1995). Training will include how to classify habitat types (Marcus et al., 1995; Roper and Scarnecchia, 1995) and objectively measure habitat parameters (Roper et al., 2002a). Annual field training is required for all DEQ employees collecting data (Montana Department of Environmental Quality, 2005b). Training for this assessment method will include a manual containing clear instructions describing how to set up sampling sites, properly use measurement tools, and correctly record measurements. A two-phased training will be implemented; phase one will consist of a demonstration of habitat classification and parameter measurement and phase two will consist of the trainee(s) collecting data while being overseen by the trainer(s). Proper training of how to collect sediment data is essential to keeping data consistent over time and between collectors and must be part of making a defendable impairment decision. Field teams should consist of at least two people; one person will be familiar with the protocols, including field assessment and data analysis techniques. Assessments should be performed by staff with knowledge and understanding of geomorphology, hydrology, and factors that influence stream morphology.

The foundation of data collection for this assessment method is the appropriate identification of morphological habitat units within a stream. Agreement between observers for habitat identification can be quite low when compared to random assignment and reducing the number of habitat types to be identified maximizes the likelihood of observer agreement (Roper and Scarnecchia, 1995). Three habitat units (pools, pool tails, and riffles) will be explicitly sampled (**Figure B-1**).

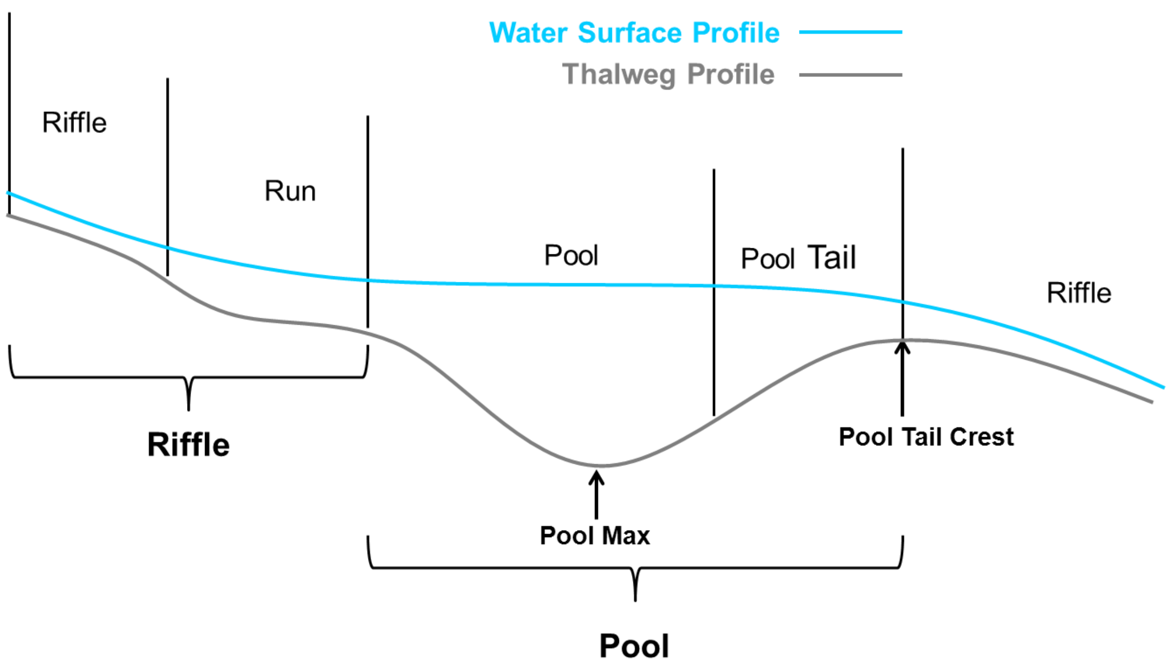


Figure B-1. Longitudinal profile of a stream bottom along the thalweg and the water surface.
For this assessment, run habitat will be considered riffle, and pool tail habitat will be considered pool.

Equipment List:

- Two 300’ measuring tapes (ft)
- Chain man
- Two 5’ measuring poles (0.1 ft)
- Gravelometer
- Grid
- Piece of plexiglass
- Ruler (mm)
- Clinometer
- Bank Pins/Silvey stakes
- Hammer
- Counter
- GPS
- Camera
- Pencils
- Field forms

Order of Activities:

Step 1 – Locate, flag, and map the sampling site
Step 2 – Check map accuracy
Step 3 – Set up EMAP reach and collect biological samples – if sampling within the site
Step 4 – Collect Pool Tail Grid Toss, Riffle Pebble Count, RSI, W/D, and Flood-prone Width Measurements
Step 5 – Collect site cross section, sitewide pebble count, and slope measurements
Step 6 – Rosgen Channel Type measurement
Step 7 – Set up EMAP reach and collect biological samples – if sampling upstream of site
Step 8 – Site Roundup

Step 1 – Locate, flag, and map the sampling site

I. Locate the sampling site:

The location of the sampling site will be predetermined based on GIS analysis. The start of the site will be at the downstream extent of a pool (i.e., pool tail). If no pools are present, start at the predetermined location.

1) Flag the location.

2) Record GPS coordinates on the “Assessment Site Location, and Map” form.

3) Photograph the area making sure to include landmarks (write this information as well as a brief description of the area on the photo form).

   Note: If the location you have previously chosen for sampling does not meet the requirements necessary for the assessment (e.g., it is a transport reach, contains multiple stream types, etc.), or the location is inaccessible, the site can be moved to an appropriate location.

II. Determine the site length by recording five bankfull measurements (Figure B-2):

1) Identify bankfull using the following indicators (all six may not be present):

- **Examine streambanks for an active floodplain.** This is a relatively flat, depositional area that is commonly vegetated and above the current water level unless there is a large amount of spring runoff or there has been a substantial rain event (i.e., stream running at bankfull stage).

- **Examine depositional features such as point bars.** The highest elevation of a point bar usually indicates the lowest possible elevation for bankfull stage. However, depositional features can form both above and below the bankfull elevation when unusual flows occur during years preceding the survey. Large floods can form bars that extend above bankfull whereas several years of low flows can result in bars forming below bankfull elevation.

- **A break in slope of the banks and / or change in the particle size distribution** from coarser bed load particles to finer particles deposited during bank overflow conditions.

- **Define an elevation where mature key riparian woody vegetation exists**. The lowest elevation of birch, alder, and dogwood can be useful, whereas willows are often found below the bankfull elevation.

- **Examine the ceiling of undercut banks.** This elevation is normally below the bankfull elevation.

- **Stream channels actively attempt to reform bankfull features such as floodplains after shifts or down cutting in the channel.** Be careful not to confuse old floodplains and terraces with the present indicators.

2) The 1st bankfull width measurement will be taken at Transect 1 (the bottom of the site).

3) The 2nd-5th bankfull width measurements will be taken upstream from the 1st, spaced at 53 foot intervals following the thalweg.

4) Record all five bankfull widths on Form 1 and calculate the average. Use the average to determine the width category from **Table B-2**. The width category will determine the spacing of additional transects.

   NOTES: In some instances a measurement cannot be taken due to dangerous obstacles or a tributary/side channel confluence. Move that measurement upstream to the next location where a measurement can be obtained. Space each of the following measurements at 53 foot intervals.

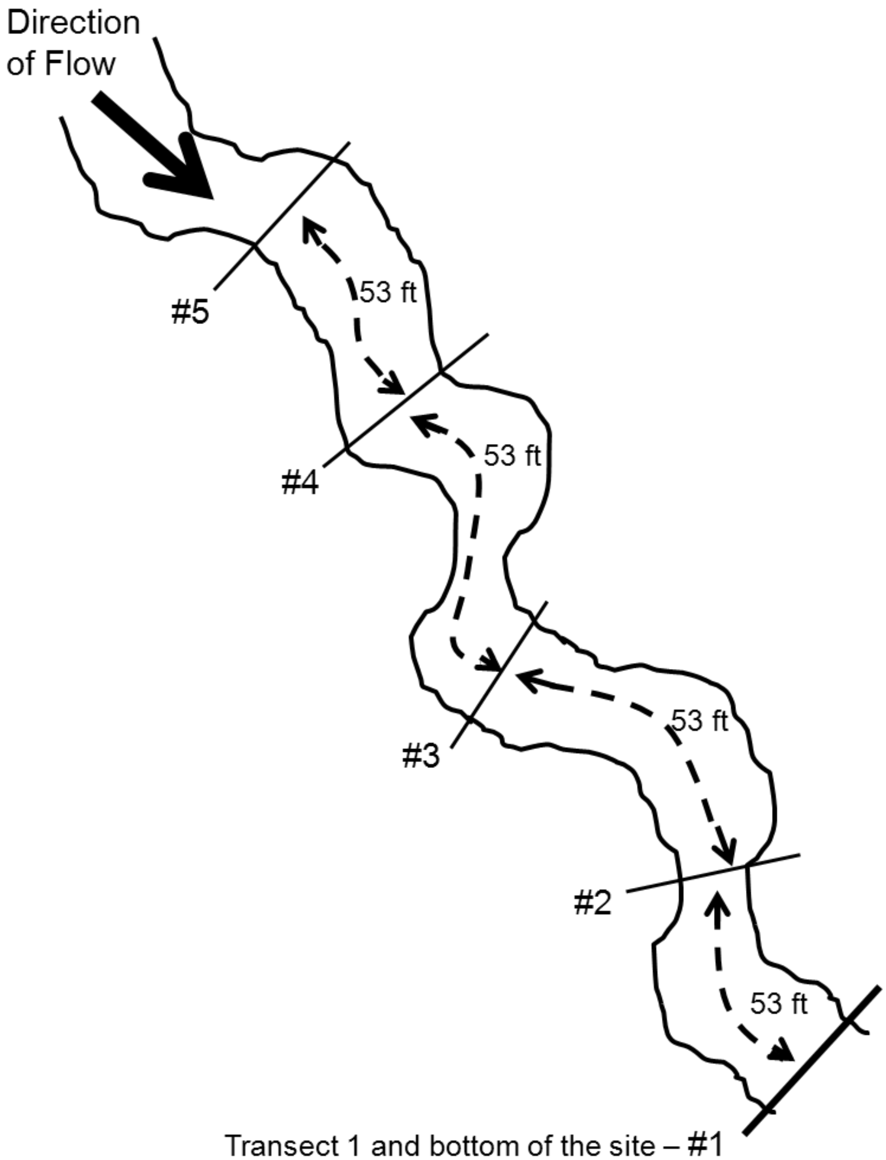


Figure B-2. Initial bankfull width measurement locations for determining width category (adapted from Heitke et al., (2008))

III. Calculate the average bankfull width for the five measurements:

Record this value on the "Assessment Site Location and Map" form. Use the mean bankfull width to determine the width category in **Table B-1**.

Table B-1. Width categories for determining minimum site length (adapted from Heitke et al., (2008)).

Average bankfull width (ft)	Width Category	Minimum site length (ft)
0 to 26	26	520
26.1 to 33	33	660
33.1 to 39	39	780

39.1 to 46	46	920
46.1 to 53	53	1060
53.1 to 59	59	1180
59.1 to 66	66	1320
66.1 to 72	72	1440
>72	79*	1580

* If a stream's average bankfull width is greater than 79 ft, the minimum site length will be 20 times the measured value.

IV. Delineate the site

Use a measuring tape or chain man to follow one side of the stream along the bankfull width and measure the site length from the downstream extent. You will continue upstream until you have reached the minimum site length determined by the bankfull width **Table B-1** and you have reached the same feature type as you started the site at (i.e., pool tail). As you travel upstream follow the main channel and identify pools, riffles, and pool-forming woody debris, flag instability index (ISI) transects (if collecting ISI data), and map the site.

NOTES: <u>If the site has no pools</u>, end at the location of the minimum site length distance from the starting point. <u>If more than one channel exists</u>, the one containing the higher discharge (visual estimate) should be followed and measured.

1) Identify pools that have a maximum depth ≥ 1.5 times the pool tail depth along the pool's thalweg. Measure the maximum pool tail depth and maximum pool depth to ensure that the depth requirement is met. If a pool, visually approximated, occupies at least 50% of the wetted channel width at any location in the pool it will be called a large pool. If it never spans more than 50% of the wetted channel width at any point, it is a small pool. This information may be recorded on the "Residual Pool Depth and Pool Tail Fines" form now or when performing **Step 4/I**.

   Also identify riffles. **Figure B-1** shows a longitudinal profile of a pool and a riffle and the different portions of each. Look upstream at the water surface for slope breaks to help identify features (the water surface will look sloped in riffles, but flat in pools).

   NOTES: Only consider main channel pools where the thalweg runs through the pool, and not backwater pools. <u>When islands are present</u>, only consider pools in the main channel; don't measure pools in side channels. If a stream length has a small pool (i.e., < 50% of wetted width), but is otherwise riffle, that section will be considered "pool."

2) If you are collecting ISI data, you will flag transects as you proceed upstream. Each transect will be spaced a distance equal to two times the width category. If the stream is greater than 79 feet average bankfull width, each transect will be spaced a distance equal to twice the measured bankfull width. Once 10 transects have been flagged, you do not need to add any more.

NOTE: If a transect lands on a location that is not suitable for a cross section measurement (e.g., debris jam, bedrock slide), move the transect upstream to the first location where a cross section can be measured.

3) Draw a map on the "Assessment Site Location and Map" form as you move upstream, referencing the most downstream location of pools and riffles (with reference to the distance from the downstream extent of the site; **Figure B-3**).

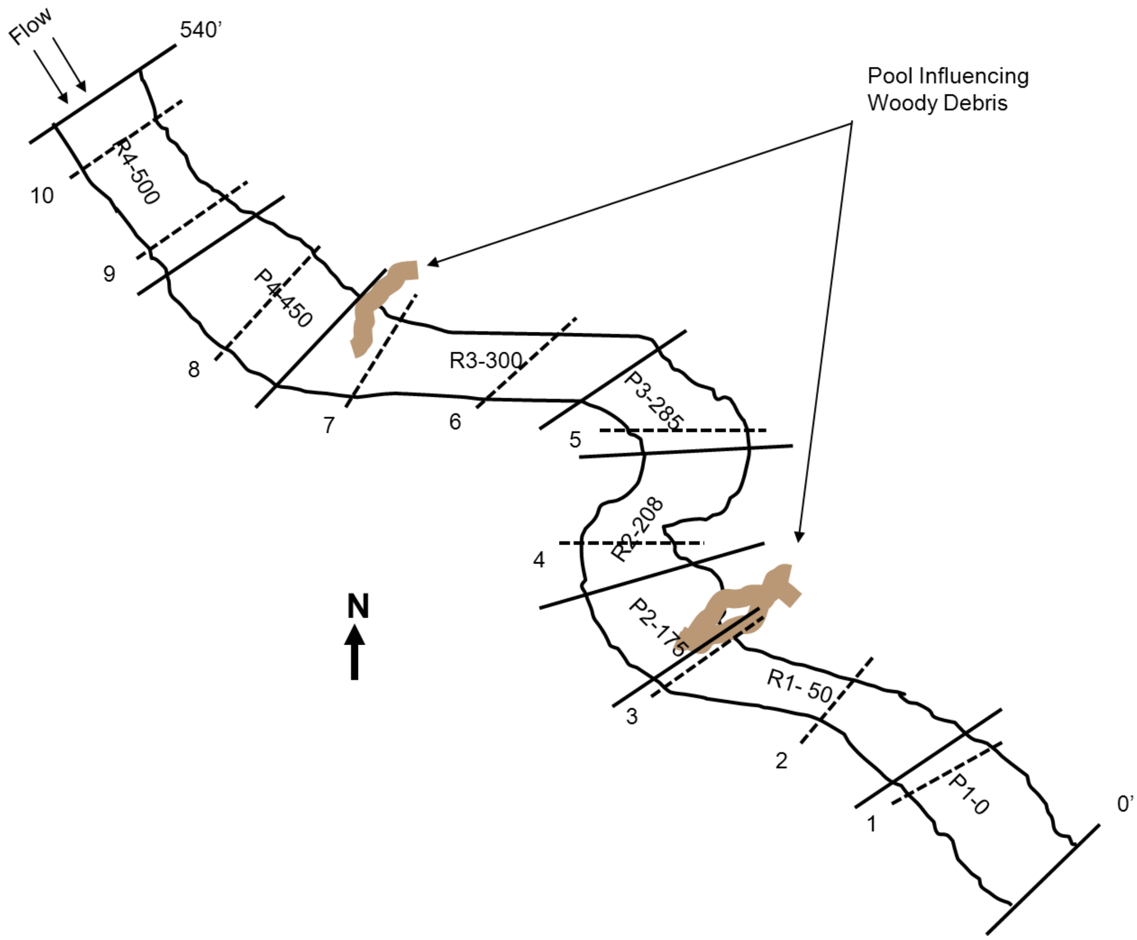


Figure B-3. Example of a sediment site map drawn at the sampling site.

VI. Finish delineating the site:

1) Use flagging to mark the location.

2) Record the actual site length and GPS coordinates on the "Assessment Site Location, and Map" form.

3) Take a photograph of the area making sure to include landmarks (write this information as well as a brief description of the area on the photo form).

4) Complete the map by labeling each pool and riffle with a number and a distance from the downstream extent of the site, starting at the bottom of the site (e.g., P1-0 and R1-40),

increasing the number in the upstream direction (**Figure B-3**). Put the corresponding information in the "Riffle and Pool Count Form." For each pool counted, mark (Yes/No) if the pool is formed, in any way, by woody debris and/or boulders. Also mark which features will be sampled with a pebble count, grid toss, and/or for residual pool depth (this can be done as you move back upstream and individually assess the suitability of each feature for a given measurement). Mark the location of the 10 ISI transects on the map and label them with a number (**Figure B-3**; the lowermost transect will be 1 and the uppermost 10). The even-numbered transects will be used for cross section measurement.

Step 2 – Check map accuracy
Working in a downstream direction (from the top of the site), make sure that all pools, riffles, pool-forming woody debris, and ISI transects are accurately represented in the map.

Step 3 – Set up EMAP reach and collect biological samples – if sampling within the site
This will be done if required by the sampling and analysis plan. The preferred option is for this to be collected in a reach directly upstream of the sediment sampling site after all of the sediment parameters have been collected. If access, stream width, or topography (e.g., a change in stream type) precludes sampling upstream of the sediment site it will be done within the site as **Step 3**.

I. Return to the center of the sediment site and record five wetted widths using the measuring tape. Measure the first one at the center of the site, two upstream of the center, and two downstream of the center. Take the measurements from places considered to be the *typical wetted width* of the stream. Average the measurements and multiply by 40. If the final value is less than 150 m, use 150 m as the minimum reach length. Divide the total reach length by 10 to determine the distance between each transect.

II. Place flagging at the center transect (at the center of the sampling site). Label the flagging at this transect "F." Proceed upstream along the shore of the stream and flag each transect at intervals 1/10 of the reach length (labeled "G" through "K"; **Figure B-4**). Then, proceed downstream, and repeat the process for the downstream portion of the EMAP reach (labeled "E" through "A"). Return to the downstream end of the EMAP reach and begin biological sampling.

Note: When the EMAP reach extends beyond the sediment reach, you will take photos of both ends of the EMAP reach facing inwards (i.e., upstream at Transect A, and downstream at Transect K) to show that the EMAP reach is still representative of the sediment site. If the ends of the EMAP reach do not represent the setting of the sediment site you will shift the EMAP reach either up or downstream until they are relatively the same.

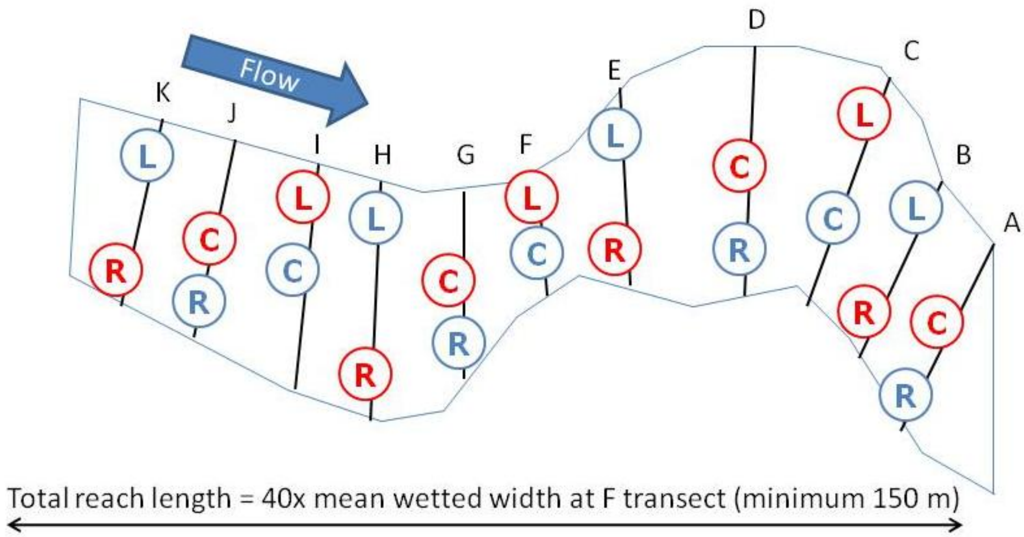


Figure B-4. An example of the EMAP sampling reach for biological samples.
The blue and red circles indicate the respective macroinvertebrate and periphyton sampling locations at each transect.

III. You will collect macroinvertebrates in the EMAP reach following the "right," "center," "left" pattern. So, at Transect A, you will collect the periphyton from the right locale of the channel. Afterward, you will collect the next portion of the sample from the center locale at Transect B. You will then collect the next sample portion from the left locale at Transect C. The blue circles on **Figure B-4** demonstrate where the macroinvertebrate samples should be collected throughout the EMAP reach.

Macroinvertebrate samples will be collected using a 500 µg mesh D-shaped net (Montana Department of Environmental Quality, 2012). To collect the sample, place the net at the established locale along each transect (right, center, or left) with the flat portion of the net frame firmly against the substrate. Manually pick up and clean all large particles (greater than golf ball size) at least halfway within a visually estimated 1 ft^2 area directly upstream of the net mouth so that everything cleaned off of the particles flows into the net. After the particles are cleaned, discard them downstream of the net. All large particles that are not at least halfway within the 1ft^2 area will be moved to the side. After all of the large particles are cleaned, use your feet to stir up the stream bottom within the same 1ft^2 area for 30 seconds (use a stopwatch). Once the kick is finished, remove the net from the water.

Next, dip the net into the water several times so that fine sediments, detritus, and organisms concentrate at the end of the net. Be sure to avoid allowing any water or material to enter the mouth of the net during this process. Invert the net into a 500 µg sieve and pick any organisms off of the net using forceps and place into the sieve. Place all material from the sieve (clean substrate particles, bark, and leaves can be removed from the sample) into a labeled 1 L bottle and fill with 95% ethanol. Once a bottle is 50% filled with material, the remaining sample will be placed into (an) additional bottle(s) and topped off with ethanol.

Optional: You can elutriate the sample in a 5 gallon bucket to reduce the amount of sediment in the final sample. You do this by emptying the contents of the D-frame net into the bucket and adding enough water to the bucket to float organic material away from the inorganic material. Vigorously stir the contents and then pour the liquid into a sieve. You can then transfer the sieve contents to the sample jar. After you are certain that you have removed 90 – 95% of the organic portion from the sample, you may discard the remaining substrate to the stream and preserve the sample in ETOH.

IV. Periphyton will be collected with the EMAP reachwide approach using the PERI-1mod method (Montana Department of Environmental Quality, 2012). It is a single composite sample that is a miniature replica of the stand of algae which are present at the study site. You will collect both micro- and macroalgae using this protocol. You will collect the periphyton in the EMAP reach following the same "center," "left," "right" pattern used to collect the macroinvertebrates except that it will be offset so that the sample location on the transect is not sampled. The red circles on **Figure B-4** demonstrate where the periphyton samples should be collected throughout the EMAP reach.

Starting from the most downstream transect, at each of the 11 transect sampling locales algal material should be collected from substrate representative of the right, left, or center locale. Collection tools should include a toothbrush or test-tube brush, a small pocket knife, a turkey baster (used to suck up fine sediments), a small stainless steel spoon, and a plastic tray to place the material in prior to transfer to the storage container. The standard storage container, a 50 cm^3 centrifuge tube, is fairly small and will fill quickly; do not over-add any particular batch of sampled material. To aide in this, larger volumes of material collected in the plastic tray can be sub-sampled and the subsample transferred to the centrifuge tube. Be sure to thoroughly mix the material prior to sub-sampling.

As the collector works his/her way upstream, it should be noted whether or not any substrate type that is common along the site has been precluded from sampling due to the manner in which the 11 transects happen to have fallen along the longitudinal length. <u>If an important substrate type has been precluded the sampler should, after completing the uppermost transect, return to the substrate in question and collect algae in an amount approximately proportional to the substrate's presence in the reach.</u>

Step 4 – Collect Pool Tail Grid Toss, Riffle Pebble Count, RSI, W/D, and Flood-prone Width Measurements

Working in the upstream direction, perform the appropriate sampling depending on the feature encountered.

I. If a pool is encountered, perform a grid toss and measure residual pool depth:

For a grid toss to take place the pool must: 1) be formed by the scouring action of water (not formed by logs or some other debris completely damming the downstream end of the pool; partial damming of the pool is acceptable as long as a scour-formed pool tail is present), and meet the depth criteria previously described. Every pool suitable for measuring pool-tail fines within a site will be measured. Every pool within a site will be measured for residual pool depth (RPD).

<u>Pool Tail Grid Toss</u>

1) Sampling within the wetted channel, place the bottom edge of the grid upstream from the pool tail crest a distance equal to 10% of the pool's length or one meter, whichever is less (**Figure B-5**).

2) Moving from river left to river right, place the center of the grid at three locations equal to 25, 50, and 75% of the distance across the wetted channel, making sure the grid is parallel to and following the shape of the pool tail crest. Grid placements are estimated visually.

3) For each of the 49 internal intersections on the grid, count the number of intersections that are overlain with fine sediment < 6 mm in diameter at the b-axis (each intersection is approximately 6 mm). Mark this number on the "Residual Pool Depth and Pool Tail Fines" field form.

4) For each placement, estimate the median (i.e., D_{50}) substrate size class of the substrate under the grid. Mark this estimate in the appropriate box as: s = sand (< 2 mm), g = gravel (2 mm - 64 mm), c = cobble (64 mm - 256 mm), b = boulder (256 mm - 2048 mm), and bd = bedrock (> 2048 mm).

5) On the field form, record the number of particles < 6 mm out of the number assessed (e.g., 8/40). If, in small streams, the grid tosses overlap, note in the "Comments" section of the field form to indicate that overlap occurred.

   NOTES: If a portion of the grid lands on a particle that is a small boulder or larger (> 512 mm b-axis), do not assess the intersections that fall on such substrate. If algae or organic debris on the streambed blocks visual identification of the particles underneath, do not move the obstruction(s). Record the number of intersections covering particles < 6 mm out of those that are not obstructed and can be assessed on the field form.

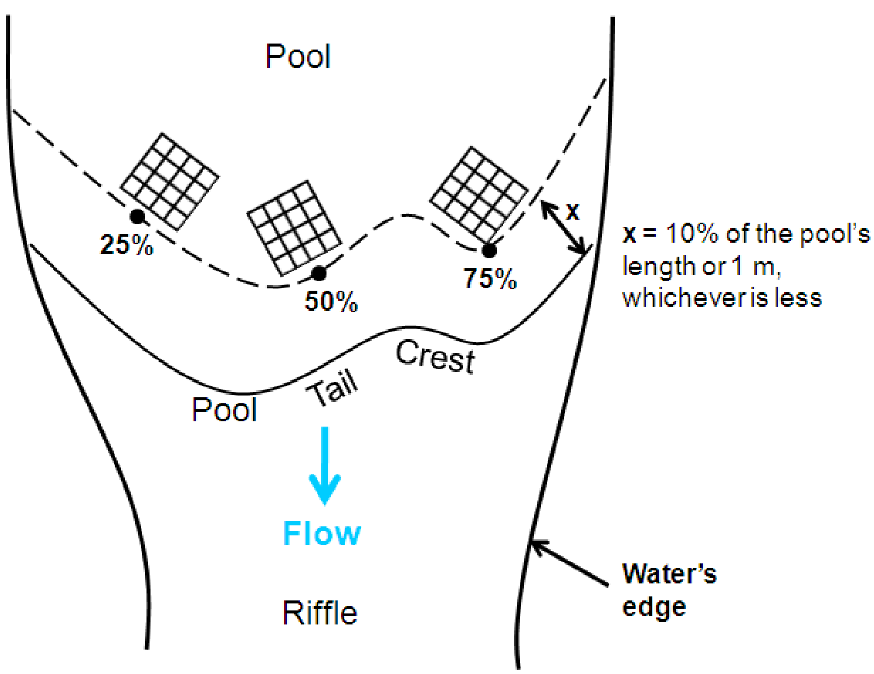


Figure B-5. Locations within a pool tail to be sampled with the grid toss (figure is adapted from Archer et al. (2012)).

Residual Pool Depth

6) Measure the maximum depth of the pool tail at the crest, normally but not always the thalweg (d_{rc}) (**Figure B-6**) and record this to the nearest 0.05 ft on the “Residual Pool Depth and Pool Tail Fines” field form. To find this point, imagine that the water in the stream is ‘turned off’. You want to measure the depth of the last spot that would have flowing water before the stream stopped flowing.

7) Measure the maximum depth in the pool along the thalweg (d_p) (**Figure B-6**) and record this to the nearest 0.05 ft on the “Residual Pool Depth and Pool Tail Fines” field form. Locate it by probing the pool with the measuring rod.

8) The RPD (d_r) = d_p - d_{rc}. <u>Calculate and record RPD</u> on the “Residual Pool Depth and Pool Tail Fines” field form.

9) If a pool, visually approximated, occupies at least 50% of the wetted channel width at any location in the pool it will be called a large pool. If it never spans more than 50% of the wetted channel width at any point, it is a small pool. <u>Record the pool size</u> on the “Residual Pool Depth and Pool Tail Fines” field form.

NOTES: <u>If the pool is too deep to wade</u>, measure the depth of the pool from the side, where it is wadeable and calculate the depth using **Figure B-7** and the equations that follow. Calculate the actual depth in the “Comments” section of the “Residual Pool Depth and Pool Tail Fines” form.

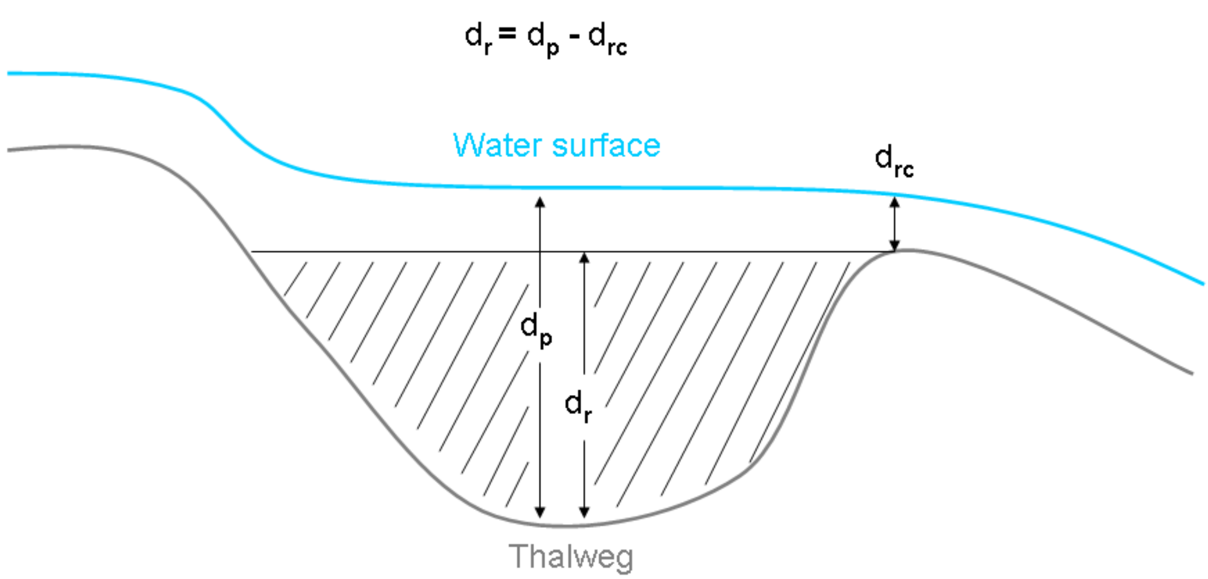


Figure B-6. Profile of a pool and locations to measure when determining residual pool depth (adapted from Lisle 1987).

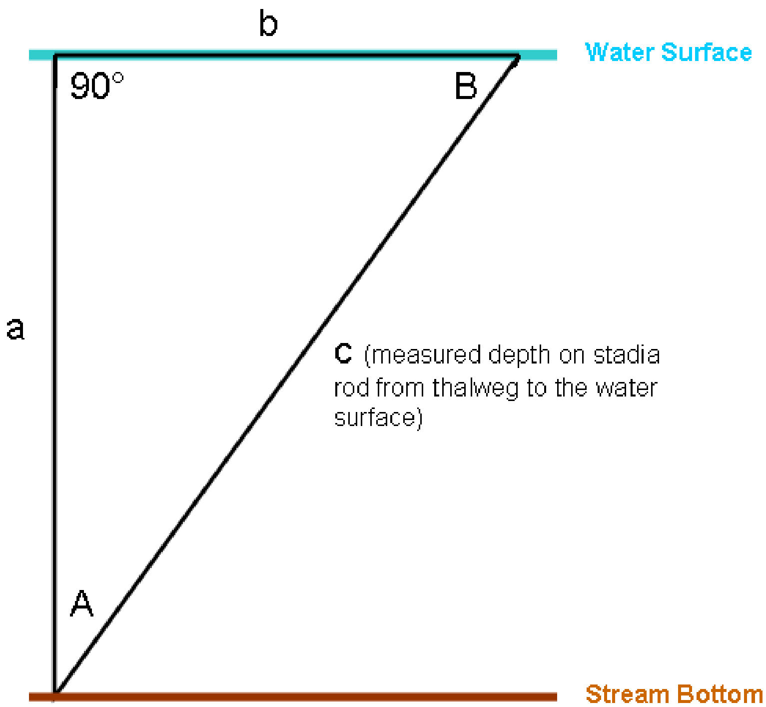


Figure B-7. Trigonometric values used to determine depth of a pool if the pool is too deep to wade.

Step 1: Estimate angle **B** using a large compass or clinometer (water surface relative to stadia rod measurement)
Step 2: Determine angle **A** as: **A** = 180 – [90 + **B**]
Step 3: **b** (actual depth of pool) = **c** cos **A**

II. If a riffle is encountered, perform the riffle pebble count, RSI data collection, W/D, and flood-prone width measurements:

<u>Riffle Pebble Count</u>

1) Sample four riffles, each with a 100 pebble count. If more than four riffles are present, sample the first four riffles encountered moving from downstream to upstream. If fewer than four riffles are present, a total of 400 particles will still be counted. The count will be spread out evenly among the riffles that are present using the same four-transect setup (e.g., if two riffles are present, each will have a 200 particle count with each sampling location being a maximum of 1/50 of the bankfull width apart). If the entire site is one riffle, 25 pebbles will be measured at 16 transects evenly distributed throughout the site. If there are fewer than four riffles, W/D will be measured at those present. If the entire site is one riffle, W/D will be measured at four evenly spaced transects within the site.

2) Measure the length of the riffle. Within each riffle, evenly distribute four transects (from downstream to upstream) and perpendicular to the flow at 20, 40, 60, and 80% of the riffle

length. Calculate the distance between each transect by dividing the length of the riffle by five. Riffle length is calculated by subtracting the riffle name distance from the next upstream pool distance (e.g., R4-170 and P4-378: 378' – 170' = 208'; R4 = 208').

3) Determine the distance between each selected particle. Along each transect, 25 sampling locations (assuming a 100 pebble count; it would be at 34 locations for a 134 pebble count in each of three riffles) will be evenly spaced within the bankfull width so that the maximum distance between each is 1/25 of the bankfull width (use a calculator to divide the bankfull width by the number of particles being selected and round the value down to ensure that the desired number of particles are sampled; **Figure B-8**). The person selecting each particle will look at the calculated distance on a tape measure before sampling the transect so that they can estimate the appropriate distance between each particle. You may use your foot as a guide to measure the distance between each particle. Make sure you collect **at least 25 particles per transect**; more is good but if you collect fewer you will have to start over.

4) Sample the riffle, by starting at the downstream transect and sampling from river left to river right, then proceed to the next upstream transect and sample from river left to river right, and repeat this pattern while moving upstream to the final two transects (**Figure B-8**). Begin sampling at the bankfull height at each transect. Walk along the transect selecting each pebble by pointing directly down off the tip of your boot at each sampling location. If there are obstructions to the pebble such as algae/vegetative mats or woody debris, attempt to carefully move the obstruction covering the substrate so that the pebble can be sampled. If algae/vegetation cannot be moved, select a pebble on the upstream side of the transect where there is no obstruction.

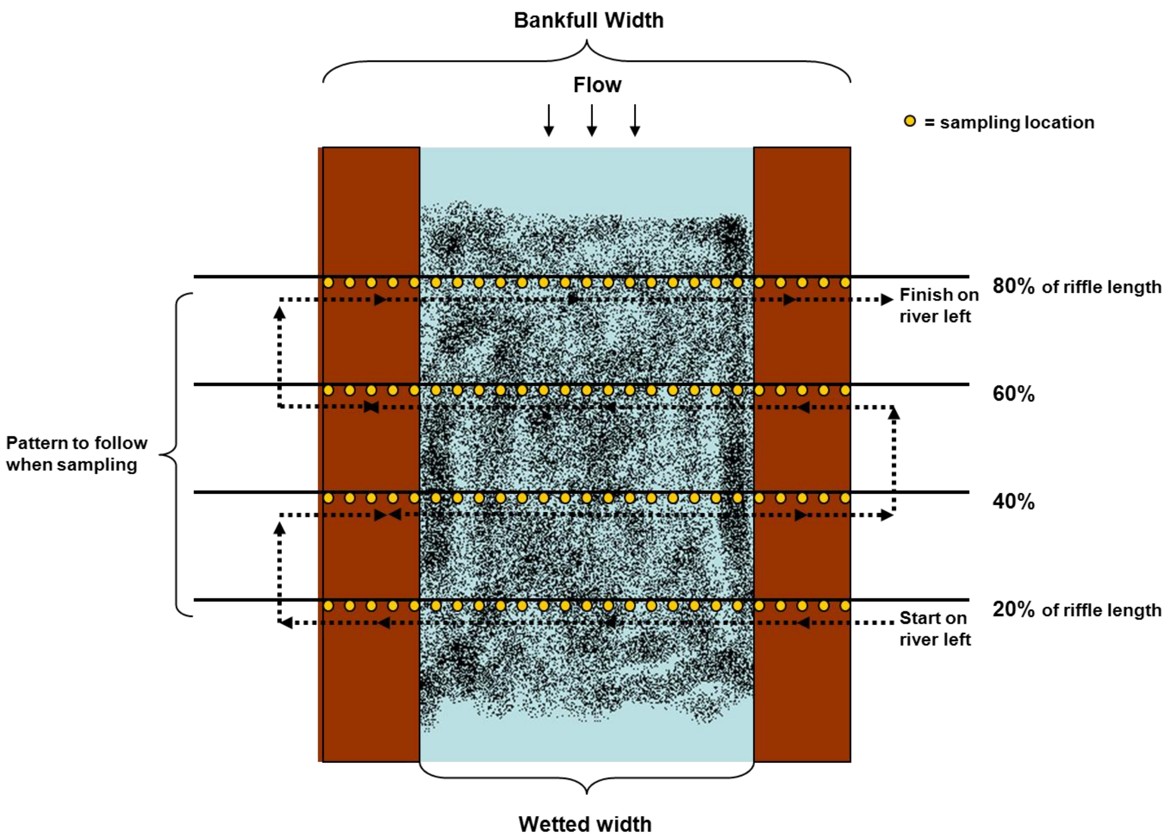
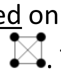


Figure B-8. Setup for performing a riffle pebble count.

5) Measure each particle by finding the smallest hole in the gravelometer that the particle will fit through (if the particle fits through the 22.6 mm opening but not the 16 mm opening, the particle will be recorded within the "16.1-22.6 mm" size box). For particles less than 4 mm, use the edge (width) of the gravelometer to measure the particle's intermediate axis (**Figure B-9**) to determine if the particle is within the 2.1 – 4 mm or < 2 mm size category. Particles greater than 128.1 mm will be measured along the edge of the gravelometer. Particles greater than 2056 mm are considered bedrock and will be visually estimated. If present, the 6.35 hole **will not** be used to measure particles. After measuring a particle, place it downstream of the transect so that it is not measured again. If the particle cannot be moved from the stream bottom, estimate its size. If the particle cannot be moved from the stream bottom and your finger falls on it multiple times, record each time as an individual count. Particle size data will be recorded on the "Riffle Pebble Count" form using the "dot/slash" system where 10 particles = . The four dots should be filled in first, followed by the outside lines of the box, and, finally, the diagonal lines.

6) Record each particle on the form in the appropriate location: under "Wet" if collected within the wetted channel, and under "Dry" if collected between the water's edge and bankfull. Record the particle size in the categories provided, as appropriate.

7) To describe riffle units, record whether the transect is primarily within run or riffle habitat on the "Riffle Pebble Count." Below are descriptions of riffles, runs, and pools (adapted from

Vermont Agency of Natural Resources (2009)) to help make this qualification. **Figure B-9** is provided to show how the cross section profile of each habitat type typically looks.

Riffles: Riffles typically are marked by fast, turbulent water running over rocks. Riffles represent the sections of the stream with the steepest slopes and shallowest depths at flows below bankfull. Riffles may have a poorly defined thalweg.

Runs: Runs are characterized by moderate current and little or no turbulence on the surface. They differ from riffles in that depth of flow is typically greater and slope of the bed is less than that of riffles. Runs will also often have a more defined thalweg.

Pools: Pools are the deepest locations of the reach and hold slow moving water. Water surface slope of pools at below bankfull flows is near zero. Pools are often located at the outside of meander bends, or on the downstream end of large obstructions such as rocks or large wood.

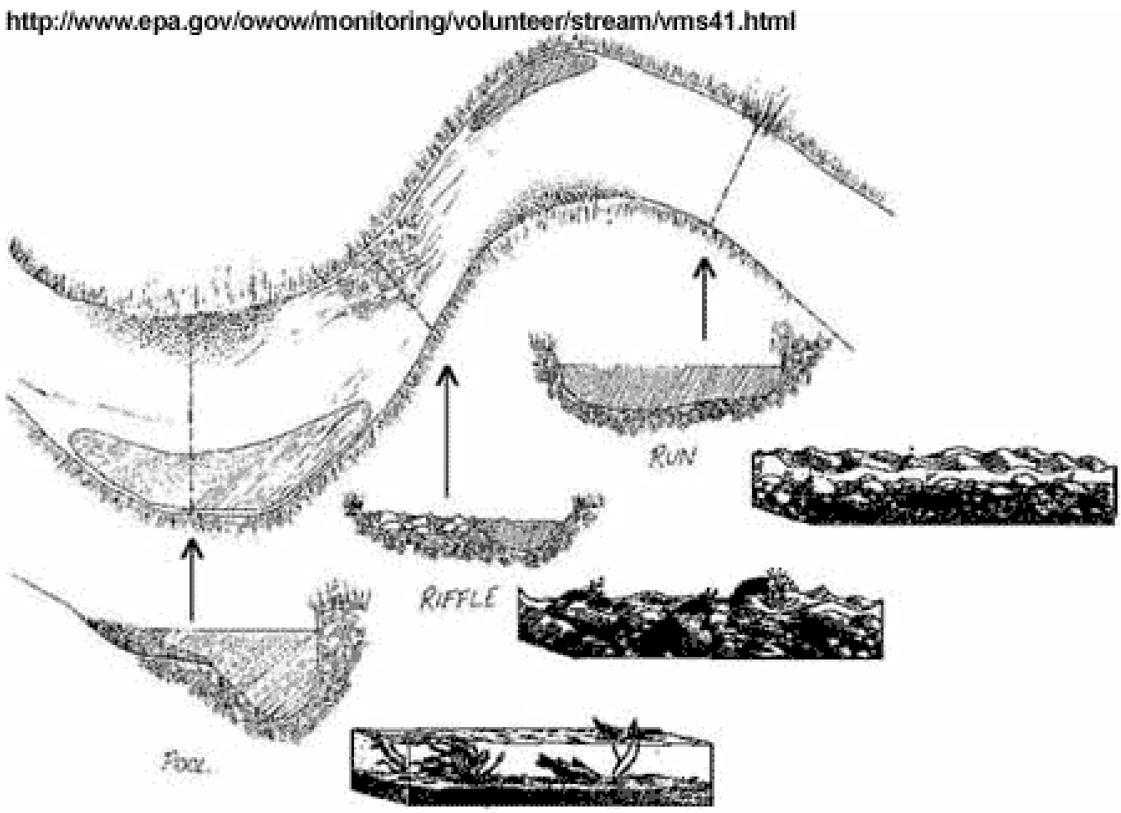


Figure B-9. Cross section profile and aerial view of typical riffles, runs, and pools.

__**Collect additional data for RSI**__

8) Identify the lateral bar or depositional feature directly downstream of the riffle sampled for the pebble count.

9) Identify the dominant large particles present and select 15 of those that have been freshly moved. Freshly moved particles are those that are brighter in color, not embedded, and lack staining, algae, or attached moss.

10) Measure the intermediate (B-axis; **Figure B-10**) of each particle with a ruler. The B-axis is the width of a particle. It can be visualized as the smallest width of a hole that the particle could pass through.

11) Record these values on the “DEQ Sediment Assessment Pebble Count” form.

NOTE: If there is no lateral bar or depositional feature directly downstream of the riffle sampled for the pebble count, do not collect this data. If at least 10 freshly moved particles are not present, do not collect the RSI data. If you do not collect the RSI data, record why it was not collected in the “Comments” section on the “DEQ Sediment Assessment Pebble Count” form.

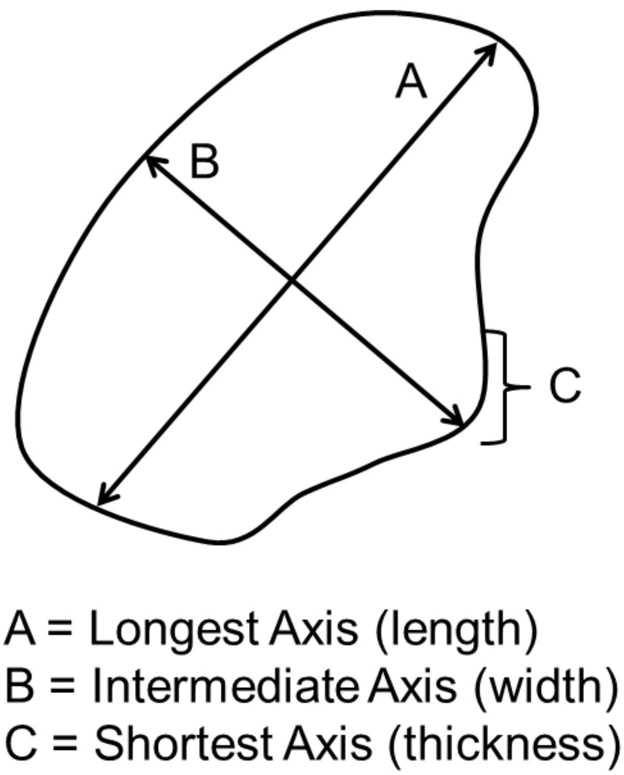


Figure B-10. The three axes of a pebble (adapted from Archer et al., 2012).

Measure the riffle W/D ratio

11) Find the most suitable location within each riffle sampled for a pebble count. When doing this try to avoid undercut banks, islands, boulders, bars, brushy banks, logs and log jams, and uneven water surface.

12) Once the location has been determined, set up a cross section using a tape measure and pins. Determine the bankfull elevation on each bank. Stretch the tape perpendicular to the channel between bankfull elevations with the “zero” end of the tape on the river left bank (RL) looking downstream. Make sure the tape is straight and not bowed. If the tape sags due to stream size or wind, use a laser level.

13) Measure the width of the stream at the cross section and moving from river left to river right, measure at least 10 depth measurements (from the channel bottom to the tape measure) across the cross section at equidistant intervals using a measuring stick (**Figure B-11**). To calculate the distance between each measurement, divide the bankfull width at the transect by 11 and round down. Bankfull depths (on either side of the transect) will typically be "0" on the "Riffle W/D Ratio" form unless the bank is vertical at the bankfull location. When this occurs, measure the depth at this location and record it on the form.

14) <u>Record the cross section width and depth</u> information on the "Riffle W/D Ratio" form.

<u>Flood-prone Width</u>

15) Measure the deepest point on the cross section (at the thalweg). Multiply this value by 2. This is the flood-prone elevation (i.e., Flood-prone elevation = 2 * maximum depth).

16) Starting at the left streambank, place the measuring rod on top of the tape ("line level") at the bankfull channel margin so that "zero" on the rod is at the bankfull elevation.

17) Identify the height of the previously measured maximum bankfull depth on the measuring rod. This is the height of the flood-prone elevation.

18) Place the clinometer at the height of the flood-prone elevation on the measuring rod and look "through" the clinometer towards the floodplain.

19) Level the clinometer using the "zero" percent slope reading.

20) The person with the clinometer will hold one end of a 300' tape measure while the second member of the crew measures the flood-prone width on the left side of the stream.

21) The crew member with the clinometer will guide the crew member with the tape to the point where the "zero" percent slope reading on the clinometer meets the ground elevation. This is the edge of the flood-prone area and corresponds with the flood-prone elevation at "2 x maximum depth."

22) Measure the flood-prone distance out as far as possible, or to 200 feet, whichever is encountered first.

23) <u>Record this distance</u> on "Riffle W/D Ratio" form. If the floodplain distance is >200 feet, record "> 200 ft" on the field form.

24) Repeat this process for the right side of the channel.

NOTE: <u>If three people are present</u>, the one at the max depth can hold the tape at the flood prone height while the other two string a 300' tape out to the edges of the flood-prone area. The person in the middle will use a clinometer to guide the two crew members and ensure that the tape is level.

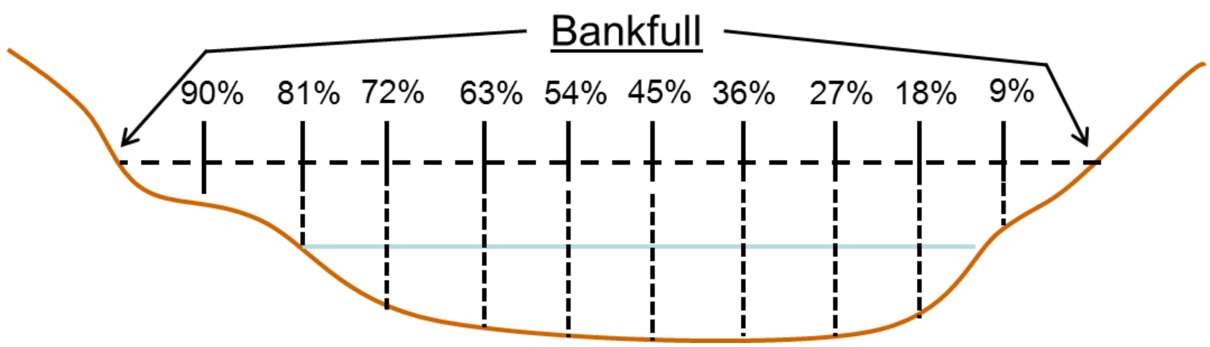


Figure B-11. Location across transect for taking cross section depth measurements (adapted from Archer et al., 2012).

Step 5 – Collect site cross section, sitewide pebble count, slope, and sinuosity measurements
These measurements will be collected as directed by the SAP so that ISI can be calculated. They will be collected using the twenty transects flagged in **Step 1**. These measurements can be made by moving in the downstream direction after completing **Step 4**.

I. **Determine the exact location of each transect:**

Find the most appropriate location to place each transect. It must be within a distance equal to ½ the width category (either upstream or downstream of the flag). When looking for this location, try to avoid undercut banks, islands, boulders, bars, brushy banks, logs and log jams, and uneven water surface. If you cannot find a suitable cross section within ½ the width category, do your best and locate the transect where it avoids the most of the variables listed above. All transects will be perpendicular to the channel.

II. **Sitewide Cross Sections:**

At each of the transects collect cross section measurements in addition to collecting the sitewide pebble count.

1) Determine the bankfull elevation on each bank. Stretch the tape perpendicular to the channel between bankfull elevations with the “zero” end of the tape on the river left bank (RL) looking downstream. Make sure the tape is straight and not bowed.

2) Measure the width of the stream at the cross section and take at least 10 depth measurements (from the channel bottom to the tape measure) across the cross section at equidistant intervals using a measuring stick (**Figure B-11**). To calculate the distance between each measurement, divide the bankfull width at the transect by 11 and round down. Bankfull depths (on either side of the transect) will typically be “0” on the “Sitewide Cross Section and Slope” form unless the bank is vertical at the bankfull location. When this occurs, measure the depth at this location and record it on the form.

2) Record the cross section width and depth information on the “Cross Section and Slope” form. Be sure to sample all 10 transects.

III. Sitewide Pebble Count:

You will measure **at least 10 particles** from each of the 10 transects.

1) One particle will be taken from each of the locations where the bankfull depth was measured (**Figure B-11**). Sample each particle by pointing a finger straight down at the depth measurement location. Measure the first particle that your finger touches. Measure the B-axis of each particle using a ruler (**Figure B-9**).

2) Record the measurement of each particle on the "Sitewide Pebble Count" form. Be sure to sample all 10 transects collecting at least 10 particle measurements at each.

IV. Slope:

Slope will ideally be measured from the top of the sampling site to the bottom (i.e., from the pool tail crest at the top of the site to the pool tail crest at the bottom of the site). If there is not a clear path between these two points, then slope will be measured between transects where there is visibility. Sinuosity (**Step 5/V**) should be measured at the same time as slope.

1) One person will stand at the downstream transect holding a measuring pole vertically with flagging attached at a particular height with the bottom of the pole at the water's edge (**Figure B-12**). A second person will stand at the upstream transect with a measuring pole held vertically on the same side of the stream with the bottom at the water's edge (alternatively each person can place their measuring poles at the same depth in the water).

2) The person at the upstream transect will have a clinometer. They will place it at the same height as the flagging on the downstream pole and aim it at the flagging. The clinometer records both percent slope and degrees of the slope angle. Be sure to record the percent slope which is typically the scale on the right-hand side of most clinometers.

3) Record the slope information on the "Sitewide Cross Section and Slope" form. Repeat this process so that the entire site is surveyed for slope. If skipping transects (e.g., measuring from TR4 to TR1), draw an arrow starting in the "TR4 to TR3" box and extending to the "TR2 to TR1" box and record the slope in the "TR2 to TR1" box. The slope weighted average will be calculated in the office and does not need to me done in the field.

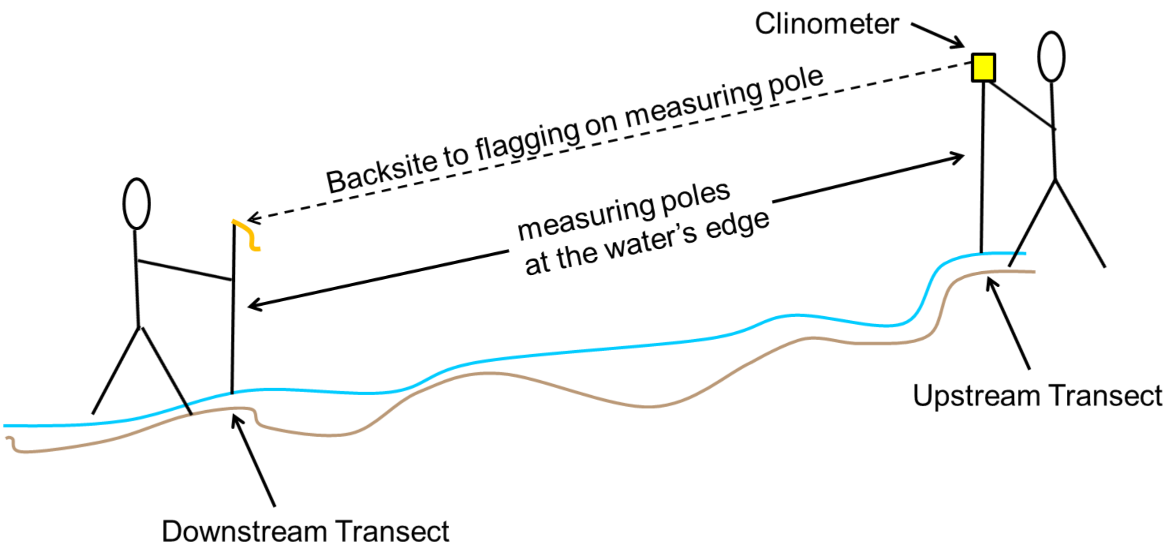


Figure B-12. Measuring angle between transects.

V. Sinuosity:

Sinuosity will be calculated in the office using GIS. Sinuosity may be calculated using aerial photos if they are of high enough resolution and the active stream channel can be viewed. If sinuosity cannot be measured from aerial photos, the coordinates from each end of the site and the site length (all found on the "Assessment Site Location and Map" form) can be used to calculate sinuosity.

Step 6 – Rosgen Channel Type measurement

Rosgen channel type is determined by measuring a cross section and collecting the following data:

- Entrenchment – ratio of the flood-prone width divided by bankfull channel width
- W/D Ratio – bankfull width divided by bankfull mean depth
- Channel Slope – for a site approximately 20-30 bankfull channel widths
- Sinuosity – stream length divided by valley length; or estimated from the ratio of valley slope divided by channel slope

The "Rosgen Stream Classification" form will be completed at the office using the field forms.

Step 7 – Set up EMAP reach and collect biological samples – if sampling upstream of site

This will be done if required by the sampling and analysis plan. The preferred option is for this to be collected in a reach directly upstream of the sediment sampling site after all of the sediment parameters have been collected (i.e., as **Step 7**). If access, stream width, or topography (e.g., a change in stream type) precludes sampling upstream of the sediment site it will be done within the site as **Step 3**. See **Step 3** for specific biological data collection instructions.

Step 8 – Site Roundup

Ensure that all of the necessary information has been collected. Review the sampling and analysis plan and confirm that all of the correct data has been collected. Review all of the field forms checking for typos and empty fields. Make sure that all of the necessary fields are filled in appropriately. If you missed something, go back and do it.

Appendix C. Field Forms

The following pages are the field forms to be used when collecting the primary metrics of the sediment assessment protocol. Field forms for secondary metrics (with the exception of ISI) have not been developed at this time.

Assessment Site Location and Map Form

Site Name:_____________________________ Date:________________ Site Visit Code:____________

Site ID:____________________________ Personnel:____

Stream/River Site Determination

Latitude (NAD 83)	Longitude (NAD 83)	Bankfull Measurements (ft)	Mean Bkf Width (ft)	Category Length (ft)	Site Length (ft)
At Downstream end of Site					
At Upstream End of Site					

Comments:

Riffle and Pool Count Form

Date: **Site Visit Code:**

Waterbody:

Personnel:

Record each structure starting at the downstream extent of the site and moving upstream, circling the appropriate option under each heading. Label structures as in **"Name"** as "R1-2.7" for the first riffle located 2.7ft from the bottom extent of the site, "P1-10.2" for the first pool located 10.2 ft from the bottom extent of the site, "R2-15.6" for the second riffle, etc. **"Wood influenced"** and **"Boulder Influenced"** pertains to pools only and could be damming the stream to form the pool or simply causing scour. The **"Pebble Ct"** will only take place in riffles, the **"Grid Toss"** in scour or plunge pools, and **"Residual Pool Depth"** in all pools.

Structure		Name	Wood Influenced		Boulder Influenced		Pebble Ct		Grid Toss		Residual Pool Depth	
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Pool	Riffle		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No

Comments:

Riffle Pebble Count Form - for ONE Riffle

Date: **Site Visit Code:**

Waterbody:

Personnel:

Record transect width and sample spacing, and circle if the transect is predominantly in a riffle or a run. Use the "dot/slash" system to record particles on this form. Four dots should be filled in first to make a box, followed by the outside lines of the box, and, finally, the diagonal lines. Record each particle on the form in the appropriate location: under **"Wet"** if collected within the wetted channel, and under **"Dry"** if collected between the water's edge and bankfull. If there is no lateral bar or depositional feature directly downstream of the riffle sampled for the pebble count, OR if there aren't at least 10 freshly moved particles, do not collect the RSI data and record why it was not collected in the **"RSI"** box. All distances will be measured in 0.1 feet (ft).

RIFFLE #: R **Distance Between Transects:**

	Transect 1 w:		**Transect 2 w:**		**Transect 3 w:**		**Transect 4 w:**	
	Riffle or Run		Riffle or Run		Riffle or Run		Riffle or Run	
	Sample Spacing:		**Sample Spacing:**		**Sample Spacing:**		**Sample Spacing:**	
Size (mm)	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
< 2[1]								
4 - 2								
5.7 - 4								
8 - 5.7								
11.3 - 8								
16 - 11.3								
22.6 - 11.3								
32 - 22.6								
45 - 32								
64 - 45								
90 - 64								
128 - 90								
180 - 128[2]								
256 - 180[2]								
362 - 256[2]								
2056 - 362[2]								
>2056[3]								
Total #								

[1] As measured across the b-axis against the width of the edge of the gravelometer
[2] As measured across the b-axis along the edge of the gravelometer
[3] Estimated; particles larger than 2056 mm across the b-axis are considered bedrock

RSI: Sizes (mm) of 15 freshly moved particles in downstream lateral bar or depositional area:

Write comments on the back ---->

Riffle W/D Ratio Form

Date: **Site Visit Code:**

Waterbody:

Personnel:

This form is used to measure width to depth ratio at the riffles where pebble counts are collected. Calculate the distance between measurements by dividing the bankfull width by 11 and rounding down. In each **"Distance"** cell enter the distance from the starting point. In each **"Depth"** cell enter the depth at that point. All measurements will be made in feet (ft). Collect measurements from river left to river right. Measure depth to 0.05 ft, bankfull width to 0.1 ft, and all other distances to the nearest foot. Total flood-prone distance is from the edge of the flood prone area on river left to the edge on river right. It may be measured all at once or in two measurements from the deepest point in the channel to either side of the stream. Bankfull depths (on either side of the transect) will typically be "0" unless the bank is vertical at the bankfull location. When this occurs, measure the depth at this location and record it on the form. If a riffle W/D transect corresponds with an ISI transect, record this information in the **"Comments"** section.

RIFFLE #:R			Bankfull Width:				Distance between Measurements:					
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%
Distance (ft):	Bankfull											Bankfull
Depth (ft):												
Flood-prone height:			Flood-prone distance river left:									
			Flood-prone distance river right:						Total:			

RIFFLE #:R			Bankfull Width:				Distance between Measurements:					
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%
Distance (ft):	Bankfull											Bankfull
Depth (ft):												
Flood-prone height:			Flood-prone distance river left:									
			Flood-prone distance river right:						Total:			

RIFFLE #:R			Bankfull Width:				Distance between Measurements:					
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%
Distance (ft):	Bankfull											Bankfull
Depth (ft):												
Flood-prone height:			Flood-prone distance river left:									
			Flood-prone distance river right:						Total:			

RIFFLE #:R			Bankfull Width:				Distance between Measurements:					
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%
Distance (ft):	Bankfull											Bankfull
Depth (ft):												
Flood-prone height:			Flood-prone distance river left:									
			Flood-prone distance river right:						Total:			

Comments:

Residual Pool Depth and Pool Tail Fines

Date: ______________________

Waterbody: ______________________ **Site Visit Code:** ______________________

Personnel: ______________________

This form pertains only to pools. Write in the appropriate number for each pool name. For **"Residual Pool Depth"**: dr = residual pool depth; dp = total pool depth at the deepest point along the thalweg; drc = depth of the riffle crest at the thalweg. For **"Size"**: enter ***Large*** if the pool occupies > 50% of the wetted stream width at any location; enter ***Small*** if the pool occupies < 50% of the wetted stream width at any location. For **"Grid Results"**: Starting on river left, T1 = 25% of the wetted width, T2 = 50% of the wetted width, T3 = 75% of the wetted width, and Total = the combined values from all three counts. Values should be entered as: (# of fines < 6 mm) / (# of intersections assessed). The dominant substrate lying under each toss should be marked in **"Sub"** as: s = sand (<2 mm), g = gravel (2 mm - 64 mm), c = cobble (64 mm - 256), b = boulder (256 mm - 2048 mm), and bd = bedrock (>2048 mm). Note in the **"Comments"** section if any tosses overlapped.

Name	Residual Pool Depth			Size	Grid Results						
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /
P	d_p =	d_{rc} =	d_r =		T1: /	Sub:	T2: /	Sub:	T3: /	Sub:	Total: /

Comments:

Sitewide Pebble Count Form

Date: ____________ **Site Visit Code:** ____________

Waterbody: ____________

Personnel:

This form is used for collecting a sitewide pebble count used to calculate ISI. Calculate the distance between measurements by dividing the bankfull width by 11 and rounding down. The particles will be collected at the same locations as the depth measurments on the "Sitewide Cross Section and Slope" form. In each "Distance" cell enter the distance (ft) from the starting point. In each "B-axis" cell enter the length (mm) of the b-axis of the selected particle. You may use a riffle W/D transect as your ISI transect as long as it is within 1/2 the distance of the site width category upstream or downstream from where the ISI transect is flagged.

Transect 1	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										
Transect 2	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										
Transect 3	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										
Transect 4	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										
Transect 5	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										
Transect 6	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										
Transect 7	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										
Transect 8	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										
Transect 9	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										
Transect 10	Bankfull Width:				Distance between Measurements:					
	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%
Distance:										
B-Axis (mm):										

Comments:

Sitewide Cross Section and Slope Form

Date: ____________ **Site Visit Code:** ____________

Waterbody: ____________

Personnel:

This form is used to measure cross sections and slope to calculate ISI. Calculate the distance between measurements by dividing the bankfull width by 11 and rounding down. In each **"Distance"** cell enter the distance from the starting point. In each **"Depth"** cell enter the depth (ft) at that point. Measure slope (%) over the greatest distance possible and so that the entire site is measured. All distances are in feet (ft). Measure depth to 0.05 ft, bankfull width to 0.1 ft, and all other distances to the nearest foot. If skipping transects (e.g., measuring from TR4 to TR1), draw an arrow starting in the "TR4 to TR3" box and extending to the "TR2 to TR1" box and record the slope in the "TR2 to TR1" box. **"Slope Weighted Average"** will be calculated in the office. You may use a riffle W/D transect as your ISI transect as long as it is within 1/2 the distance of the site width category upstream or downstream from where the ISI transect is flagged.

													Slope (S)
													TR1 → bottom of site
Transect 1		Bankfull Width:				Distance between Measurements:							TR2→ TR1
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													
Transect 2		Bankfull Width:				Distance between Measurements:							TR3→TR2
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													
Transect 3		Bankfull Width:				Distance between Measurements:							TR4→TR3
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													
Transect 4		Bankfull Width:				Distance between Measurements:							TR5→TR4
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													
Transect 5		Bankfull Width:				Distance between Measurements:							TR6→TR5
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													
Transect 6		Bankfull Width:				Distance between Measurements:							TR7→TR6
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													
Transect 7		Bankfull Width:				Distance between Measurements:							TR8→TR7
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													
Transect 8		Bankfull Width:				Distance between Measurements:							TR9→TR8
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													
Transect 9		Bankfull Width:				Distance between Measurements:							TR10→TR9
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													
Transect 10		Bankfull Width:				Distance between Measurements:							TR10
	0%	9%	18%	27%	36%	45%	54%	63%	72%	81%	90%	100%	
Distance (ft):	Bkf											Bkf	
Depth (ft):													

Record Comments on back of page →

Slope Weighted Average:

ROSGEN STREAM CLASSIFICATION FORM

Date: ______________________________ **Site Visit Code:** __________

Waterbody: ______________________________ **Station ID:** __________

Personnel: ____

Bankfull Width (W_{bkf}) ______________ **ft**

WIDTH of the stream channel, at bankfull stage elevation, in a riffle section

Mean DEPTH (d_{bkf}) ______________ **ft**

Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section.

______________ **Sq. ft**

AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.

Width/Depth RATIO (W_{bkf} / d_{bkf}) ______________ **ft**

Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.

Maximum DEPTH (d_{mbkf}) ______________ **ft**

Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and thalweg elevations, in a riffle section

WIDTH of Flood-Prone Area (W_{fpa}) ______________ **ft**

Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone

Entrenchment Ratio (ER) ______________ **ft**

The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH. (W_{fpa} / W_{bkf})

Channel Materials (Particle Size Index) D50 ______________ **mm.**

The D50 particle size index represents the median diameter of channel materials, as sampled from the channel surface, between the bankfull stage and thalweg elevations.

Water Surface SLOPE (S) ______________ **ft/ft**

Channel slope = "rise" over "run" for a reach approximately 20-30 bankfull channel widths in length, with the "riffle to riffle" water surface slope representing the gradient at bankfull stage.

Channel SINUOSITY (K) ______________ **ft/ft**

Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL/VL); or estimated from a ratio of valley slope divided by channel slope (VS/S).

Stream Type:

Comments: