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Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation

Technical Reference 1737-23, Version 2

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Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation

Technical Reference 1737-23, Version 2

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Preface to Version 2

Interest in riparian area management has increased tremendously over the past 35 years. This interest has created a growing need to effectively monitor the attributes and processes that occur in these valuable systems. Monitoring the most sensitive or most responsive attributes is critical to understanding how management influences streams and riparian areas. Monitoring within stream channels and at their margins is particularly useful to the management of stream-dependent resources, including water quality and quantity, aquatic biota, and near-stream terrestrial biota (Winward 2000).

Due to the widespread use of stubble height for monitoring and managing riparian areas by the federal land management agencies, in 2003, the U.S. Department of the Interior (USDI) Bureau of Land Management (BLM) and U.S. Department of Agriculture (USDA) Forest Service commissioned the University of Idaho to evaluate how the agencies were applying stubble height. As a result, the university established a study team consisting of researchers, university professors, livestock producers, and agency technical specialists. Based on their findings, the team recommended that monitoring include both short-term, annual grazing-use indicators and long-term resource condition indicators to determine if objectives are being met. The team also recommended that data from multiple indicators (short- and long-term) needed to be statistically reliable to provide a sound basis for management decisions (University of Idaho Stubble Height Review Team 2004).

“Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation” was initially developed in 2004 in response to the Stubble Height Team’s recommendations. It was published as a BLM Idaho State Office Technical Bulletin multiple times until 2011, when the first version of the national technical reference was published (Burton et al. 2011, TR 1737-23). The MIM protocol is based on the following objectives: (1) address multiple short-term annual use and long-term condition and trend indicators, (2) measure important indicators that are most likely to detect early changes (i.e., “leading indicators”), (3) use existing methods to the extent possible, (4) improve efficiency through electronic data collection, (5) yield statistically acceptable results within realistic time constraints, and (6) provide useful data to inform management decisions. There are many different indicators and methods that can be used to monitor streams; MIM is not designed to monitor every possible stream attribute. The 10 methods in MIM were chosen to meet these 6 objectives. MIM can be supplemented with additional stream and riparian methods depending on individual monitoring needs.

With more than 13 years of experience using MIM Technical Reference TR 1737-23, the protocol has proven to be one of the most useful tools for monitoring the effectiveness of grazing and similar management actions on stream channels and streamside vegetation. The data acquisition and analysis tools have undergone many refinements through the years, yet the original objectives and basic approach to monitoring have remained unchanged over that same time. This update to the technical reference reflects and documents those many refinements.

1. Introduction

"Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation" was developed to provide information necessary for managers, landowners, and others to adaptively manage riparian resources.

The MIM protocol is designed to be objective, efficient, and effective for monitoring streambanks, stream channels, and streamside riparian vegetation. The protocol integrates short-term annual grazing-use indicators and long-term condition and trend indicators, allowing for evaluation of livestock grazing and other management activities. Streamside riparian vegetation is a critical component for stabilizing physical stream processes and functions that influence streambank stability and channel geometry.

Many previous monitoring approaches have been relatively inefficient, partly because they addressed only one or two indicators at a time. For example, greenline vegetation would be gathered using the Winward method, and then in separate sampling, stubble height would be obtained using the methods in BLM Technical Reference 1734-3 (1996b). Sometimes data were acquired using different stream reaches at varying times of the year, making it difficult to develop relationships between grazing influences and the observed stream conditions. The MIM protocol combines observations of up to 10 indicators along the same stream reach into one protocol, using minor adaptations of existing methods. In addition, the collection of multiple indicators with one protocol per location reduces travel frequency to field sites, saving time and improving efficiency.

Elzinga et al. (1998a) defined monitoring as "the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective." In contrast, inventory is "the systematic acquisition and analysis of information needed to stratify, describe, characterize, or quantify resources for land use planning and management of the public lands" (BLM 1996a). Information derived from inventory, such as characterization and ***stratification***, is an important part of establishing a monitoring program. Because the location of monitoring sites is a critical component of obtaining useful monitoring data, the MIM protocol addresses stratifying stream reaches and riparian vegetation complexes and locating ***designated monitoring areas (DMAs).*** The DMA is the location on the stream where all monitoring procedures described in this protocol occur.

This protocol includes methods for monitoring 10 indicators. Three indicators provide data from which short-term livestock (or other ungulate) use can be derived; these indicators are also referred to as annual grazing-use indicators:

1. Stubble height (adapted from BLM 1996b) and Challis Resource Area (1999)
2. Streambank alteration (adapted from Cowley 2004, unpublished)
3. Woody riparian species use (adapted from BLM 1996b)

Monitoring of grazing-use indicators provides information necessary to help determine whether the current season's livestock grazing is meeting grazing-use criteria. They can be used as early warning indicators that current grazing impacts may prevent the achievement of management objectives. They can also help explain changes in riparian vegetation and channel conditions over time.

Seven methods provide data from which long-term resource condition information can be derived:

1. Greenline composition (adapted from Winward 2000 and BLM 1996a)

2. Woody species height class (Kershner et al. 2004)
3. Streambank stability and cover (adapted from Kershner et al. 2004)
4. Woody riparian species age class (adapted from Winward 2000)
5. Greenline-to-greenline width (Burton et al. 2008)
6. Substrate (Bunte and Abt 2001)
7. Residual pool depth and pool frequency (Lisle 1987)

Monitoring of long-term indicators provides data to assess the current condition and trend of streambanks, channels, and streamside vegetation. These indicators help determine if local livestock grazing management strategies and other land management actions are making progress toward achieving the long-term goals and objectives for streamside riparian vegetation and aquatic resources.

In addition to providing methods for monitoring the 10 indicators described above, the MIM protocol suggests establishing permanent photo points. Photo points provide visual records of long-term streambank and riparian vegetation condition and trend.

Seven of the ten methods in MIM use the ***greenline*** as the primary sampling location. The greenline as defined by Winward (2000) is the “first perennial vegetation that forms a lineal grouping of community types on or near the water’s edge.” There are several advantages to using the greenline location for sampling these indicators (these are discussed in Section 5).

This document is organized according to the order in which this protocol is typically conducted:

1. Stratify stream reaches and identify the sensitive riparian complex.
2. Develop monitoring objectives.
3. Determine the type of DMA (i.e., representative, reference, or critical DMA).
4. Locate the DMA.
5. Determine indicators to monitor.
6. Establish systematic procedures.
7. Locate the greenline.
8. Collect data.

There are many different indicators and methods that can be used to monitor streams; MIM is not designed to monitor every possible stream attribute. The 10 methods in MIM were chosen to meet the aforementioned objectives. MIM can be supplemented with additional stream and riparian methods depending on individual monitoring needs.

With more than 13 years of experience using MIM Technical Reference TR 1737-23, the protocol has proven to be one of the most useful tools for monitoring the effectiveness of grazing and similar management actions on stream channels and streamside vegetation. The data acquisition and analysis tools have undergone many refinements through the years, yet the original objectives and basic approach to monitoring have remained unchanged over that same time. This update to the technical reference reflects and documents those many refinements.

To help facilitate consistent application of the MIM protocol, Section 7 contains a list of commonly used abbreviations and acronyms, which are found throughout the document in all capital letters. Section 8 contains a glossary that defines the technical terms used throughout the protocol. Glossary terms are distinguished in bold and italic typeface when first introduced in the document.

1.1 Changes from the 2011 Version 1

Following 6 years of testing and continuous protocol improvement, the first version of "Multiple Indicator Monitoring (MIM) of Stream Channels and Streamside Vegetation" was published in 2011 (Burton et al. 2011). Since 2011, MIM has been implemented on an extensive basis across the Western United States by several state and federal agencies, nongovernmental organizations, and private entities. Widespread implementation over 13 years, on hundreds of perennial and intermittent stream systems, has created a considerable learning opportunity to improve the protocol. In summary, modifications in the version 2 MIM:

- Move data entry and data analysis instructions into the online "Multiple Indicator Monitoring Data Instructions Guide" (or MIM Data Instructions Guide, Burton et al. 2024 or latest version). This document will be updated frequently to incorporate changes in data collection and analyses and the addition of new metrics.
- Change the default DMA length for newly established DMAs from 110 m to 150 m, with a default quadrat/sample point interval of 3.75 m to address spatial autocorrelation. Eighty samples is still the target sample size for 150-m DMAs because many stream/riparian systems containing moderate amounts of shrubs require higher sample sizes.
- Change the sample interval in previously established, 110-meter DMAs to 3.75 m, resulting in fewer samples per DMA. Updated analyses of the sample sizes needed to acquire adequate representation of site variability indicates that the desired confidence interval can be achieved with fewer than 80 samples at many sites. Instructions regarding sample spacing of short-term indicators (i.e., grazing-use indicators) is covered in Section 4.
- Modify the practice of obtaining additional samples to achieve a desired level of precision. Obtaining additional samples will not occur within the existing DMA because doing so could result in spatial autocorrelation. The MIM Data Instructions Guide and the MIM Data Analysis Modules provide a spatial autocorrelation tool that observers can use to evaluate sampling intervals.
- Provide additional clarification of the methods/rules to ensure accurate implementation and repeatable measurements among practitioners for a variety of stream types.
- Provide more detailed instructions on setting up a DMA and sampling dewatered channels that have plants occupying the entire channel and/or vegetated drainageways.
- Include additional diagrams and photos of features and attributes.
- Update the literature cited, as appropriate, to incorporate new findings and considerations that directly relate to the protocol.
- Change the quadrat size for the woody riparian species age-class method, from 42 cm x 2 m to 1 m x 2 m. This revision allows for a larger sample size of woody plants, which is beneficial on sparsely wooded streams.
- Add a "no use" category for the woody riparian species use method, replacing the "none to slight" category used in version 1.
- Include key woody plants overhanging the woody riparian species use quadrat (in addition to those rooted in the quadrat). Version 1 only included key woody riparian species rooted in the quadrat. This change allows for a larger sample size of woody plants, which is beneficial on sparsely wooded streams.
- Change greenline-to-greenline width (GGW) method to omit islands of anchored wood and embedded rock (in addition to vegetation) from the measurement. Previously, anchored wood and embedded rock were included as part of the channel. **Users should be aware of this rule change when analyzing trend from previous DMAs with wood and rock covered islands.**

- Change the number of samples for GGW to 40, measuring GGW from one side of the stream only and not from both sides as done previously. This is done to avoid spatial autocorrelation in this indicator.
- Remove the ecological status value for wood and rock. Wood and rock are abiotic factors and should not enter into the determination of ecological status, which is based on biotic factors (i.e., plants) in the environment.
- Add instructions for decontaminating gear and equipment to prevent the spread of aquatic invasive species.

1.2 Intended Stream Applications

1.2.1 Flow Regimes

The MIM protocol was originally developed and tested on relatively low-gradient (< 4%), perennial snowmelt-dominated and spring-fed streams in the Western United States. However, it has been implemented on a widespread basis on both intermittent and perennial streams. Although version 1 of MIM did not specifically state its applicability to intermittent streams, it clearly did not preclude them; in fact, version 1 stated and/or implied its utility for intermittent streams. Since 2011, it has been used on many intermittent streams. To clarify MIM applicability to intermittent streams, additional detail is provided in MIM version 2.

According to Bureau of Land Management (2015), intermittent streams:

> flow only at certain times when it receives water from springs or gradual and long, continued snowmelt. The character of streams of this type is generally due to fluctuations of the water table whereby part of the time the streambed is below the water table and part of the time it is above the water table. The term intermittent may be arbitrarily restricted to streams or stretches of streams that flow continuously during periods of at least 1 month (Meinzer 1923). An intermittent stream may lack the biological and hydrological characteristics commonly associated with the continuous conveyance of water (Nadeau 2011). The channel may or may not be well defined.

Some ***intermittent systems*** may exist as vegetated drainageways with no distinct continuous defined channel, while others may have relatively well-defined continuous channels with a discernable ***scour line***.

Practitioners should validate the flow regime of streams considered for MIM because the protocol is not intended for ***ephemeral streams*** that lack riparian or ***hydrophytic*** vegetation. In addition to the defining criteria listed above for intermittent streams, it is also important to ensure the presence of hydrophytic vegetation, specifically obligate wetland, facultative wetland, or facultative species (Lichvar et al. 2016). The presence of hydrophytic vegetation in or directly adjacent to the channel or ***thalweg*** is evidence that the flow regime is likely intermittent or perennial.

In summary, MIM can be used on intermittent streams, regardless of whether streamflow is present at the time of monitoring.

1.2.2 Stream Size

MIM has been successfully implemented on streams of various sizes, but it is most effective on smaller, mostly wadeable stream systems with an ***active channel*** width under approximately 10–15 m. However, a modification of MIM was developed for the Upper Missouri River that may be useful on large rivers as well (see Smith et al. 2013).

1.2.3 Management Considerations

While the MIM protocol includes annual grazing-use indicators, its use is not exclusive to grazed stream systems. The MIM protocol also includes methods for documenting stream condition and trend. Therefore, the long-term indicators described in this protocol are useful for monitoring changes to streambanks and channels that resulted from management activities other than grazing (e.g., impacts from wild ungulates, wild horses and burros, road placement/construction, recreation, mining, water diversion, or timber harvest). MIM can also be used to monitor the effectiveness of restoration actions or post fire recovery.

1.2.4 Integration with Other Monitoring Protocols

The MIM protocol can be integrated with other monitoring protocols as desired. The BLM has a stream monitoring protocol commonly used in conjunction with MIM entitled “AIM National Aquatic Monitoring Framework: Field Protocol for Wadeable Lotic Systems” (BLM 2021). A “living” field guide that provides detailed guidance for integrating MIM with this protocol will be updated annually and made available as online resource through the BLM library. The 2024 version is entitled “Field Guide for Integration of the MIM Protocol with Lotic AIM” (Gonzalez 2024). The BLM also has a monitoring protocol for wetlands entitled “AIM National Aquatic Monitoring Framework: Field Protocol for Lentic Riparian and Wetland Systems.”

2. Monitoring Objectives, Stratification, and Selection of Designated Monitoring Areas (DMAs)

An efficient and effective monitoring program is based on a systematic process that determines where, when, what, how, and why to monitor. The integrated riparian management process (IRMP, Figure 1) is one such process that informs a riparian monitoring program. The IRMP consists of 7 steps and includes a provision to develop an adaptive management plan and monitoring program to maintain or improve the condition of riparian habitat and resources (Figure 1). The IRMP is described in detail in the lotic and lentic proper functioning condition (PFC) assessment protocols (BLM 2015; BLM 2020.) Interested readers are encouraged to review the IRMP in the source documents to determine how to best integrate riparian monitoring with riparian management. The IRMP provides a rationale for where, what, and why to monitor by focusing on reaches that have been prioritized based on results of rapid riparian assessments (e.g., the PFC assessment protocol), interdisciplinary evaluation of values of individual reaches, and the management issues associated with each reach. This section discusses a process to locate DMAs to address management questions in an efficient and effective manner.

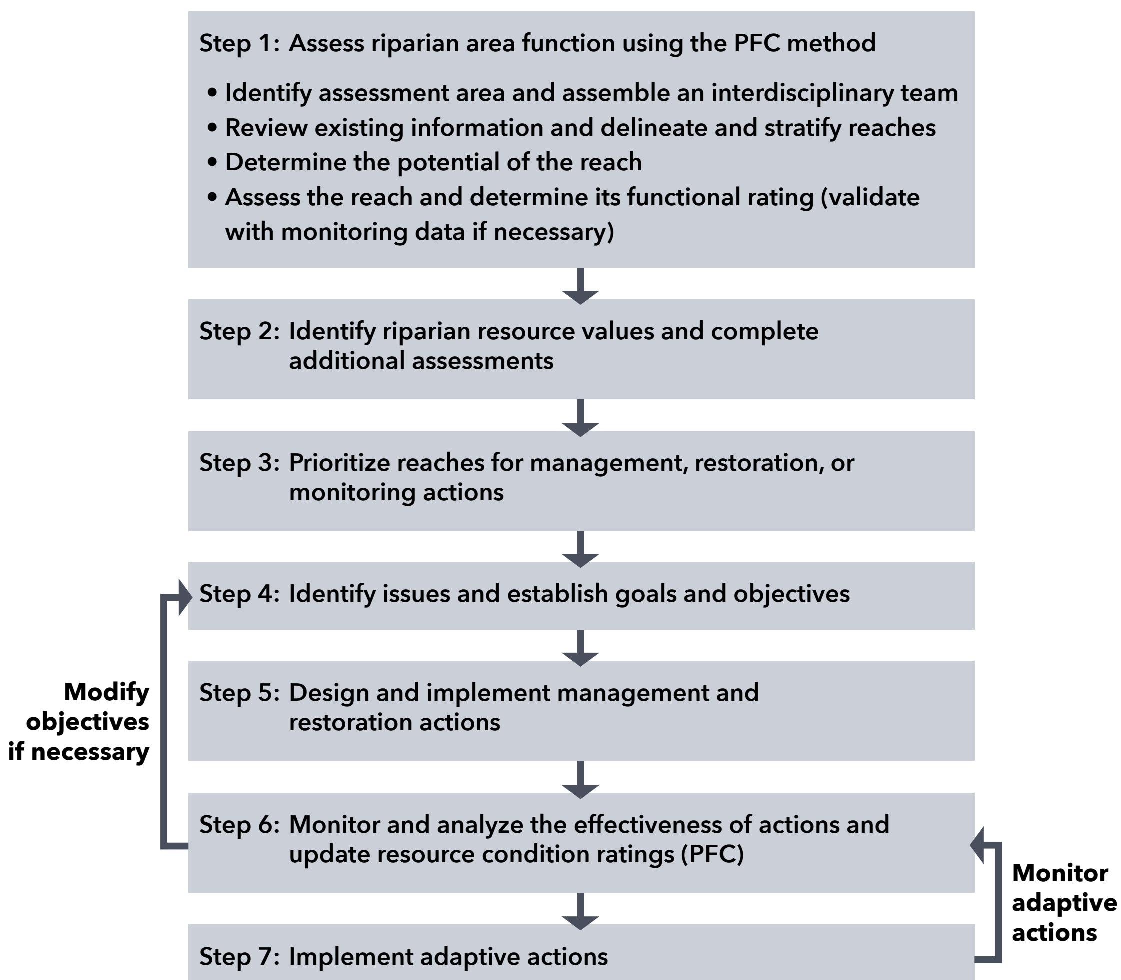

Figure 1. The integrated riparian management process (IRMP) summary (BLM 2015; BLM 2020). After effectiveness monitoring has been completed (step 6), initial objectives are validated and modified if necessary. After implementing adaptive actions, step 6 is repeated to monitor the effectiveness of those actions.

The IRMP is not a conceptual construct unique to the PFC or MIM protocols. It was developed from, is modeled after, and is consistent with the planning framework and management principles described in many land management documents, including:

- BLM H-4180-1, Rangeland Health Standards (2001)
- BLM H-4400-1, Rangeland Monitoring and Evaluation (1998)
- BLM Technical Reference 1734-4, Sampling Vegetation Attributes (1996a)
- Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems. Volume 1: Core Methods. (Herrick et al. 2009)
- Technical Reference 1730-1, Measuring and Monitoring Plant Populations (Elzinga et al. 1998a)
- National Range and Pasture Handbook, Revision 1 (NRCS 2003)
- Technical Reference 1737-20, Riparian Area Management: Grazing Management Processes and Strategies for Riparian-Wetland Areas (Wyman et al. 2006).

2.1 Sampling Approach

The MIM methods can be used with different sampling designs (Table 1); however, a stratified random sampling approach is generally used to locate ***representative DMAs***. In this approach, stream reaches are stratified by their physical and vegetation characteristics, ***sensitive riparian complexes*** are identified, management and monitoring objectives are developed for those sensitive complexes, and representative DMAs are located and established in a random fashion within the stratum or strata that contains sensitive complexes. Other sampling approaches can be used with the MIM methods such as those described in Table 1, from “AIM National Aquatic Monitoring Framework: Field Protocol for Wadeable Lotic Systems” (BLM 2021). For specific information and procedures for integrating MIM methods into the aquatic AIM protocol, see “Field Guide for Integration of the MIM Protocol with Lotic AIM” (Gonzalez 2024). Critical and reference DMAs are also used in MIM, and they are described below.

Table 1. Summary of sampling approaches commonly used in stream monitoring protocols.

Random Sampling Approaches		Nonrandom Sampling Approaches	
GRTS*	Stratified random	Targeted	Purposive
Aquatic AIM	MIM – representative† DMAs “Stratified, random” key areas	Aquatic AIM	MIM – reference† and critical† DMAs “Traditional” key areas

* GRTS is generalized random tessellation stratified survey design (Stevens and Olsen 2004).

† Representative, reference, and critical DMAs are described in Section 2.4.

2.2 Stratify the Stream Reaches

Stratification is one way a monitoring program can account for variation among streams (Roper et al. 2002). It can also identify groups of reaches of highest management and monitoring priority. ***Stratification*** is a process of grouping reaches and riparian complexes based on similarities in their form (i.e., vegetation and physical characteristics) and their function. Stream reaches in a stratification group, or stratum (plural strata), share a common set of attributes, processes, and management practices. Strata are generally delineated so that sampling units within the same stratum are very similar while units between strata are very different (Elzinga et al. 1998a). Stream reaches are first stratified according to riparian complexes and land uses. ***A riparian complex*** is defined by overall ***geomorphology*** (including valley-bottom type and width, stream channel type), substrate characteristics, dominant soil family, ***stream gradient***, hydrology, vegetation patterns along the stream (Winward 2000; USFS 1992; Herrick et al. 2009), and land uses.

Before undertaking stratification, an interdisciplinary (ID) team should inspect agency records and project files to determine if the stream reaches have already been stratified. For example, many watersheds have already been stratified in preparation of PFC assessments. There is no reason to repeat the stratification process if it has already been completed and general basin-wide properties of vegetation, hydrology, and geomorphology have not changed substantially. The stratification process is described in more detail in the lotic and lentic PFC technical references (BLM 2015; BLM 2020).

Much of the stratification process can be completed with the aid of geographic information systems (GIS) and aerial or remote sensing imagery in an office or laboratory setting. Reaches delineated in the office should be validated in the field to ensure that the GIS and remote sensing information is accurate, current, and adequately representative of the features observed on the ground. When necessary, adjustments should be made to strata and reaches if current field conditions differ from GIS or remote sensing information.

An example of delineated and stratified stream reaches is shown in Figure 2. Within the grazed unit, there are two complexes or strata. Complex B has a wider valley bottom, which supports a wide riparian area. It contains a mix of riparian herbaceous and woody vegetation. Complex C occurs in a narrower valley bottom and a correspondingly narrower riparian zone. Note that complexes B and C occur in a repeating pattern along the stream. The repeating sequence reflects the influence of side valley fans that locally affect stream gradient, soil type, and therefore, valley-bottom width and dominant streamside vegetation types.

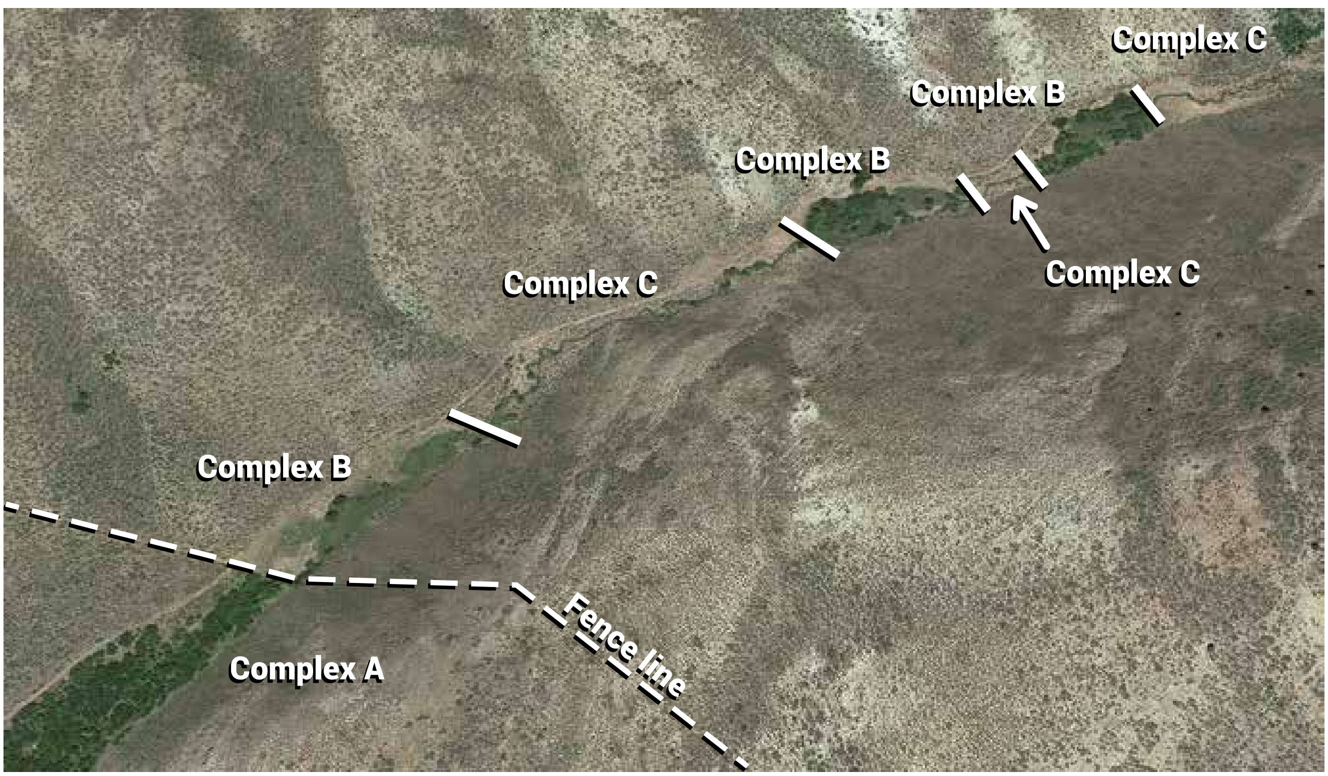

Figure 2. Delineation and stratification of complexes, or stream reaches, on Telephone Draw near Montpelier, Idaho. Each reach is uniform in geomorphology, hydrology, and potential vegetation patterns. Note repeating complexes (Bs and Cs) within a grazed unit (pasture). Complex A is likely the same riparian complex as B in geomorphic, hydrologic, and potential vegetation characteristics. However, Complex A is ungrazed and located outside of the grazing management unit; therefore, it has a different land use and is stratified as a separate complex from B. Aerial image from ©2024 Airbus, Maxar Technologies, via Google Earth.

Identification and selection of the sensitive complex to use for monitoring purposes should be performed by an experienced ID team with local, in-depth knowledge of the terrain, plant communities, hydrology, and land management (Herrick et al. 2009). The process should be documented (see Appendix A) thoroughly to link management objectives with identification of sensitive complexes. The term ***sensitive complex*** is used to denote complexes that are responsive to management actions as well as complexes that are vulnerable or at risk, such as spawning reaches of endangered fish. The complex selected for monitoring depends on the monitoring objectives. The complexes that are the most sensitive or most responsive to management influences should be selected for monitoring. Sensitive riparian complexes are generally characterized by relatively low gradient reaches with relatively fine streambank and streambed material, where vegetation is a controlling influence (especially where herbaceous vegetation is abundant on streambanks or has the potential to become abundant with proper management.) Sensitive complexes tend to have a high sensitivity to disturbance. Once a stratum with the most sensitive complexes is identified and mapped, one or more DMAs can be randomly positioned within a stratum deemed to be "representative" of the target population. The process of randomly positioning DMAs is described in Section 2.5.

Note: The degree and detail of stratification is somewhat dependent on the complexity and controversy of a project area. Short inclusions of a different complex could be incorporated into a surrounding, longer complex if doing so would have minor effect on the statistical calculations and the consequences to management. However, in contentious or controversial situations, where stringent grazing-use criteria are applied, it might be best to avoid inclusions of non-target complexes, which might dilute or alter the quantitative measurements and complicate evaluation of use criteria. Recognizing that individuals differ in their proclivity to lump or split complexes, the ID team should strive to delineate and stratify reaches in a manner that best addresses management objectives given the scale of analysis and scale of management, personnel, monetary resources, time constraints, competing priorities, and level of controversy.

Stratification is important prior to the selection of key areas and can be effectively used with MIM data. Key areas traditionally have been used in rangeland management and monitoring to evaluate condition, trend, and the effects of management. Key areas are indicator areas that can reflect what is happening on a larger area as a result of on-the-ground management actions. A key area should be a representative sample of a large stratum, such as a pasture, grazing allotment, wildlife habitat area, herd management area, watershed area, etc., depending on the management objectives being addressed by the study. Proper selection of key areas requires appropriate stratification (BLM 1996a; BLM 1996b).

One of the criticisms of nonrandom or targeted monitoring sites is the appearance of handpicking the location with some bias or ulterior motive. The stratified random key-area approach used to locate representative DMAs adds a randomization process to remove potential bias in selecting the monitoring plot. See Section 2.5, where the randomization process is explained in detail. Essentially, where there are multiple discontinuous reaches of the same complex, the specific reach to sample is randomly selected and then the location of the DMA in the reach is also randomly determined.

The stratification process is important in monitoring because (1) it provides a contextual basis for interpreting results based on reach potential; (2) it identifies the reaches and riparian complexes that are most sensitive to the management actions; (3) it provides an objective basis for prioritizing management, restoration, and monitoring; (4) it minimizes variability associated with environmental heterogeneity (Roper et al. 2002); (5) it defines populations/strata (e.g., sensitive complexes) that can be sampled to obtain statistical inferences if desired;

and (6) it permits extrapolation of findings through ***logical inference*** by using supplementary information (e.g., assessments, photos, range inspections, and field visits) from other reaches in the same stratum (Elzinga et al. 1998a).

2.3 Develop Monitoring Objectives

Quantitative monitoring objectives should be determined for each DMA. These objectives often determine the kind of DMA selected for monitoring (representative, critical, or reference DMA as described later in Section 2.4). Objectives should relate to a planning document (e.g., a land-use plan, resource management plan, allotment management plan, and/or land health standards and guidelines) or address a resource issue identified in a local assessment (e.g., a PFC assessment) (BLM 2015; BLM 2020). Broad-scale objectives developed in land-use plans should be carefully evaluated to ensure the riparian complex associated with the DMA has the potential to address them. If a reference in the same riparian complex is available, objectives may be quantified by measuring the indicators within the reference DMA. When the potential of the riparian complex is not known, interim objectives may be developed and subsequently refined as more data become available.

Good objectives should be based on the potential of the stream reach and should include components illustrated by the acronym SMART from Adamcik et al. (2004):

- **S**pecific
- **M**easurable
- **A**chievable
- **R**esults-oriented
- **T**ime-fixed

The process of writing an effective monitoring objective involves determining (1) the current state of an attribute, (2) how much it may need to change, and (3) the timeframe necessary to achieve it. For example, if a PFC assessment determines that stabilizing riparian vegetation is inadequate to provide stable streambanks, then baseline monitoring would be used to determine the current extent of stabilizing riparian vegetation and set an objective for recovery of this vegetation. A SMART objective, based on findings of baseline monitoring, might state, “Increase the amount of stabilizing riparian vegetation cover from 45% to 80% in 5 years along reach 3 of Bear Creek.”

2.4 Determine the Type of DMA

A key to good monitoring is using a sampling design that can minimize variation associated with environmental heterogeneity and observer error. One way to minimize environmental variation is to evaluate condition and trend of stream attributes at permanently marked monitoring sites (Roper et al. 2002) and to evaluate change over time. A DMA is a permanently marked segment of stream that is selected for monitoring. The standard DMA has a default length of 150 m. Longer DMAs may be needed to monitor larger streams or complexes that have high variability, such as those with moderate to high shrub and tree cover. The DMA should be at least two meander lengths or approximately 20 times the average GGW. For example, if the average GGW is 8.3 m, the DMA would be 166 m long (8.3 m x 20). In this updated MIM protocol, the default length of the representative DMA has been increased from 110 m to 150 m to provide better spatial independence between samples (see MIM Data Instructions Guide, Appendix A).

The DMA concept was originally established for grazing management applications, but DMAs may also be used to monitor the effects of wildlife (particularly large ungulates), wild horses and burros, recreation, roads, stream restoration projects, and other activities on stream channels and streamside vegetation.

The process of locating and establishing DMAs should be performed by an experienced ID team with local knowledge of the terrain, plant communities, hydrology, and land management.

There are three types of DMAs: representative, critical, and reference. The characteristics of each are described in this section.

A ***representative DMA*** is a monitoring site in a riparian complex that is representative of a larger area. This is the most common type of DMA used by land managers. Representative DMAs should be located within a single reach and should not straddle an ecotone (a transitional area of vegetation between two riparian complexes).

When there is more than one riparian complex in a management unit, the DMA should be placed in the riparian complex that is the most sensitive to management influences. The reasoning for concentrating limited time and resources on complexes most sensitive to the management activity of interest is that if the management proves to be appropriate to meet management objectives in the sensitive complex, then one can assume that less sensitive complexes are meeting management objectives too.

The criteria for selecting representative DMAs include:

- The riparian complex for the DMA should be selected by an experienced ID team.
- The DMA should be in a complex that represents and is accessible to the management activities of interest.
- The DMA is randomly located in the riparian complex that is the most sensitive or responsive to the management activities of interest.
- When the most sensitive riparian complex is spatially discontinuous within the management unit (i.e., there are multiple reaches of the same complex that are discontinuous and interrupted by different complexes (Figure 3.A), the reach selected for the DMA location is chosen randomly.
- When it is important to monitor streambank stability and ***streambank alteration***, the DMA is located on a site that is sensitive to disturbance and is not located on reaches impervious to disturbance. It should be noted that the degree of sensitivity to disturbance is a relative concept and can vary among management units.

  Note: A representative DMA can be placed in a complex that is not particularly sensitive to disturbance, but this is an exception. DMAs are generally only placed in marginally sensitive complexes if there is a clearly defined management objective to obtain representative MIM data within that complex. In those kinds of complexes, the annual grazing-use indicators are generally not useful or appropriate (usually due to bank armoring and/or dense woody vegetation).

- The DMA will respond to the management influence of interest and resource objectives can be achieved at the DMA (i.e., the site has the potential to respond to and demonstrate measurable trends in condition resulting from changes in grazing management or other management activities influencing stream channels and riparian vegetation). This criterion is also applicable to a reference DMA.
- The gradient of the stream reach at the DMA is generally < 4%. The gradient may exceed 4% if the reach has a distinctly developed ***floodplain*** and the riparian vegetation heavily influences channel stability, as occurs in a vegetated drainageway. This criterion is also applicable to a reference DMA.
- The DMA is located outside of a livestock concentration area. DMAs should not be located at water gaps or locations intended for livestock concentration (e.g., a stock tank) or in areas where riparian vegetation and streambank impacts are the result of site-specific conditions (e.g., along fences where livestock grazing use is not representative of the riparian area). These local areas of concentration may be monitored to address highly localized issues, if necessary. In these cases, they would be described as critical DMAs, as defined in this section.
- The DMA should be free from the influence of compounding activities. It is difficult to establish cause-and-effect relationships in areas affected by compounding or

multiple types of activities. Preferably, the representative DMA will allow for isolation of the management activity of interest. For example, an area used heavily by both recreationists and livestock would not make a good DMA to determine the effects of livestock grazing on stream conditions.

Note: If the site has compounding activities, for example, livestock grazing and wild horse or wildlife (e.g., elk) impacts, a representative DMA can still be used but the DMA should be read multiple times during the year (e.g., before and after grazing and at the end of the growing season) to differentiate livestock impacts from other ungulate impacts.

Note: An important resource area affected by compounding activities, which is not suitably addressed by representative DMAs, can be addressed with a critical DMA, described below, which are restricted to sites where one management activity can be isolated for analysis and evaluation.

A ***critical DMA*** is not representative of a larger area but is important enough that specific information is needed at a particular site. Critical DMAs are monitored for highly localized management objectives and to address site-specific monitoring questions. Extrapolation of data or logical inferences from a critical DMA to a larger area may not be appropriate within the complex containing the critical area. A critical DMA does not have to meet the criteria for a representative DMA. Examples of a critical DMA include, but are not limited to:

- A livestock concentration area where there is an important and site-specific management question.
- A localized, critical spawning reach where monitoring the effects of concentrated livestock use is needed.
- A short DMA in a reach that does not meet the 150-m standard length. Such DMAs with substandard length are established where there is an important (i.e., critical) management issue.
- A stream restoration project where the DMA is established specifically on the restored portion of the stream to conduct a before/after study of recovery.
- A DMA immediately downstream of a water diversion, used to monitor the immediate effects of the diversion on the stream channel and streamside vegetation.
- A DMA adjacent to a recreational activity, such as a wilderness packhorse holding area or a boating access point, used to monitor the immediate effects of the activity on the stream channel and streamside vegetation.

A ***reference DMA*** is chosen to obtain reference information useful for identifying potential natural conditions or determining initial desired condition objectives for a similar riparian complex. A common example of a reference DMA is a grazing exclosure where livestock access to the stream is restricted and good ecological conditions and proper stream functions exist. Ungrazed pastures used for reference DMAs need to be carefully analyzed to ensure their usefulness as a comparison. For example, long-idled riparian areas may be in poor condition because of excess thatch buildup or shifts in plant communities.

Reference DMAs should be selected to ensure that they match the geomorphic and ecological strata of the representative or critical DMA they will be compared to. Otherwise, they will not be a good reference. Reference DMAs meet many of the same criteria as representative DMAs.

When the monitoring objective is to assess management effects over time, it is best to use both a representative DMA and a reference DMA. For example, in Figure 2, complex A could serve as a reference DMA since it is outside of the grazed unit and complex B as the representative DMA since it is common within the pasture and comparable (at potential) in channel and vegetation characteristics to the reference complex. If the monitoring objective is to assess management effects on cutthroat trout habitat, a critical DMA might be established in complex B where spawning or some other critical life cycle requirement is concentrated.

Single Versus Multiple DMAs. The number of DMAs per grazing unit depends on the resource values in the area as well as the monetary and personnel resources available for monitoring all the sensitive complexes in a particular field area. Usually, one measured DMA per pasture is adequate and serves as a compromise between the need for quantitative information and the limitations of finite resources (Elzinga et al. 1998a). If long-term indicators are measured on a rotating panel of 3–10 years, then a network of representative DMAs can be quite substantial and yet manageable in terms of repeat monitoring.

When only one representative DMA is used for a complex or management area, the DMA serves as a **stratified, random key area**. This differs from a **traditional** key area since it randomly locates the DMA within a target stratum. A traditional key area is purposively located in a nonrandom fashion. As indicated, key areas that are not randomly located are commonly used in rangeland management and monitoring to evaluate condition, trend, and the effects of management. Because an inclusive process is used to identify and select sensitive complexes that contain key areas, there is an agreement among interested parties (e.g., land managers, user groups, environmental groups, or state, federal, and Tribal partners) to use the observations and quantitative data from the key area or representative DMA as representative of conditions in other areas in the same stratum or riparian complex. Recognize that with a single DMA in a complex, statistical inferences can only be made to the actual extent of the sampled DMA. However, the common desire in land management is to apply what is learned or observed in the representative DMA to other areas within that same stratum through logical inference; this is how the key area approach is used. The idea is to extrapolate quantitative data from a sampled representative DMA and supplement it with qualitative data (e.g., photo points, riparian assessments such as PFC, riparian inventories, pasture inspections, and field notes) from other stream reaches or complexes dispersed through the same stratum. This will allow practitioners to make logical inferences about conditions of a stratum throughout a pasture or management unit (Elzinga et al. 1998a). Although one cannot conclusively state that the monitored condition in the DMA is representative of conditions elsewhere, the supporting qualitative data may be sufficiently strong for management decisions (Elzinga et al. 1998a).

Alternatively, multiple randomly located DMAs within the same stratum might be monitored to assess conditions throughout the stratum. When multiple DMAs exist in the stratum, statistical inferences can be made to the target population. Additional DMAs in a single stratum are commonly justified when the resource conditions and management issues are especially complicated or contentious, or when the stratum or complex of interest is highly variable.

The type of complex may also necessitate additional DMAs. For example, the authors' test data indicate that resource conditions are more highly variable in woody/herbaceous mixed communities than in herbaceous-dominated communities. Therefore, the ID team should consider adding DMAs where mixed woody/herbaceous communities are the sensitive complex or the complex of greatest management concern. The number of DMAs can be informed by a pilot study and power analysis (see Elzinga et al. 1998a, Chapter 7 - Sample Design for a discussion of power analysis).

2.5 Locate the DMA

Step 1. Randomly locate the DMA within the complex or reach. Randomly locate the lower end of the DMA within the selected complex or reach. A random process is used for representative and reference DMAs to reduce biases that might result from handpicking the DMA location. Because critical DMAs are meant to capture conditions at a specific location, these types of DMAs do not have to be randomly selected. The process of randomly locating the DMA includes these steps:

a. **Identify the sensitive complex.** Identify the complex that is most sensitive (i.e., it will be most responsive to the management actions of interest or is in a complex that is highly vulnerable to the action). If this complex occurs as discontinuous reaches within the study area (e.g., pasture or allotment), randomly select a reach to monitor. In Figure 3.A, there are 2 complexes. There is a meadow complex marked with yellow line segments and a forest complex marked with red line segments. The meadow complex has a relatively low gradient, wide valley bottom and wide riparian zone, fine-textured soils, and abundant herbaceous forage. The forested complex has less forage and a lot of downed timber, which impedes the movement of livestock. The sensitive complex and monitoring priority is the meadow complex in this example. Because there are 6 individual, discontinuous reaches of the meadow complex, the specific monitoring reach within the meadow complex is randomly selected. A random number is picked between 1 and 6 to select a reach randomly. However, in Figure 3.A, reach 5 is too short to hold a DMA. Therefore, the random number will be rejected if it happens to be a 5 and another random number will be generated. For discussion purposes, reach 4 is selected (Figure 3.A).

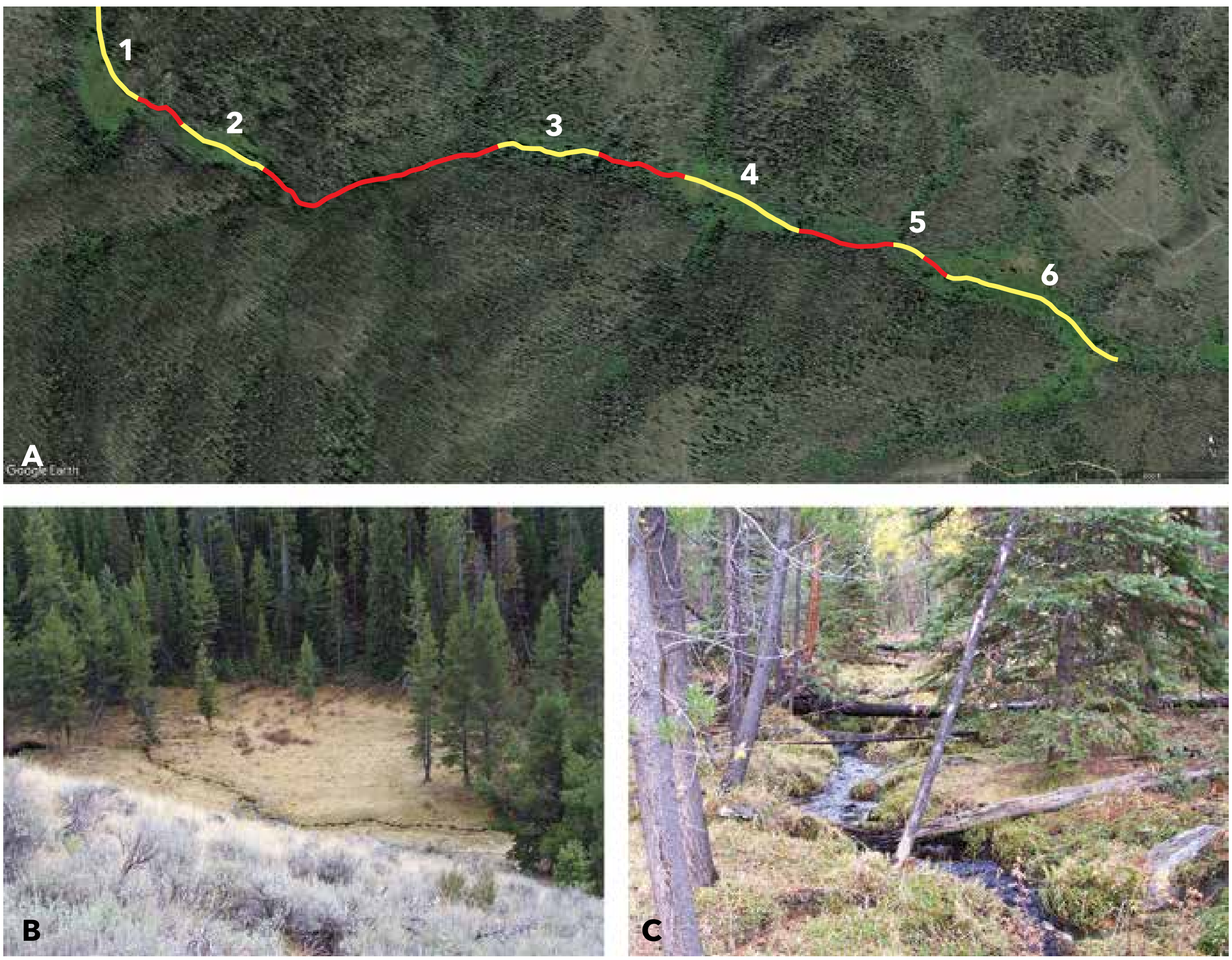

Figure 3. Examples used to identify the sensitive complex. A. A discontinuous meadow complex (marked by yellow line segments), alternates with a coniferous forest complex, (marked by red line segments). Aerial image from Google Earth. B. The meadow is the sensitive complex because it provides abundant forage and easy travel to livestock and wild ungulates. C. The forest complex is little used by livestock due to lack of forage and the amount of downed timber impeding livestock movement. Therefore, management issues and monitoring priorities are in the meadow complex.

b. **Randomly locate the bottom of the DMA.** Identify any concentration points or anomalies that should be excluded from the DMA. For example, exclude areas near fences where livestock tend to gather or trail. Exclude road crossings; these can back water upstream of the road or cause excess erosion downstream. Exclude watering facilities or other known localized concentration points; these are not considered 'representative' of the complex. Measure the remaining length of the selected reach. Subtract the length of the DMA from the length of the selected reach. This subtraction ensures that the entire DMA fits within the selected reach and does not cross an ecotone, straddle more than one complex, or extend into a concentration area. The default length of the DMA is 150 m, but for wide streams where GGW is > 7.5 m, the length of the DMA will be 20 times the average GGW.

- In Figure 4, the length of the selected reach 4 section is 220 m. Subtracting 150 m (the DMA length) leaves a difference of 70 m.

c. **Select a random number between 1 and the difference calculated in step b to locate the bottom of the DMA in a random fashion.**

- Because the length of reach 4 is 70 m longer than the length of a default DMA, a random number between 1 and 70 is selected to mark the bottom of the DMA. For illustrative purposes, let's say the random number is 19 (Figure 4).

- **Note:** An edge effect might exist in the reach. For example, an end may be bordered by a fence (as is the case in Figure 2 between the top of complex A and the bottom of the adjacent complex B). Livestock commonly trail along fences or concentrate along a fence when pushed by wind or a desire to move to a new pasture. If there are known edge effects, the ID team should factor this when determining how much of the reach is truly representative and how much flexibility there is in randomizing the location of the DMA.

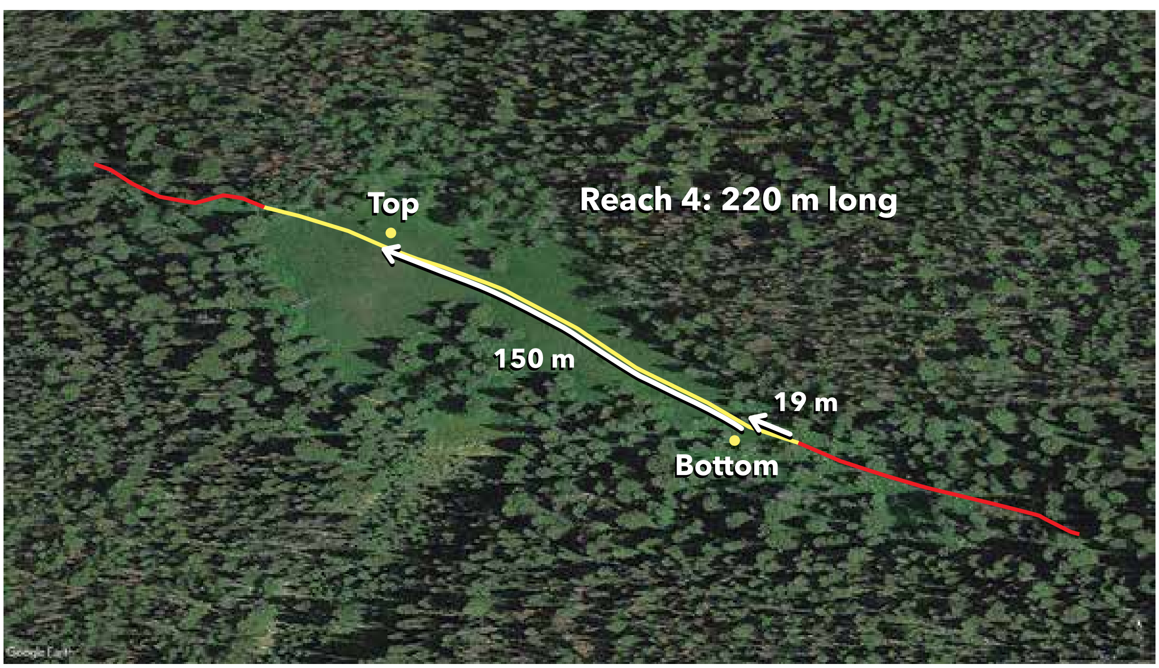

Figure 4. Locate the top and bottom of the DMA within the randomly selected reach. First, measure the length of the selected reach. In this example, reach 4 of the meadow complex is 220 m long. Subtract the length of the DMA (150 m) from the length of the reach: 220 m – 150 m = 70 m. Next, randomly select the DMA starting point by choosing a random number between 1 and 70 (i.e., the difference in length between the reach and the DMA). In this example the random number is 19; measure 19 m upstream (short white arrow) from the downstream end of the reach to locate the bottom of the DMA. Then measure 150 m upstream from the bottom of the DMA to locate the top of the DMA. Aerial image from Google Earth.

d. **From the downstream end of the complex, measure upstream by the randomly selected length and locate the bottom of the DMA.**

   - In this example, measure 19 m upstream from the downstream end of the reach segment. This location is the bottom of the DMA (see short white arrow, Figure 4).

e. **From the bottom of the DMA, measure 150 m upstream along the stream's thalweg to locate the top, upstream end of the DMA** (see long white arrow, Figure 4). The length of the default DMA is 150 m. Large streams where GGW is > 7.5 m will have longer DMAs (calculated as 20 times the average GGW). Measure the appropriate distance to locate the top of the DMA.

f. **Identify alternative DMA points. The ID team should select a second and third random location for a DMA if the first random location proves anomalous or otherwise not representative of the complex.** Although the rejection of a DMA and the need for a second random point is rare, it is efficient to generate additional points so alternative locations can be objectively located when necessary. If field inspection indicates that the initial DMA location doesn't meet the criteria for inclusion in the target population or doesn't meet the criteria of a representative DMA, then this DMA is excluded. An alternative site should be randomly identified by **repeating steps b–e** above. However, if the entire reach is not suitable for a representative DMA (e.g., the remainder of the area outside a livestock concentration area is too short to accommodate a representative DMA), then **repeat steps a–e** above and locate a random point in a different reach for a representative DMA.

ENCOUNTERING UNIQUE SITUATIONS IN THE FIELD WHEN SELECTING A DMA

The authors once experienced a situation in which a temporary fire fence had been installed to exclude livestock from a burned area. Unfortunately, this temporary fence wasn't included in the GIS layer of range improvements and wasn't accounted for when locating representative DMAs. During field inspection of the randomly selected point, the ID team recognized the fence was creating a livestock concentration area and conditions were not representative of the stratum (they were highly anomalous). This recognition led to the rejection of the initial randomly selected point. Instead, an oversampling point was used to locate the DMA in an area outside the concentration area and representative of conditions throughout the rest of the reach.

In another field exercise, poor aerial imagery (which can result from cloud cover, dense tree cover, or poor acquisition timing [dormant season images generally lack desired visual details for stratifying riparian complexes]) led to the selection of a random point that wasn't representative of riparian conditions in the reach. Good planning in the office and selection of oversampling points allowed the ID team to quickly and objectively relocate DMAs when field inspections resulted in the rejection of the initial sampling point.

Step 2. Set up and monument the DMA. Once the top and bottom of the DMA have been located, permanently mark the DMA.

a. **Permanently mark the lower and upper ends of the DMA.** Place the downstream marker (starting point) on the left bank (as determined when looking upstream) and the upper marker 150 m upstream (or farther if a longer reach is used) on the right bank (looking upstream). The marker should be located at least 2 m away from the top of the bank to reduce the risk of losing the marker from channel migration. Reach markers should be made of securely capped or bent-over rebar, angle-iron, or a similar material. Straight, jagged, rebar stakes present a serious hazard to animals and humans. Although hard to relocate, some choose to locate markers under shrubs where they are less likely to be stepped on by an animal. Avoid placing a marker directly on or next to a path.

b. Install a permanent reference marker. Reference markers facilitate relocation of the DMA since rebar can be difficult to find. Reference markers should be located well away from the channel (at least 30 m) in case the channel erodes laterally or sediment buries the DMA marker. Reference markers can be steel posts, a marked post in a fence line, a marked tree or unique rock, or another natural feature (Figure 5). Be aware that single steel posts tend to attract livestock and can create concentrated impacts where they are placed.

c. Document the location of the markers. Record a global positioning system (GPS) location in decimal degrees for both reach markers and the reference marker. Universal Transverse Mercator (UTM) coordinates are optional. Also record the datum and the UTM zone, if used. Where possible, record the distance and azimuth from a reference marker/feature to a DMA marker (Figure 5). The sketch map and/or a satellite photograph containing position of DMA markers should be included with the field data.

Figure 5. An easily identified, unique landmark or reference point is useful in relocating DMA markers. A single rock crib in a fence line within eyesight of the bottom of a DMA provides an unambiguous landmark to relocate a DMA marker. In this example, the azimuth (white arrow, 203 degrees) and distance (41 m) from the rock crib to the DMA marker have been recorded to facilitate relocation of DMA markers.

d. **Take photographs.** After the DMA markers are placed, photographs should be taken before data are collected as the monitoring process may result in some visible disturbance to the site. At a minimum, take photographs showing the markers from the following locations:

- Looking upstream with the lower marker in view
- Looking across the channel in line with the lower marker
- Looking downstream with the upper marker in view
- Looking across the channel in line with the upper marker

An overview photo from a nearby hillside or across a meadow can also provide context and document highly visible changes in riparian conditions at the reach scale (Figure 6). A view that captures part of the skyline or a distinct landmark or local feature will help subsequent monitors relocate the DMA (Figure 5). Take additional photographs as needed and describe the location of each photo in relation to the downstream marker.

Figure 6. An elevated photo point can document visible changes in riparian conditions through time. A photograph from a nearby hill can provide context between site visits.

It is useful to include a satellite image or aerial photograph of the DMA (Figure 7) in the project file (see MIM Data Instructions Guide, Data Analysis Module: Header Tab). The image becomes a permanent record of the DMA's location and aids in relocating existing DMAs. Both field photos and aerial imagery can provide pertinent monitoring information. In situations where riparian conditions are good and management objectives are met, photos may be adequate to document continued achievement of objectives or to verify that the DMA is adequately representative of the entire sensitive complex.

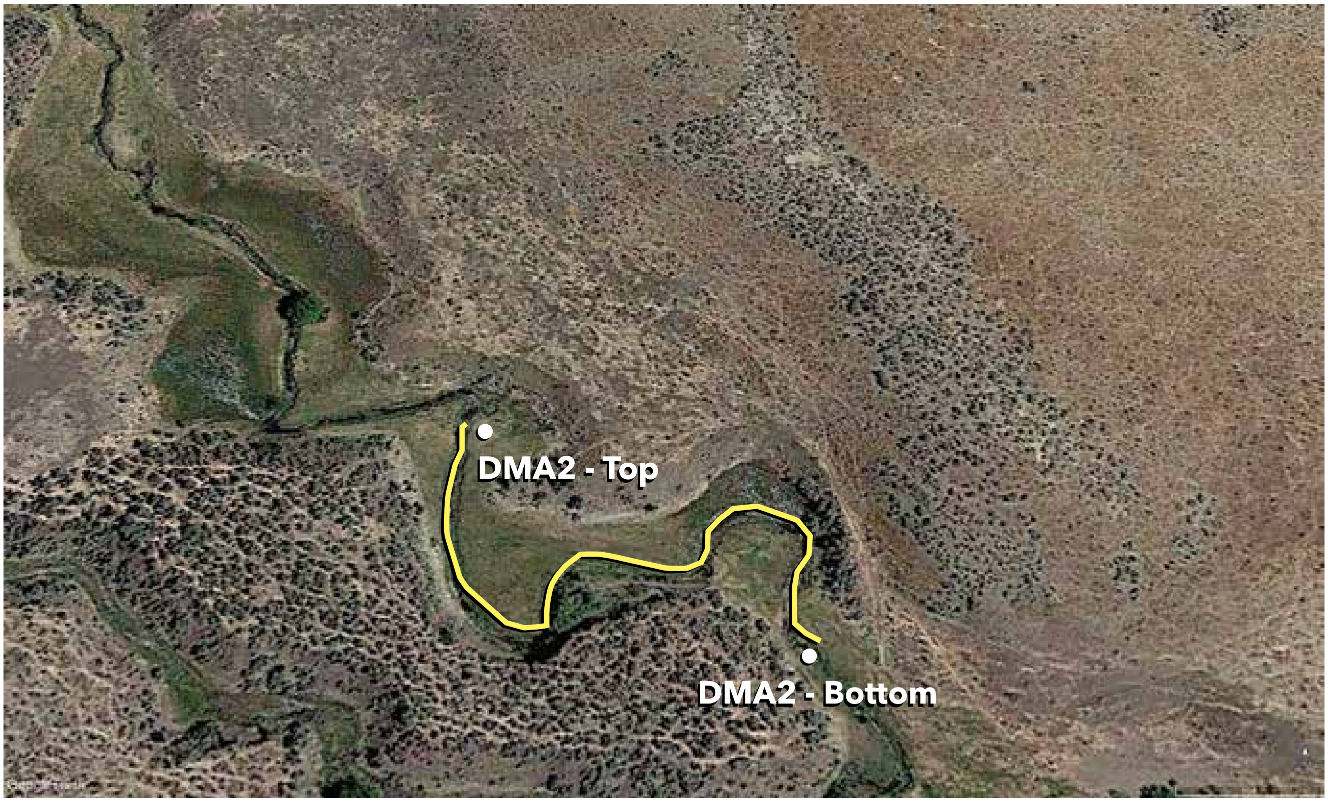

Figure 7. An aerial image (from a drone, airplane, or satellite) can facilitate relocation of a DMA. Using GPS, the latitude and longitude (or UTM coordinates) of the top and bottom markers of the DMA can be recorded to sub-meter accuracy. Additional landmarks, such as meander bends or riparian trees, provide additional navigational aids to relocate DMA markers. Aerial image from Google Earth.

3. Monitoring Guidelines

A rigid, comprehensive list of criteria regarding which indicators to measure, when to monitor, and how frequently to monitor is not appropriate, as site conditions and management issues are highly variable. Therefore, guidelines are provided for practitioners to consider. It is important that an experienced ID team is involved in making decisions regarding which indicators to monitor, when to monitor, and how frequently to monitor. Once these decisions are made, they should be carefully documented. A failure to carefully consider these aspects of monitoring could result in poor and/or erroneous data and ineffectual management decisions.

3.1 Which Indicators to Monitor

Use only the indicators and corresponding methods appropriate for the site that help answer monitoring questions. Some key questions for the ID team to address regarding which indicators to monitor are:

3.1.1 Is the attribute present? Or does it have the potential to be present?

For example, if woody vegetation is not present in any measurable amount, and there is no potential for it to be present, the woody riparian species age class and woody riparian species use indicators would not be used. However, if no woody species are present but the site has the potential for woody species, these two indicators should be monitored to document establishment and subsequent use intensity of woody riparian plants as the site recovers. The presence of any woody riparian plants would indicate a need to monitor both the woody riparian species age class and woody riparian species use indicators, even if sample sizes may initially be too small to inform management decisions (as the site would be early in the recovery process).

Similarly, if herbaceous vegetation is limited at a site dominated by a dense cover of woody vegetation, measuring stubble height on the few patches of herbaceous vegetation present would be of little value. This is because herbaceous vegetation does not significantly contribute to stream function and habitat values on sites dominated by heavy woody cover. Stubble height data would not provide information beneficial for grazing management and sample sizes would be too small to provide useful data. However, herbaceous vegetation would still be recorded in the greenline composition method.

3.1.2 If the attribute is present, is there a related monitoring question?

If the attribute is present, one must define the related monitoring question that needs to be addressed. If there is no monitoring question, collection of data on the attribute may not be necessary. Occasionally, there are instances where the attributes of the indicator are present but don’t provide useful data. For instance, recording substrate on a sand bed stream would not yield useful data, as only one particle size is present. Another example would be recording streambank alteration on a stream composed of cobble-dominated and/or boulder-dominated streambanks that are resistant to alteration. Finally, measuring the three annual grazing-use indicators would be of little value on streams where there is no grazing by livestock or browsing use by wild ungulates.

- **Prior to monitoring, the ID team must review monitoring objectives, desired metrics, and monitoring methods that may already be established in resource management plans, allotment management plans, grazing decisions, NEPA documents, biological opinions, agreements, etc. to ensure that the appropriate MIM indicators are monitored.**

This is important because different monitoring methods can yield different results or metrics that may not match the metrics or descriptive requirements in the respective enabling document(s). For instance, if the prescribed streambank alteration criterion has been established for a stream, the ID team should ensure that MIM streambank alteration is appropriate because there are differences in protocols to measure alteration (and they may yield uncomparable values). Therefore, for many methods, the indicator values, metrics, or grazing-use criteria should also cite the specific monitoring method as they are written.

- **It is recommended that all long-term indicators present at the site be recorded the first time the DMA is monitored.** This is because it may be difficult to determine which indicators may be important at some later date. For example, if substrate data is not collected during the first site visit, and five years later bank stability decreases, it would be helpful to determine how the stream is processing sediment from unstable banks. If no substrate data exist, it would be difficult to analyze this relationship.

- **If the stream is grazed or browsed by any animals, it is recommended that annual grazing-use indicators at the site be recorded each time long-term indicators are measured.** Measuring the three grazing-use indicators adds a relatively minor amount of time and the data can be very useful for providing context to the long-term data for analysis and interpretation purposes. For example, because bank alteration will affect bank stability, it would be important to know how much bank alteration was present to help understand the bank stability metrics that were measured at the same time. The exception would be if the site clearly did not show any indication of ungulate use; in those cases, practitioners may want to simply take a photograph and make a note that there was no visible use.

3.2 When to Monitor

3.2.1 Flow and Disturbance Considerations

The methods in the MIM protocol are designed to be completed at low waterflows. High waterflows obscure greenlines and streambanks. Attempts to collect data during these periods will greatly limit its utility. Significant natural disturbances such as severe flooding or stream impacts from wildfire are not uncommon. These monitoring methods may be used shortly following those events if desired to fully document recovery. However, in many cases, it may be best to postpone monitoring until the stream has started to recover from substantial channel adjustments. This is because considerable erosion may have occurred or sediment deposition may have temporarily buried vegetation, making it difficult or impossible to obtain reliable information or determine the effects of livestock use. In any case, the ID team must determine which approach to use following these kinds of natural disturbances (see Appendix B for more detail).

3.2.2 Phenological Considerations

Because estimates of trend are made at each individual DMA, temporal variation may be introduced if resampling is not done at the same time of year. The best time to sample vegetation composition, when the initial monitoring event establishes a baseline for plant composition, is when the plants are flowering so plant species can be identified more accurately, which may be at different times during the growing season.

3.2.3 Seasonality Considerations

Flowering characteristics may not be as critical once a baseline composition is known. However, to accurately evaluate trend on greenlines, it is important to obtain repeat samples during the same stage of seasonal progression or the same time that baseline data were collected. For example, during the year baseline data were gathered at a DMA, seasonal runoff occurred early and sampling was done about one month after high flows. In future years, every effort should be made to collect data under the same conditions that were present during initial sampling, even if it occurs later or earlier in the season. Thus, if monitoring was previously conducted prior to or well after high seasonal streamflows, then repeat sampling should be conducted at that same time of year to determine trend. Also, to isolate long-term condition data most effectively and reduce "noise" in the data, long-term condition data should be recorded before any significant level of grazing has occurred (if possible).

It should also be noted that measuring some indicators outside of the growing season may be marginally useful. For instance, it is not possible to obtain useful greenline composition data if leaves are not present on deciduous trees.

3.2.4 Management Considerations

Users should also carefully consider the objectives and purpose for gathering the monitoring data when determining the most appropriate time to monitor. For instance, because streambank alteration can influence streambank stability, long-term streambank stability conditions would be most appropriately and accurately monitored prior to livestock use and after the stream has recovered from the previous year's disturbances. In addition, monitoring greenline vegetation on a DMA that has received considerable alteration will cause the greenline to be located farther up the bank and likely in another plant community than if done prior to grazing or after recovery the following year. Users need to understand these relationships, clearly determine why they are collecting data, and how the data are to be used.

Grazing-use indicator data may be collected at a different time than the long-term indicators that provide trend data. Short-term data should be collected when it is appropriate, typically immediately following livestock use; these data will be used to help establish cause-and-effect relationships once long-term data are collected. If the management prescription has a streambank alteration criterion that should be met, monitoring should be done to determine when to move livestock (sometimes referred to as "trigger" monitoring), or as soon as livestock have been removed from the area. This will document the level of alteration on the DMA for that year.

Grazing-use indicators may also be collected while livestock are in a particular grazing unit if move triggers are established and based on annual grazing-use criteria tied to the MIM indicators. Other aspects of timing should also be considered; for example, woody riparian species use data cannot be gathered until the annual growth of new leaders on woody species begins. Also, streambank alteration should be measured as soon as possible after livestock vacate a grazing unit as the alteration features become increasingly less distinct with time, high flows, freeze-thaw cycles, and precipitation events. As another example, if the management prescription requires a certain amount of residual vegetation at the end of the growing season, stubble height would be measured after the growing season has ended and livestock have been removed from the area.

An additional application would be to record herbaceous regrowth. For example, if stubble height is measured both immediately after the use period and at the end of the growing season, regrowth can be calculated from the difference between those two measurements.

3.2.5 Wild Ungulate Use and Other Considerations

If significant wild ungulate use is common at a particular time of year, long-term monitoring should be timed to try and avoid recording data after animals have impacted a DMA. Also, annual grazing-use indicators may be measured prior to livestock grazing so other uses may be estimated separately from livestock uses (e.g., wildlife, wild horse and burro, or recreation impacts). Further, it may be useful to measure grazing-use indicators from the time livestock vacate an area until the end of the growing season.

3.2.6.Summary

Many variables can affect when to measure the indicators, however, several common considerations should be kept in mind when planning monitoring. Long-term condition indicators should generally be measured:

- After spring high flows recede
- When vegetation expression is most obvious
- Before any significant grazing/browsing occurs

Annual short-term grazing-use indicators should be measured when they are most appropriate to inform management.

The most important aspect of determining when to monitor is for the practitioners and the ID team to clearly understand what information is needed and how it is going to be used once obtained. This can be complicated and highly variable, however, taking the time to do this will lead to careful planning and to an efficient and effective monitoring effort.

3.3 How Frequently to Monitor

In general, long-term (or trend) monitoring data should be gathered at 3–5-year intervals, or more often if the occurrence of natural disturbance events needs to be factored into the trend and/or condition (or for other reasons identified by the ID team). Practitioners should consider repeating monitoring following management adjustments, commonly 2 or 3 years after they are established. Riparian areas are resilient and vegetation usually responds quickly following management adjustments, especially in sensitive complexes that are customarily used to locate MIM monitoring sites. Therefore, management actions can be evaluated soon after baseline monitoring, making it possible to establish a trend. More frequent trend monitoring can establish a more definitive trend curve. However, following the initial analysis and interpretation, the long-term monitoring cycle may be extended to every 3–5 years. In some cases, the period may be extended because of slower recovery rates or when less sensitive sites are slower to respond. Ten years should be the longest interval used on any site.

Annual short-term monitoring data (stubble height, streambank alteration, and woody riparian species use) may be recorded annually, or even more frequently. Answers to specific questions (e.g., livestock versus elk streambank alteration) may require some indicators to be monitored two or more times during the year. The frequency and timing of annual short-term monitoring is also addressed under each method.

4. Systematic Procedures, Equipment, and Gear Decontamination

4.1 Systematic Procedures

Whether collecting monitoring data for the first time at a newly established DMA, or revisiting an existing DMA to resample it, individuals should use a systematic approach to collect data. By repeating a systematic approach, observers are less likely to forget a critical step and more likely to become increasingly efficient during each site visit.

Step 1. Develop a list of plant species using standard Natural Resources Conservation Service (NRCS) naming conventions. Assuming the newly established DMA has already been located, monumented, and photographed (Section 2.4), complete a reconnaissance of the DMA and make a list of the most abundant and common vascular plant species along the greenline. This list need not include species found in trace or minor amounts unless these have special significance to management, for example they are endangered species, noxious weeds, or important forage species for wildlife. Use the plant species codes in the USDA-NRCS PLANTS Database (USDA, NRCS 2022), or standardized genus codes, if appropriate. The PLANTS Database species codes are preferable over genus codes, especially when the ***wetland indicator status rating*** (Lichvar et al. 2016), successional status or seral stage, and ***Winward greenline stability rating*** (Winward 2000) characteristics vary widely across a particular genus. In addition to official PLANTS Database species codes, MIM uses some codes to record the occurrence of plant structural-functional groups (for example, MFE for mesic forb early seral, or UG for upland grass) or some non-plant greenline features (for example, RK for rock, WD for anchored wood). The additional codes used in MIM are summarized in Table 2.

While making the list of plant species:

- Avoid trampling vegetation on the greenlines. Where possible, plants along the greenline should be observed from the stream channel, which allows a good observation position at right angles to the streambank and avoids trampling the greenline.
- Identify ***key species*** if recording stubble height and woody riparian species use. Key species are plants that are relatively palatable to grazing/browsing animals, relatively abundant, important for stream/riparian function and habitat, and serve as indicators of environmental and management changes.

If an existing DMA is being reread, use the species list generated from the previous monitoring visit. Complete a reconnaissance to determine if any new species have established along the greenline since the last visit and add new species to the previous species list.

Collect plants or photograph diagnostic features for identification of unknown plants. Record unknown plants as UNK1, UNK2, etc. and collect specimens for identification at the office. After identification, replace the unknown codes with the appropriate plant code.

Table 2. Additional MIM codes for greenline composition.

Code	Name	Wetland Indicator Status Rating*	Successional Status	Winward greenline stability rating†
CAREXRH	Rhizomatous sedge	FACW	Late seral	8.5
CAREXTU	Tufted (clumped) sedge	FACW	Mid-seral	2
JUNCURH	Rhizomatous rush	FACW	Late seral	8.5
JUNCUTU	Tufted (clumped) rush	FAC	Mid-seral	2
MFE	Mesic forb early seral	FAC	Early seral	2
MFL	Mesic forb late seral	FACW	Late seral	8.5
MFM	Mesic forb mid-seral	FAC	Mid-seral	2
MG	Mesic grass	FAC	Early seral	2
MGRH	Rhizomatous mesic grass	FAC	Mid-seral	5
MGTU	Tufted mesic grass	FAC	Early seral	2
MS	Mesic shrub	FAC	Mid-seral	5
NG	No greenline	UPL	Early seral	1
RK	Embedded rock			10
UF	Upland forb	UPL	Early seral	2
UG	Upland grass	UPL	Early seral	2
US	Upland shrub	UPL	Early seral	2
WD	Anchored wood			10

* FAC = facultative; FACW = facultative wetland; UPL = obligate upland

† Winward greenline stability ratings vary from 1 (lowest stability) to 10 (highest stability).

Step 2. Determine the appropriate sampling interval. Random systematic sampling along the greenline and within the channel allows for even spacing to estimate vegetation and site characteristics precisely (Elzinga et al. 1998a). The sampling interval is the distance between quadrats; it should be large enough to make spatial autocorrelation highly unlikely and should generate an adequate sample size to achieve a desired precision. During preparation for the revision of the MIM protocol, the authors studied spatial autocorrelation and sampling intervals at 100 existing DMAs. The results of this investigation are summarized in the MIM Data Instructions Guide, Appendix A. The main findings suggested that the sampling interval should be increased from 2.5 or 2.75 m to 3.75 m for long-term indicators. Consequently, **the default length of the DMA has increased from 110 to 150 m to obtain a desired sample size of 80 per DMA**. This will apply to the establishment of new DMAs. For streams with a GGW > 7.5 m, use a sampling interval of 1/40th the DMA length. For example, a 180-m-long DMA would have a 4.5 m sampling interval (180 m ÷ 40 = 4.5 m).

- For previously established DMAs that are 110 m long or greater with a sample interval of 2.5–2.75 m, the sampling interval should be increased to 3.75 m to eliminate the likelihood of spatial autocorrelation. This will reduce the sample size from 80 to 58 on 110-m-long DMAs.
- For discontinuous channels and vegetated drainageways, use a 150-m-long DMA and a 3.75 m sampling interval for newly established DMAs; sample only in an upstream/upslope direction. For existing DMAs that are 110 m long, the sampling interval should be increased

to 3.75 m to reduce or eliminate spatial autocorrelation; sampling should also be done only in an upstream/upslope direction. This change in sampling interval will reduce the sample size from 80 to 29.

- The three grazing-use indicators (stubble height, bank alteration, and woody riparian species use) and two long-term indicators (streambank stability and cover) generally are unlikely to have spatial autocorrelation with a 2.5–2.75 m sampling interval. If these are the only indicators measured and users are striving for a small margin of error and a more precise estimate of true mean value, a 2.5–2.75 m sampling interval can be used to collect a larger sample.
- As an option, if the sample size is too small or spatial autocorrelation is indicated in the data analysis, then the user can accept spatial autocorrelation as being present in the data. Doing so underestimates the confidence interval calculated for variability in the data collected locally. Analysis of the data then becomes limited to significance testing using the confidence intervals for precision as computed from observer variability (see MIM Data Instructions Guide, Data Entry Module: Spatial Tab).

Step 3. Establish the location of the first sample. The first sample point is randomly selected every time the DMA is monitored. Use a random number generator to select a number from 1 to 5. Beginning in line with the bottom marker of the DMA on the left-hand bank (looking upstream), take that random number of steps within the stream channel. From the front boot tip of the last step, move the frame perpendicular to streamflow toward the streambank and place on the greenline once encountered (see Section 5.2). Place the monitoring frame down with the center bar oriented along the greenline (Figure 8).

Monitor indicators in the following order to minimize movement of the frame and to expedite collection of data: **(1) greenline composition, (2) woody species height class, (3) streambank alteration, (4) streambank**

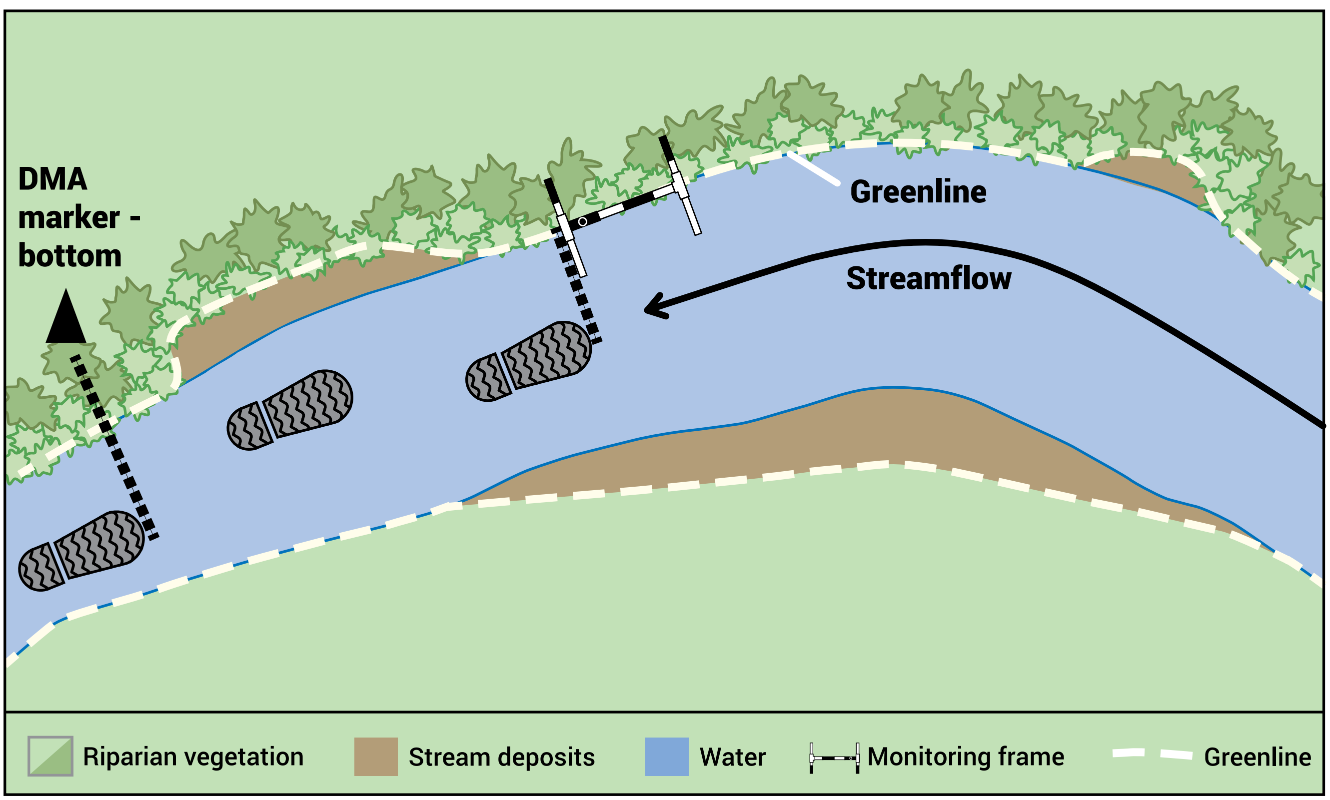

Figure 8. To locate the first sample, begin at the bottom (downstream end) of the DMA and align front of boot with DMA marker. Select random number from 1 to 5. Take a random number of steps upstream (example shows 2 steps). Align the monitoring frame with the front of boot and along the greenline. The center of the frame parallels and falls along the greenline.

stability and cover, (5) stubble height, (6) greenline-to-greenline width, (7) woody riparian species age class, (8) woody riparian species use, and (9) substrate. GGW width is measured only in the upstream direction. Substrate measurements are generally made at only the even sampling locations in the upstream direction. Finally, ***residual pool depth*** and ***pool*** frequency are recorded in a separate pass along the thalweg.

Step 4. Measure the sampling interval. After data have been collected at the randomly located first point, the next sample point is located using a fixed sampling interval. The sampling interval may be measured or paced. A 2-m rod is useful for measuring the sampling interval (see Appendix C for details on construction of a 2-m measuring rod).

The interval between sampling points is measured within the stream channel along the path that approximates the main streamflow, which usually parallels the thalweg (Figure 9). If the streamflow is parallel to the streambank, then the sampling interval could be measured along the streambank. This is easy to do along a straight channel segment but does not work well along meander bends. The rod is used to simplify the measurement of the interval by removing small irregularities (Figure 9).

- If the interval between sampling points is determined by the pacing technique, the observer must first determine their pace, or the distance of each step. To calculate the length of each step, mark a distance, usually 30 m, and count the number of steps over the selected distance. The calibration distance divided by the number of steps determines the length of each step, which is then used to pace the sampling interval. For example, if one makes 40 steps to traverse 30 m, the pace is 0.75 m (30 m ÷ 40 steps = 0.75 m per step). This would equate to 5 steps for a standard 3.75 m sampling interval (5 steps x 0.75 m per step = 3.75 m).
- Pacing is recommended only on those channel beds with a uniform substrate (e.g., a sand-bed stream) that are easily walked and uniformly paced. Highly irregular channel beds are difficult to pace in a consistent fashion.

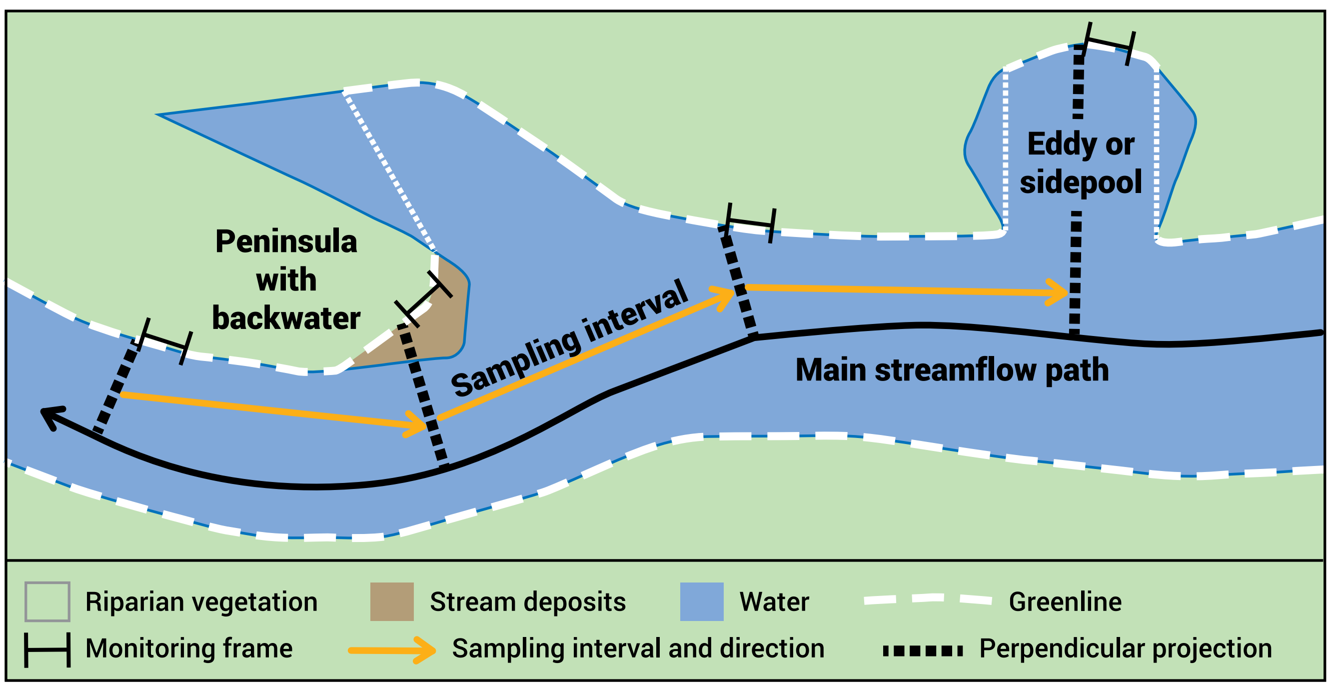

Figure 9. The sampling interval generally follows the main streamflow path. The sampling interval is customarily measured with a 2-m rod, which has the practical effect of smoothing out minor bank irregularities and facilitating even spacing of quadrats. The orange lines depict a default 3.75-m sampling interval. The black dashed lines illustrate the path perpendicular to streamflow toward the streambank and greenline. Note some unusual situations, such as peninsulas (place frame on the outermost streambank) and eddies (measure length based on path of streamflow, not bank length, especially around irregular banks of side pools or eddies).

Step 5. Sample the entire DMA. Monitor along the greenline at the appropriate sampling interval to the end of the DMA. The typical number of samples on each side of the stream is 40, with exceptions (see Layout of the DMA in a Vegetated Drainageway, this section). Also, the top and bottom of the DMA have some additional rules to ensure all observers are following the same procedures.

At the top of the DMA. In most situations, after sampling the last sample point on the left bank (Figure 10, sample #40, for example), measure or pace the distance from the last sample location to the end marker, cross the stream perpendicular to flow and on the right bank, continue measuring or pacing downstream until the sampling interval is reached to locate the next sample (Figure 10, sample #41). For example, if the sampling interval is 3.75 m and it is 1.75 m from the last sample location to the top of the DMA, cross the stream and measure 2 m downstream from the top of the DMA and place the monitoring frame on the greenline (Figure 10). In this example, the (1) greenline composition, (2) woody species height class, (3) streambank alteration, (4) streambank stability and cover, (5) stubble height, and (6) woody riparian age class indicators would all be measured on the right streambank, whereas (7) the woody riparian use indicator would be evaluated on both left and right streambanks from the start of sample #40 to the start of sample #41 (Figure 10).

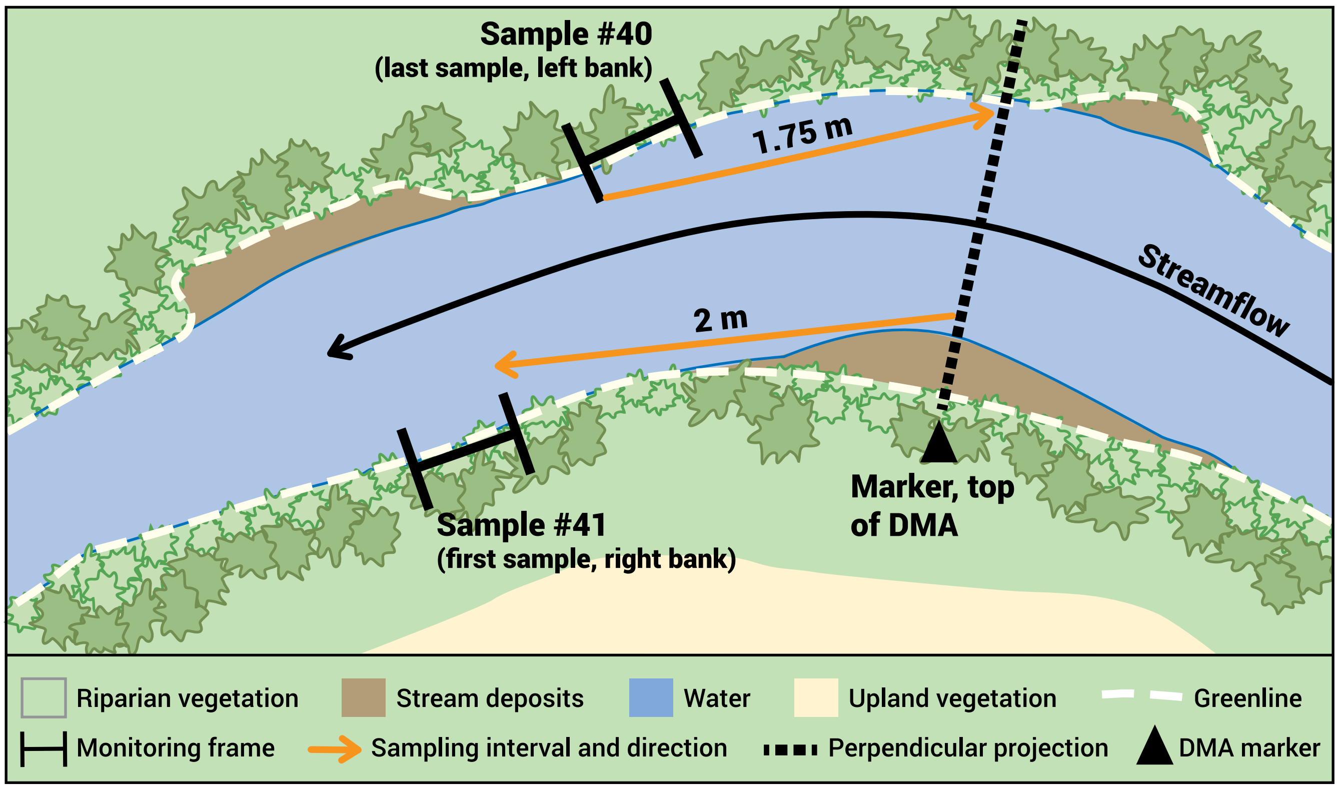

Figure 10. Maintain the sampling interval between quadrats when reaching the top of the DMA (black dashed line). Measure to the top of the DMA, cross over to the opposite bank, and then measure downstream the balance of the sampling interval to locate the next quadrat. A straight line (orange lines) is used to illustrate how a distance would be measured along an irregular greenline. In this scenario, the sampling interval is the default 3.75 m, the last quadrat on the left bank is 1.75 m from the top of the DMA and the first quadrat on the right bank is located 2 m below the top of the DMA (i.e., 1.75 m + 2 m = 3.75 m).

When the sampling frame is less than 1 m from the top of the DMA (see sample point #40 in Figure 11), all the frame-based indicators will be measured on the left streambank, while the woody riparian species age-class indicator (which is evaluated in a 2 m x 1 m quadrat) will be measured at the top of the right bank (Figure 11). Woody riparian species use will be measured on both left and right banks to the start of the next sample point.

Note: The length of the DMA is intended to acquire 80 sample points in total, generally 40 on the left and 40 on the right streambank. However, because the first sample point is randomly selected from the bottom of the DMA and because meander bends can shorten or lengthen the sampled distance along a streambank relative to the thalweg length of the DMA, it is possible to have more or fewer than 40 points on each bank. Nonetheless, it is important to evenly sample the entire length of the DMA. **Do not stop collecting data on one streambank if you reach the 40th sample point before the top of the DMA or the 80th sampling point before the bottom of the DMA**. The entire DMA must be evenly sampled.

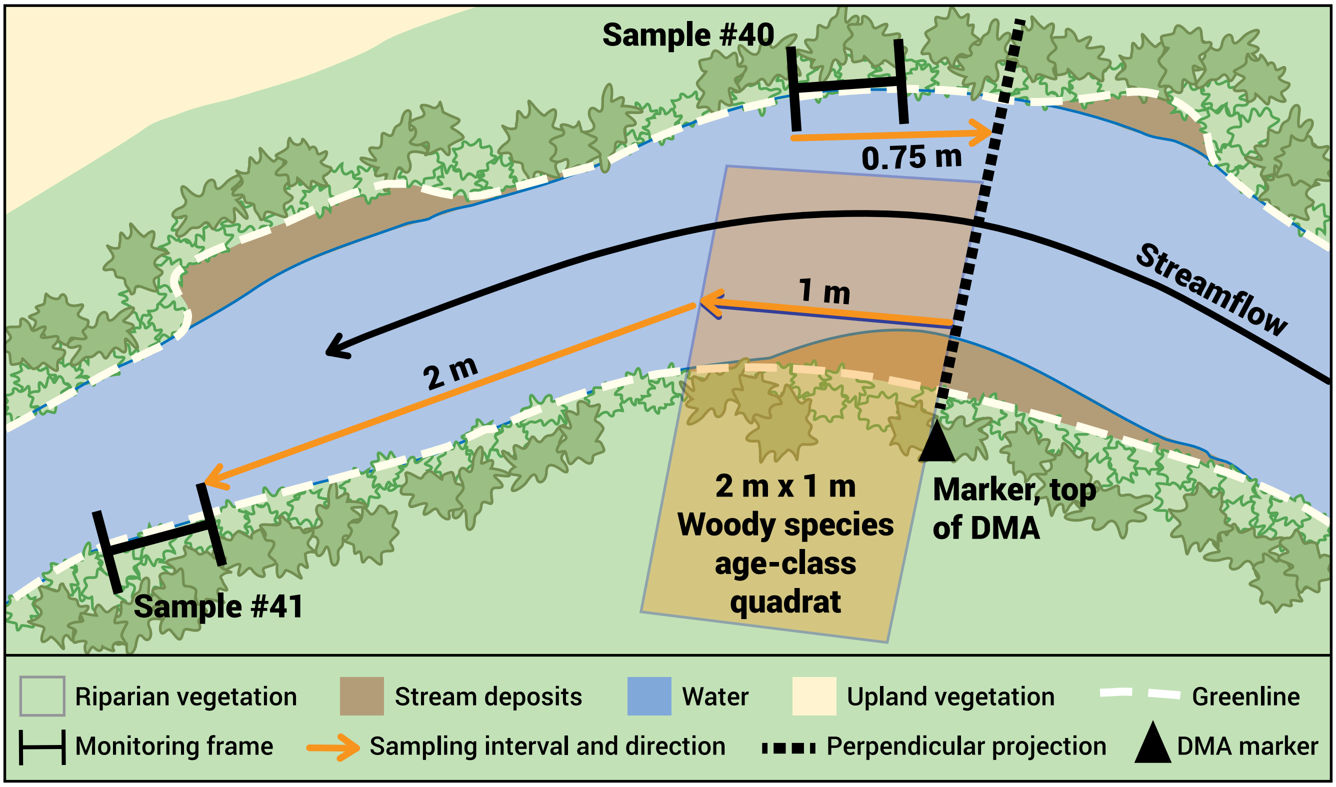

Figure 11. When the sampling frame (here, #40) is less than 1 m from the top of the DMA, all the frame-based indicators will be measured on the left streambank, while the woody riparian species age-class indicator (which is evaluated in a 2 m x 1 m quadrat) will be measured at the top of the right bank. Woody riparian species use will be measured on both left and right banks to the start of the next sample point.

Continue collecting data along the right-hand side (if looking upstream) using the same sampling interval until the downstream end of the DMA is reached. The entire length of the DMA on both sides of the stream is sampled (Figure 12).

When reaching the bottom of the DMA, if any part of the sampling frame extends beyond the bottom of the DMA, stop. Do not collect any more information. If the sampling frame is entirely within the DMA, measure all the quadrat-based indicators. In the case of woody riparian species age class and woody riparian species use, measure only to the bottom of the DMA. Do not extend the quadrats of these indicators beyond the bottom of the DMA. There are several reasons why the area just beyond the bottom of the DMA may not be representative of conditions in the DMA. Therefore, do not collect any information downstream of the bottom of the DMA.

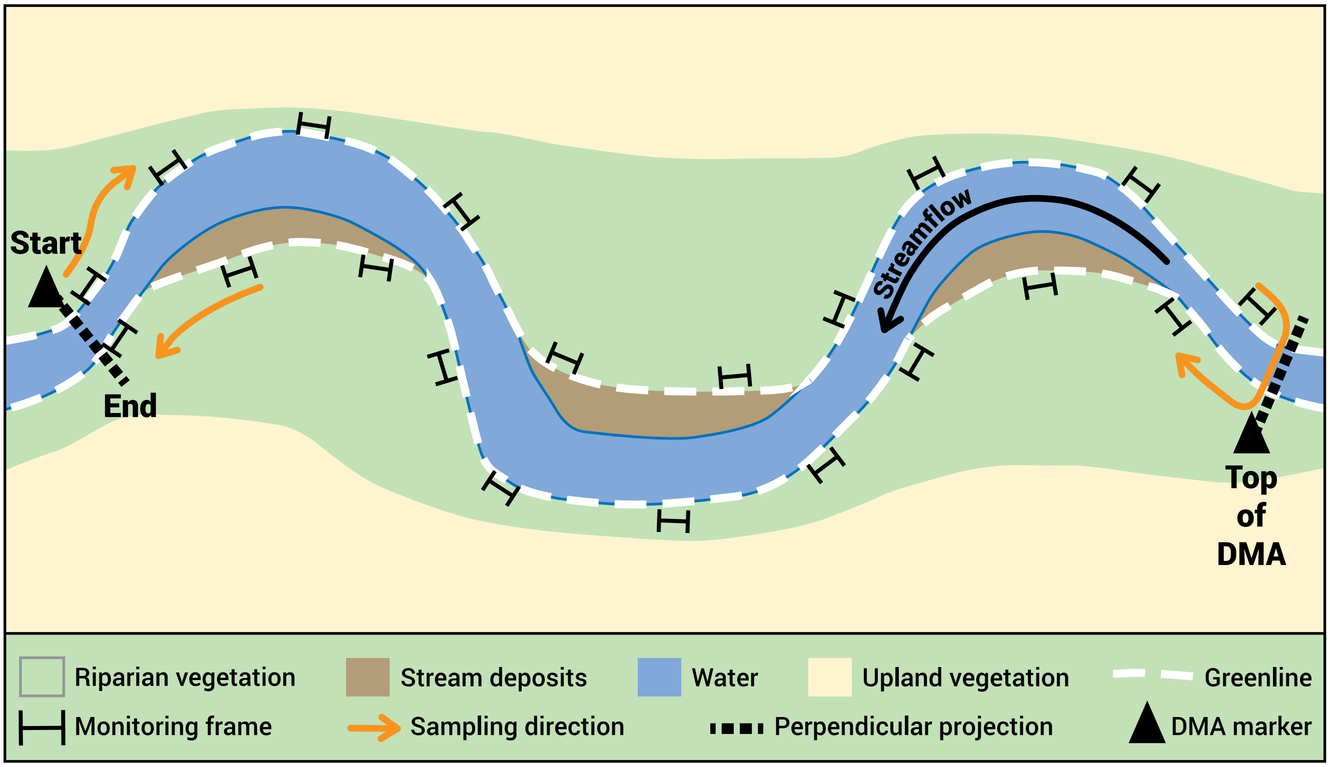

Figure 12. A random systematic sampling design is used for monitoring MIM indicators along the greenline. The first quadrat is randomly located on the left bank (determined looking upstream) and the remaining samples are regularly spaced along the reach using a 2-m rod or pacing technique. The entire DMA is monitored with equally spaced quadrats. For simplicity, only 1 out of 4 sampling quadrats is shown. Approximately 40 quadrats are typically located on each bank.

Layout of the DMA in a Vegetated Drainageway. The MIM procedures for vegetation indicators (i.e., greenline composition, woody species height, stubble height, woody riparian species age class, and woody riparian species use) and streambank alteration can be used in vegetated drainageways that lack a continuous scour channel (Figure 13). Commonly, GGW, residual pool, streambank stability and cover, and substrate are not recorded in vegetated drainageways. However, these indicators could be recorded if the DMA has a combination of vegetated drainageway alternating with sections of scour channels, pools, or wetted flow paths. The GGW would be recorded wherever bare ground, a scour channel, or pool exists along the DMA. GGW is also measured to track the migration of a headcut and upward propagation of an incised stream (Figure 14).

Monitoring along a vegetated drainageway occurs along the greenline, which generally follows the thalweg or deepest part of the drainageway in the absence of a scour channel or pool. The center bar of the MIM frame is placed along the thalweg and vegetation composition, woody species height, and stubble height are measured in the Daubenmire quadrat on alternating sides of the thalweg (Figure 13). Streambank alteration is measured across the entire MIM frame in the quadrats on both sides of the thalweg, whereas the woody riparian age class and woody riparian species browse quadrats are centered on the thalweg, which serves as the greenline (see Section 6 for details on monitoring each of these indicators).

When collecting data in a DMA in a vegetated drainageway, monitoring occurs only in an upstream or upslope direction to avoid resampling of the greenline in the downstream/downslope direction. This will result in a dataset of approximately 40 sample points for most MIM indicators. The authors' test data indicate that vegetated drainageways tend to be fairly homogenous. A reasonably precise dataset can be acquired from these types of sites with fewer samples than are needed for scoured channels that contain alternating ***point bars, cutbanks, pools, and riffles***. Because fewer samples are collected, the data will need to be evaluated carefully to determine if the DMA should be extended beyond 150 m to acquire a larger dataset. It is best to make this decision a priori, that is, to run some test data prior to sampling the entire DMA. If the sample size targets are higher than 40 sample points, expanding the DMA length to get more samples may be warranted.

Figure 13. In vegetated drainageways, the greenline follows the thalweg (dashed line). Vegetation composition and cover, woody species height class, and stubble height are read in quadrats (see blue quadrats) on alternating left and right sides of the thalweg.

Figure 14. Two examples of headcuts. Headcuts commonly appear in degraded vegetated drainageways. Headcuts represent the upstream extent of channel incision. Left unchecked, headcuts tend to continue to migrate upstream/upslope through vegetated drainageways until they reach some grade control. Measuring GGW can document migration of headcuts and elongation of an incised channel through a vegetated drainageway.

If bare ground, a pool, a short interval of scoured channel, or flow path interrupts a vegetated drainageway, the greenline will be at the water's edge or normal greenline position (Figures 15 and D.24). Again, sample only in the upstream/upslope direction and alternate left and right sides of the channel.

Figure 15. A vegetated drainageway with discontinuous pool or scour channel. The greenline follows the thalweg (orange-dashed line) through the vegetated drainageway but then splits to go on alternating sides of the scour channel or pool (white-dashed lines). Sampling locations alternate between left and right sides of thalweg or alternating sides of pools/scour channels.

Step 6. Evaluate the precision level based on the sample size. After sampling the entire DMA, check the sample-size estimator, which is programmed into the data entry module, to determine the precision of the data for several indicators (i.e., for those that produce a mean or proportion). In general, the more samples measured in the DMA, the smaller the margin of error and the closer the mean should be to the true population mean. Therefore, a larger sample will more precisely estimate the true mean value for an indicator. Too small a sample can result in a wide confidence interval making it more difficult to detect change. The sample-size estimator in the data entry module uses for its confidence interval (or margin of error) the value derived from testing of observer error for the indicator (see MIM Data Instructions Guide, Chapter 3). This is basically the precision of the metric or indicator. The default confidence level is set at 95%. Therefore, if the sample size estimated in the module from the data being collected at the DMA is larger than the number of samples actually collected, then the user has the option to increase the sample size by permanently expanding the length of the DMA. The other option is to complete the DMA with fewer than the number predicted from the sample-size estimator, which will result in a wider margin of error than derived from observer variation. This latter option is preferrable when detecting change is less important than the time spent to acquire more samples or when expanding the DMA is not possible due to limited availability of space. The sample-size estimator and data entry module are discussed in greater detail in the MIM Data Instructions Guide, Chapter 3.

The advantage of a lower confidence level is that it produces a narrower, more precise confidence interval; however, the disadvantage is that it has lower confidence for estimating the population parameter (mean or proportion) that you are interested in. Therefore, select a lower confidence level only if the advantage of more precision is greater than the disadvantage of lower confidence, which generally occurs when it is not advantageous, or not possible to collect a larger sample size (e.g., when there is a limited number of woody plants available in a DMA).

- **Note:** Additional samples are not collected within the DMA due to potential issues with spatial autocorrelation. To obtain more samples, extend the length of the DMA.
- In many cases, some or most indicators might have an adequate sample size for the user-defined confidence level and only one or some indicators do not. The user does not have to necessarily lower the confidence level for all indicators, only for those where the sample-size estimator indicates a problem.

4.2 Equipment

4.2.1 Required equipment

The following items are necessary or recommended for collection of MIM indicators in wadeable streams. Specifications for personal field equipment and supplies (e.g., clothing, sunscreen, beverages, food, first aid kits, and emergency response/communication devices) vary considerably depending on field location or preference and are not explicitly listed here.

- **Data recorder** (tablet, laptop computer, or data logger) – There are no requirements other than the data recorder must be able to run the data entry modules. Ruggedized data recorders are recommended. Ruggedized recorders should be designed for:
  - Dusty and wet environments
  - Bright sunshine
  - Extreme high and low temperatures
  - Extended battery life (8 or more hours of continuous use per day)
- **MIM frame** – A 42 cm x 50 cm H-shaped frame with 1-m handle (Figure 16.A). Instructions for construction of a collapsible MIM frame using PVC pipe are provided in Appendix C.
- **2-m measuring rod** – The rod should have 1-cm and 10-cm divisions (Figure 16.B) and can be a single piece of wood or PVC. For convenience of transportation, many rods are broken down into two pieces. Instructions for construction of a collapsible, two-piece, 2-m rod using PVC parts are provided in Appendix C.
- **Waders and wading boots** – Depending on the presence and depth of water, personnel should have appropriate footwear (e.g., hip, waist, or chest waders) to monitor the stream, including the deepest pools in the DMA. Some states have restricted the use of felt-soled waders; observers must read and comply with the respective state regulations.
- **Ruler** – Preferably a two-sided ruler with inches and centimeters on opposite sides (Figure 17.A.). A folding carpenter's ruler is easy to transport and use in the field. It is important that the edge of the ruler begins at '0' and does not include a border or margin that offsets the zero mark. A metal fastener at the edge of the ruler will extend the life of the ruler (Figure 17.B.).
- **Camera** – Bring a camera or use the camera built into some data recording devices. Photographs of the DMA are required. Additional photographs of particular features, conditions, plants, or unusual situations are encouraged.
- **GPS device** – A GPS device with submeter accuracy (desirable, but not mandatory) is used to establish the upstream and downstream ends of the DMA, as well as any reference markers. The GPS could be built into the data recording device.
- **Laser rangefinder** – A +/- 0.1-m-precision, engineer-grade laser rangefinder (Figure 18)

with metric units having the capacity to measure horizontal, vertical, and slope distances and a vertical height calculator. The rangefinder is used to record distances for pool frequency. It is helpful whenever GGW measurements routinely exceed 4 m, a channel is especially deep, or a bed is especially hard to walk across due to large irregular particles or slippery mud. Finally, a laser rangefinder with a vertical distance or height calculator can be used to determine the woody height class of tall trees and shrubs.

- **MIM Technical Reference** – This technical reference (BLM TR 1737-23, Version 2).
- **MIM Field Guide** – This is a condensed field booklet containing only the MIM rule sets for the 10 methods. Field personnel should bring an electronic or paper copy of the MIM Field Guide to the field.
- **MIM data forms** – Paper copies of the MIM data forms are recommended as a backup if a technical difficulty arises with a data recorder. See the MIM Data Instructions Guide, Appendix C for copies of the data forms.
- **Chargers** – Both wall outlet and vehicle charging devices or a portable power bank are recommended. The best practice is to fully charge all electronic devices prior to use.
- **Batteries** – Bring fresh replacement batteries for all battery-operated devices.

4.2.2 Optional equipment

The items listed below are not essential but are useful and can save time in certain monitoring situations or for certain indicators.

- **Gravelometer** – A millimeter-scale gravelometer is used to measure the substrate or particles on the channel bed. It is a metal frame with precise openings ranging from sand to cobble sizes. Gravelometers provide for increased observer agreement and higher precision substrate measurements (Figure 19). A carabiner or clip attached to a belt or waders provides a handy way to carry a gravelometer and to keep hands free while performing other measurements and observations.
- **Densitometer** – A densitometer (Figure 20) with a leveling bubble is used to identify if trees and shrubs are directly over the monitoring frame when determining greenline composition and cover. This device is especially helpful when large trees with high canopies are found at a DMA.
- **Hand lens** – A hand lens (6x to 10x) is helpful in examining plant details to identify plants to the species level.
- **Field map/aerial image/georeferenced photos** – A high resolution field map or aerial image showing the location of the DMA and latitude and longitude of the DMA markers is helpful in relocating DMAs. Photos previously taken at the top and bottom of the DMA are also helpful in relocating DMAs.
- **Plant guides** – Local or regional plant guides and the MIM Plant List are recommended, as plants should be identified to the species level whenever possible and practical.
- **Plant press** – A plant press is useful as plants should be collected to develop a local herbarium of riparian vegetation or to collect unknown species for subsequent identification.
- **Plastic sample bags** – Used to collect and temporarily store unknown species of plants (preferably kept in a cooler until identified).
- **Line level** or **hand level** – A level (Figure 21.A.) can be used with a 2-m rod, mason line, or measuring tape to measure residual pool depth and frequency in dry channels (see Section 6.2.7).
- **Mason line** – A mason line (Figure 21.A.), 2-m rod, or measuring tape can be used to measure residual pool depth and pool frequency in dry channels (see Section 6.2.7).
- **Measuring tape** – A 10–150 m-measuring tape (Figure 21.B.) can be used to measure GGW (see Section 6.2.5), to determine the active channel width and sampling interval for substrate (see Section 6.2.6), or to measure

pool frequency in dry channels (see Section 6.2.7). Tapes with a metal end hook or end loop are preferable so the tape can be staked, pulled taut, and operated by a single individual.

- **Survey or chaining pins** – Pins are handy to secure measuring tapes, tag lines, or mason lines or to temporarily mark features or locations.
- **DMA markers** – DMA markers (Figures 22.A–D) are used to permanently mark the upstream and downstream ends of the DMA, as well as reference markers. Avoid using rebar with an exposed end, as it can injure people and animals and can puncture tires. Capped rebar, capped pipe, t-posts, and similar markers are recommended for their durability and safety.

4.2.3 Recommended supplies

The following supplies are recommended when conducting MIM fieldwork.

- Binoculars
- Backpack or handbag – to organize and transport equipment
- Pliers – to disassemble frozen PVC parts of the MIM frame or rod
- Clipboard
- Electricians tape – to mark MIM frame and handle
- Field vest, multi-pocket for carrying miscellaneous field supplies and equipment
- Notebook
- Pencil
- Permanent marker
- Pin flags or flagging
- Sledgehammer (3–5 pound) or large framing hammer – to install DMA markers
- Wading staff
- Two-way radios

Figure 16. A MIM frame and a 2-m measuring rod.
A. An H-shaped MIM frame with a 1-m-long handle, constructed from PVC material.
B. A 2-m measuring rod.

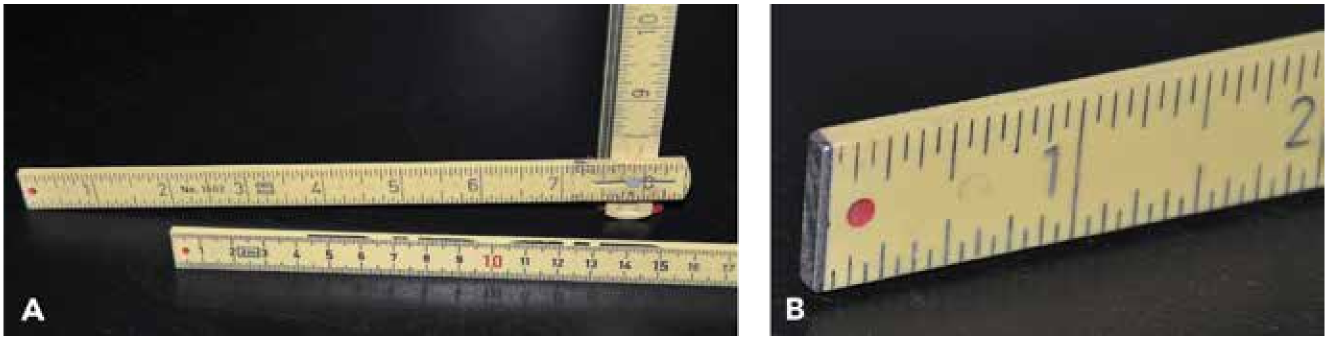

Figure 17. Images of a carpenter's ruler.
A. A folding carpenter's ruler with centimeters and inches on opposite sides is versatile in collecting MIM data. B. A close-up of a carpenter's ruler showing the end beginning at "0" and the tip reinforced with metal edge for durability.

Figure 18. A precision laser rangefinder. The laser rangefinder is useful in laying out DMAs, measuring GGW and residual pool depth and frequency, and measuring the active channel width to collect substrate data.

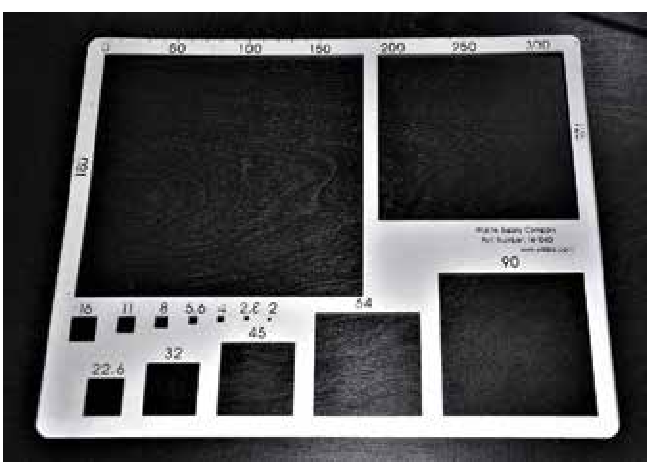

Figure 19. A gravelometer used to measure substrate.

Figure 20. A densitometer. Densitometers provide a bull's-eye leveling bubble and sighting cross hairs to determine if overstory plants are directly overlying sampling quadrats.

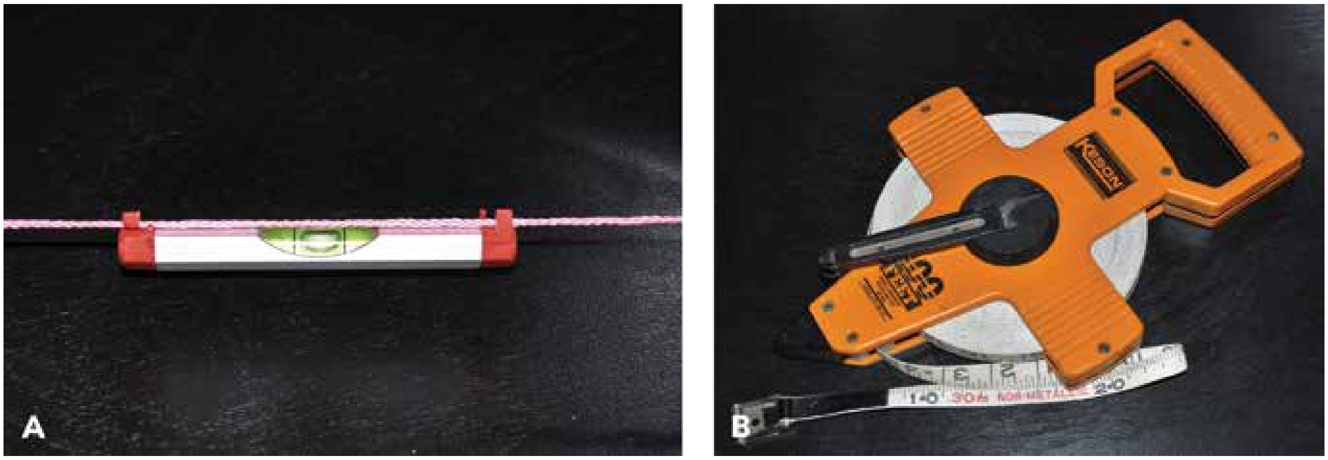

Figure 21. Examples of measuring tapes and lines.
A. A line level attached to a mason's line.
B. A measuring tape with both metric and standard units provides flexibility in the field. Minimum practical length for a measuring tape is 10 m.

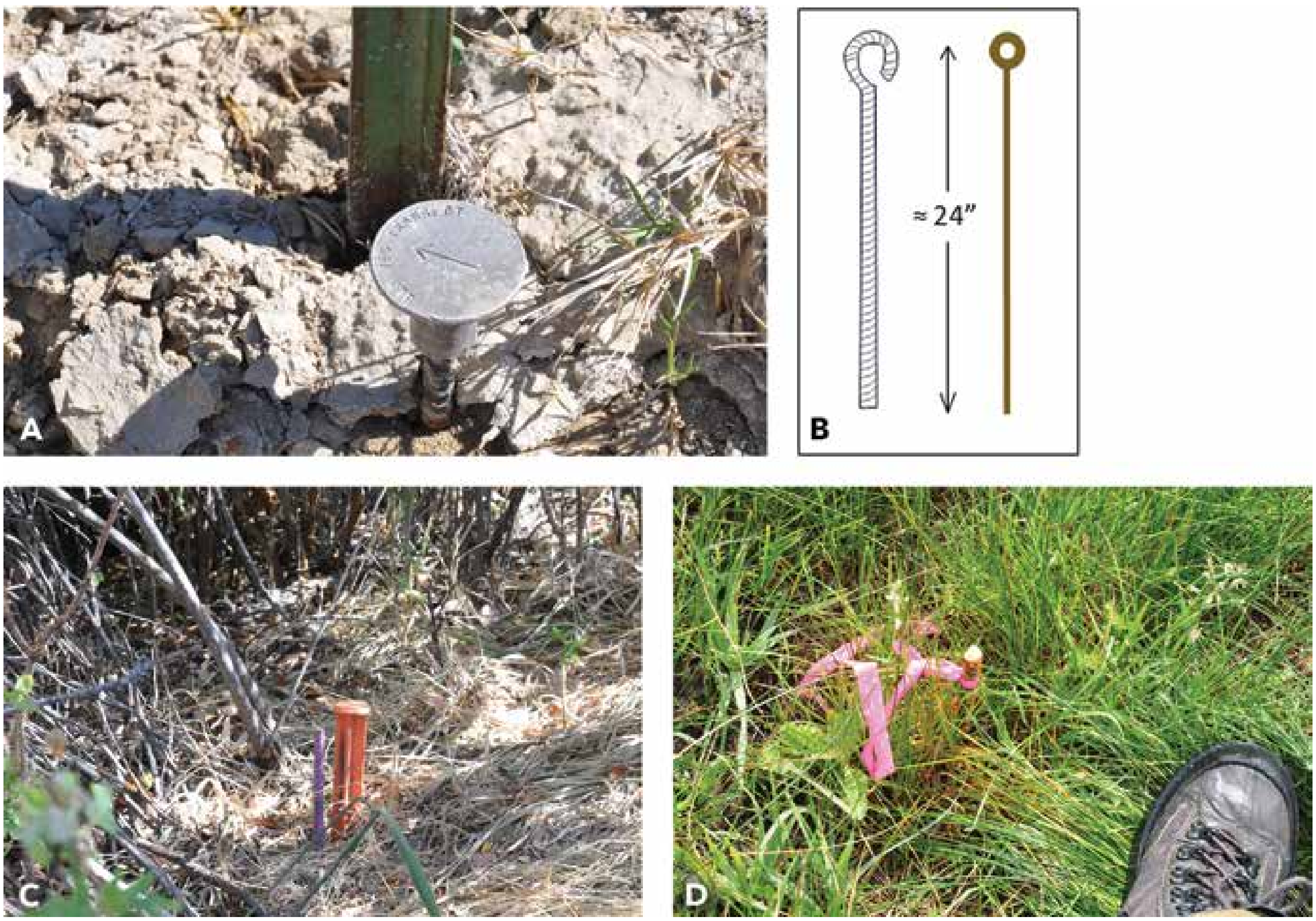

Figure 22. Examples of materials used to permanently monument or locate a DMA.
A. A t-post beside a rebar stake with an aluminum cap. The aluminum cap is stamped with an identification number for the DMA.
B. Tightly bent ¾″ rebar (left) or ¾″ rope stakes (right). If using rebar, a machine shop can cut, heat, and bend the rebar to form the tight loop. This is important to allow the stake to be driven effectively with a hammer; both A. and B. are safe and durable options.
C. Plastic peg and rebar placed side-by-side under a shrub and out of the path of animals. Plastic pegs are safer than straight rebar, but they also can burn in a fire.
D. A straight piece of rebar is not recommended; it can pose a hazard to people, animals, and tires.

4.3 Gear Decontamination

Gear decontamination is important to prevent the spread of aquatic invasive species (AIS). However, there are some factors to consider when determining the need and frequency of decontamination.

How many field sites will be visited in a day and how much time will elapse between field visits? Complete air drying for multiple days (one week or longer) is effective at killing most AIS. Therefore, one site visit per week is generally considered low risk for spread of AIS.

Is field work concentrated in one stream or one watershed? Given the mobility of AIS, continuous work in the same water body is not likely to contribute to AIS spread. The time to decontaminate gear is when work in one water body ends and before work begins in another water body or watershed.

Is the field work being conducted in water bodies with known AIS? Is the area absent of any AIS survey data? There is a difference between a known status that concludes no AIS detected through testing and observations, versus an unknown status due to a lack of recent testing and observation. If the status is known and AIS is present, or status is unknown, err on the side of caution and decontaminate gear.

To prevent the spread of AIS such as didymo or rock snot (*Didymosphenia geminate*), Chytrid fungus, whirling disease, or Zebra or Quagga mussels (*Dreissena polymorpha* and *Dreissena rostriformis bugensis* respectively), disinfect gear that has come in contact with water, either between reaches or before entering a different watershed, especially in areas with known AIS.

Quaternary ammonium compounds (or quats) are a group of chemicals that provide chemical control of a broad spectrum of AIS. There are many quats on the market, including Green Solution High Dilution 256, Sanicare Quat 128, HDQ, and Super HDQ. This is not a comprehensive list, and the authors make no commercial endorsements. The important thing to note is that quats are a widely used and preferred chemical for gear contamination due to their low corrosive nature and effectiveness. Personnel using these products should read product information to determine the desired concentration, shelf life, and handling and disposal requirements for the decontamination solutions. **Consult the product label and Safety Data Sheet (formerly Material Safety Data Sheet or MSDS) for additional information**.

4.3.1 General Practices and Guidance for all Quaternary Ammonium Compounds.

Specific equipment for decontamination may vary, but some general equipment includes:

- Quaternary ammonium compound of choice
- 2–5-gallon mixing jug
- 1-gallon pump sprayer (type used in the application of herbicide solutions; optional)
- Personal protective equipment (rubber, chemical-resistant gloves; goggles)
- Long-handled scrub brush to remove soil, vegetation, and debris
- Tap water
- Large tub (40-quart or larger) for soaking gear in disinfectant
- Funnel to return disinfectant solutions back to mixing jug
- Quat check 1000 strips to test solution strength and to determine when solutions should be replaced

4.3.2 Disinfection Method.

1. Read all product information, handling and disposal requirements, product label, and Safety Data Sheets before mixing solutions. Use appropriate personal protective equipment when handling disinfectants. Before leaving for the field, prepare a quat solution to the desired concentration. Mixing can be done in a 2–5-gallon jug or in

a 1-gallon pump sprayer depending on the decontamination method selected.

2. Prerinse and scrub gear to remove mud, vegetation, and debris.
3. In a safe location (at least 100 ft from a water body), soak gear in large tub or spray gear with pump sprayer. Allow at least 10 minutes of contact with disinfectant. Scrub gear while soaking to ensure complete contact with disinfectant.
4. Remove gear and return disinfectant from soaking tub to mixing jug using a funnel to minimize spillage and skin contact.
5. Check concentration of the used solution with quat check 1000 strips. Properly discard of and replace solutions that have lost desired potency. See product label for disposal. Most quaternary ammonium solutions can be dumped into a drain that leads to a wastewater facility.
6. Rinse equipment with tap water, if possible, upon return to the office. Rinse water should go into a drain that leads to a wastewater treatment facility and should not lead to a waterway or storm sewer.

4.3.3 Safety Precautions.

Concentrated quats contain toxic ingredients. Read product label and consult product Safety Data Sheet before handling. In general, when handling concentrated quats wear personal protective equipment and:

- Do not swallow or ingest quats. If swallowed, rinse mouth, do not induce vomiting, and contact poison control (800-222-1222) if necessary.
- Do not inhale concentrated quats. If inhaled, move to fresh air and rest in a comfortable position.
- Avoid skin and eye contact. If compound comes in contact eyes or skin, rinse with fresh water for several minutes.

5. Locating the Greenline

Locating the greenline is key to using the MIM protocol. Most of the monitoring methods in this protocol require the identification of the greenline as a reference point for collecting data.

5.1 The Significance of Monitoring at the Greenline

The greenline as defined by Winward (2000) is the "first perennial vegetation that forms a lineal grouping of community types on or near the water's edge." Given the annual scour of the stream, this line often forms at or just below the ***bankfull level*** of the stream channel. The greenline often coincides with the presence of water in the plant rooting zone, which allows for the growth of robust, ***hydrophytic*** plant species with deep roots that resist the erosive forces of the stream (Winward 2000). Plant species distribution in arid and semiarid ecosystems is largely controlled by the availability of water from groundwater or instream sources (Jewett et al. 2004). As stated by Cagney (1993):

> Typically, a soil moisture gradient is exhibited when moving away from the channel in a riparian area. In a trend transect placed in a typical western floodplain, a different soil moisture could conceivably be encountered at each quadrat. Attempting to average the vegetation found in these divergent quadrats into a single set of data can be problematic. The greenline is a point of reference that minimizes problems associated with changing moisture gradient.

The greenline represents a particularly critical location for monitoring. Sampling along the greenline minimizes problems associated with the steep moisture gradient oriented perpendicular to the channel, allows for more efficient monitoring, and produces results that best reflect grazing influences and other disturbances. Because changes occur on the greenline more rapidly, a land manager can make an early evaluation of effects (Winward 2000). Livestock and other ungulates are attracted to streamside areas, which can affect the condition of streamside vegetation, streambanks, and the streambed (Wyman et al. 2006; Clary and Kruse 2004; Platts 1991). Not only is the riparian ecosystem affected, but the channel and stream habitat are also strongly influenced by actions at this location. Changes to riparian vegetation at the greenline may also result in: (1) accelerated streambank erosion, (2) increased width/depth ratios, (3) altered channel patterns, (4) increased sediment supply, (5) decreased sediment transport capability, and (6) damaged fisheries habitat (Rosgen 1996). Conversely, positive changes to riparian vegetation at the greenline could result in improvement of all six of these attributes.

The formation of the greenline is strongly influenced by the flood regimes of the stream and sometimes occurs at the bankfull level. The shape of the channel cross section reflecting the bankfull level is related to the annual flood level. As stated by Rosgen (1996):

> The term bankfull was originally used to describe the incipient elevation on the bank where flooding begins. In many stream systems, the bankfull stage is associated with the flow that just fills the channel to the top of its banks and at a point where the water begins to overflow onto a floodplain.

The energy of the stream tends to peak at bankfull discharge, causing the formation of a trapezoidal- or rectangular-shaped channel. Vigorously growing vegetation at the channel margin is constantly attempting to expand in distribution, even into the channel, but the energy and saturation of the ***active channel*** (a short-term geomorphic feature formed by prevailing stream discharges and typically along the edge of permanent vegetation; Lawlor 2004) inhibits or limits encroachment. This process contributes to formation of the greenline. Stream channels associated with highly variable streamflows within season and from year to year, such as arid channels in the Desert Southwest or channels that often discharge high volumes of sediment, may form complex greenlines. These greenlines vary in elevation along the margins of the channel and occur commonly in a less stable streambank environment.

The greenline does not necessarily conform to the bankfull level within the channel because the first vegetation may occur above or below the bankfull elevation. The primary purpose of the greenline is to have a consistent sampling point to monitor vegetation and other stream attributes.

The greenline was selected as a monitoring location because data suggest that observers more consistently identified the greenline than the bankfull position on the streambank (Henderson 2003), thus improving the precision. The authors found good agreement among observers in locating the greenline (authors' unpublished data). Tests of observer variation for GGW resulted in a mean difference among trained observers of 0.26 m and an average 95% confidence interval of 0.45 m (see MIM Data Instructions Guide, Observer Variation).

5.2 Rules for Establishing the Greenline Location

5.2.1 Defining the Greenline

The greenline is generally defined as a linear grouping of live perennial vascular plants, embedded rock, or anchored wood on or near the water's edge (adapted from Winward 2000). It often forms a relatively continuous line of perennial vegetation adjacent to the stream (Cagney 1993; Figures D.1. and D.2.). Individual linear groupings of perennial vegetation are considered part of the greenline when they meet the rules described in this section. The greenline can also be composed of partially or entirely embedded rock and/or anchored wood. For incised streams, the greenline may be located above the floodplain on a ***terrace*** (Winward 2000). In these cases, the greenline may include, or be limited to, non-hydrophytic species (i.e., upland species). See Appendix D for greenline examples.

The greenline may occur on either a flat or sloped surface. In addition, there is a list of other specific conditions or features that will further define the greenline (e.g., roots, bases of overstory woody plants, presence of ***slump blocks***). Those features are defined in Sections 5.2.3 and 5.2.4.

5.2.2 Placing the Monitoring Frame on the Greenline

A frame is placed on the greenline to designate the sampling or observation point. The monitoring frame consists of two side-by-side, 20 cm x 50 cm Daubenmire quadrats (Figure 23), which are commonly applied to vegetation sampling. The 50-cm-long center bar of the frame is placed on the greenline (Figure 24). Elzinga et al. (1998a, p. 103) stated: "It is best if the quadrat length (i.e., the length of the long side of the quadrat) is longer than the mean distance between clumps." Because streamside vegetation is usually high in spatial density, a quadrat 50 cm in length is adequate to avoid empty spaces between clumps and small enough to be reasonably efficient. Details for constructing the frame are found in Appendix C.

At the selected sample interval, the greenline is located by moving the monitoring frame in a direction perpendicular to the streamflow, up the streambank to the location closest to the channel that meets the greenline rules described in Section 5.2.3. Note that when there is no streamflow, use the thalweg to approximate the direction of streamflow. If there is no qualifying greenline within 6 m slope distance (the length of the slope as measured along the ground from the water's edge or from the scour line if the channel is dry), there is no greenline (see 5.2.4).

See Section 4.1 for establishing and measuring the sample interval. The center bar of the monitoring frame is placed along the edge of the perennial vegetation, embedded rock, and/or anchored wood, or at the base of the overstory shrubs or trees (in accordance with the other greenline rules in Sections 5.2.3 and 5.2.4) (Figure 24).

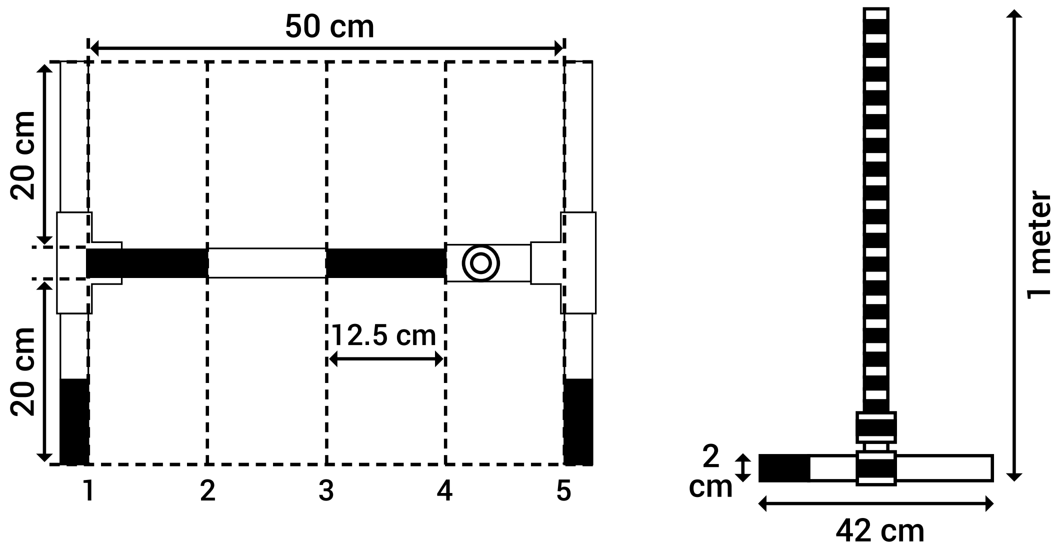

Figure 23. A multiple indicator monitoring (MIM) frame. Based on field experience, this is the preferred frame configuration. It is light, easy to carry, and easy to manipulate in herbaceous and shrub type vegetation. Dashed lines are visualized and not part of the actual frame. Observers must be careful to extend these lines within the confines of the frame.

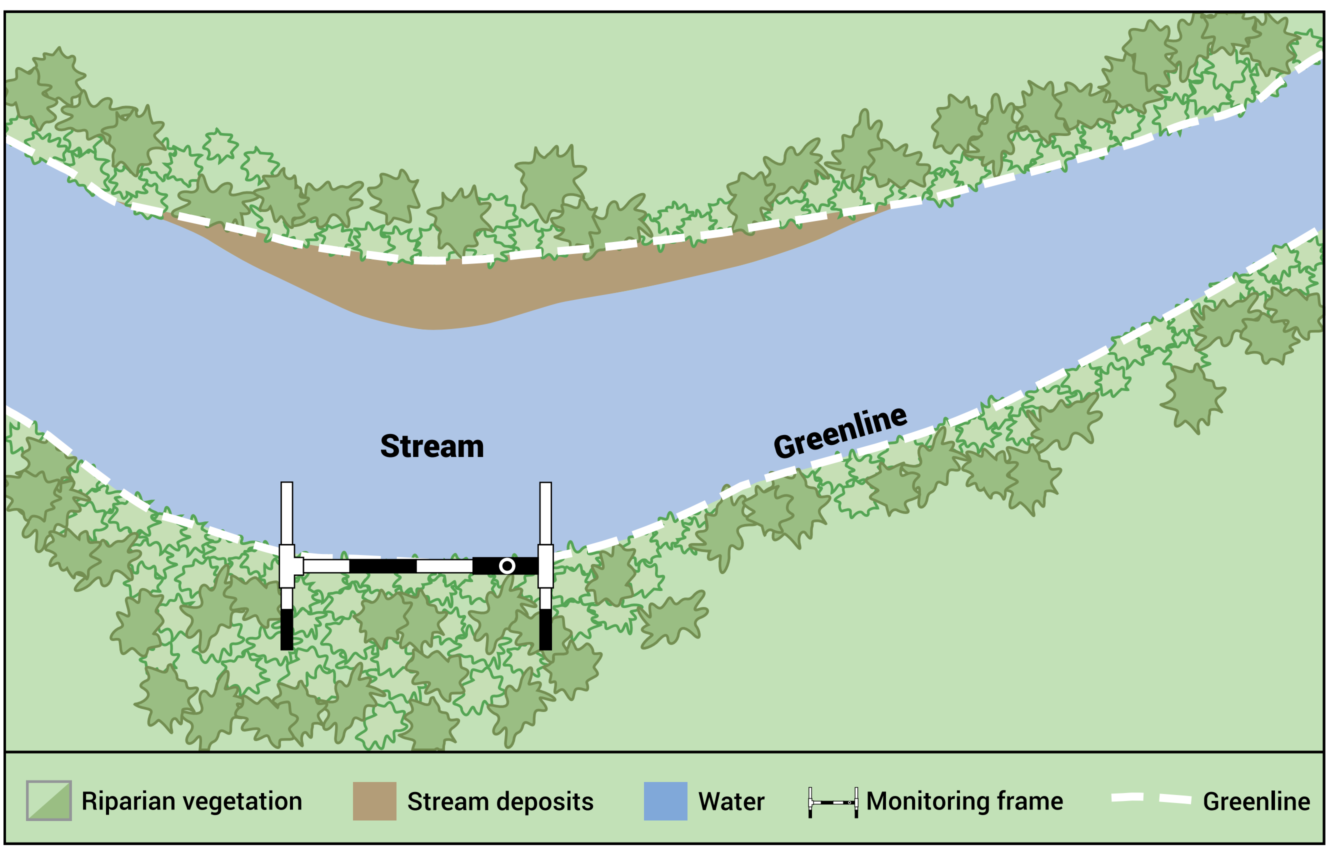

Figure 24. MIM frame placement. The monitoring frame is placed with the center bar on the greenline.

The greenline must be aligned roughly parallel to the stream. Sometimes the linear continuity of the streambank is interrupted by side/eddy pools and bank scallops. Where this occurs, the frame is placed such that it does not exceed an angle of 75 degrees to the streamflow (Figure 25). However, the greenline must also maintain its linear characteristics. Where these side/eddy pools or bank scallops exist, this is accomplished by establishing the greenline as a nonoverlapping, interrupted line along the stream when viewed from above (Figure 25). The sampling interval is measured within the active channel, so it is important that the greenline sampled maintains a linear, non-overlapping progression up and down the bank from a planimetric (or bird's-eye) view (Figures 25 and D.3).

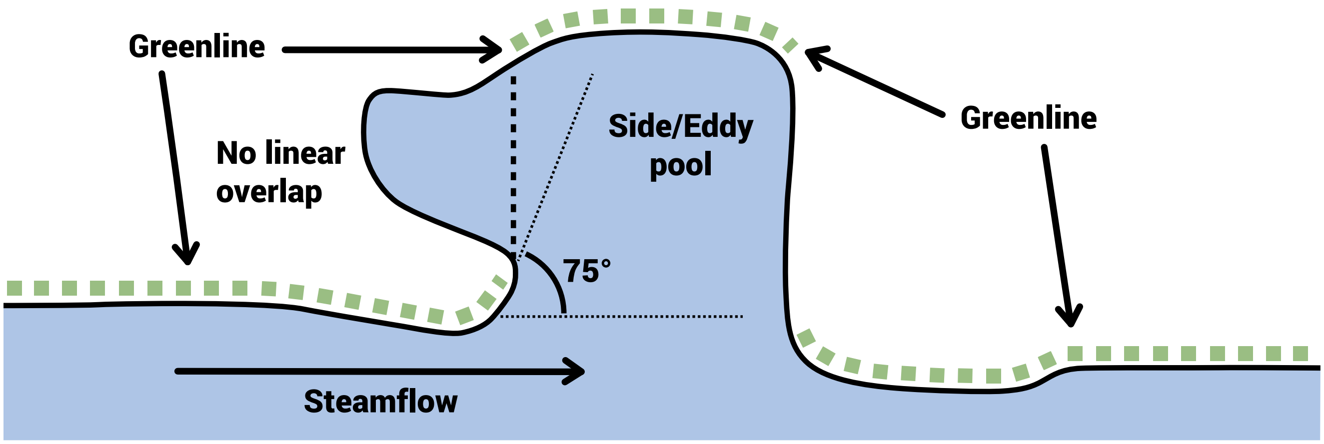

Figure 25. Locating the greenline where side/eddy pools and/or bank scallops occur. The greenline must be aligned roughly parallel to the streamflow or scour line in a dry channel. The greenline cannot exceed 75 degrees from the alignment of the streamflow. Where these side/eddy pools/bank scallops exist, from a planimetric view, ensure that the greenline maintains a linear, nonoverlapping but interrupted line along the bank.

5.2.3 Greenline Rules

There are two greenline rules; either rule a. or rule b. (below) must be met.

a. Live, perennial, vascular herbaceous vegetation; live woody understory; embedded rock; anchored wood: When viewed at 90 degrees from the ground surface, the greenline must have at least 25% absolute cover of any combination of: (1) live, perennial ***foliar cover*** of vascular herbaceous vegetation or live woody understory, (2) embedded rock, or (3) anchored wood (not live) AND no bare patches > 10 cm x 10 cm within the Daubenmire quadrat (Figures D.4–D.6). Bare patches are defined as any combination of rocks smaller than 15 cm (intermediate axis), litter, annual plants, dead plants that do not qualify as anchored wood (see below), or nonvascular plants (Figure 26). ***Absolute cover*** is defined as the area of the ground surface covered by vegetation or other qualifying material (i.e., embedded rock or anchored wood). It is expressed as a percent of area.

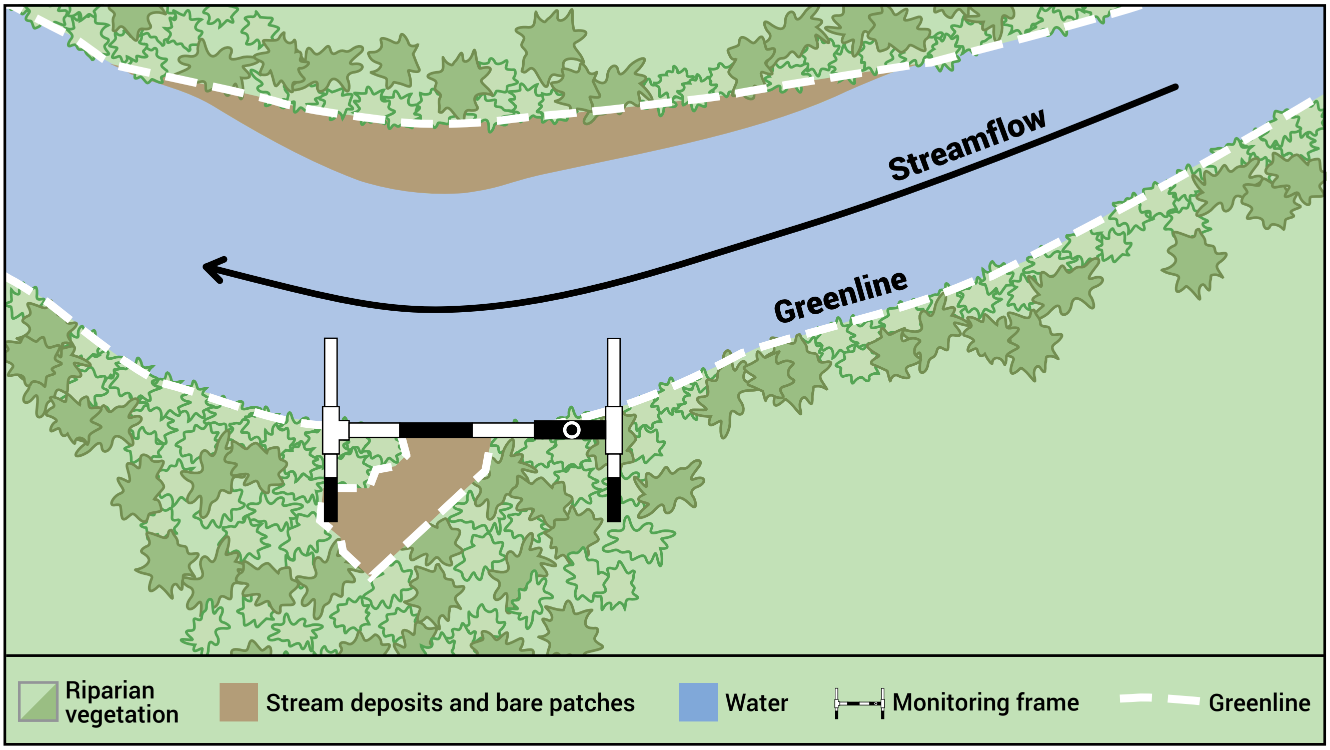

Figure 26. Locating the greenline when a bare patch is encountered. The frame is placed along the line of vegetation closest to the stream. The center of the frame is placed along the edge of the perennial vegetation, rock, or wood. Due to the presence of a bare patch > 10 cm x 10 cm, **the frame placement shown in this diagram is not on the greenline.** To meet the greenline rule, the frame must be rotated as shown in Figure 27.

(1) **Live perennial foliar cover of vascular herbaceous vegetation and/or live woody understory:** Foliar cover, in general, includes all live plant parts and is the shadow cast if the sun was directly overhead. Before concluding a plant is dead and moving the frame, ensure that it is not just senesced. Live shrubs or trees < 0.5 m tall are considered woody understory. **All vegetation must be rooted within the quadrat**; foliar cover rooted outside the quadrat is not considered (i.e. foliar cover hanging over the quadrat but not rooted in the quadrat is not considered).

(2) **Embedded rock:** The greenline may include rock that is at least 15 cm in diameter (intermediate axis) and at least partially embedded in the streambank with no evidence of erosion behind it; this includes all talus slopes (with at least 15 cm diameter rock) and bedrock.

Embedded rock must be above the scour line (i.e., not in the active channel). See Figure D.10.

(3) **Anchored wood:** The greenline may include logs or root wads that are at least 10 cm in diameter and are anchored into the streambank such that high flows are not likely to move them. Standing dead shrubs and trees (including their root systems) are considered anchored wood if they are not likely to move during high flows. There should be no evidence of erosion behind them.

Anchored wood at the location of the greenline must be above the scour line and not in the active channel (Figures D.11 and D.12), although parts of the log or root wad may extend below the scour line.

- **Orientation of the frame on the greenline.** The frame may be rotated right or left away from parallel with the streamflow until the cover requirements are met. The rotation angle cannot exceed 75 degrees from parallel with the streamflow (i.e., it cannot be < 15 degrees from a right angle to the streamflow; Figure 27).

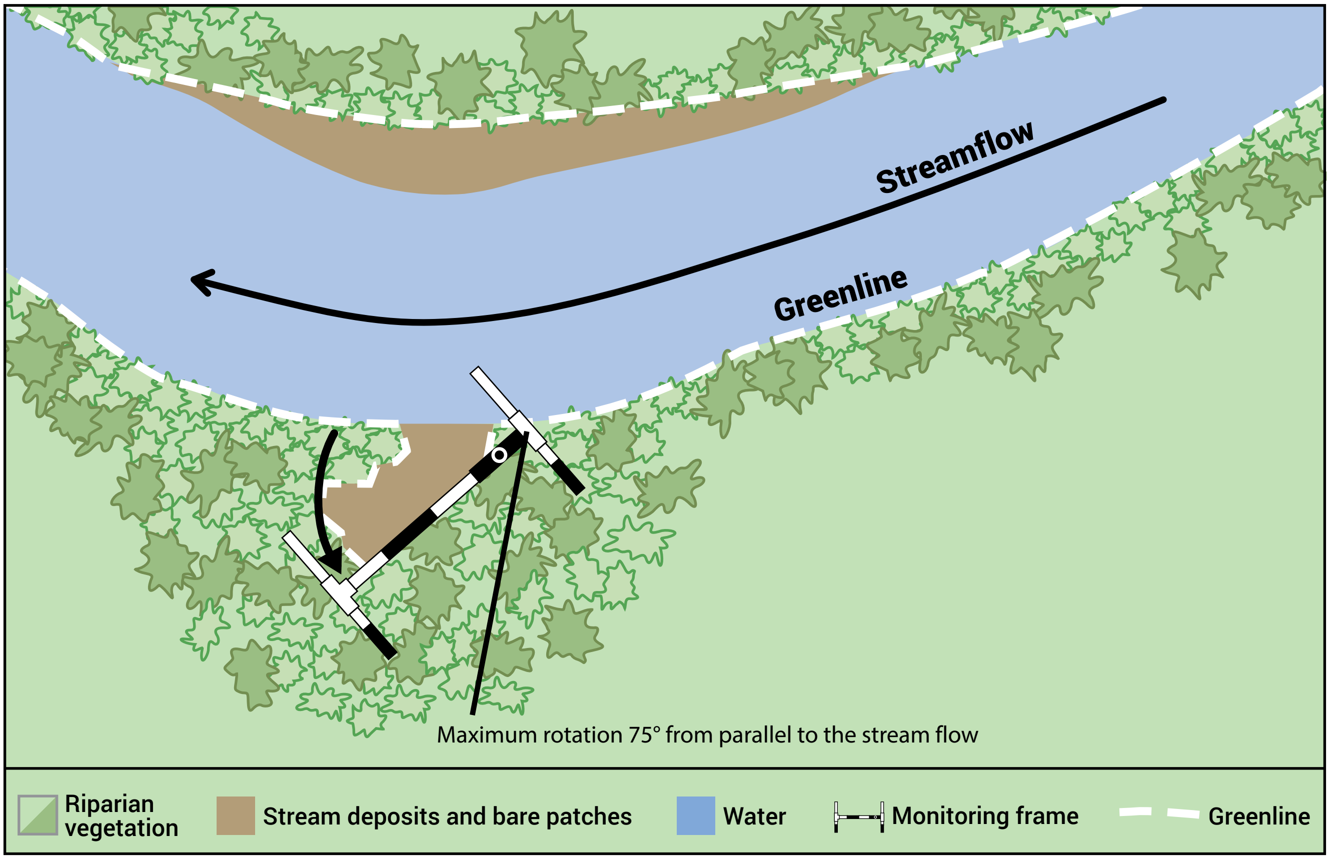

Figure 27. Rotating the MIM frame when a bare patch is encountered. The frame may be rotated right or left away from parallel with the streamflow until the cover requirements in a. or b. are met. The rotation cannot exceed 75 degrees from parallel to the streamflow. Note that the frame is moved to completely eliminate the bare patch. It is not simply moved to reduce the size of the bare patch.

b. Woody overstory: Live woody plants are considered woody overstory if they are ≥ 0.5 m tall (these are considered young and mature plants for this protocol). If the base(s) of woody overstory plants are located closer to the water line or scour line than qualifying perennial herbaceous vegetation, woody understory, rock, or wood (as described in Section 5.2.3. a), the greenline is located at the base of the overstory plant(s) (Figures 28 and D.14). The woody overstory plant(s) must be rooted above the scour line. **Foliar cover of woody overstory vegetation is not considered for identifying the greenline; as a result, the woody base(s) do not need to comprise 25% of the quadrat** (Figure 28) and the bare patch rule does not apply.

When there is woody overstory and little or no understory (i.e., if the understory is < 25% absolute cover), and if the shrub or tree canopy is directly overhead, the frame is placed on a simulated line connecting the rooted base of the shrubs or trees roughly parallel to the streamflow (≤ 75 degrees) on the stream side of the rooted base of shrubs or trees (Figure 29). When there is no canopy cover directly above the line joining the bases of woody species, the frame is moved away from the stream until the greenline is encountered or the distance from the scour line (or water's edge if the scour line is under water) is 6 m slope distance (Figures 30, D.15, and D.16).

Exposed live shrub or tree roots of woody overstory plants rooted above the scour line are part of the greenline (Figures D.17 and D.18).

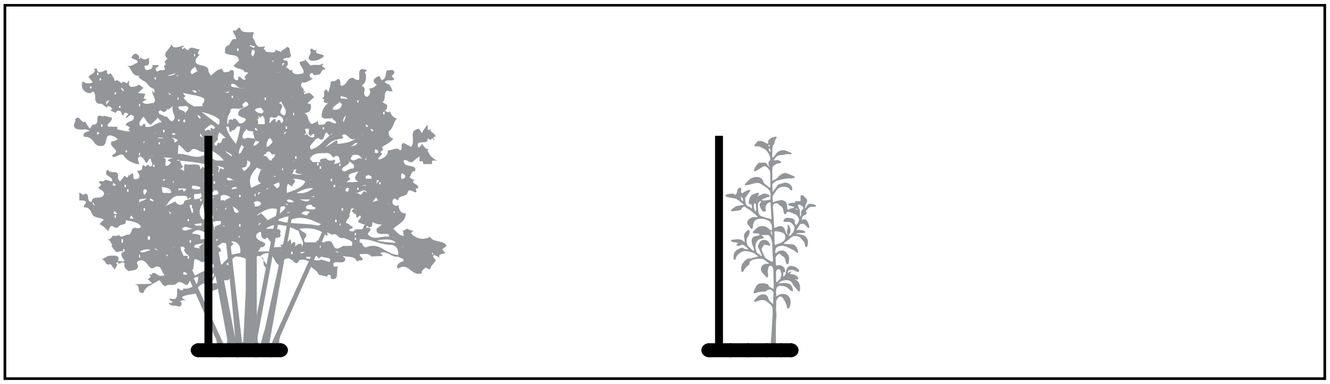

Figure 28. Locating the greenline when woody overstory is present. The monitoring frame is placed at the base of a woody overstory plant (≥ 0.5 m tall) to establish the greenline. It may be the base of a multi-stemmed shrub or tree (left) or a single-stemmed shrub or tree (right). In either case, the woody plant(s) must be at least 0.5 m tall. The frame handle is 1 m long.

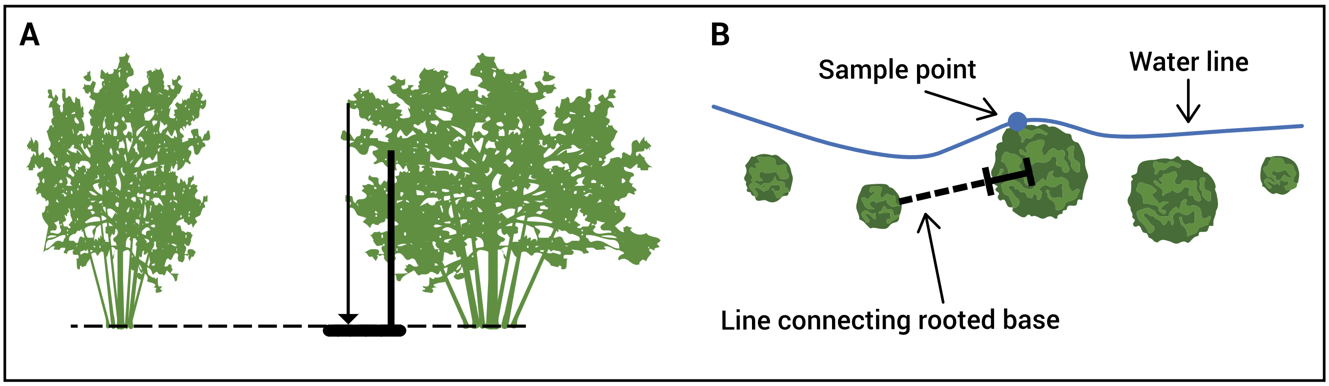

Figure 29. Examples of locating the greenline where woody overstory is present. A cross-section view (A) and a planimetric view (B) of the same location. When there is woody overstory and little to no understory, and if the shrub or tree canopy is directly overhead, the frame is placed on a simulated line connecting the rooted base of the shrubs or trees (on the stream side of the shrubs or trees). This frame is on the greenline.

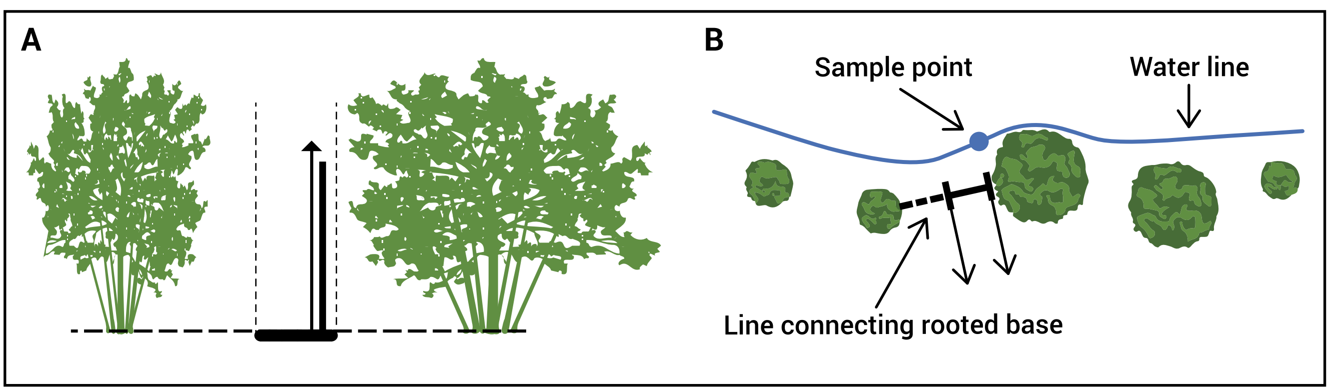

Figure 30. A cross-section view (A) and a planimetric view (B) of the same location. When there is no canopy cover above the line joining the bases of woody species, the frame should be moved away from the scour line or water's edge until the greenline is reached or the slope distance from the scour line or water's edge is 6 m. The frames in the figures represent where an observer would start to assess if the greenline rule is met. As the greenline rule is not met at the initial locations (no canopy), the black arrows indicate the need to move the frame back away from the stream until the greenline rule is met.

5.2.4 Follow Additional Rules for Identifying the Greenline

- **Flooded greenline.** Do not sample vegetation indicators or GGW when the greenline is inundated during high streamflow. **The greenline is never located in the water** (Figure D.19). Sampling when greenlines are inundated should be avoided, as this practice can significantly affect data analysis and interpretation (e.g., plant communities commonly change moving away from the greenline). When hoofprints or other depressions are filled with standing water at the stream margin, the frame is placed behind the hoofprint/depression or rotated so that the 20 cm x 50 cm quadrat on the bank side of the center bar is entirely out of the water.

- **Perennial vegetation growing in water.** During low-flow periods, some plants will be observed growing in slow-moving water at the stream margin. Some sedges, spikerushes, rushes, and bulrushes are adapted to grow in the water for most or all the growing season. Brookgrass is a common obligate wetland grass that is adapted to grow in standing or slow-moving water and can be rooted on the bank out of the water. Aquatic herbs, which include submerged plants, floating plants, and floating leaf plants, also commonly grow in water for most of the season; these include watercress (*Nasturtium officinale*) and American speedwell (*Veronica americana*). When plants with these tendencies are observed growing in the water, continue to the water's edge to determine if enough perennial vegetation is present (and rooted) to satisfy the greenline rule in (Section 5.2.3.a). Commonly, perennial aquatic herbs (particularly floating plants and floating leaf plants) will not be observed growing outside of the water. However, if any of these aquatic plants are found growing out of the water and rooted above the scour line, they would count towards meeting the greenline rule. Regardless of the kind, species, or amount of vegetation growing in the water, **the greenline is never located in the water** (Figures D.20–D.22).

- **Perennial plants occupying the entire channel or drainageway.** For dewatered channels on intermittent streams, dry channels, or vegetated drainageways (those with no distinct channel), if vegetation occupies the entire width of the channel or drainageway, the greenline is at the deepest part of the channel (thalweg) or the lowest point in the vegetated drainageway (Figure D.23). Sometimes, discontinuous pools or small scoured sections of "channel" or a shallow narrow flow path occur within what is otherwise a continuously vegetated drainageway. In those instances, the greenline follows the edge of the scoured section or water's edge as indicated in other greenline rules, and then reverts to the vegetated thalweg once beyond the scoured section or flow path (Figure D.24). See Section 4.1 for details on how to layout the DMA in vegetated drainageways.

- **Slump blocks and bank fractures.** Slump blocks are relatively discreet blocks of soil/sod that have obviously broken from the bank or terrace and slipped towards or into the streambed. Slump blocks must be at least 1/4 of the MIM frame length (or 12.5 cm). Slump blocks must have an obvious fracture, stream scour/bare ground, or streambed between the block and the streambank or terrace. If a slump block is present, the greenline is located on the bank or terrace behind the block at the location nearest the channel where the greenline rules are met. Note that sometimes a bank fracture can exist without an obvious slump block. If the fracture is at least one-fourth of the MIM frame length, the greenline is up the bank behind the fracture as described above for slump blocks (Figures D.25–D.28).

- **False banks.** ***False banks*** are sections of bank that have broken off (i.e., a slump block) from a high bank, terrace, or streambank and have become reattached to the streambank. False banks are stable features and do not have fractures, stream scour, or streambed between the former block (now a section of bank) and the bank or terrace. They may or may not be vegetated to the base of the terrace wall, but they must be stable (i.e., unlikely to move during high flow events). If a false bank is present, the greenline is located at the edge of the vegetation above the water's edge or scour line (Figures D.29 and D.30).

- **Islands.** Islands are defined as areas within the channel at an elevation at or above the scour line and are surrounded by water at summer low flow, or bounded by a channel that is scoured frequently enough to keep perennial vegetation from growing. If a channel around an apparent island has 25% foliar cover of live perennial vegetation across the entire width of the channel for at least 50 cm in length (one frame length) anywhere in the "side" channel adjacent to the island in question, the area in question is not considered to be a scoured channel (and therefore not an island). The greenline follows the outside channel on each side of the island and does not cross onto an island (Figures D.31–D.32). Boulders within the channel are considered islands provided they meet the definition above.

- **No greenline present.** When the greenline is not present within 6 m (slope distance) from the scour line (or from the water's edge if the scour line is under water), **the greenline is considered absent at that sample point** (NG is recorded for vegetation composition and 100% is recorded for the percent cover). Note that this rule is infrequently used but must be included to limit observers from "chasing" a greenline too far from the stream to be relevant.

  - If there is no greenline present, the monitoring frame is placed on the edge of the first ***bench*** within 6 m of the scour line (or water's edge if the scour line is under water) and only streambank alteration and streambank stability and cover are recorded (see Figure 31).

  - If there is no bench present within 6 m, the frame is placed at 6 m slope distance from the scour line (or from the water's edge if the scour line is under water) and only streambank alteration and streambank stability and cover are recorded (see Figures 32 and D.34).

    Note: If the 6-m mark falls on a vertical or near vertical face, or on an otherwise inaccessible location, only streambank stability and cover would be recorded (and may have to be visually estimated if it is beyond the reach of observers).

  - If a sharp meander bend results in encountering the water's edge upstream or downstream within 6 m slope distance (on the opposite side of the peninsula), and the greenline rules cannot be met between the two channels, the frame is placed at the top of the peninsula.

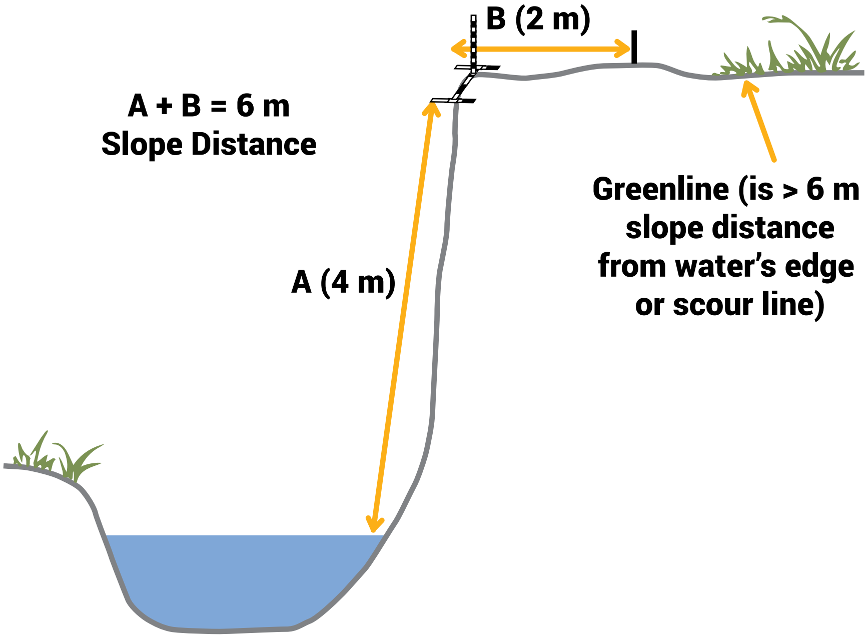

Figure 31. Placing the MIM frame when there is no greenline present. In this figure, the greenline is > 6 m slope distance from the scour line (or water's edge if the scour line is under water). The frame is placed on the edge of the first bench within 6 m.

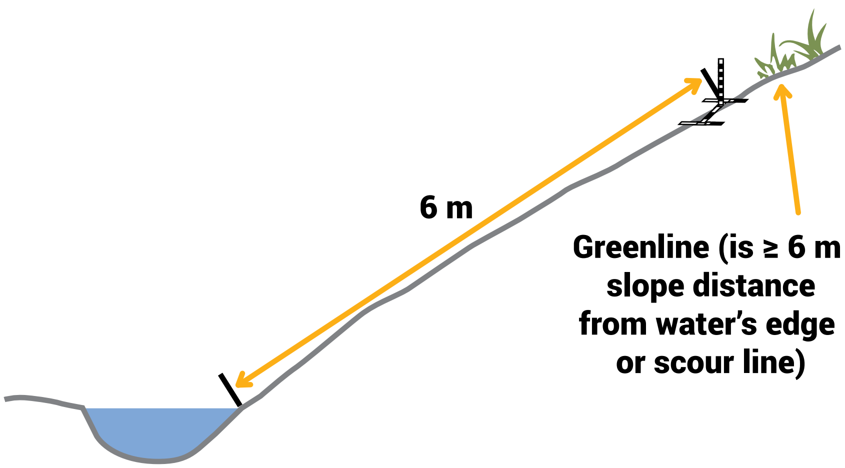

Figure 32. Placing the MIM frame when there is no greenline or bench present. In this figure, the greenline is > 6 m slope distance from the scour line (or water's edge if the scour line is underwater). There is no bench within 6 m so the frame is placed at 6 m.

6. Indicators

6.1 Short-Term Grazing-Use Indicators

6.1.1 Stubble Height

Purpose: Stubble height is a measure of the residual height of key graminoid species remaining after grazing. It is strictly a grazing-use indicator and not a measure of the vertical structure of graminoids. The amount of foliar cover remaining is important for keeping plants healthy, maintaining or promoting strong root systems, protecting streambanks from erosion, slowing water during high streamflows, and building floodplains (Clary and Webster 1989). There is increasing evidence that stubble height is a rapidly assessed stream metric that integrates how livestock disturbance influences stream habitat conditions important to fish (Roper 2020). The measurement may be used in at least two ways. First, it is used to determine when livestock should be moved from the riparian area (sometimes referred to as a form of “trigger monitoring”). Second, it can be used at the end of the grazing season and growing season to help determine cause-and-effect relationships between livestock grazing and stream-riparian conditions (when paired with long-term condition data), and whether livestock grazing management changes may be needed the following year.

Background: A stubble height method designed for upland monitoring is described in Technical Reference 1734-3, “Utilization Studies and Residual Measurements” (BLM 1996b). The MIM protocol modifies the upland stubble height methods for use with a quadrat located in riparian areas. Because many of the important riparian graminoid species are rhizomatous, they grow in dense mat-like patches of vegetation, making it difficult to identify individual plants. Therefore, a 3-inch (7.5-cm) circle of vegetation is used rather than an individual plant.

This method is an ungulate use indicator; it is designed to measure forage plants used by grazing animals. It should not be confused with methods or procedures used to measure vegetation height of all graminoid species (both forage and non-forage plants). Therefore, the number of plant species measured is restricted to ***key species***, which are plants that are relatively palatable to grazing animals, relatively abundant, important for stream/riparian function and habitat, and serve as indicators of environmental and management changes. Due to varying palatability among graminoid species, stubble height measurements should focus on key riparian plant species (University of Idaho Stubble Height Review Team 2004). The method that provided the basis for the MIM stubble height method (BLM 1996b) also prescribed a key species approach.

Assumptions and Limitations: Stubble height has been widely adopted to measure livestock vegetation use in riparian areas (Clary and Leininger 2000). It allows a large number of samples to be collected in a short time. It can be used as a trigger for moving livestock to another grazing unit, or as an indicator of the amount of use after grazing (University of Idaho Stubble Height Review Team 2004). Stubble height is not a substitute for vegetation condition or trend; however, it may be used as an indicator to help assess the effects of livestock grazing on the achievement of vegetation management objectives.

Stubble height is not an appropriate measure on streams that are dominated by extensive and dense cover of woody species, boulders, or bedrock and should generally not be used where herbaceous species are infrequently scattered along the DMA. Stubble height is less useful in larger streams (e.g., > 15 m wide) or steeper reaches (e.g., > 6%) where stream energy, rather than the effects of management of streambank vegetation, primarily drives streambank conditions (Roper 2020).

Relationship to Other Indicators: Stubble height data can be enhanced when analyzed with percent utilization of graminoids by livestock (not in the MIM protocol), woody species use, and streambank alteration to estimate levels of grazing intensity during the current grazing season. When coupled with other short-term and long-term monitoring indicators, stubble height may be used to develop relationships between condition and trend and livestock grazing management. Stubble height alone does not provide adequate information to develop a relationship between livestock grazing and vegetation conditions on the streambank. Commonly, streambank disturbance, measured by the streambank alteration method, is the most important factor relating to streambank stability conditions. The authors analyzed 30 DMAs to evaluate the relationship of stubble height to other indicators. Of note are the positive correlations to vegetation biomass, streambank stability, site wetland rating, streambank cover, the D84 substrate particle size (see Section 6.2.6), and the greenline ecological status rating. Stubble height had an inverse correlation with GGW, woody species use, and streambank alteration, as would be expected given that increased stubble height is typically associated with less grazing use (authors' unpublished data).

Procedure: Stubble height is recorded at the sample point on the greenline. Stubble height is measured within a 20 cm x 50 cm quadrat placed along the greenline. This is the same quadrat used for the greenline composition and woody species height class methods (Figure 33).

Step 1. Conduct a reconnaissance to determine key graminoid species. *Key graminoid species* are grass and grass-like plants that are relatively palatable to grazing animals, relatively abundant, important for stream/riparian function and habitat, and serve as indicators of environmental and management changes. Stabilizing ***hydrophytic*** species make effective key species due to their contributions to soil stability and wetland function.

- If stabilizing hydrophytic graminoids are severely lacking or absent, choose palatable and relatively abundant non-stabilizing mesic (or hydrophytic) graminoids, even if they are not part of the desired plant community. Examples of common palatable mesic graminoids that are not generally considered to be desirable in the plant community include Kentucky bluegrass (*Poa pratensis*), creeping bentgrass (*Agrostis stolonifera*), meadow foxtail (*Alopecurus pratensis*), etc. Observers should make every effort to identify the plants used for key species, however, it is acceptable to use graminoid groups if necessary (e.g., mesic graminoid – MG, or Carex Rhizomatous - CAREXRH). See Table 2 for additional graminoid groups.

  Note: Avoid using prostrate (i.e., ground-hugging) graminoids for key species, for example, brookgrass (*Catabrosa aquatica*), or prostrate forms of creeping bentgrass (*Agrostis stolonifera*).

- More than one key species may be used; collectively, the combination of all key species should be abundant enough for an adequate sample to be obtained (preferably at least 50 samples per DMA). Generally, no more than four key species are used at a DMA.
- Make a list of key species using the USDA-NRCS PLANTS Database species codes. Indicate whether the measurements are made in inches or centimeters (default is inches as most grazing-use criteria are defined in inches).
- If it is not possible to sample at least 50 plants due to a lack of key species, stubble height data is still informative; however, the smaller sample size will decrease data precision.
- When moving from one end of the DMA to the other while observing plants, it is important to avoid trampling vegetation on the greenline. Where possible, greenline plants should be

observed from the stream channel, which allows a good observation position at right angles to the streambank and avoids trampling the greenline.

Step 2. Locate the stubble height quadrat. The stubble height quadrat is 20 cm x 50 cm. This is the same quadrat used for the greenline composition and woody species height class methods (Figure 33).

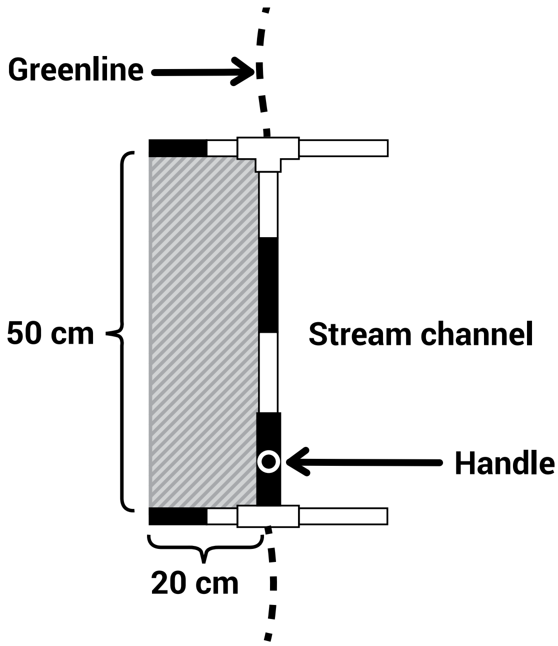

Figure 33. The stubble height quadrat located on the greenline.

Step 3. Locate the available key species within the stubble height quadrat. Locate each available key species that occurs nearest to the inside corner of the quadrat near the handle of the frame (Figure 34). When the key species is not located within the inside corner of the quadrat, search the entire quadrat and locate the key species closest to the inside corner (Figure 35).

- ***Available key graminoids*** are plants that are accessible to grazing animals. ***Unavailable key graminoids*** are those that are completely inaccessible to grazing animals (e.g., located beneath dense woody overstories, rock outcrops, or on steep slopes).
- Most riparian graminoid species grow tightly together, forming dense mats with little distinct separation of individual plants. As a result, the sampling method uses a 7.5-cm (3-in) diameter circle of the vegetation (tuft) for a single species. Even if part of the 7.5-cm diameter patch is outside the quadrat, measure the entire 7.5-cm patch.
- If multiple individuals of the same key species occur within the quadrat, only the individual plant located nearest to the inside corner is measured.
- First, search for and measure the height of a tuft > 7.5 cm in diameter. If the selected key species do not comprise a 7.5-cm diameter tuft anywhere in the quadrat but occurs as an individual plant or several individual plants < 7.5 cm in diameter, select the individual plant of each key species nearest the inside corner of the quadrat by the handle.
- If the selected key species do not occur anywhere in the quadrat, do not record a key species for that quadrat.

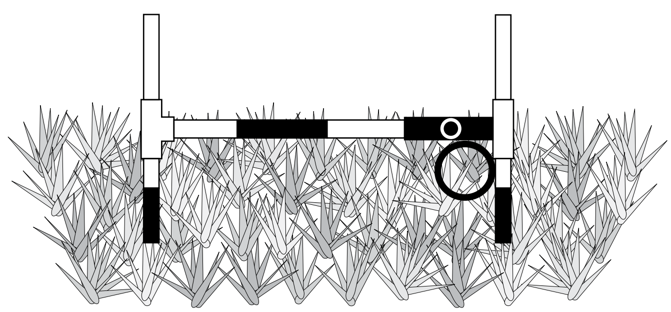

Figure 34. Residual vegetation height (stubble height) is measured within a 7.5-cm (or 3-inch) diameter circle at the back, right-hand corner of the quadrat nearest the frame handle.

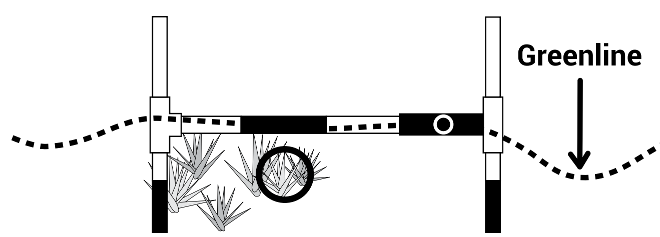

Figure 35. When key species plants are not within the inside corner by the frame handle, select the key species plants nearest the inside corner.

Step 4. Measure the stubble height. Use a ruler with 1-inch increments to determine median stubble height. Measure the median leaf length of all the leaves of the key species plant(s) within the 7.5-cm circle and round it to the nearest inch. Alternatively, use a metric ruler with 1-cm increments, note the units, and round it to the nearest 2-centimeter increment.

Note: Make sure the zero mark on the ruler begins at the edge of the ruler. Some rulers include a blank margin before the zero mark. Do not use rulers with these margins.

- Determining the median residual vegetation height will take some practice. Be sure to include all the key species' leaves within the sample. The easiest method of doing this is to grasp the sample near the base of the leaves, stand the leaves upright, move the hand up the leaves until about half of them fall away, and measure the height at that location (Figure 36).
- If part of the plant or the 7.5-cm circle occurs outside the quadrat, measure the median leaf length of the entire plant or 7.5-cm circle, even though part of the plant is outside the quadrat.
- Measure and record the stubble height for each key species found within each quadrat.
- Do not measure seed stalks (culms) on grass and sedge species. Grasses, in particular, have tall and relatively unpalatable culms and relatively short basal leaves.

  Note: Some species of spikerushes (*Eleocharis* spp.), rushes (*Juncus* spp.), and bulrushes (*Schoenoplectus* spp., *Scirpus* spp.) have relatively palatable, leaflike culms that are commonly grazed. For these species, include culms in the measurement of stubble height.

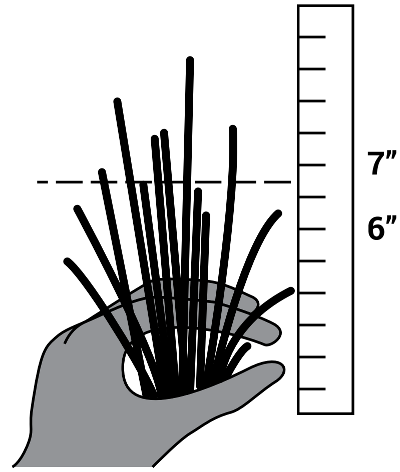

Figure 36. Stubble height is measured by forming your hand into an approximate 7.5-cm (or 3-inch) diameter circle. Grasp the plant near the base of the leaves and stand them upright, then move the hand up the leaves until about half of the leaves fall away. Stubble height is then read at that height. In this example, the stubble height would be recorded as 7 inches (i.e., rounded to the nearest inch).

Step 5. Record the plant species, stubble height, and presence of grazing. Record the USDA-NRCS PLANTS Database species code and the stubble height to the nearest 1 inch (or alternatively, to the nearest 2-cm increment).

- Mark a Y (Yes) in the 'grazed' column if it appears that the plant you are measuring has been grazed. Mark an N (No) in the 'grazed' column if it appears that the plant being measured has not been grazed. This estimate allows practitioners to distinguish samples that are clearly grazed from those that are not. Stubble height data will be summarized for all key species, all grazed key species, and all ungrazed key species. This is useful for developing utilization estimates based on height-weight relationships. If there are no key herbaceous species within the quadrat, leave blank.

Timing:
Pre-grazing monitoring. Stubble height monitoring may be done throughout the season depending on the questions that needs to be answered. If there is a concern regarding the amount of utilization by elk, domestic or wild horses, or other large herbivores, monitoring may be done prior to livestock entering the grazing unit.

Monitoring during grazing. To determine when livestock should be moved to meet a grazing-use criteria, trigger monitoring is done while livestock are still in the area and when the vegetation is close to reaching the prescribed grazing-use criterion.

Post-grazing monitoring. The most common time to measure stubble height is at the end of the grazing period and the growing season (called post-grazing monitoring), which provides some of the information necessary to develop possible relationships between condition and trend and livestock grazing. Measuring stubble height immediately after grazing and again at the end of the growing season can be used to document regrowth.

6.1.2 Streambank Alteration

Purpose: Streambank alteration was originally intended to gauge the degree to which streambanks are affected by ungulate hoof action, but it is equally useful in monitoring human foot traffic and vehicular traffic. The physical alteration of streambanks by animals and other sources can degrade the integrity of stream systems. Some of the direct and indirect consequences of excess streambank alteration include:

- A decrease in streambank stability commonly recognized as an increase in slump blocks, bank fractures, or collapse of undercut banks.
- An increase in stream channel width (Platts 1991; Bengeyfield 2007) and/or GGW. As channel width increases, streams tend to lose access to their floodplains and thus lose an important mechanism to dissipate high energy associated with high streamflow.
- The production of excess sediment leading to a corresponding increase in in-channel sedimentation (Bengeyfield 2007). In-channel sedimentation may manifest as a decline in the quality of macroinvertebrate and fish habitat, as fine sediments can restrict macroinvertebrates of living space and deprive spawning redds of oxygen (Bjornn and Reiser 1991). In-channel sedimentation can also lead to an inability of streams to process sediment efficiently with loss of the number, volume, and depth of pools.
- A decline in water quality (Platts 1991) related to excess sedimentation and an increase in water temperature that is possible when an increase in channel width results in an increase in solar radiation (Beschta 1997, Bowler et al. 2012).
- A loss of water storage capacity from a direct loss of streambank or floodplain extent and from compaction of streambank soils.
- A shift in streambank vegetation from deep-rooted, hydrophytic willows and sedges to drier-site species with lower root densities and lower bank stabilizing properties (Bengeyfield 2006).

Like stubble height, streambank alteration is an annual or short-term indicator of the effect of grazing impacts on streambank stability and cover. As such, it can be used as a tool to assess grazing intensity and to determine when such intensity may be excessive. It can also be used to help determine cause-and-effect relationships between livestock grazing and stream-riparian conditions, and whether livestock grazing management changes may be needed the following year.

Bengeyfield (2006) examined short-term indicators (forage utilization, stubble height, and streambank alteration) at 14 stream reaches in southwestern Montana and found:

> ...the only streams that showed significant improvement were those where the streambank alteration levels were met. Neither a forage utilization of 45 percent nor a stubble height at 4 inches initiated the upward trend in stream channel shape that is necessary to achieve riparian function.

Background: Stream channels are naturally dynamic with varying rates of annual disturbance, but streams are constantly adjusting to maintain channel capacity, competence, and stability (Leopold et al. 1992). As a result, streams have a natural ability to repair a certain degree of streambank disturbance each year. Several factors, including ***stream gradient***, composition of the streambed substrate and streambank soil, type and amount of vegetation cover, channel geometry, streamflow rate and timing, and frost action affect the amount of alteration that streambanks can repair each year. As stated by Clary and Kruse (2004):

> …concentrated impacts under rotation systems can cause sufficient woody plant or streambank damage in a single season or year that recovery might take several years. Therefore, the best approach is to limit grazing stress to the site's capability for annual recovery.

The capability for annual recovery would be evaluated by measuring both streambank alteration and streambank stability at the DMA as described in Relationship to Other Indicators, this section.

Another way to consider the relationship between streambank alteration (a grazing-use indicator) and streambank stability (an indicator of condition) is through the idea of "carry-over" effects. The idea is to limit the amount of annual disturbance from management activities, such as livestock grazing, as well as from other sources, such as wild ungulates, so that the net amount of disturbance does not exceed the stream's ability to repair itself before the next grazing or management period. In a well-managed stream system, there should not be carry-over effects of disturbances from one year to the next or from one grazing period to the next.

In the past couple decades, several methods have been developed and tested to evaluate streambank alteration (e.g., Bengeyfield and Svoboda 1998; Bengeyfield 2006; Burton et al. 2008; PIBO-EM 2008). Heitke et al. (2008) evaluated several of these methods including a greenline method, greenline precise method, and a bankfull method using data collected in Montana in 2003 and 2004.

The bankfull method, which was a precursor to the MIM approach, evaluated streambank alteration in a monitoring frame that was positioned on the bankfull line of the streambank. The bankfull method was modified in the MIM protocol to use the greenline rather than the bankfull line because observers more often agreed on the location of the greenline than the bankfull line (Henderson 2003). In addition, the monitoring frame in the MIM approach has been modified from the bankfull method by changing the frame dimension and by reducing the number of observation lines from 10 to 5 to reduce double counting of individual hoofprints. In the bankfull method, the observation lines were so closely spaced that one average-sized hoofprint (13-cm diameter) would routinely intersect 2 or 3 lines (spaced only 5.5 cm apart).

Heitke et al. (2008) assessed variability among observers for different alteration protocols. They used the standard deviation between observations made by the same or different observers. The greenline precise method had a standard deviation of 4.7 with a coefficient of variation (CV) of 56 (Table 3). In comparison, the greenline method had a standard deviation of 6.3 with a CV of 20, and the bankfull method had a standard deviation of 8.1 and a CV of 35 (Table 3). The MIM authors conducted 35 tests for observer variability on the MIM approach and found a standard deviation of 4.3 and a CV of 22.7 (Table 3). The CV is a dimensionless index of variability between and among observers' repeated observations and is represented by the standard deviation divided by the mean.

Table 3. Summary of observer variability for different streambank alteration methods.

Evaluation of observer variability*				
Method	Greenline	Greenline Precise	Bankfull	MIM
Standard Deviation	6.3	4.7	8.1	4.3
Coefficient of Variation	20	56	35	22.7

* Results for greenline, greenline precise, and bankfull methods reported by Heitke et al. (2008) and for MIM by Burton et al. (2011).

The part of the streambank that is measured using this method is a 42 cm x 50 cm quadrat (two Daubenmire plot widths plus the 2-cm-wide center bar of the MIM frame) centered on the greenline. This part of the streambank, where the forces of water meet the first perennial vegetation, focuses the observation where stability and the resistance to erosion is most influenced by vegetation in most instances.

Assumptions and Limitations: Like any indicator, streambank alteration is prone to misinterpretation and misuse by untrained and uninformed users. Three of the most common misapplications or misinterpretations deal with (1) what the measurement signifies, (2) the uncommon situation where greenline locations and alteration impacts do not coincide, and (3) the importance of matching grazing-use criteria with a specific methodology.

Interpretation of the measurement. In the MIM protocol, streambank alteration is reported as the percentage of observation lines that intersect an alteration. The sampling frame is divided into 5 observation lines to record occurrences of alteration. These lines are perpendicular to the center bar of the frame and extend 20 cm on each side (Figure 37). If one or more alterations intercept any part of an observation line, a value of 1 is recorded for each line with an alteration. In a typical DMA, streambank alteration is measured at 80 quadrats, each with 5 observation lines for a total of 400 observations (80 quadrats multiplied by 5 lines). The percent streambank alteration is a simple proportion (number of “hits” or lines with alterations divided by total number of observation lines times 100%).

Figure 37. Streambank alteration is measured using a 42 cm x 50 cm monitoring frame. Five reference lines (shown in red) are projected across the width of the frame. Observation lines are 12.5 cm apart.

The number of alteration intercepts or hits is limited to five per sample. The spacing between intercept lines approximates the diameter of a cattle hoof print (13 cm), which minimizes double counting of single hoofmarks. Generally, the alterations are most evident on the unvegetated side of the greenline.

Trampling impacts must be the **obvious result** (i.e., easily seen, clear to the eye, not to be doubted, or plain) of current season use. **Obvious streambank alterations** are defined as those that are readily observed from approximately 2 ft from the ground surface. In general, these are impacts that are evident without kneeling close to or lying on the ground.

This straightforward calculation does not suggest or pretend to represent the area altered. In fact, as reported in Burton et al. (2011), streambank alteration measured by the MIM method best approximates the linear length of the greenline or transect that is altered rather than the area altered. In their test data:

The percent greenline length altered = 0.914 x (percent MIM alterations) + 5%, r^2 = 0.85.

The area of the quadrat altered had a weaker relationship:

The percent quadrat area altered = 0.32 x (percent MIM alterations) + 3%, r^2 = 0.55.

The monitoring frame is 42 cm x 50 cm (or 2100 cm^2) and the average cattle hoofprint is 12 cm by 17 cm or approximately 200 cm^2. Therefore, one hoofprint in the frame represents approximately 10% of the area within the frame that is altered. The width of an average hoofprint oriented along the greenline is 12 cm, so its length along the greenline is 12/50 cm or about 24%. Because the MIM protocol uses a line-intercept approach with the intercept lines spaced slightly wider than the average hoofprint, that same hoofprint would intercept one of the five lines and be recorded as 20% alteration for that plot. Thus, alteration using the MIM protocol more closely approximates length of greenline altered, not the area of the plot altered.

When greenline location and streambank alteration poorly align. In some instances, the greenline quadrat location underrepresents the amount of streambank alteration because highly degraded bank conditions (related to devegetation from disturbances, bank instability, and/or high erosion rates on cutbanks) have moved the greenline away from the streambank and up onto the terrace or uplands. Although this reality presents a temporary problem in precisely and accurately determining streambank alteration, a grazing-use indicator, the greenline sampling points maintain high-observer agreement and a very accurate and precise measure of long-term indicators (primarily greenline composition, bank stability and cover, and GGW), which are more important in assessing condition and trend of riparian resources. When situations arise where there is a disconnect between greenline quadrat locations and locations of maximum streambank alterations, take a photograph, capture this disparity in a narrative, and use long-term conditions to guide management actions.

Importance of matching grazing-use criteria with a specific method. Evaluations of different streambank alteration protocols (Heitke et al. 2008; Goss 2013) concluded that different methods for measuring the same indicator produce different results. Therefore, it is imperative that whenever a streambank alteration criterion is given as an annual-use threshold or target, the method for measuring streambank alteration must be specified too. Otherwise, it is likely that one method might artificially determine acceptable levels while another would consistently conclude unacceptable levels of streambank disturbance (Heitke et al. 2008; Goss 2013). For example, the modified bank alteration method discussed in Goss (2013) provides a method for estimating area altered. This method exhibits a nonlinear relationship to the MIM alteration method (Figure 38). This relationship suggests that a 25% streambank alteration measured by the MIM method might equate to an 8% streambank alteration measured by the modified method (Goss 2013, Figure 38). Therefore, setting a grazing-use criterion of 20%, for example, would find the criterion had been exceeded with the MIM method, but not with the modified method. It is critical to know which method is intended for use when the grazing-use criterion is set so that the right type of data is collected to evaluate the criterion. The MIM method for evaluating streambank alteration had a signal-to-noise ratio of 8.4, whereas the modified alteration method had a signal-to-noise ratio of 3.3, indicating that the MIM alteration method provides a more sensitive or robust metric (see Goss 2013, p. 45). Also, the MIM protocol correlated better with more of the long-term stream conditions than the modified protocol (see Goss 2013, p. 70).

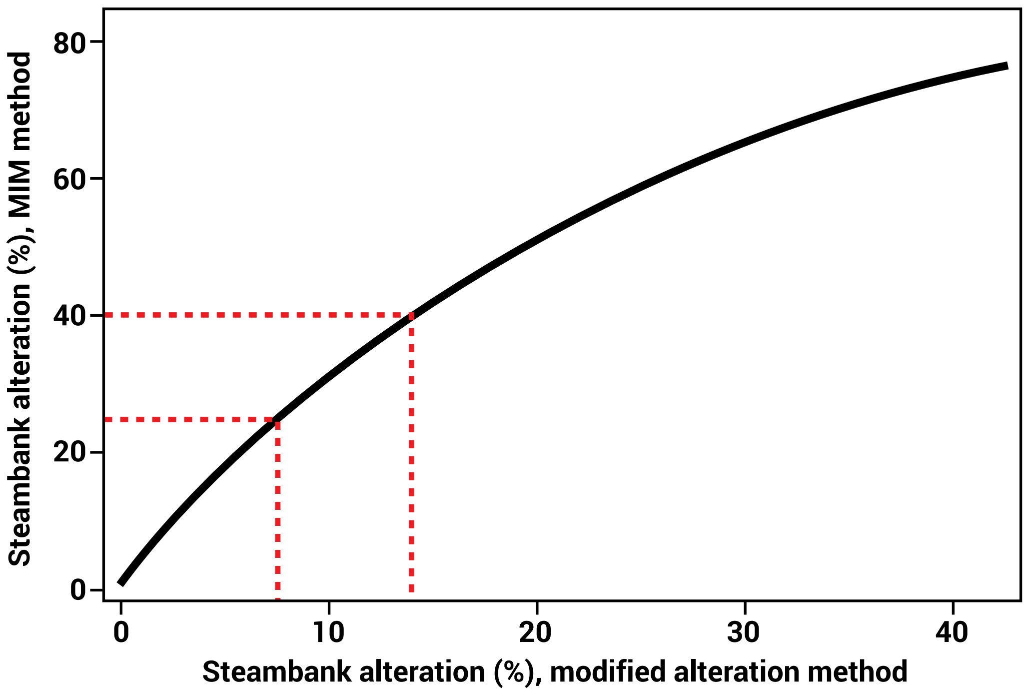

Figure 38. Different methods used to measure streambank alteration can generate significantly different results. This graph (modified from Goss 2013) illustrates the nonlinear relationship between the MIM and modified alteration methods. Two examples are delineated showing that 25% MIM alteration equates to about 8% modified alteration method and 40% MIM alterations equates to about 14% modified alteration method.

Relationship to Other Indicators: Streambank alteration is inversely related to streambank stability. Higher amounts of alterations coincide with lower degrees of bank stability and vice versa. Streambank alteration is also related to greenline composition. Alterations tend to be fewer along greenlines with healthy riparian stabilizer plants, such as rhizomatous sedges, rather than along greenlines dominated by plants with weak root systems, such as Kentucky bluegrass (*Poa pratensis*) or creeping bentgrass (*Agrostis stolonifera*).

Throughout the year, stream processes and vegetation growth have the ability to repair a certain amount of streambank alteration. Therefore, to maintain desired conditions or to demonstrate improvement and recovery in degraded systems, it is important that the intensity of annual disturbance, or streambank alteration, is less than the annual amount of streambank repair. The amount of repair can be estimated by measuring the amount of recovery that occurs between disturbance periods. To estimate the amount of repair, both streambank alteration and streambank stability are (1) measured immediately after one period of grazing and (2) then just before the next period of grazing. This would allow an estimate of the change in streambank stability during the period of rest or recovery, which occurs between periods of grazing. The net amount of repair reflects natural processes of streambank recovery, along with natural sources of streambank instability (e.g., wild ungulate disturbances and high-magnitude flow events that can erode streambanks).

Another way to evaluate potential streambank repair rates is to compare measurements of streambank stability along the stream reach of interest with a comparable stream reach within a reference area. Changes in streambank stability caused by flooding, ice scour, and other natural processes can then be factored into the relationship between streambank alteration and streambank stability.

Procedure: Streambank alteration is measured in the entire 42 cm x 50 cm monitoring frame. Five lines (two end bars of the frame and 3 intermediate lines spaced 12.5 cm apart) are projected across the frame perpendicular to the center bar of the frame (Figure 39).

Step 1. Locate the streambank alteration quadrat and observation lines: The frame is placed with the center bar on the greenline. This is the same position used to locate some other indicators, including greenline cover and composition and stubble height.

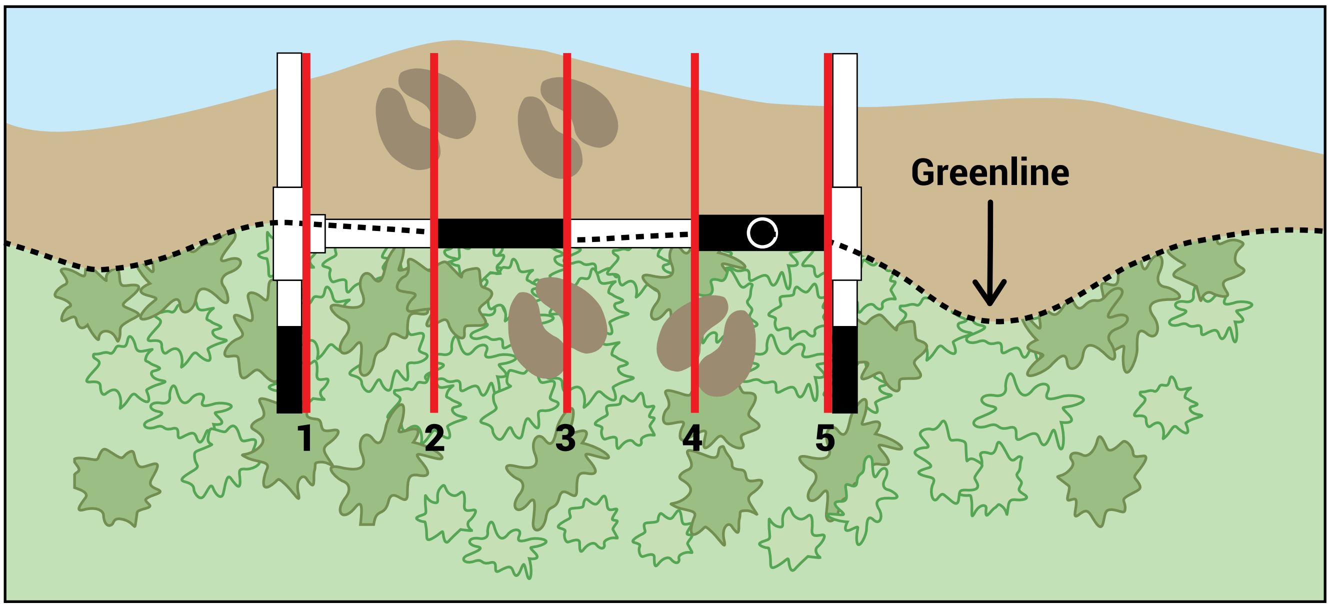

Figure 39. A monitoring frame with five observation lines projected on the quadrat. There are four hoofprints depicted in this quadrat. Lines 2 and 4 each intersect one hoofprint. Line 3 intersects two hoofprints. Three lines intersect hoofprints, so the number of alterations on this quadrat is recorded as 3.

Step 2. Count the lines that intercept an alteration: Look down at the entire frame and determine the number of lines within the quadrat that intersect an alteration. The streambank is considered altered when there is obvious evidence of trampling, shearing, trailing, or pugging:

- Trampling is the result of hoofprints, footprints, or wheel or tread-tracked depressions in the soil at least 0.5 in (13 mm) deep and exposure of bare soil. The depression is measured from the top of the soil surface to the bottom of the impression. Alternatively, displaced soil is moved into a pile or ridge that is at least 0.5 in (13 mm) high (Figures 40.A, E.1, and E.4).
- Shearing results in the removal of a portion of the streambank by ungulate hooves, leaving a smooth vertical surface and an indentation of a hoofprint at the bottom or along the sides. Shearing may also result in the formation of a slump block that is roughly the area of a single hoofprint (Figures 40.B, E.3, E.6, and E.7).
- Trailing occurs when hooves, feet, or wheels/treads have repeatedly moved over the same area to create a compacted or devegetated path, even though the soil may be depressed < 0.5 in (13 mm) (Figures 40.C, E.2, and E.5).

- Streambank alterations may also produce a rut, depression, or pug that has formed from hoofprints, footprints, or wheels/treads and has held or is able to hold water or alter surface hydrology (Figure 40.D).

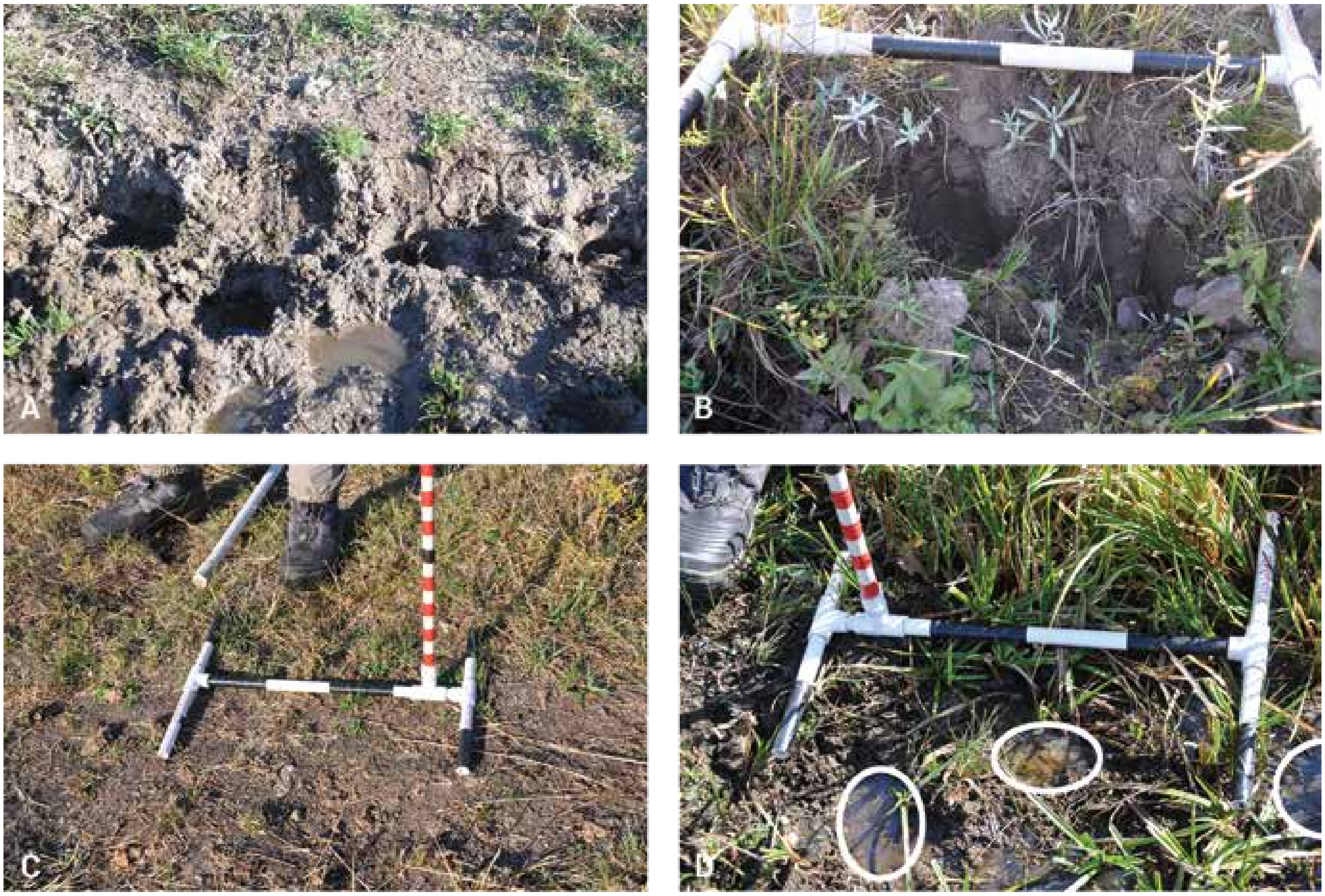

Figure 40. Examples of streambank alteration. Additional examples of streambank alterations are included in Appendix E.
A. Trampling with soil depressions and soil displacement ≥ 13 mm.
B. Hoof shear on vertical face with hoofprint at base.
C. Trail created by repeated hoof action without leaving discernible soil depressions.
D. Pugs created by hoof action (outlined) that hold water.

Step 3. Record the number of lines (0–5) that intersect one or more alterations. Record only one occurrence of alteration, trampling, shearing, trailing/compaction, or pugging per line.

Note: There may be multiple alterations along a single observation line, but only the number of lines with alterations are counted, not the number of alterations that intersect a single line. **It is important to record only the current year's streambank alterations, i.e., features that are obvious.** Disturbance features that are old, such as relict disturbances from a previous year, tend to be nondistinctive (Figure 41). Current year's alterations commonly include bits of live vegetation pushed into the soil. Follow these guidelines when determining the number of alterations:

Figure 41. Determining current year's alteration. Recent high streamflow has wetted the banks and caused soil aggregates to slake (or disintegrate into individual particles), which leaves indistinct outlines of possible hoofprints. These indistinct or not distinct features are not counted as current year's alterations.

- Do not record hoofprints or trampling on streambanks with fully developed, deep-rooted hydrophytic vegetation (e.g., *Carex* spp., *Juncus* spp., and *Salix* spp.), unless plant roots or bare soil is exposed, and the minimum 0.5 in (13 mm) displacement or impression has been created (Figure 40A).
- Record an alteration when an observation line crosses a vertical face that has formed from ***hoof shear*** (Figure 40B).
- Record alterations from compacted or devegetated livestock, game, or foot trails (or vehicle paths) on or crossing the greenline that are the obvious result of the current season's use (Figure 40C). Preexisting trails that have revegetated are not considered current season's alterations and are not counted.
- When there is no greenline identified within 6 m from scour line (or the toe of the streambank), streambank alteration is recorded at the edge of the first bench (or 6 m from the scour line). If the scour line is under water, the 6 m limit is measured from the water's edge.
- Do not omit a measurement if there are no alterations. Record "0" if none of the lines in the quadrat intersect an alteration.
- If the sampling point falls underneath a shrub and the surface is inaccessible to view, it is improbable that a large ungulate could have or would have stepped on the quadrat; record "0" alterations.
- While collecting monitoring data, avoid walking or stepping on the greenline so that the act of monitoring does not generate streambank alterations.
- A ruler can be used to trace the path of an observation line when there is a question whether the line intersects or misses an alteration (Figure 42).

- A hoofprint that is in or under water is not considered an alteration and is not counted. In contrast, a deep hoofprint referred to as a pug and that holds water below the ground surface, is an alteration (Figures 40D and 42).

Step 4. Evaluate streambank alteration along the entire DMA. Evaluate streambank alteration at each sampling quadrat at the predetermined sampling interval along the entire DMA.

Figure 42. Using a ruler to measure streambank alteration. A folding carpenter's ruler is handy for simulating the path of the observation lines in the MIM frame to determine if these lines intersect an alteration. Note the standing water in the depressions created by recent hoofprints.

Timing: Streambank alterations are counted when they are the obvious (i.e., easily seen, clear to the eye, not to be doubted, or plain) result of current season's use. Because rainfall, streamflow, plant growth, freeze-thaw action, and erosion can immediately act to obliterate soil alterations, it is important to measure alterations as soon as possible after livestock leave a pasture or use area. Preferably, streambank alterations should be measured within a week of a pasture move. Work with rangeland specialists and determine the time of pasture moves so that streambank alteration can be evaluated within a week of a pasture move.

Alterations are also measured routinely during a grazing period when there is a trigger or grazing-use criterion used to inform a pasture move. The grazing-use criterion might be designed to evaluate the level of annual use with the resulting degree of streambank instability or the amount of bare ground over time.

Finally, when there is a need to isolate the effect of livestock grazing from the effects of wildlife or from wild horses and burros, streambank alterations could be measured 2 or 3 times per year. They should be measured once immediately before livestock enter a pasture (to evaluate wild ungulate alterations), again immediately after livestock leave a pasture, and if necessary, at the end of the growing season (to assess alterations occurring after livestock leave a pasture).

6.1.3 Woody Riparian Species Use

Purpose: Woody riparian species use is a short-term indicator of grazing utilization on woody shrubs and trees along streambanks. Woody vegetation (shrubs and trees) is an important component of many stream-associated riparian areas. Many healthy woody riparian species provide strong, deep root systems that stabilize streambanks, filter water, trap sediment, shade streams, and provide habitat diversity. Most riparian woody plants require freshly deposited or disturbed soil to germinate and establish. Within and immediately adjacent to the stream channel, the most frequent deposition or disturbance is near the streambank. This area, within 1 m of the greenline, has the highest occurrence of woody species establishment along a stream (Winward 2000). Cattle commonly graze on palatable woody plants occurring on gravel, sand bars, and deposits along the floodplain (Kauffman et al. 1983).

Woody riparian species use may serve as a trigger for moving livestock at a predetermined level of use (e.g., light or moderate use). It may be used to determine the level of browsing during the grazing period. Woody species use may help establish the relationship between the level of grazing use by large herbivores (e.g., cattle, sheep, horses, elk, moose, and deer) and the long-term condition of woody riparian plants and their regeneration along the greenline. This indicator may also be used to help distinguish between livestock and wildlife browsing.

Background: The method described here was adapted from the landscape appearance method described in Technical Reference 1734-3, “Utilization Studies and Residual Measurements” (BLM 1996b), which is an ocular estimate of key woody species (e.g., willow, alder, birch, dogwood, aspen, and cottonwood) use. It is based on the percent of the current year’s leaders browsed by animals. The quadrat used to evaluate browse is 2 m wide (centered on the greenline) x the length of the sample interval. Estimates are based on a range or class of use of the available current year’s leaders on a single plant.

The method was adapted for use along streambanks to evaluate livestock and other large herbivore use on those shrubs that most directly affect the streambanks. Only key riparian shrubs, with more than 50% of the current year’s leaders within reach of grazing animals, are evaluated. This method is an ungulate use indicator and is designed to measure plants that grazing animals use (i.e., forage/browse plants). It should not be confused with methods or procedures used to measure vegetation use of all species (both forage and non-forage plants). Therefore, the number of plant species measured is limited to ***key species***, which are plants that are relatively palatable to grazing animals, relatively abundant, important for stream/riparian function and habitat, and serve as indicators of environmental and management changes. Due to varying palatability among woody species, measurements should focus on key riparian woody plant species (University of Idaho Stubble Height Review Team 2004).

Other methods were considered, including the twig length measurement and the Cole Browse Method. These methods were developed for upland shrubs, such as bitterbrush and mahogany, which have limited water availability. None of these methods have been extensively tested on riparian shrubs.

The twig length measurement method was found to be time consuming and to have high observer variability (Hall and Max 1999). The variability was a result of the uncertainty about knowing what and how to measure. This was further complicated by twig growth continuing after grazing on some riparian shrubs and the apparent stimulation of the growth of lateral twigs following grazing. Another compounding factor was the inability to differentiate use by bud-eating birds such as grosbeaks from use by large herbivores (Hall and Max 1999).

The Cole Browse Method employs incidence of leader (twig) use, i.e., the percent of individual twigs used on available shrubs. This method appeared to have some of the same problems as the twig length method, particularly the stimulation of the lateral twig growth, continued growth after grazing, and inability to differentiate between different animals using the terminal bud (BLM 1996b).

Assumptions and Limitations: Where they have the potential to occur, woody riparian plants are important for the stability of streambanks; they also provide shade and habitat diversity. Hall and Max (1999) suggest that it is difficult to measure livestock use on riparian woody plants with any reliable degree of accuracy and precision. Since these plants are important, it is assumed that having an estimate of the use is important for determining the success of a grazing management prescription. Detailed rules for describing browsing on woody vegetation help with consistency among observers. In tests of observer variability using the current method, the mean difference between observers at 35 test sites was 8%; however, the mean difference was 24% at 5 controlled test sites with substantial woody browsing. Tests of repeatability using the 95% confidence interval from 25 samples indicated that woody use could be estimated to within 15% of the actual use level, suggesting that the method can estimate the true use class with a reasonable degree of accuracy (MIM Data Instructions Guide, Observer Variation).

Many stream reaches have low numbers of riparian woody species due to years of heavy use, mechanical and chemical removal, and stream channel alteration activities such as straightening. Low numbers of woody plants may result in relatively small sample sizes that produce lower precision and accuracy. Because samples are taken randomly along the streambanks, these low numbers of plants make it difficult to get an adequate sample. Tests of sample size adequacy at 21 DMAs indicated an average of 27 samples would be needed to acquire a precision comparable to that for observer variability (margin of error 5%). If the DMA has a total of 80 quadrats, 34% of the quadrats, on average would need to have at least one woody species use measurement to match the precision for observer variability, however not having that many samples is still valuable. The result would have a wider margin of error than that of observer variability, thus making the detection of a significant difference more challenging, depending on the size of margin of error.

The average percent of use should not be used as a grazing-use limit as this method places use within a use class. For example, if the average woody species use is 38%, which is in the upper part of the light category, the amount of use should be described as light to moderate. This provides managers with information necessary to determine if the management prescription is likely making progress toward the objectives or if adjustments to the management prescription should be considered. Since a value is assigned to each woody use class (the midpoint on Table 4), and woody use typically produces a non-normal distribution of measurements, it may be more desirable to use the median percent use (although the mean can be used after bootstrapping; see MIM Data Instructions Guide, Appendix B) to describe woody use. This automatically produces a result associated with a use class (i.e., if the calculated median is 30, that equates to the light use class).

Relationship to Other Indicators: Woody species use along with woody riparian species age class and greenline composition can be used to help determine the health of the woody plants within 1 m of the greenline. The health of these plants is an important factor contributing to the stability of the streambanks, aquatic habitat, and water quality. In our assessment of the linkages between woody use and other indicators, the authors found those with the highest coefficients of correlation were: woody species frequency (-0.61), stubble height (-0.60), streambank alteration (+0.56), greenline ecological status (-0.36), site wetland rating (-0.28), and Winward greenline vegetation stability rating (-0.24) (authors' unpublished data).

Procedure: Woody riparian species use is recorded at the sample interval at the location where the greenline rules have been met. Woody riparian species use is measured in a quadrat that is 2 m wide (with 1 m on each side of the greenline) and the length of the interval between quadrats (Figure 43).

Step 1. Conduct a reconnaissance to determine key woody riparian species. Key woody riparian species are relatively palatable to grazing animals, relatively abundant, important for stream/riparian function and habitat, and serve as indicators of environmental and management changes. Record all species that meet the key woody species criteria. Common key woody species in riparian areas include most species of willow (*Salix* spp.), alder (*alnus* spp.), birch (*Betula* spp.), dogwood (*Cornus* spp.), cottonwood (*Populus* spp.), and aspen (*Populus tremuloides*). There are many woody species common in riparian areas that do not experience significant browsing because they are not palatable to ungulates; therefore, they are not key woody species. Examples include boxelder (*Acer negundo*), hawthorn (*Crataegus* spp.), ash (*Sorbus* spp.), spruce (*Picea* spp.), and chokecherry (*Prunus virginiana*).

- Make a list of key species using the USDA-NRCS PLANTS Database species codes.
- When moving from one end of the DMA to the other and observing plants, it is important to avoid trampling vegetation on the greenlines. Where possible, greenline plants should be observed from the stream channel, which allows for a good observation position at right angles to the streambank and avoids trampling the greenline.

Step 2. Locate the woody riparian species use quadrat. The woody riparian species use quadrat is 2 m wide (1 m on each side of the greenline) and the length of the sample interval (3.75 m is a common default for small streams; larger streams will have a longer sample interval and a longer quadrat).

- Use a 2-m rod or the handle of the MIM frame (1 m long) to define the 2 m width of the quadrat (Figure 43).

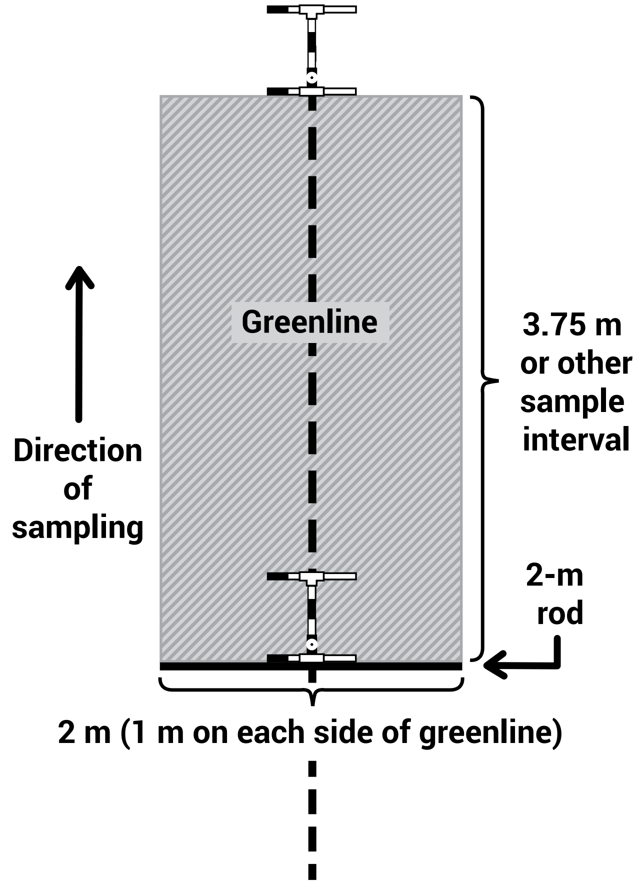

Figure 43. The woody riparian species use quadrat located on the greenline. The quadrat length is the distance between the sample points—from the start of the first sample point to start of the next sample point—and so forth down the greenline transect. The width is 2 meters (1 meter on each side of the greenline).

- Because the woody riparian species use quadrat is larger than the greenline composition quadrat, sometimes the top of the DMA interrupts the 2 m x 3.75 m quadrat. If this occurs, record the appropriate woody plants from the sample point to the top marker of the DMA, cross to the other bank, measure the remaining distance and record the woody plants as instructed. If the bottom marker interrupts the woody riparian species use quadrat (i.e., shortens the quadrat), record only those woody plants from the sample point to the bottom marker (see Section 4 .1).

- For very narrow streams with woody plants in the channel, the width of the woody riparian species use quadrat does not extend beyond the middle of the channel (this will also avoid sampling plants rooted on the opposite bank).

Step 3. Locate the available key woody riparian species within the quadrat. The default procedure is to use the individual of each key woody species rooted in or overhanging the quadrat that is closest to the start of the quadrat (i.e., only consider the first plant of each key species encountered when proceeding up or down the greenline transect from one sample point to the next).

- ***Available woody species*** are plants having > 50% of the current year's leaders within reach of the browsing animal (Section 4, Table 2). If the plant being evaluated has > 50% of the current year's leaders above the reach of the browsing animal, the shrub is considered unavailable for browsing and the plant is not assessed for woody species use. For example, for assessing cattle use, observers would only consider key woody plants having > 50% of their current year's leaders below 1.5 m (5 ft), which is considered browsable; if woody plants have > 50% of the current year's leaders above 1.5 m (5 ft), they are considered unavailable.
- If a key woody plant straddles the boundary of the quadrat (i.e., some parts are rooted both inside and outside the quadrat), evaluate the entire plant, even if part of the plant is outside the quadrat (Figure 44).
- If any part of a key woody plant is hanging over the quadrat, evaluate the entire plant.
- If a key woody plant straddles the sample interval (is rooted in or overhanging two adjoining quadrats), estimate its browse in only one quadrat.

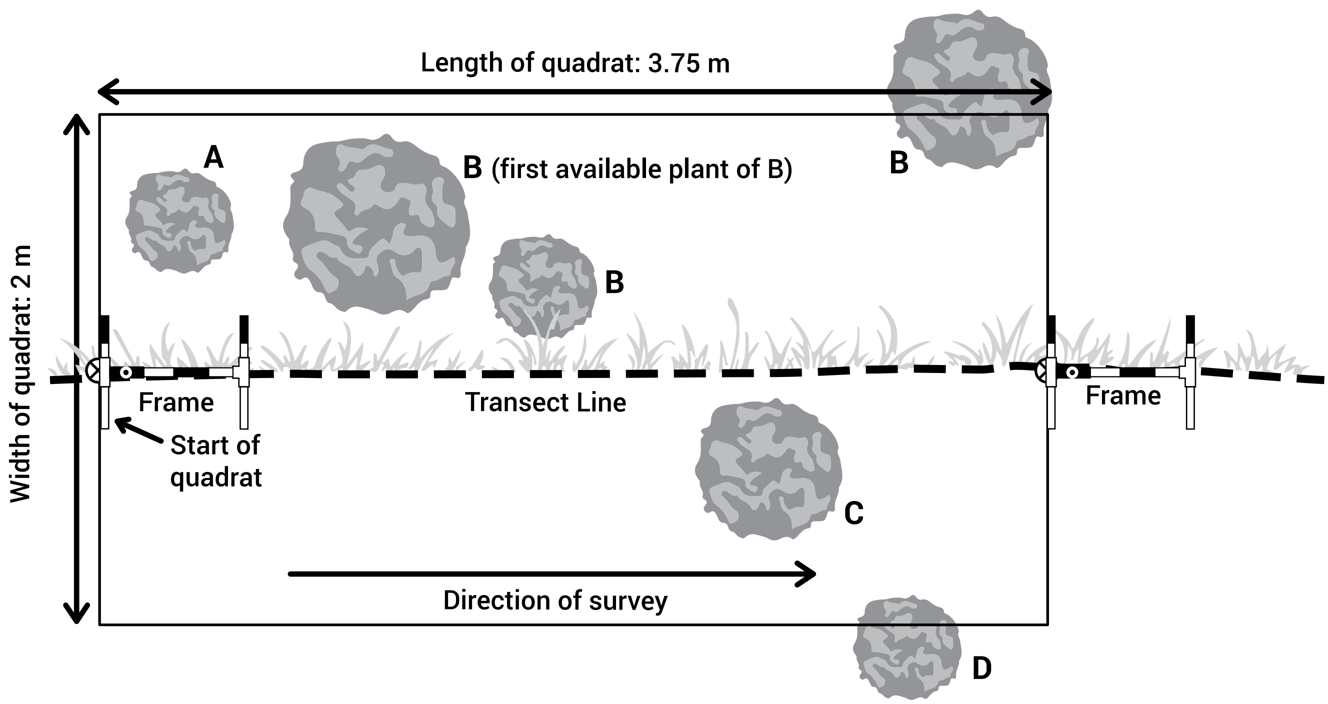

Figure 44. Example demonstrating measuring of woody riparian species in a quadrat. There are four key woody plant species in this quadrat. Key species B has three individual plants. The default method is to select the first available key woody plant of each species either rooted in or overhanging the quadrat that is closest to the start of the quadrat. Utilization is then determined on those plants. In this example, sample only the "first" available plant of species B encountered when moving from one quadrat to the next (closest to the start of quadrat). Note that species D and one plant of species B are intended to represent plants overhanging the plot (not rooted in).

- Distinguishing individual plants may be difficult in some situations.

  - Clonal, root sprouting, or rhizomatous plants can have multiple stems that comprise a single plant (e.g., coyote/sandbar willow [*Salix exigua*], wild rose [*Rosa* spp.], snowberry [*Symphoricarpos* spp.], root-sprouting cottonwood [*Populus* spp.], golden currant [*Ribes aureum*], and aspen [*Populus tremuloides*]). Although generally not as pronounced, clumped willows can also have multiple stems that are part of the same plant. In both cases, consider all stems growing in a relatively defined cluster to be part of the same plant. To help distinguish a defined cluster, consider all stems within 30 cm (12 inches) of each other at ground level as the same plant. Often, several shoots or stems may be outside the quadrat. As indicated above, if any live part of the woody plant is **rooted in or overhanging the quadrat** and it is the closest plant of that key species to the start of the quadrat, estimate its use class. See Appendix F for a list of common rhizomatous woody plants.

  - **Note:** Seedlings commonly germinate and initiate growth very close together and are clearly individual plants and they should be recorded as such. Often this results in stems being closer than 30 cm from each other.

  - If it is still difficult to distinguish individual plants using the 30 cm rule (commonly because they are dense, contiguous patches of clonal/root sprouting/rhizomatous woody plants), assess the use classes on all the stems together within the 2 m x 3.75 m (or other length) quadrat.

Step 4. Determine the available current year's growth. Current year's leaders are the current year's growth represented by long, thin, twig-like extensions growing from terminal buds that have not yet hardened into fibrous woody material. As leaders mature, cell walls thicken and harden into coarse, woody material in the second year. Browse on second-year and older leaders is not considered.

Step 5. Determine the woody species use class for selected plants. Plants are classified into a "use class" (Table 4). Table 4 use class descriptions are the standards by which use is judged.

- This process is repeated for the **first available individual** of each key woody species encountered within the quadrat as described in step 3.
- Review descriptions of use classes periodically while reading the quadrats to maintain precision and accuracy.

Step 6. Record the species code and use class. Record the USDA-NRCS PLANTS Database species code.

- Record the value that represents the midpoint for the appropriate use class for each key woody species evaluated. The midpoint is the numerical value in the middle of the range of each use class. For example, the slight use class has a range of 1–20%. The midpoint is 10%. The ONLY midpoint choices are 0, 10, 30, 50, 70, and 90 (see Table 4).
- If there are no available key woody species within the quadrat, leave blank in the data form. If woody plants are commonly unavailable, note this as a comment. This is a common occurrence when mature large woody plants dominate a site.

Table 4. Woody species use class and descriptions.

Use Class	Midpoint	Description
Unavailable	Blank	Shrubs and trees that have most (> 50%) of their actively growing stems > 1.5 m (5 ft) tall for cattle browsing. This should be adjusted if the questions to be answered involves other herbivores (see Table 5).
None	0	No browse of key woody plants.
Slight (1–20%)	10	Browse plants appear to have little or no use. Available leaders may show some use, but 20% or less of the available current year's leaders have use.
Light (21–40%)	30	There is obvious evidence of use of the current year's leaders. The available leaders appear cropped or browsed in patches and 60–79% of the available current year's leaders of browse plants remain intact.
Moderate (41–60%)	50	Browse plants appear rather uniformly used and 40–59% of the available current year's leaders remain intact.
Heavy (61–80%)	70	The use of the browse gives the general appearance of complete search by browsing animals. Most available leaders are used, and some terminal buds remain on browse plants. Between 20–39% of the available current year's leaders remain intact.
Severe (81–100%)	90	The use of the browse gives the appearance of complete search by browsing animals. There is browsing use on second- and third-year's leader growth. Plants show a clublike appearance, indicating that most active leaders have been removed. Only 0–19% of the available current year's leaders remain intact.

Table 5. Woody species browse height by animal class (BLM 1992).

Class of Animal	Height Browsed	
	Meters	Feet
Sheep, antelope, or big horn sheep	1.1	3.5
Deer	1.4	4.5
Cattle	1.5	5.0
Horses, elk, or moose	2.1	7.0

Timing:

Pre-grazing monitoring. Woody riparian species use monitoring may be done throughout the season depending on the questions that need to be answered. If there is a concern regarding the amount of utilization by elk, domestic or wild horses, or other large herbivores, monitoring may be done prior to livestock entering the grazing unit.

Monitoring during grazing. This is used to determine when livestock should be moved to meet a grazing-use criteria (i.e., trigger monitoring). This is done while livestock are still in the area and when the vegetation is close to reaching the prescribed grazing-use criterion. Such monitoring may also provide an early warning of impending damage to the plants.

End of season monitoring. The most common time to measure woody use is at the end of the grazing period or the end of the growing season (called post-grazing monitoring) to provide some of the information necessary to develop possible relationships between condition and trend and livestock grazing.

6.2 Long-Term Indicators

6.2.1 Greenline Composition

Purpose: Riparian vegetation is critically important for the stability of streambanks, streambank morphology (width, depth, and shape), water quality, and aquatic habitat quality (Hansen et al. 1988). Livestock grazing, as well as other anthropogenic disturbances, may impact vegetation through reduced vigor, soil compaction, changing species, and physical disturbance of the streambanks (Platts 1991; Swanson et al. 2015). Sampling along the greenline is designed to account for the continuous line of vegetation occurring along most streambanks (Winward 2000). Since streams are dynamic, measuring vegetation along the greenline, which can move in response to annual streamflow levels and management activities such as livestock grazing, is particularly effective for understanding the overall condition and health of the stream reach. The species of plants along streambanks provide an indication of condition, based on the health and proportion of deep, strong-rooted vegetation, and the trend toward or away from the vegetation objectives established for the stream reach.

The greenline can also be composed partially or entirely of embedded rock and/or anchored wood, which influences stream function and habitat quality. Because of this, both embedded rock and anchored wood are also recorded.

Note that the sources and criteria used to develop plant wetland indicator status, modified Winward greenline stability rating, and successional status are discussed in Appendix G.

Background: The concept of greenline composition was developed to provide a way to observe and measure the vegetation that is most critical to maintaining stream channel stability (Winward 2000). Winward describes a method using a continuous measurement and stratifies vegetation by riparian community type. The current method estimates vegetation composition by species.

Cover data collected in quadrats is commonly based on visual estimates of cover. Relative cover refers to the amount of the surface of the quadrat or stand sampled that is covered by one species (or physiognomic group) as compared to or relative to the amount of surface of the quadrat or stand covered by all species. Thus, 50% relative cover means that half of the total foliar cover of all species or physiognomic groups is composed of the single species or group in question. Relative cover values are proportional numbers and, if added, total 100% for each stand (or sample) (Klein et al. 2007). Relative cover is often a more useful measure of plant species abundance than absolute cover because it measures abundance independent of overall vegetation density, is comparable among different sites, and minimizes observer bias (Minnesota Board of Water and Soil Resources 2021).

To facilitate monitoring the understory on the greenline, the MIM protocol specifies that the relative foliar cover of herbaceous perennial vegetation, embedded rock, and anchored wood is recorded. Overstory is not recorded using relative cover; rather, if any part of a woody plant (at least 0.5 m tall) is rooted in or hanging over the Daubenmire quadrat, it is recorded by species and considered overstory. Each species is assigned an equal proportion so that all overstory species total 100% (e.g., if 2 species are in/over the quadrat, each is given 50%).

Assumptions and Limitations: The greenline follows the streambank as erosion and deposition occur along a stream. Therefore, the composition of vegetation in this zone directly affects the condition of streambanks and overall stream condition. The major plant species along the greenline are helpful for analyzing the effects of livestock grazing along a stream.

The method described here is not intended to identify all plant species along the greenline. It is intended to identify and document those plants that are in a large enough proportion to directly affect the stream and streambanks. This method may be modified to identify all species. However, such a method would be much more time consuming and require a high degree of plant identification skills with little added benefit when it comes to riparian management decisions.

A key limitation to cover estimates in general is that they are affected by growing season changes. As stated by Elzinga et al. (1998a, p. 178):

> …cover measures can change dramatically over the course of a growing season. The change in cover over the course of the growing season may make it hard to compare results from different portions of large areas where sampling takes several weeks or a few months. You may be unable to determine whether measured cover changes are due to density or production changes, cover trends can be difficult to interpret.

In addition to production, herbivory can change cover measures during the growing/grazing season as well because herbage removal (grazing) is the inverse of production (i.e., cover is decreased via grazing as opposed to being increased by growth). Laine et al. (2015) found that "percent live vegetation and bare ground, consistently reflected a seasonal effect of grazing." Although both absolute cover and relative cover are affected by changes within a season due to flood events, plant growth, grazing, and other variables, relative cover can minimize this problem as proportions of species are recorded.

It is important to note that **relative composition** is the indicator of interest, not cover in particular. Cover is the attribute that is estimated and recorded to calculate relative composition. The total cover of plants is not evaluated using this method, because total cover is dynamic, varies considerably throughout the growing and the grazing seasons, and cannot be used to track trend in long-term conditions the way relative cover can.

Relationship to Other Indicators: Greenline composition is closely related to streambank stability, woody species age class, and GGW. Streambanks dominated by deep-rooted riparian vegetation result in stable streambanks, narrow channel widths, shading, habitat diversity, and terrestrial insect production.

Procedure: Greenline composition is recorded at the sample interval at the location where the greenline rules have been met. The greenline composition quadrat is 20 cm x 50 cm.

When the DMA is initially established, a species list is developed for the greenline vegetation. In subsequent monitoring of greenline composition, the initial plant list is used but may be supplemented with additional plants if new species have become established or have been newly discovered in the DMA.

The total composition for all understory combinations (herbaceous plants, woody plant understory, embedded rocks, and/or anchored wood) must be 100%. The total for all woody overstory composition must also be 100%.

If a quadrat has both understory and woody overstory, the total composition will be 200%. Steps 3, 4, 5, and 6 refer to recording understory, and step 7 is specific to woody overstory.

Step 1. Conduct a reconnaissance and develop a plant species list. Prior to collecting greenline composition data, it is critical that observers identify the plant species located on the site.

- Complete a reconnaissance of the DMA and make a list of the most abundant and common vascular plant species along the greenline. When moving from one end of the DMA to the other, it is important to avoid trampling vegetation on the greenline. Where possible, greenline plants should be observed from the stream channel, which allows a good observation position and avoids trampling the greenline.
- If recording stubble height and woody species use, identify key species for those methods at the same time.
- For identification of unknown plants , collect plants or photograph diagnostic features. Record unknown plants as UNK1, UNK2, etc. and collect specimens for later identification. After identification, replace the UNK codes with the appropriate plant code.

Step 2. Locate the greenline composition quadrat. The greenline composition quadrat is 20 cm x 50 cm. There are two sides to the MIM frame that are divided by a 50-cm-long center bar. The greenline composition quadrat is 20 cm x 50 cm and uses only the vegetated side of the MIM frame, upslope from the greenline (Figure 45).

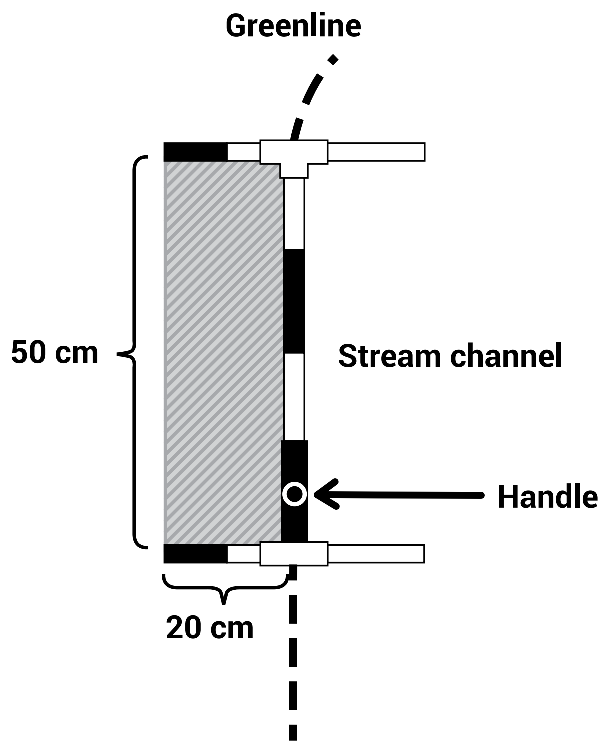

Figure 45. The greenline composition quadrat located on the greenline.

Step 3. Record herbaceous understory. This is the relative foliar cover of all live, perennial herbaceous vascular plant species. Viewing above the quadrat frame at 90 degrees to the ground surface, record by species the **relative amount** of live foliar cover of herbaceous plants rooted in the quadrat having 10% or more foliar cover by composition. The monitoring frame is marked to provide references for 12.5%, 25%, and 50% areal extent (Figure 46). Although relative cover is recorded, these markings just help to provide a visual estimate of the proportions of the quadrat. The markings help calculate proportions whether absolute or relative. When cover is 100%, the proportions work for either relative or absolute cover. The proportional markings are also helpful when plants are distributed uniformly throughout frame with small gaps.

- For example, if a quadrat contains 25% absolute foliar cover of Nebraska sedge and 25% absolute foliar cover of Kentucky bluegrass with 50% other (bare ground, litter, moss, etc.) for the purposes of relative cover, the observer will record compositions of 50% Nebraska sedge and 50% Kentucky bluegrass (see Figure 47 for an example of how to record relative cover in a greenline quadrat).
- Senesced leaves from the current year are considered live.
- Do not record herbaceous plants or plant parts that are clearly dead. Do not count dead leaves of previous season as cover; they should be moved if they obscure live vegetation.
- Annual and non-vascular plants, bryophytes, litter, dead plants, and bare ground are not recorded.
- When recording data, use the USDA-NRCS PLANTS Database species codes (http://plants.usda.gov/).
- The total for all understory composition (herbaceous plants, woody plant understory, rock, and/or wood), must be 100%.

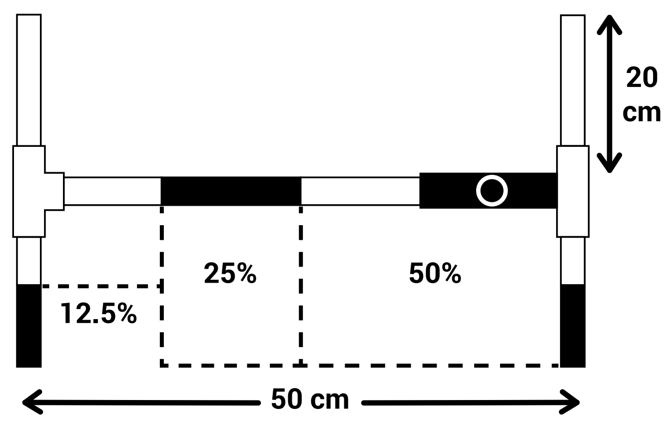

Figure 46. A MIM frame with modified Daubenmire quadrat markings. These markings provide a visual estimate of the proportions of the quadrat.

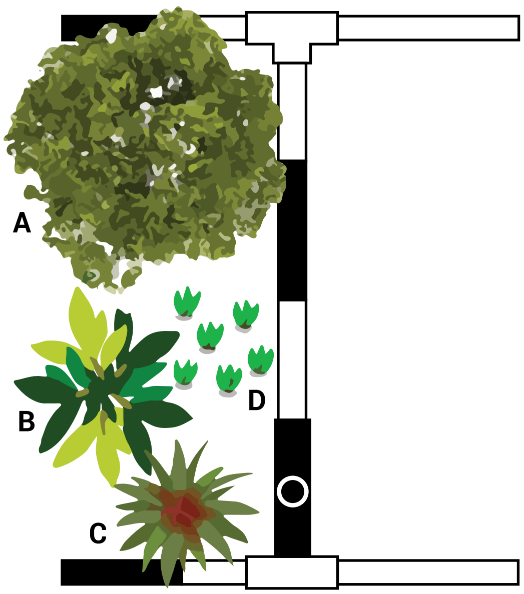

Figure 47. Understory for this quadrat is recorded as: Species A = 40%, Species B = 30%, Species C = 20% D = 10% (total = 100%).

Step 4. Record woody species understory. Woody species understory includes all live woody plants < 0.5 m tall that are rooted in the quadrat and have 10% or more foliar cover by composition. Woody species understory plants are recorded as a percent relative foliar cover by composition along with the herbaceous vegetation. Record by species the **relative amount** of live foliar cover for woody understory plants rooted in the quadrat having 10% or more foliar cover by composition (Figure 48).

- Exposed live roots of woody understory plants rooted in the quadrat are recorded in the same manner as understory woody stems—note the species code and percent foliar cover of the total understory. If it is not possible to determine the species of the observed roots, assume the roots are part of the most dominant woody plant that is closest to the quadrat and record that species. Roots of overstory woody plants are considered differently (see step 7).
- Do not record dead woody understory plants or plant parts that are clearly dead (dead woody plants are usually dry and brittle). Caution should be used to ensure plants are not simply dormant.
- When recording data, use the USDA-NRCS PLANTS Database species codes (http://plants.usda.gov).

Step 5. Record understory of embedded rock and anchored wood.

- Embedded rock (the code is RK) is defined as rock that is at least 15 cm in diameter (intermediate axis), at least partially embedded in the streambank, has no evidence of erosion behind it, is above the scour line, and is not likely to move during high flows.
- Anchored wood (the code is WD) is defined as dead woody plants or dead woody plant parts (including dead roots) that are at least 10 cm in diameter, are anchored into the streambank, have no evidence of erosion behind them, are above the scour line, and not likely to move during high flows. This includes standing dead overstory shrubs or trees. If the quadrat contains a standing dead overstory shrub or tree, it must be entirely dead. If any part of the woody plant is alive, it is not anchored wood but is considered woody understory (if < 0.5 m tall) or woody overstory (if ≥ 0.5 m tall; see step 6.)
- Embedded rock and anchored wood must also have 10% or more relative cover in the quadrat.
- Record rock and wood as a relative percentage of the total understory cover (vegetation, rock, and/or wood), totaling 100%.

Step 6. Record important plants with < 10% cover and grouped understory plants.

- **Important plants with < 10% foliar cover.** Generally, understory plants with < 10% relative foliar cover are not recorded; however, if desired, plants that have < 10% relative foliar cover can be recorded. This is usually done if there is a need to monitor minor or rare species more closely for management purposes. If there is no need to record the amount of these minor species, but their occurrence is of interest (e.g., presence of noxious weeds), the observer records the plant(s) species name on the comments sheet by quadrat number.

- **Grouped plants.** To the extent possible, all plants with 10% or more foliar cover should be identified by species. When individual plant species are < 10%, but together comprise at least 10% of the relative foliar cover, they may be recorded as a group. Examples would be mesic forbs (MFE for early seral and MFL for late seral) or mesic grass (MG), upland grass (UG), sedge (CAREXRH for rhizomatous and CAREXTF for tufted), and rush (JUNCUS) (see Section 4, Table 2 for additional groups). If known, include a list of the individual plant species that comprise the groups for a particular DMA in the DMA narrative.

Step 7. Record woody species overstory. Woody species overstory includes all live woody plant species at least 0.5 m tall that are either rooted in or overhanging the quadrat. Woody plants overhanging the composition quadrat must be rooted on the side of the stream being sampled. Do not record plants that are rooted on the opposite bank or those that are on islands that overhang the quadrat.

- **Foliar cover is not used for woody species overstory composition.** If any live part of the woody overstory (at least 0.5 m tall) is either rooted in or directly above the quadrat, it is counted as part of the composition. The observer does not attempt to estimate the relative cover of woody overstory by species but records 100% if there is one species in the overstory, 50% for each if there are two species in the overstory, 33% for each if there are three species in the overstory (arbitrarily designating one as 34% to total 100, most commonly the plant with the highest cover), and so forth. The total overstory percentage must add up to 100%. If there are many large shrubs or trees on the site, a hand-held densitometer (sighting periscope) is helpful to determine if the woody plant parts are directly above the quadrat (Figures 48–50).
- **Live woody roots, ground-level stems, or bases of woody overstory plants.** If woody overstory plants have exposed live roots or one or more woody stems/shrub or a tree bole(s) rooted in the quadrat at the ground/understory level, they are recorded as overstory (not anchored wood or understory) (Figures 49, D.17, and D.18).
- **Multiple sizes of the same species in a quadrat.** It is possible to have multiple sizes of the same woody species in both the understory and the overstory. They are distinguished in the data form by their composition percentages and height class designations (see woody height class method). For example, a quadrat may have yellow willow (*Salix lutea*, code SALU2) in the understory (i.e., < 0.5m tall and rooted in the quadrat) and one or more overstory SALU2 plants 0.5 m or taller rooted in or overhanging the quadrat. The plant code SALU2 would be recorded along with its percentage of the total understory for the short plant. SALU2 would be recorded again on another row and given the appropriate percentage of the overstory as described above. Both entries would then be given a separate height class as described in the woody species height class method.
- **Same overstory plant in multiple quadrats.** If a single overstory shrub or tree has branches or leaves hanging over more than one quadrat (i.e., spans the sampling interval), it is included in each quadrat because cover, for the purpose of calculating species composition, is the metric of interest. In addition, the occurrence and height of large overstory plants are used to calculate a shade index, which requires large plants to be recorded in every quadrat they occupy.
- **Dead woody overstory plants/plant parts.** Do not record woody overstory plants that are clearly dead. Caution should be used to ensure plants are not simply dormant. Plant parts either rooted in or hanging over the quadrat must be alive to be considered overstory (e.g., completely dead stems or branches rooted in or over the quadrat, even if connected to what appears to be a live plant, are not overstory).

- When recording data, use the USDA-NRCS PLANTS Database species codes (http://plants.usda.gov).

- Total woody overstory cover, when present, will be 100%. If a quadrat has vegetation, rock, or wood in the understory and a woody overstory, the quadrat total will be 200%.

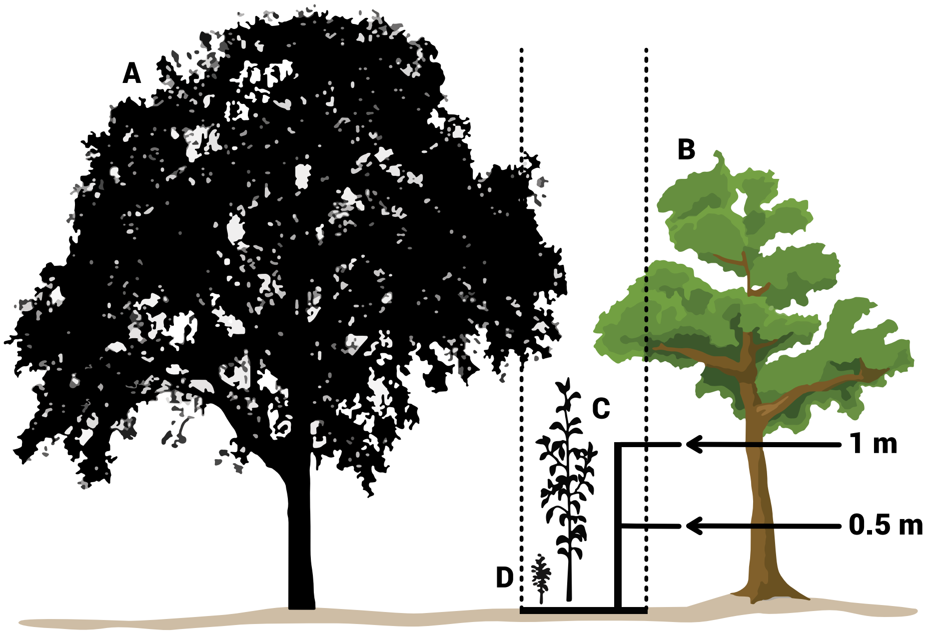

Figure 48. Example demonstrating recording woody overstory and woody understory. When recording woody overstory and woody understory, all woody plants are either rooted in or overhanging the quadrat. In this figure, greenline composition species A = 34%, species B = 33%, and species C = 33% (for a total of 100% overstory). Species D is less than 0.5 m so it is recorded as a relative percentage of the foliar cover with any other understory species. Species D could be the same species as the other three woody plants in this quadrat or a different species. In either case, species D would be recorded in a separate cell than the other woody overstory plants. The vegetation composition of this quadrat would total 200% as it has both understory and overstory.

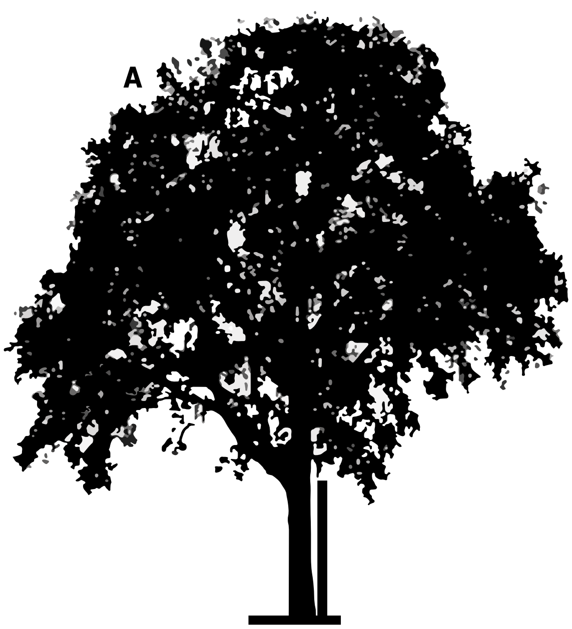

Figure 49. Recording woody overstory. Any live woody plant 0.5 m or taller is recorded as overstory. Sometimes, a large tree is rooted in the quadrat and comprises most or all the greenline quadrat at the ground level. In this situation, it is recorded as overstory, not understory or anchored wood. In this example, with only one woody overstory plant, the quadrat would total 100% if no other plants are in the understory (i.e., species A = 100%). If understory species are present, they would need to total 100% (and the vegetation composition for the quadrat would need to total 200%).

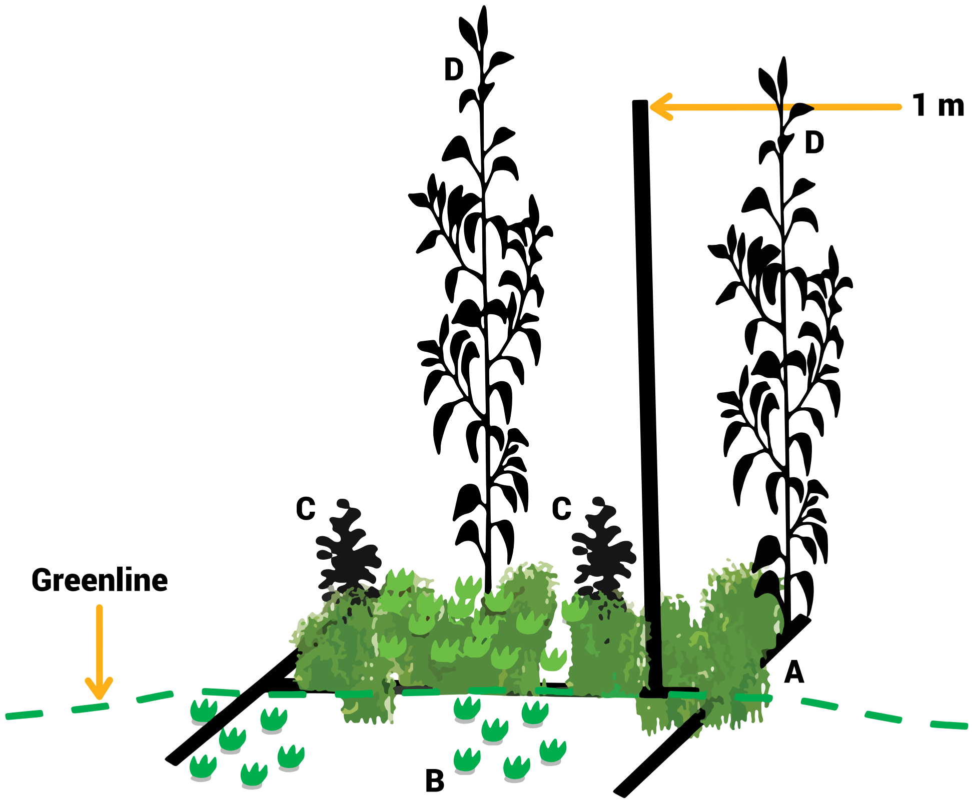

Figure 50. Recording woody overstory and herbaceous understory. Understory relative foliar cover: Species A (sedge) = 70%, species B (forb) = 20%, species C (low willow – 2 plants) = 10%. Understory total = 100%. Overstory: Species D (cottonwood – 2 plants, record species only, not the number of plants of each species) = 100% (overstory total). Quadrat total is 200%.

Step 8. Record no greenline cover. When no greenline cover exists (i.e., vegetation, embedded rock, or anchored wood) within 6 m (slope distance) of the scour line or water's edge (if the scour line is under water), record "NG" in the species column and "100" in the percent cover column.

Timing: Samples should be collected when plants are identifiable. Timing may vary according to climate and intensity of grazing use. The greenline should not be flooded at the time of sampling. As indicated in Section 3, it is important to obtain repeat samples during the same stage of seasonal progression or the same time that baseline data was collected.

6.2.2 Woody Species Height Class

Purpose: This indicator estimates the heights of woody plants adjacent to the stream. Because heights are estimated by observation, height classes were developed to facilitate a reasonable level of observer agreement. Heights are indicators of stream shading and woody biomass production. Woody species height is useful in monitoring trends in woody plant structure adjacent to the stream.

Background: The temperature of a stream is an important factor determining the types, abundance, and distribution of aquatic organisms that live in a stream (Gordon et al. 2004). Water temperature in streams (particularly small streams < 10 m wide) is directly affected by the amount of shading along the stream (Allan and Castillo 2007). Woody species adjacent to the stream are effective for providing shade and thermal insulation to the water (Gordon et al. 2004). Temperature is a common water quality issue for cold water biota in many states. As stated by Environmental Protection Agency (2023), "At the organism level, modified thermal regimes can affect survival, growth rate, gamete production, swimming speed, disease susceptibility, migratory behavior, timing of metamorphosis and other traits."

Woody species along the edge of streams provide a large amount of biomass. Woody species along with herbaceous vegetation influence terrestrial insect production. Research has demonstrated that terrestrial insect production associated with streamside vegetation is a major component of the diets of salmonid fishes; they can also be influenced by livestock grazing effects on that vegetation (Saunders and Fausch 2007).

The method for measuring woody species height is described by the PacFISH/InFISH Biological Opinion Monitoring Program (PIBO-EM 2008) and is based upon the protocol documented in Bonham (2013). It is an easy and efficient method of describing the structure of woody vegetation along the edge of the stream channel.

Assumptions and Limitations: Many woody species encountered along the streambanks are shrubs and small trees that are < 8 m tall. These plants may include species such as willow, alder, birch, snowberry, and rose. This method allows for describing the overstory layers of woody vegetation along the streambanks by identifying the height class by species. Because this indicator provides information on shade potential and vegetation structure, it applies to all woody species sampled along the greenline. These species do not have to be riparian or hydrophytic species to produce shade or vertical structure.

The tallest height class used in this method is all woody vegetation > 8 m. Thus, trees more than 8 m tall, such as mature aspen, cottonwood, conifers, and alder are estimated by a broad range > 8 m.

Relationship to Other Indicators: Woody species height class provides additional information describing the condition of greenline vegetation. It provides information concerning the growth of woody species over time.

Woody species height class provides useful input to vegetation height in the optional shading variable of the stream segment temperature (SSTEMP software) model widely used to predict stream temperature (Bartholow 2002). Shading is one factor that contributes to stream temperature regulation. Stream width, as measured by GGW, also relates to the amount of solar energy reaching the water surface; it therefore has a direct effect on stream temperature (Bartholow 2002).

Procedure: Woody species height class is recorded at the sample interval at the location where the greenline rules have been met. This method is completed in conjunction with the greenline composition method and is recorded immediately after recording greenline composition. For each woody plant recorded in the 20 cm x 50 cm greenline composition quadrat, estimate the height of the tallest live plant part of those plant species and record the corresponding height class based on the ranges in Table 6.

Step 1. Locate the woody species height class quadrat. The woody species height class quadrat is 20 cm x 50 cm. The woody height quadrat is identical to the greenline composition quadrat (Figure 51).

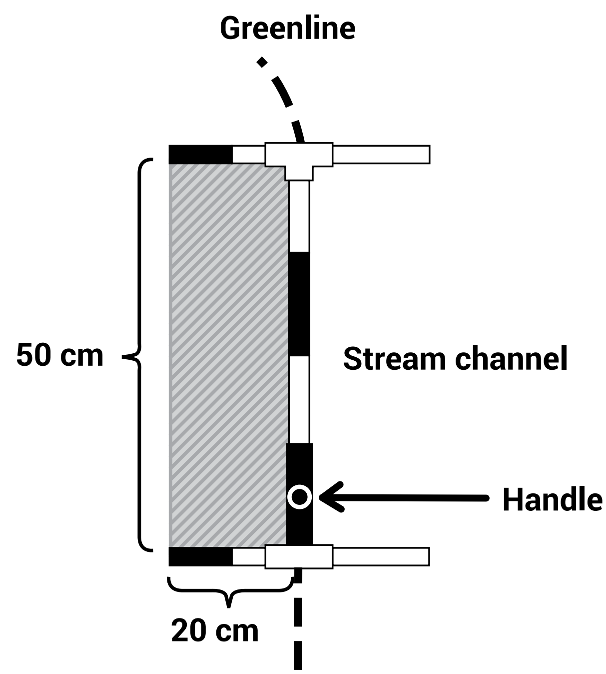

Figure 51. The woody species height class quadrat located on the greenline.

Step 2. Locate and record the height of all woody plants recorded in the greenline composition quadrat.

- Locate the tallest live part of the woody plant(s) species recorded in the composition quadrat. For example, if a yellow willow (*Salix lutea*) has one live branch hanging over the quadrat at 1 m above the ground, but it has connected live plant parts that extend to 3 m in height (tallest live part), record height class 4 (2–4 m) (see Table 6). **The tallest part does not need to be in or over the quadrat** (Figure 52). Exclude the tallest plant part of the shrub or tree if it is a dead branch. Find and record the tallest live plant part. Note that this method records all woody plants, not just woody riparian plants.
- Record the height class according to Table 6, based on an estimate of the height of the plant from its rooted base to the tallest live part of the plant. This can be done by one of several methods: (1) estimating the height class visually comparing it to the height of a known object, such as a person or a measuring rod; (2) estimating the height class by extending the measuring rod vertically from the ground up to the top of the plant; or (3) estimating height using the vertical distance or height measurement with a laser range finder.

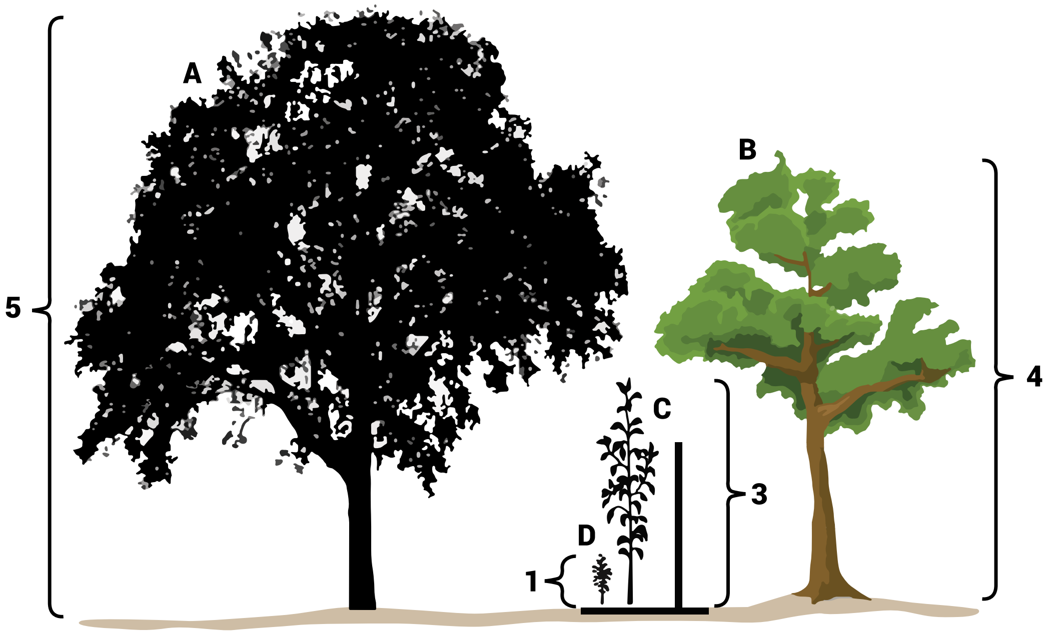

Figure 52. Recording woody heights. All woody plants in this figure were recorded in greenline composition. Note that that the height of the tallest live plant part of the species recorded in greenline composition is used, not the height of the plant part overhanging the quadrat. In this example, plant A = class 5, B = class 4, C = class 3, D = class 1.

- Record the height of clonal, root sprouting/rhizomatous species. It may be difficult to determine which plant is attached to the qualifying plant part when encountering clonal, root sprouting, or rhizomatous species that have multiple stems that comprise a single individual plant. Examples include coyote/sandbar willow (*Salix exigua*), wild rose (*Rosa* spp.), snowberry (*Symphoricarpos* spp.), root-sprouting cottonwood (*Populus* spp.), golden currant (*Ribes aureum*), and aspen (*Populus tremuloides*); see Appendix F for a list of common rhizomatous, woody plants. In these cases, consider all stems of the same species growing in a relatively defined cluster to be part of the same plant. To help distinguish a defined cluster, consider all stems of the same species growing within 30 cm (12 in) of each other at ground level as the same plant. If it is still difficult to distinguish individuals of these kind of species, record the tallest part of the clonal/rhizomatous plant that occurs from the existing sample point to the next sample point.

Table 6. Woody species height classes.

Height Class	Height Range	Composition Category
1	< 0.5 m	Understory
2	0.5–1.0 m	
3	1.0–2.0 m	
4	2.0–4.0 m	Overstory
5	4.0–8.0 m	
6	> 8.0 m	

- Seedlings of non-rhizomatous woody plants commonly germinate and initiate growth very close together. They are clearly individual plants and should be recorded as such. Often this results in stems being closer than 30 cm from each other.
- Be aware that woody seedlings with < 10% foliar cover will not be recorded in the composition method and therefore will not receive a woody species height class (these plants will be recorded in the woody riparian species age class method).
- The handle of the frame (which by design is 1 meter in length) and/or a survey rod can be used to help estimate the height of woody plants that are > 1 m.
- A densitometer can be used to assist in determining if a woody plant is overhanging the quadrat.
- If there are no woody species in the composition quadrat, leave blank.

Timing: Woody species height should be measured at the same time as the greenline composition.

6.2.3 Streambank Stability and Cover

Purpose: Streambanks are the sloped sides of the stream channel and are most susceptible to erosion during high-flow events. The area most vulnerable to water erosion is from the stream scour line to the first bench (or ***bankfull stage***) because it typically fills with water annually (Leopold 1994). Bankfull discharge performs most of the geomorphic work in most river systems (Wolman and Miller 1960). Streambank stability is strongly influenced by streamside vegetation (Bauer and Burton 1993). The loss or modification of dense and deep-rooted bank vegetation is problematic for bank stability.

Streambanks can become unstable and unable to resist the erosive effects of high streamflow as a result of improper livestock grazing, extensive trampling by large wild ungulates, or other actions that directly affect the streambank. Bare streambanks, either in erosional or depositional positions of the stream, are considered unstable due to their vulnerability to erosion. The effect of excessive grazing is the alteration of streamside vegetation composition, resulting in a dominance of plants that are more vulnerable to erosion (Platts 1991; Bauer and Burton 1993). Bank erosion may also result from breakoffs, hoof slide, and ***hoof shear***, related to the physical disturbances of trampling (Bauer and Burton 1993; Powell et al. 2000). Unstable streambanks can lead to accelerated bank erosion and subsequent channel widening, increased sediment supply, decreased sediment transport capability, and damaged fisheries habitat.

At each quadrat location, features that describe streambank stability are recorded. Those features are used to compute the percent streambank stability and cover. Quadrats are a subsample of the length of the streambank; therefore, streambank stability using this method evaluates the proportion of the streambank (percent of quadrats) that are stable and covered.

Background: This method is based on an earlier version described by Bauer and Burton (1993) and later by Overton et al. (1997). Modifications were made by the PacFISH/InFISH Biological Opinion Effectiveness Monitoring (PIBO-EM) Program to minimize subjectivity (Kershner et al. 2004). The current version further reduces subjectivity by allowing observers to record features that define the condition rather than to record the stability class. Rules are used to increase measurement precision.

Assumptions and Limitations: Streambank stability can be used to monitor the effects of livestock grazing and other disturbances only if the procedures are adhered to strictly and the definitions are understood and followed. Streambank stability should be assessed by well-trained observers as untrained observers have documented poorer outcomes (Heitke et al. 2008).

Because of how observations are made, streambank stability can only be assessed when the stream is flowing below the scour line, usually well after the seasonal peak flow event. Streambank stability monitoring is voided if assessments are made when the banks are flooded, or the scour lines are inundated.

From tests on 12 different streams, the authors determined that an average of 54 samples were needed to detect a change of 10%. However, site variability can greatly influence the sample size requirements. The authors' tests indicated sample-size estimates as low as 5 and as high as 102 to estimate streambank stability within 10% of the mean (see MIM Data Instructions Guide, Estimating Sample Size). Use of an electronic sample-size estimator will help determine the precision level and the confidence interval based on the data collected at each site.

In tests of repeatability for streambank stability from 43 sites, the authors found an average difference between observers of 8.2% for stability and 8.5% for cover, with coefficients of variation of 9% for stability and 8% for cover (MIM Data Instructions Guide, Testing Observer Variation).

Note for vegetated drainageways:
Streambank stability and cover are designed to be recorded on streams with distinct streambanks and usually a scoured channel. Because vegetated drainageways commonly do not have continuous streambanks, these indicators (streambank stability and cover) are not always appropriate for those parts of vegetated drainageways that lack channel and streambank features. Where channel and streambank features are discontinuous, users should determine if it is informative to monitor streambank stability and cover.

Relationship to Other Indicators: Streambank stability is inversely related to streambank alteration (correlation coefficient of -0.71,) and affects GGW (correlation coefficient of -0.50). In addition, streambank stability is related to the Winward greenline stability rating (correlation coefficient of +0.50), an estimator of the vegetative contribution to bank stability (authors' unpublished data).

Procedure: Streambank stability and cover consist of three observations: (1) the type of streambank (depositional or erosional), (2) the amount of cover resulting from the combination of perennial vegetation, rock (≥ 15 cm in diameter), and anchored wood (≥ 10 cm in diameter), and (3) the type of streambank instability feature, if present. These observations are made in the streambank stability and cover quadrat, which is 50 cm long and extends from the scour line to the lip of the first bench (or the top of the bar for depositional banks without a distinct bench) (Figure 55).

Step 1. Identify the streambank. Streambank stability is assessed on that part of the streambank between the scour line and the lip or edge of the first relatively flat bench above the scour line (for erosional banks, and the top of the bar for depositional banks). The top of the bar is commonly about the same elevation as the bankfull stage, which is associated with the floodplain elevation.

- Locate the scour line. The scour line is generally identified by (1) the lower limit of sod-forming or perennial vegetation on depositional banks (Figure 53.A), or (2) the ceiling of undercut banks at or slightly above the base-flow elevation (Figure 53.B), or (3) the elevation of the trim line or erosional line that forms on erosional banks and which corresponds to the elevation of undercut banks elsewhere in the DMA (Figure 53.C). The scour line is best observed on a straight, well-vegetated section of a reach. Look upstream, downstream, and across the channel for a consistent elevation that matches the description of the scour line. The scour lines are not always continuous;

however, by noting the approximate elevation or height above the water surface where scour lines are well defined, one can extrapolate or project them to streambanks where scour lines are not evident due to a lack of vegetation, bank trampling, or collapse of undercut banks (Figure 53.D). For example, if the ceiling of undercut banks and the lower limit of sod-forming vegetation are located 5 cm (2 in) above the water-surface elevation, then that height above water surface is used consistently at all quadrat locations to define the location of the scour line, even where evidence of a scour line is locally absent.

Figure 53. Examples of scour lines.
A. A scour line illustrated by lower limit of sod-forming vegetation.
B. Scour line at the ceiling of an undercut banks.
C. A scour line indicated by the trim line or erosion line (notice the shadow of slightly undercut bank at white arrows) associated with streamflow action on an eroding bank.
D. Scour lines can be projected through areas where they are not evident by noting the height of obvious scour lines above the water surface. In D, the lower limit of sod-forming vegetation is 2–3 cm above the water surface in the foreground. This elevation can be projected (white dashed line) through bare banks where hoof action has obliterated bank vegetation and scour-line features.

- Locate the first bench above the scour line. The lip or edge of the first bench is the point on the streambank where the slope changes from the relatively flat top to the slope toward the stream. The first relatively flat bench may coincide with an in-channel depositional bar below the floodplain (Figure 54.A), with the top of the bank at the floodplain elevation (Figure 54.B), or with the lip of a terrace above the bankfull stage Figure 54.C). On depositional banks, the bench is commonly associated with a gentler slope break (Figure 54.A) and may not be distinct (see the point bar in Figure 53.C). And on erosional banks, such as cutbanks located on the outside bank of a meander bend, the evaluated streambank and cover quadrat may extend to the edge of a terrace (Figure 54.C). In stable systems, the edge of the first bench and the top of the bar commonly coincides with the floodplain or bankfull elevation (Figure 54.B).

Figure 54. Locating the first bench can vary (pictured in all three images as a white dashed line).
A. The lip of the first bench might coincide with an inset depositional bar below the floodplain (yellow dashed line).
B. The edge of the first bench is located at the level of floodplain (yellow dashed line).
C. Alternatively, the edge of the first bench coincides with a geomorphic surface, such as a terrace (red dashed line) above the floodplain.

Step 2. Locate the streambank stability and cover quadrat. The streambank stability and cover quadrat is 50 cm long (i.e., the length of the MIM frame), extends from the scour line to the lip of the first bench, and runs straight up the streambank (Figure 55). This means that the width of the stability and cover quadrat will vary depending on the distance between the scour line and the first bench. The lip of the first bench is the point where the slope changes from a relatively flat surface to the slope inclined toward the stream channel (Figure 54).

Figure 55. Positioning the streambank stability and cover quadrat from the scour line to the lip of the first bench. The quadrat to evaluate streambank stability and cover extends from the scour line (or water's edge or edge of the active channel) to the lip of the first bench. The quadrat is oriented straight up the bank and is 50 cm long (i.e., the length of the MIM frame).

- Always assess streambank stability and cover when streamflow is at or below the scour line.
- Small intermittent channels with relatively dense perennial vegetation growing in the streambed (with no observable scour line, i.e., no undercut banks and the lower limit of sod is into the channel bottom) are sometimes encountered. In those cases, the streambank stability and cover quadrat is from the edge of the active channel (which typically coincides with where the channel bed meets the upward inclined streambank) and extends up the streambank to the lip of the first bench. Note that the active channel is defined in the MIM protocol as the channel bed up to the scour line.
- The greenline might coincide with or be above the scour line. The lower end of the stability and cover quadrat is not determined by the greenline, it is established by the scour line (although many times the greenline and the scour line are the same).

- Do not include any part of the channel below the scour line or within the active channel when determining streambank stability and cover. The streambed is not part of the streambank.
- The streambank stability and cover quadrat is always oriented perpendicular (straight up the streambank) and is not oriented to the greenline (Figure 56). Because the MIM frame can be rotated up to 75 degrees to follow the greenline, it is important to orient the stability and cover plot straight up the streambank and to avoid offsetting it whenever the direction of the greenline deviates from the horizontal contour of the streambank.

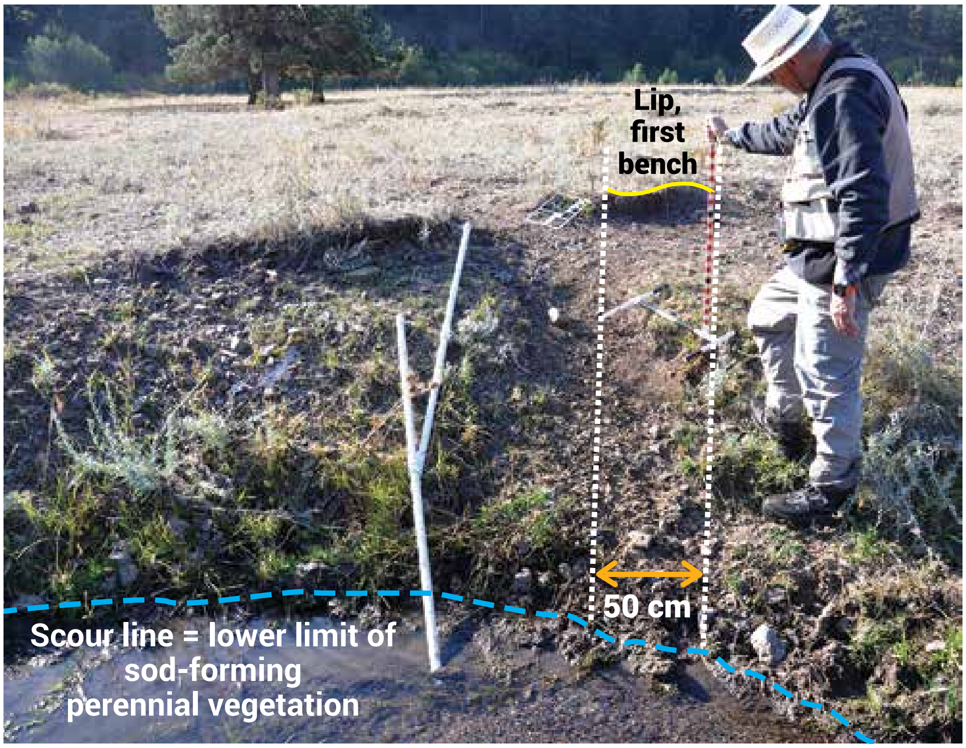

Figure 56. The streambank stability and cover quadrat extends from the scour line to the lip of the first bench. It is 50 cm long (i.e., the length of the MIM frame), is oriented perpendicular to streamflow, and extends from the scour line (or edge of the active channel) to the edge or lip of the first bench.

Step 3. Determine the kind of streambank in the quadrat. Address each of three questions to determine streambank stability and cover.

Question 1: What kind of streambank is it? The choices are depositional (D) or erosional (E), which are defined as:

- **Depositional (D).** This applies to all streambanks associated with sand, silt, clay, or gravel deposited by the stream. These are recognizable as “bars” along the channel margins adjacent to the greenline and at or above the scour line. Bars are typically lenticular-shaped mounds of deposition adjacent to the streambank. Depositional streambanks are usually at a low angle from the water surface (generally, but not always < 30 degrees) and may not be associated with a distinct bench. Depositional banks are common on the inside bank of a meander bend and may also occur along straight reaches. They are uncommon on outside banks of meander bends.

Note: Small deposits of fine sediment or micro-features in the streambank or channel bed at or near the water’s edge do not denote depositional banks. Depositional banks are a macro-feature of the stream channel and usually extend to approximately the bankfull elevation of the stream channel. It is important to ignore small patches of ***fines*** when designating the kind of bank.

- **Erosional (E).** This applies to all remaining banks that are not identified as depositional. Erosional streambanks are normally at a steeper angle to the water surface (generally, but not always > 30 degrees) than are depositional banks and are usually associated with an apparent bench, floodplain, or terrace. Such banks typically occur on the outside of meander bends and on both sides of the stream in straight reaches. When there is sufficient stream energy, erosional banks may also occur on the inside bank of a meander bend. For deep, narrow stream channels, erosional banks are dominant on both sides of the stream.

Question 2: Is the streambank covered?
View the quadrat perpendicular to the ground surface. Record covered (C) or uncovered (U) banks, which are defined as:

- **Covered (C).** This applies to banks within the streambank stability and cover quadrat that have 50% or more absolute cover of one or a combination of the qualifying cover categories described below:
  - The cover quadrat has at least 50% absolute foliar cover of perennial vegetation within 50 cm from the soil surface (i.e., no more than 50 cm above the ground surface of the quadrat). Absolute foliar cover is the percent of the ground surface that is covered by the aerial portions (leaves and stems) of plants when viewed from above.

    Note: Vegetation does not need to be rooted in the quadrat. Tall graminoids or shrub branches draped over the streambank stability and cover quadrat are considered cover provided they are within 50 cm (20 in) of the soil surface, within the vertical projections of the quadrat, and are attached to the soil either inside or outside the quadrat.

    Note: Senesced, dormant, and dead plants are counted as cover if they are rooted/attached in the soil. (Also note, this description of cover, used to determine streambank cover, is not the same as the cover criteria used to identify the greenline). Detached plant matter is regarded as litter or debris and is not cover unless it is anchored wood.
  - The cover quadrat has at least 50% absolute cover of live exposed roots of perennial vegetation.
  - The cover quadrat has at least 50% absolute cover of rocks with a diameter (as measured by the intermediate axis or b-axis) of 15 cm (6 in) or greater; refer to Substrate Section 6.2.6 for a description of the intermediate axis (or b-axis). The rock does not need to be embedded. Include bedrock as rock cover.
  - The cover quadrat has at least 50% absolute cover of anchored large woody debris with a diameter of 10 cm (4 in) or greater (standing dead trees/roots and root wads are considered large woody debris).
  - The cover quadrat has at least 50% absolute cover in a combination of perennial vegetation, roots, qualifying rock (≥ 15 cm intermediate axis) and/or large woody debris.
- **Uncovered (U).** This applies to all banks that are not covered, meaning the streambank cover quadrat has < 50% cover of perennial vegetation, rock, and anchored wood. Uncovered banks are commonly represented by inorganic material (i.e., soil and small rocks < 15 cm in intermediate or b-axis diameter) as well as organic material such as litter, fine debris, moss, etc. that are susceptible to displacement by streamflow.

After reviewing the criteria above, determine the absolute cover for each of the cover constituents: (1) perennial foliar vegetation cover, (2) rock, and (3) large wood. Record each cover constituent to the nearest 10%. If two or more cover types overlap, do not add the overlap amounts; only record the portion of overlapping cover closest to or directly on the ground surface (e.g., record rock on the ground and not the overlapping vegetation cover immediately above the rock). Do not include annual plants, moss, bare ground, and/or litter in these estimates.

Question 3: Is the streambank stable? This question applies to erosional banks only. No response is recorded for depositional banks, as covered depositional banks are considered stable and uncovered depositional banks are unstable. For erosional banks, determine if one of the instability features (***fracture, slump, slough,*** or eroding) is present, or if instability features are absent. If more than one instability feature is present, select the single most-prominent feature. Each feature class is illustrated in Appendix H and described below:

- **Fracture (F).** A fracture is a visible crack at the top of streambank where the fracture-bounded area has not detached entirely from the streambank (i.e., it is not yet a discrete slump block as defined below). Fractures indicate a high risk of breakdown or streambank failure. To qualify, the fracture must be at least one-fourth of a frame length (12.5 cm) (Figures H.4, H.5, and H.15).

  Note: The fracture feature might express itself on the surface at the top of the bank or first bench but recognize that the fracture plane extends underneath the slump to an elevation below the top of the first bench, and thus it counts as a feature of instability within the bank stability plot.

- **Slump (SP).** This applies to a portion of streambank that has obviously slipped, resulting in a block of soil and/or sod separated from the streambank. Some slump blocks are the result of hoof shear, causing displacement of a small portion of streambank downward. Other slump blocks represent collapses of large sections of the streambank considerably wider than the monitoring frame. The slump feature must be obvious and at least one-fourth of the frame length (12.5 cm) (Figures H.4, H.6, H.8, H.14, and H.15).

- **Slough, or sluff (SF).** This applies to streambanks where loose, disaggregated soil or sod material has been shed or cast off and has accumulated either on an inclined slope or at the base of a vertical or nearly vertical streambank. The slough must be obvious and at least one-fourth of the frame length (12.5 cm). Slough commonly forms from ungulate trampling on a streambank, as well as by the freeze-thaw cycles, wetting and drying, and other processes that form dry ravel (Figures H.7, H.9, and H.11). Dry ravel is defined as loose, unconsolidated, disaggregated particles moved by gravity down a slope (Gabet 2003).

- **Eroding (E).** Eroding features are bare and usually steep (within 10 degrees of vertical), and usually located on the outside bank of meander bends. Sometimes erosional features are encountered that are not steep (i.e., not within 10 degrees of vertical), do not have fractures, slumps, or slough, but they are bare and eroding. Such banks are not stable and are therefore designated as eroding. The erosion feature must be obvious and at least one-fourth of a frame length (12.5 cm) (Figures H.7–8, H.11–13, H.15).

  Note: Undercut streambanks are scoured or eroded below the elevation of the base of sod or the roots of vegetation, and because such erosion occurs mostly below the scour line, it is not considered an eroding bank. Such undercut streambanks are stable if there is no slough, slump, fracture, and/or erosion above the scour line or ceiling of the undercut bank.

- **Absent (A).** This applies when none of the above-listed characteristics are present (Figure H.3, H.12, and H.14). Absent implies a stable streambank.

Timing: Streambank stability and cover are routinely measured in conjunction with streambank alteration as the two are inversely related. Taken together, streambank alteration provides insight on the cause-and-effect relationship between a short-term measure of disturbance and the resulting effect on streambank conditions. These two indicators, collected both before and after grazing, help to establish allowable or acceptable levels of streambank alteration. If a reference is available, measurements both before and after grazing would be made in the ungrazed reference area to isolate natural effects (e.g., wild ungulate trampling) from effects related to management activities (e.g., authorized livestock grazing). In the absence of the need to quantify streambank alteration criteria, streambank stability and cover should be measured at a regular interval (approximately once every 3–5 years) when all other relevant long-term indicators are monitored.

6.2.4 Woody Riparian Species Age Class

Purpose: Woody species age class data help determine if woody riparian plants are establishing along the streambank. Winward (2000) found that use of the greenline edge as the center of the measurement ensures that sampling is generally done in a setting where regeneration of woody riparian species is most likely to occur.

Background: Winward (2000) concluded that understanding the age class, structure, and density of woody species along the stream margins provides information necessary to evaluate the results of management. Woody species regeneration, as described by Winward (2000), consists of a 6-foot-wide belt centered on the greenline and running along both sides of the stream. All woody species (excluding rhizomatous woody species) were counted and placed in an age class defined in the method described in Winward (2000).

In the MIM Technical Reference TR 1737-23, the method for woody age class was modified from the Winward belt method to a 0.42 m x 2 m quadrat (four lengths of the 42 cm x 50 cm monitoring frame). The quadrat was placed perpendicular to the greenline, with 1 m on each side of the greenline; this increased precision and allowed for evaluating the data using statistical methods. **In this latest version of the MIM, the quadrat size is modified again; the quadrat size increased from 0.42 m x 2 m to 1 m x 2 m.**

Using the 0.42 m x 2 m quadrat for several years revealed that too often the sample size of woody plants was small, taken from only 12% of the linear length of the greenline. This quadrat expansion increases the sample to more than one-fourth of the greenline (for 3.75-meter quadrat spacing) and was done to increase the probability of sampling more woody plants at a DMA. In simulations of random placements of seedlings, young, and mature plants along the greenline, the proportion of the time the 0.42 m x 2 m quadrat encountered plants averaged 35%, while the 1 m x 2 m quadrat encountered woody plants more than 50% of the time (with a 2.75 m quadrat spacing).

Single- and multiple-stem species are grouped by age class and the number of plants is recorded for each class (Tables 7–9).

Assumptions and Limitations: Stream disturbance or sediment deposition is often required for germination and establishment of many woody riparian species along streams (Winward 2000). The most frequent sediment deposition is along the margins of streams resulting from relatively frequent small floods (i.e., those with return frequencies of every 2 or 3 years). This deposition creates relatively frequent conditions conducive for woody riparian species to germinate and establish.

The method described here is designed to provide decisionmakers with information concerning the recruitment of woody riparian species along streams. For systems with the potential to produce woody vegetation, this method helps provide an understanding of whether the woody species are increasing, decreasing, or maintaining numbers and age classes.

Relationship to Other Indicators: Woody riparian species age class is only a part of the data needed to understand condition and trend. It should be used in conjunction with greenline composition, streambank stability and cover, and GGW. Woody species use provides information to assess whether browsing is a factor contributing to a change in the population and health of the woody vegetation along the greenline.

In the Elk Creek study conducted by the authors, woody browse utilization was in the moderate class in 2005 while woody age-class diversity was low at 0.31, mostly due to a lack of seedlings and young woody plants. With the modification of the grazing operation so that woody browsing was significantly reduced, woody use was reduced to the light class and the woody age-class diversity more than doubled to 0.63 in 2019, mostly because of an increase in seedlings and young plants (authors' unpublished data).

Procedure: Woody riparian species age class is recorded at the sample interval at the location where the greenline rules have been met. The woody riparian species quadrat is 1 m x 2 m wide. This indicator records the age class of woody riparian species located within 1 meter of the greenline.

Step 1. Locate the woody riparian species age-class quadrat. The woody riparian species quadrat is 1 m x 2 m wide, centered on the greenline (1 m on each side of the greenline; Figure 57).

- For very narrow streams with woody plants in the channel, the width of the woody riparian species age-class quadrat does not extend beyond the middle of the channel (this will also avoid sampling plants rooted on the opposite bank).
- At the bottom of the DMA, if the bottom marker interrupts the woody riparian species age-class quadrat (i.e., shortens the quadrat), record only those woody plants from the sample point to the bottom marker (see Section 4).

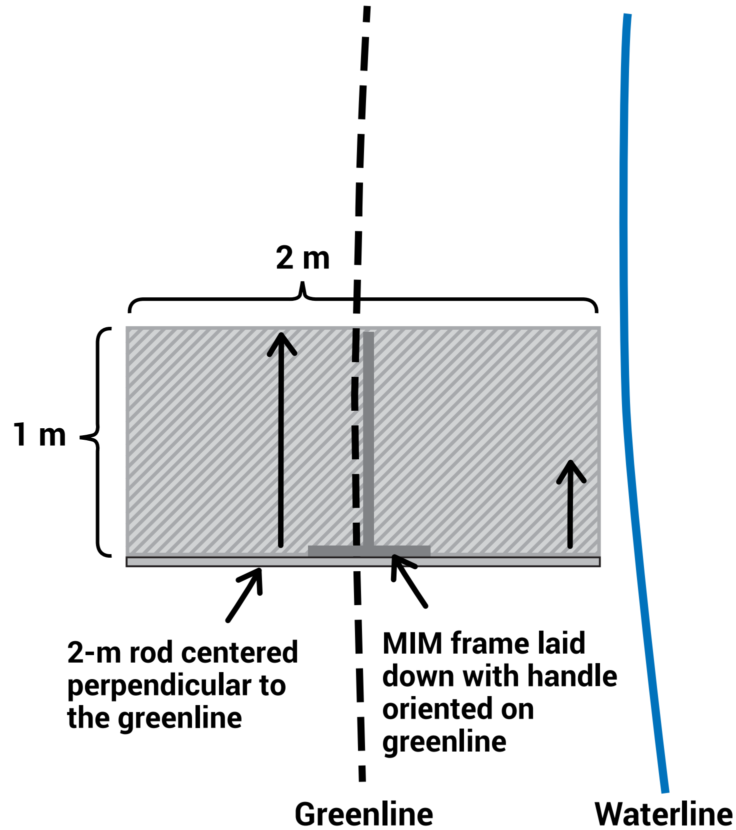

Figure 57. The woody riparian species age class quadrat. A 2-m rod and the MIM frame can be used to identify the quadrat. The MIM frame handle is laid down along the greenline and the 2-m rod is placed perpendicular to the greenline orientation with the 1-m mark centered on the greenline. The 2-m rod can then be used as a gauge and slowly moved up to the end of the MIM frame handle (1 m) to identify the quadrat.

Step 2. Identify all woody riparian plants rooted within the 1 m x 2 m quadrat. Woody riparian plants are those with a **wetland indicator status** rating of facultative, facultative wetland, or obligate. Record all woody riparian plants in the quadrat.

- An effective way to layout the quadrat is to lay the frame down along the greenline with the handle on the ground. Place the rod across the greenline with the 1-m mark centered on the greenline. To determine if a plant is in the quadrat, move the 2-m rod to the end of the handle and identify all woody riparian plants in the quadrat (Figures 57 and 58). There are other ways to layout the quadrat with the frame and rod; however, the most important aspect is to ensure that the 1 m x 2 m quadrat is centered on the greenline.

- Look carefully and closely at the ground surface to locate any woody riparian plants in the quadrat. Seedlings can be very small and are often hidden in herbaceous vegetation.
- Distinguishing individual plants can sometimes be difficult. To distinguish individual plants from one another when shrubs have multiple stems growing close together, consider all stems within 30 cm (12 in) of each other at ground level as the same plant. Record the age class of the entire shrub to which that stem is connected, even if part of the shrub is outside the quadrat. The presence of even one stem within the quadrat requires the observer to determine if that stem is connected to others outside of the quadrat (Figure 58).

  Note: Seedlings commonly germinate and initiate growth very close together and are clearly individual plants. They should be recorded as such. Often this results in stems being closer than 30 cm from each other.
- Only evaluate woody riparian species rooted in the quadrat. Do not consider plants that are not rooted in the quadrat (i.e., woody overstory hanging over the quadrat are not considered).
- For each species identified, record the USDA-NRCS PLANTS Database species code in the species column. If multiple species are rooted in the quadrat, record each one in a separate row on the data sheet.
- If an individual woody plant spans more than one quadrat, it is only recorded in the first quadrat in which it occurs.

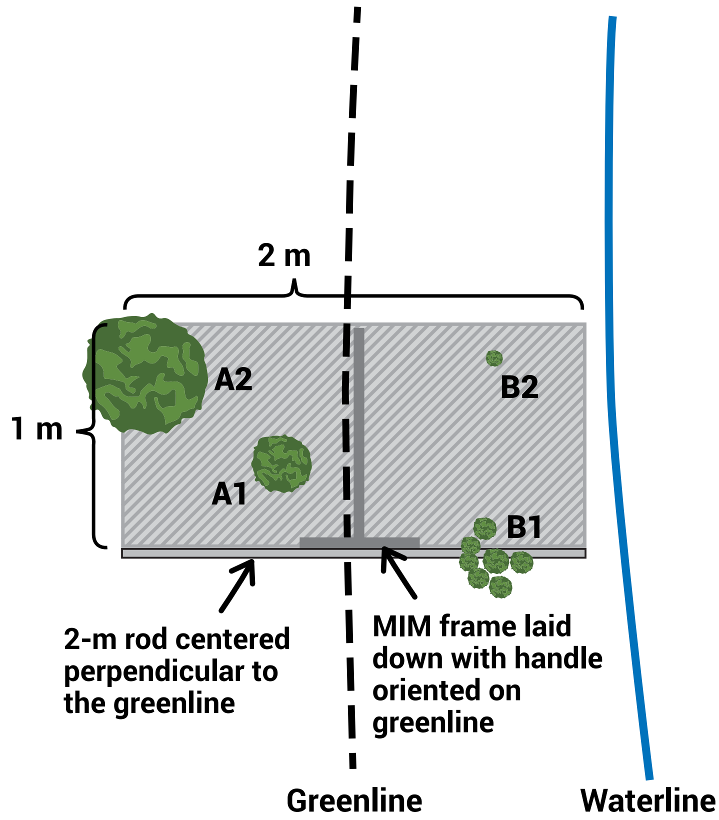

Figure 58. Four separate woody riparian plants are rooted in this quadrat. Plants A1 and A2 are the same species as are plants B1 and B2. This quadrat would be recorded as follows: Species A = 1 mature (A1), 1 young (A2); Species B = 1 seedling (B1) and 1 young (B2 is a cluster of 7 willow stems less than 1 m tall, therefore it is young). In this example, 2 stems of species B2 are rooted inside the quadrat boundary. If any part of a woody plant is rooted in the quadrat, the entire plant to which it is connected is evaluated for its age class even if some of the plant is rooted outside of the quadrat.

Step 3. Count and record each woody riparian plant by age class. For each woody riparian species recorded, count and record the number of individual plants within each age class.

Record the number of plants by species for each age class, not the number of stems (Figure 58). For single-stemmed species, use the classes in Table 7. For multi-stemmed species, use the classes in Table 8.

- **Low-growing shrubs.** Some low-growing riparian shrubs are considered mature when they are a minimum of approximately 30 cm tall, such as Wolf's willow (*Salix wolfii*), undergreen willow (*Salix commutata*), mountain willow (*Salix eastwoodiae*), shortfruit willow (*Salix brachycarpa*), and diamondleaf willow (*Salix planifolia* spp. *monica*). Table 9 should be used for most low-growing willows. It should not be used for matted willows like arctic willow (*Salix arctica*) and snow willow (*Salix nivalis*), which are even shorter statured. If a question arises, use plant growth form descriptions in the literature to determine the appropriate age class. See Appendix F for a list of common dwarf riparian shrubs.
- **Clonal, Root Sprouting/Rhizomatous Species.** It is difficult to age class rhizomatous/root sprouting species such as coyote/sandbar willow (*Salix exigua*), wild rose (*Rosa* spp.), snowberry (*Symphoricarpos* spp.), root-sprouting cottonwood (*Populus* spp.), golden currant (*Ribes aureum*), and aspen (*Populus tremuloides*); therefore, if root sprouting/rhizomatous species occur in the quadrat, record a "1" in the rhizomatous column of the DMA form. See Appendix F for a list of common rhizomatous riparian shrubs.

  Note: Aspen and cottonwood that are not root sprouting should be considered single-stemmed species.
- If there are no riparian woody species rooted within the quadrat, leave blank.

Table 7. Woody riparian species age classes for single-stemmed species (e.g., cottonwood, aspen, maple).

Age Class	Stem Height and Diameter
Seedling	Stem is < 1m tall OR < 2.5 cm in diameter at 50% of height from ground level
Young	Stem is ≥ 1m tall OR 2.5–7.6 cm in diameter at 50% of height from ground level
Mature	Stem is ≥ 1 m tall and > 7.6 cm in diameter at 50% of height from ground level

Table 8. Woody riparian species age classes for multi-stemmed (clumpy) species (most willows, alder, birch).

Age Class	Stem Height and Diameter
Seedling	1 stem < 0.5 cm in diameter at the base and < 0.5 m tall
Young	2–10 stems < 1 m tall, OR 1 stem 0.5–1 cm in diameter at the base
Mature*	≥ 2 stems over 1 m tall OR > 10 stems that are ≥ 1 cm in diameter at the base

* Mature plants can be height suppressed due to repeated, heavy browsing. Thus, the mature class includes larger diameter stems that are shorter than 1 m tall (Singer et al. 1994, Chadde and Kay 1991).

Table 9. Woody riparian species age classes for low-growing or dwarf shrubs that are generally mature at approximately 30–50 cm tall (e.g., shortfruit willow, Wolf's willow, and undergreen willow).

Age Class	Stem Height and Diameter
Seedling	1 stem < 0.5 cm in diameter at the base and < 30 cm tall
Young	2–10 stems < 30 cm tall OR 1 stem ≥ 0.5 cm in diameter at the base
Mature	≥ 2 stems over 30 cm tall

Timing: Sampling should be conducted when woody plants can be identified and at the same time as greenline composition and woody species height class are recorded.

6.2.5 Greenline-to-Greenline Width (GGW)

Purpose: Greenline-to-greenline width (GGW) is the distance between the greenlines on each side of the stream. It provides an indication of the width of the channel and can reflect the disturbance of the streambanks and vegetation. When streambanks are disturbed by trampling or excessive vegetation consumption, they may erode, leading to channel widening and loss of streambank vegetation. This change in channel shape and condition can be monitored with GGW measurements. As stated by Winward (2000):

> Most often the greenline is located at or near the bankfull stage. As flow recedes and the vegetation continues to develop summer growth, it may be located part way out on a gravel or sand bar. At times when banks are freshly eroding or, especially when a stream has become entrenched, the greenline may be located several feet above bankfull stage.

The loss of vegetative integrity and breakdown of streambanks by ungulate trampling may lead to bank erosion and subsequent channel widening (Rosgen 1996; Belsky et al. 1999; Clary 1999). Conversely, as disturbed and overwidened streams recover, perennial riparian vegetation establishes and spreads along streambanks leading to channel narrowing and a decrease in GGW. Because vegetation is frequently related to bank stability, the distance between greenlines is an excellent way to monitor the effects of chronic disturbance on channel geometry. As channels widen, water depth decreases with potentially negative effects on aquatic habitat and water temperature (Belsky et al. 1999).

Background: Improper livestock grazing (i.e., excessive streambank trampling and ***hoof shearing***) or other physical disturbances to the streambanks have resulted in overwidening of many stream channels (Clary et al. 1996; Clary 1999; Clary and Kinney 2002; Kauffman and Krueger 1984). Under improper grazing, protective vegetation is weakened or removed, and trampling may induce a change in the streambank profile (Clary and Kinney 2002). Subsequent erosion of weakened streambanks during floods results in a wider, shallower stream channel. These changes to stream channels can be detrimental to biota (Bohn 1986). Observations at research sites indicated that elimination of grazing led to 12%–20% reductions in bankfull width (Magilligan and McDowell 1997). In another research site, the average amount of narrowing was inversely associated with the level of grazing intensity (Clary 1999). Clary found that between 1990 and 1994, width changes (measured as a proportion of the original measurement) were a 41% reduction in areas with no grazing, a 34% reduction in areas with light grazing, and an 18% reduction in areas with medium grazing.

Commonly, the width of stream channels is determined by measuring channel width at the bankfull level. Detailed measurements of width and depth are made by surveying channel cross-section profiles. This method, measured at numerous positions along the stream, is impractical because it requires identification of bankfull indicators, which in disturbed streams are often missing or so poorly defined as to be ambiguous and difficult to identify reliably.

As summarized by Bauer and Ralph (2001), the major concern with use of width measurements at bankfull level is the reliability of the method. Bankfull width is determined by using field characteristics such as sediment surfaces and profile breaks to identify the elevation of the active floodplain surface. These field features can be vague; the actual selection of bankfull level is, at best, subjective, particularly in degraded systems.

Other field methods have measured the “wetted width” of the stream. Although this level in the channel is easily identifiable, unfortunately, wetted width varies dramatically by streamflow.

Because it is normally measured during low or baseflows, it provides little information about the overall channel characteristics of the measured stream. The authors have witnessed intra-day changes in wetted widths of 1 m or more in a matter of a few hours in response to summer rainstorms or diurnal changes in the rate of spring snowmelt.

To achieve an adequate sample for estimating the mean GGW, take measurements at each sample location while sampling upstream. To avoid potential spatial autocorrelation of GGW measurements, do not measure while sampling downstream in the DMA. The results are a mean width from one greenline to the other across a stream channel. As streambank conditions improve, the stream channel typically narrows and the average GGW decreases.

Assumptions and Limitations: Objectives specific to GGW should be developed from reference sites when such information is available. Results of the authors' testing at 54 sites indicated reasonably good repeatability (MIM Data Instructions Guide, Observer Variation). The coefficient of variation averaged 8%, which according to the literature, indicates good agreement among observers (Roper et al. 2002). The average difference between observers was < 0.5 m (generally, 7-8 cm per meter of GGW). This means that observer agreement is better on narrower channels and declines on wider channels. The number of samples needed to predict the mean (within 10%, at 90% confidence) averaged 67. As with other indicators, the adequate sample sizes varied among test streams from a low of 21 to a high of 109. Testing by the authors indicates that too few width measurements generally do not adequately estimate mean GGW due to site variability. For more information on the limitations associated with GGW and the results of prior field testing, reference the MIM Data Instructions Guide, Estimating Sample Size.

The measurement of GGW assumes the use of some kind of measuring instrument (measuring rod, tape, or laser rangefinder). Measure to the nearest decimeter (0.1 m). The measuring rod and tape should have centimeter markings and a rangefinder should have accuracy of at least 0.2 m, preferably 0.1 m.

Relationship to Other Indicators: Changes in GGW are a direct response to changes in the vegetative composition and stability of streambanks. A shift in vegetation from deep-rooted hydrophytic species to shallow-rooted mesic and xeric species leads to lower streambank stability and commonly results in an increase in GGW. Conversely, as streams recover from past disturbance and deep-rooted riparian-wetland vegetation establishes on the streambanks, the GGW typically decreases, because these plant communities are better able to resist stream erosion, to capture sediment, and to build stable streambanks.

Vegetation is a leading indicator of change, but changes in GGW also have effects on channel properties, including depth of pools and size of substrate. Narrower channels correspond to deeper and faster streamflow, which leads to more efficient scouring of the streambed, maintenance and deepening of pools, and processing of fine sediment. Also, narrower channels contribute to greater rates of hyporheic exchange (Movahedi et al. 2021), which can improve water quality and water temperature.

One way to evaluate the precision in locating the greenline is to consider the repeatability of GGW measurements. In a controlled experiment involving 7 teams on 5 different streams with 80 measurements per stream, the average difference in GGW was 0.07 m per meter of stream width (authors' unpublished data). Since observers must use the same procedure to both locate the greenline and to measure GGW, presumably differences among observers are influenced, and probably largely determined by, the bias in its location. Thus, it is encouraging that observers are reasonably in agreement with greenline locations and measurement of GGWs.

Procedure: Greenline-to-greenline width is a measurement of the unvegetated or uncovered horizontal distance between the greenlines on opposite streambanks. GGW is measured perpendicular to streamflow. Each end of the GGW transect coincides with the location where the greenlines rules are met.

Step 1. Measure the horizontal distance between the greenlines on each side of the stream and perpendicular to the streamflow. The GGW can be measured with the 2-m measuring rod, a measuring tape, or a laser rangefinder. Each measuring device has advantages and disadvantages depending on the channel characteristics and types of vegetation communities on the streambanks. For example, a laser rangefinder may be the most expedient way to measure GGW but may be difficult where streambanks are covered in woody vegetation and it is hard to obtain a reliable laser target. A rangefinder can take two-thirds less time to make measurements in an herbaceous-dominated community than the 2-m measuring rod. The measuring rod and tape are less expensive options. The measuring rod can be efficient where the channel is ≤ 4 m wide or where the banks are physically inaccessible because of dense woody vegetation. A measuring tape, while precise, can be quite tedious and slow. If the tape is being used to also locate sampling locations for substrate, it makes sense to also use it for GGW, though GGW is not always equal to the active channel width (scour line to scour line width) used to determine substrate sampling locations.

Measure from the greenline associated with the center bar on the monitoring frame. When the frame is rotated because the greenline is not parallel to the streamflow, measure GGW on the downstream end of the frame (Figure 59). Measuring consistently from the same end of the frame will improve observer agreement. Measure GGW to the nearest decimeter (0.1 m). The orientation of the GGW measurement must be a single straight line perpendicular to the average direction of streamflow. The measurement line does not bend for minor changes in streamflow direction within the channel.

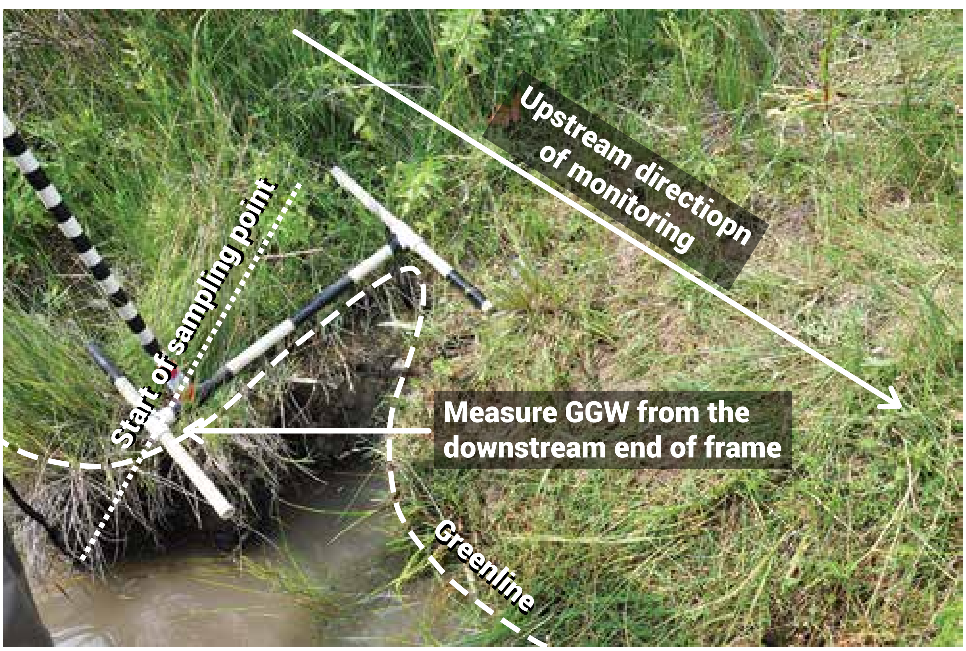

Figure 59. Measuring GGW when greenline is not parallel to streamflow. The GGW can change from one end of the frame to the other when the frame is rotated and the greenline is not parallel to the streamflow. In these situations, measure GGW consistently from the **downstream end of the frame**, which is closest to the “start” of the quadrat or sample point.

- Measure the horizontal distance between the greenlines perpendicular to the streamflow and record this distance to the nearest decimeter (0.1 meter). GGW is a straight line and does not bend.

- For consistency, measure the distance from the downstream end of the frame, which coincides with the “start” of the sample point.
- GGW is a measure of horizontal distance, not slope distance (Figure 60); therefore, it is important to hold the tape or rod as close to level as possible when making this measurement. If using a laser rangefinder, ensure that it has a specific horizontal distance mode and ensure that the device is set on that mode.

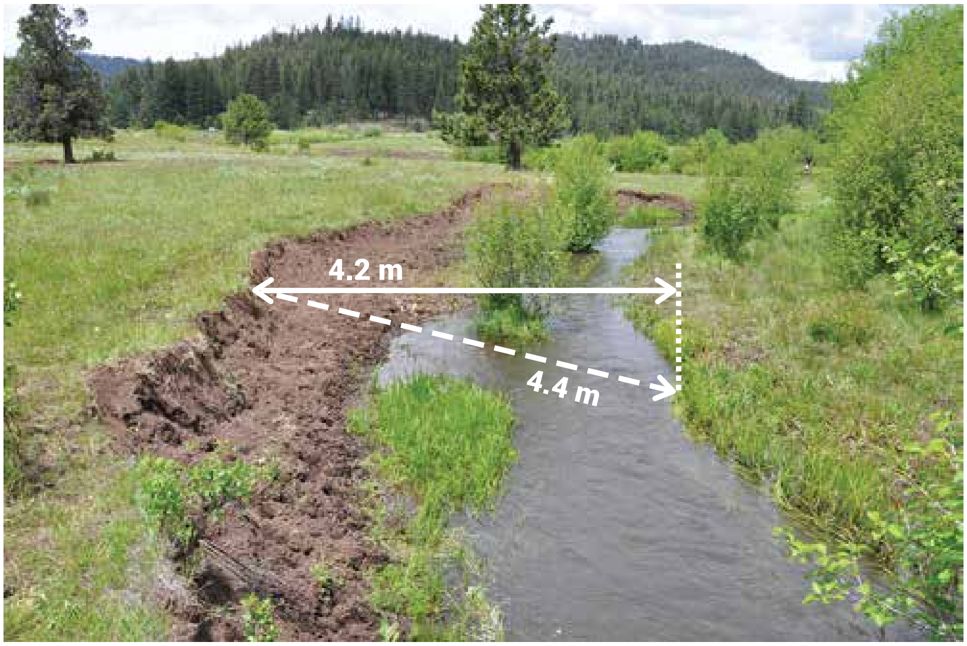

Figure 60. GGW is the horizontal distance between the greenlines on opposites sides of the stream channel. In this example, the GGW is 4.2 m (measured along solid horizontal line), whereas the slope distance (sloped dashed line) is 4.4 m. Vertical line is projected from the greenline to provide visual references of the greenline position in this channel cross section.

- **GGW is measured at each sample point in the upstream direction only.** Measurements are not made when collecting data in the downstream direction to avoid a potential issue related to spatial autocorrelation.
- Stand in the channel and downstream of the GGW transect to best judge the predominant streamflow path. Sometimes an individual standing on the streambank has a better vantage point to determine flow paths and can help orient the measuring rod, tape, or viewing direction of laser rangefinder so that GGW is measured perpendicular to streamflow.
- Pay special attention to the vector that is perpendicular to streamflow around meander bends. Being off by a few degrees on a meander can generate high observer errors in calculating GGW.
- Do not measure GGW when there is no greenline. If the greenline composition is marked “NG” leave the GGW measurement blank for the same sample point. Similarly, if there is no greenline within 6 m of the channel on the opposite bank, leave the GGW measurement blank.
- When vegetation occupies the entire channel (i.e., the vegetated drainageway), do not record the GGW (Figure I.8).
- If using a laser rangefinder, make sure to align the objective of the rangefinder directly above the greenline (Figure 61.A). Standing on or next to the greenline but holding the rangefinder 1 dm or more off the greenline introduces unnecessary error to a simple and repeatable measurement (Figure 61.B). The measuring rod can be positioned vertically on the greenline to help align the rangefinder and minimize errors.

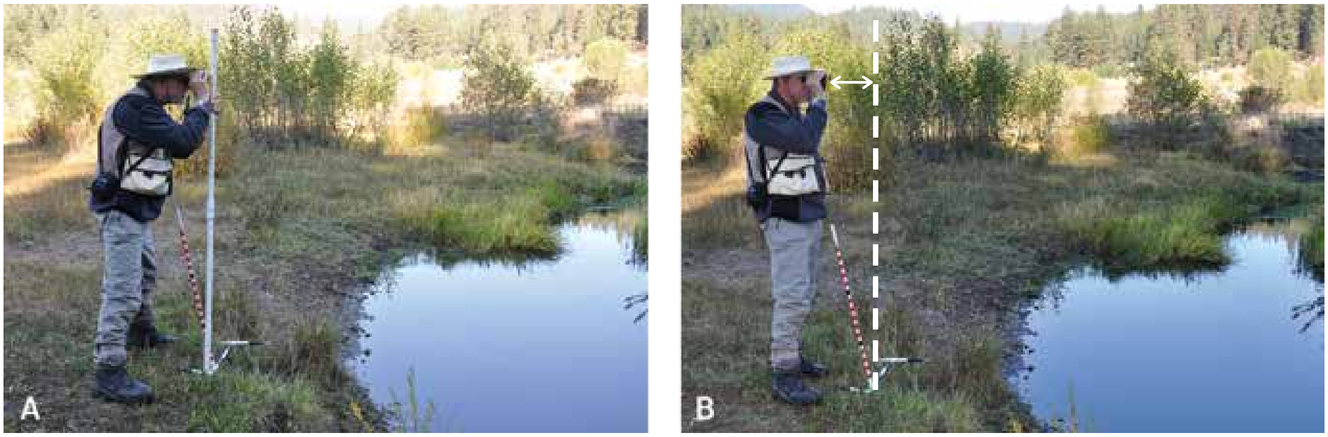

Figure 61. Examples demonstrating use of field equipment to obtain accurate GGW measurements.
A. A measuring rod helps to align the laser rangefinder above the greenline for more accurate measurements of GGW.
B. A failure to properly align the laser rangefinder with the greenline can introduce error to the GGW measurement. This photograph illustrates an observer-generated error of 0.3 m (white double arrow).

- It can be difficult to acquire a laser target in woody vegetation. If one bank is covered in dense woody vegetation, use the 2-m measuring rod to obtain a measured increment from the vegetated bank and then add the laser rangefinder distance from the end of the rod to the opposite greenline.
- When calculating GGW around islands or braided channels, the idea of main streamflow can become confusing as each sub-channel might have a different orientation. In fact, if lines are projected perpendicular to flow across islands, it is possible that the trajectory of one GGW path crosses the trajectory of another GGW path. In figure 62, notice how cross section 2, if projected perpendicular to the narrower channel, would lead to a transect that crosses transect 3. Therefore, **in multiple channel situations, establish one cross-valley transect** and measure the cumulative unvegetated or uncovered width (illustrated in black line segments) of each unvegetated vector that originates from the cross-valley transect. This cross-valley transect should be oriented to maximize separation with adjacent GGW transects to avoid introducing spatial autocorrelation to adjacent GGW measurements.
- Where 2 or more channels exist in a cross section and there is no vegetated island, the GGW is measured on lines perpendicular to streamflow in each channel to a point where the lines from adjacent channels intersect (Figure 62, cross section 5).
- Keep in mind, multi-channel situations are the exception, not the norm, and GGW is likely not a major indicator of trend in these situations, especially in braided systems that are inherently unstable and have high rates of sediment movement.

Step 2. Exclude qualifying cover measurements on islands. When an island has qualifying cover (i.e., at least 25% foliar cover of perennial vegetation, embedded rock ≥ 15 cm in the intermediate axis or b-axis, and/or anchored wood) along the greenline-to-greenline transect, exclude the length of qualifying cover (Figure 63) to obtain the GGW. Qualifying cover must be above the scour line (Figures I.1, I.4, and I.10).

- The GGW transect should be thought of as a 50-cm band from the greenline on one bank to the greenline on the other bank. However, any part of this band that contains at least 25% qualifying cover is excluded from the distance between greenlines on the opposite streambanks. In addition, there shouldn't be any bare spots larger than a 10 cm x 10 cm patch.

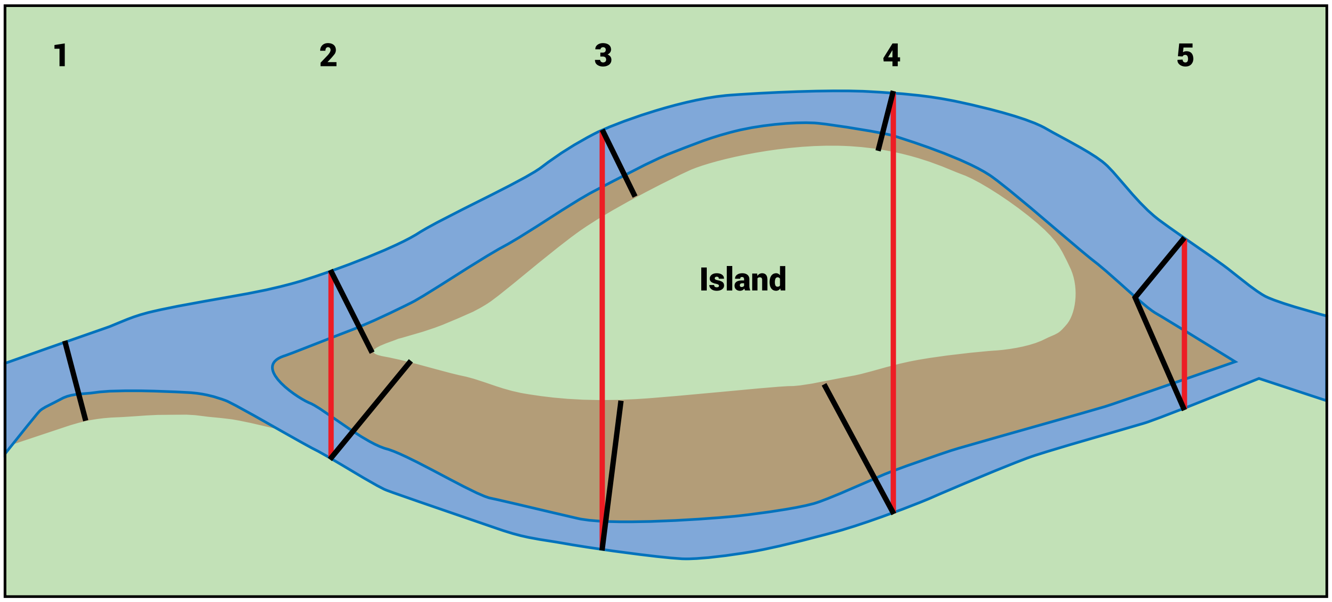

Figure 62. How to measure GGW where two or more channels exist. Cross section 1 crosses a single-thread channel. GGW is a simple line (black) oriented perpendicular to the streamflow. Cross sections 2 through 5 intersect an island, with channels on each side of the island. Establish a single cross-valley transect (red lines 2-5) to maintain maximum separation of adjacent transects across the island and two (or more) channels. At each unvegetated/uncovered segment, create a vector that originates on the cross-valley transect and is oriented perpendicular to streamflow. Measure the uncovered length of each vector and add the cumulative lengths (black lines) to determine the GGW for each cross-valley transects labelled 2–5.

Figure 63. How to measure GGW across an island. When measuring GGW across an island, exclude the qualifying covered section on the island from the total distance between greenlines. To do this, cover is evaluated in a 50-cm wide band. In this example, the red shaded area has ≥ 25% perennial foliar cover, therefore, its length is not included in the measurement of GGW.

- Establish a single cross-valley transect (red lines 2–5 in Figure 62) to maintain maximum separation of adjacent transects across the island and two (or more) channels. At each unvegetated/uncovered segment, create a vector that originates on the cross-valley transect and is oriented perpendicular to streamflow. Measure the uncovered length of each vector and add the cumulative lengths (black lines in Figure 62) to determine the GGW for each cross-valley transects.

Note: The inclusion of embedded rock and anchored wood as qualifying cover is a change from the 2011 version of MIM (Burton et al. 2011). Users should make note of this change if the DMA has a significant trend in GGW that is the result of this rule change and not from a change in channel shape or streambank conditions.

Note: Emergent or floating aquatic vegetation that are in water are not qualifying cover, mainly because these plants would be below the scour line and part of the active channel. Qualifying cover (vegetation, embedded rock, and/or anchored wood) must be above the scour line.

Timing: This indicator helps to document recovery of degraded stream channels over time. Since the recovery process may be relatively slow, it is recommended that the method be repeated every 3–5 years. The method is relatively easy and only requires about 30 minutes per DMA, slightly longer if the DMA has a lot of shrubs along the greenline that make it more difficult to access the greenline.

Measurements should be made during the low streamflow period. Some streams have stable greenlines with little seasonal fluctuation during the growing season. However, greenline position on some streambanks make considerable shifts during the growing season in response to changes in streamflow or drop in water table. In addition, considerable livestock or wildlife alterations or herbivory can lead to shifts in the greenline farther up the streambank. Therefore, to track change or to evaluate trend in GGW over time, it is important to minimize intra-annual or seasonal shifts related to changes in hydrology or ungulate use, and to make repeat measurements at approximately the same stage of seasonal progression and before a significant level of grazing has occurred.

6.2.6 Substrate

Purpose: Streams convey water, energy, and sediment. Changes in sediment supply or transport capacity are commonly reflected in the substrate of the active channel (active channel refers to the parts of the channel below the scour line). Changes in sediment supply can reflect changes in channel and watershed conditions related to both management actions (e.g., livestock grazing, wild ungulate grazing, timber harvest, road construction) and natural phenomena (e.g., wildfire, floods, overland flow events, prolonged drought). The effects of management actions and natural phenomena can generate sediment that is transported to the stream channel. Certain actions, such as ungulate trampling and grazing on streambanks, may result in streambank failures and/or channel widening, which in turn affect transport capacity and may lead to a shift from sediment transport to accumulation of fine sediment in the stream channel. Sampling of the substrate on the channel bed is used to detect the impacts of channel, streambank, and upland disturbances through time.

When the condition of watersheds or streambanks decline, excess fine sediment tends to accumulate in the channel and results in a “fining” of the substrate (Powell et al. 2000). Increases in fine sediment may degrade aquatic habitat by restricting the living spaces of substrate-dwelling organisms and by limiting the oxygen transfer to incubating eggs (Powell et al. 2000). One way to evaluate cumulative impacts related to watershed condition is through an analysis of the substrate (Bevenger and King 1995; Schnackenberg and MacDonald 1998).

Background: The measurement of substrate, also known as pebble count or Wolman pebble count, provides insight into the condition of the channel bed. Substrate analysis provides information on the quality of macroinvertebrate habitat, the quality of oxygenated redds (i.e., fish spawning nests), the quality of habitat for other benthic organisms in the stream channel, and roughness elements on the channel bed. An increase in fines (particles < 6 mm in diameter) often results from high bank alteration, low bank stability, widening of the stream channel, or degraded upland conditions that generate high runoff and sediment transport. Wolman (1954) is credited with developing an early, widely used methodology for measuring substrate. There have been myriad modifications and permutations of Wolman's original protocol (e.g., Leopold 1970; Bauer and Burton 1993; Potyondy and Hardy 1994; Bevenger and King 1995; Lazorchak et al. 2000; and Saunders et al. 2019). One of the most comprehensive reviews and testing of substrate methodologies was performed by Bunte and Abt (2001).

The different protocols describe different sample sizes, collection at different types of channel cross-sectional transects (e.g., wetted width, active channel width, and bankfull width), and collection at different locations across the channel (***pool*** only, ***pool tail*** only, ***riffle*** only, and all habitat approaches). All generally share an interest in collecting samples evenly distributed across the channel. Some protocols measure with a ruler; others use a template called a gravelometer having standardized square slots that coincide with units on the phi-scale (Wentworth 1922; Figure 19). All protocols measure the intermediate or b-axis of a particle (Figure 64). The standard particle sizes are summarized in Table 10.

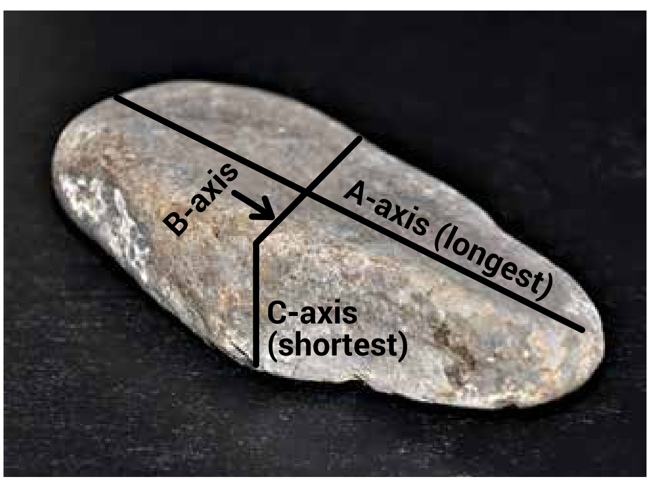

Figure 64. The length axes of a sediment particle. Sediment particles have three conventional length axes, which are: a-axis, the longest axis (particle length); b-axis, or the intermediate axis (particle width); and c-axis, the shortest axis (particle thickness).

Table 10. Standard particle size names and classes.

Particle Class Name	Particle Class Size* (mm)	ϕ (Phi Unit) †
Silt and Clay	< 0.062	
Sand	0.062–2.0	-1
Very Fine Gravel	2.0–2.8	-1.5
Very Fine Gravel	2.8–4.0	-2
Fine Gravel	4.0–5.6	-2.5
Fine Gravel	5.6–8.0	-3
Medium Gravel	8.0–11.3	-3.5
Medium Gravel	11.3–16.0	-4
Coarse Gravel	16.0–22.6	-4.5
Coarse Gravel	22.6–32.0	-5
Very Coarse Gravel	32.0–45.3	-5.5
Very Coarse Gravel	45.3–64.0	-6
Small Cobble	64.0–90.5	-6.5
Small Cobble	90.5–128	-7
Large Cobble	128–181	-7.5
Large Cobble	181–256	-8
Small Boulder	256–362	-8.5
Small Boulder	362–512	-9
Medium Boulder	512–1024	-9.5
Large Boulder	1024–2048	-10
Very Large Boulder	2048–4096	-11
Bedrock	> 4096	-12

* Classes conform to the Wentworth grade scale for particle sizes (Wentworth 1922).

† Phi scale described by Krumbein and Sloss (1963).

The MIM protocol for substrate is designed to measure 10 particles along 20 equally spaced transects (i.e., at every other monitoring plot in the upstream direction) for a total of 200 particles. Additional particles can be collected from heterogeneous substrates or where additional precision is desired. Collecting additional samples in the downstream direction is not recommended to avoid sampling on a previously sampled cross section, which could result in spatial autocorrelation.

Assumptions and Limitations: This method applies primarily to wadeable, gravel-bed and cobble-bed streams. Such streams have mean particle sizes ranging from 2 to 256 mm in diameter (Bunte and Abt 2001). Because of the wide range of bed material sizes, and because of the complex interactions of particles during erosion, transport, and deposition, the substrate may become spatially heterogeneous and difficult to sample.

To adequately sample gravel-bed and cobble-bed streams, reaches of at least 5–7 channel widths in length should be included (Bunte and Abt 2001). Sampling the entire length of the DMA (20 channel widths or more) is recommended to ensure spatial variability is accounted for in the sampling scheme. If not, variability through time may reflect spatial heterogeneity more than actual adjustments in substrate size related to management activities. Also, note that natural variability in stream flow means fines may accumulate during low water years when the substrate is not fully mobilized and the fines are processed or flushed from the channel bed during infrequent, high-magnitude discharge events.

Wadeable streams also mean that for practicality, the water depth should be < 1 m to acquire and directly measure substrate particles. Where water exceeds 1 m in depth, crude estimates of substrate sizes are made using a 2-m rod and the estimates are flagged on the data sheet. An alternative method for measuring particle sizes in deep water is described in step 3 of this section.

The purpose of substrate sampling is to determine recent changes in sediment dynamics and to corroborate possible changes in bank and channel stability; therefore, the surface of the streambed is the focus of this method. Sampling the subsurface strata (e.g., particles at depth) is more intensive and beyond the purpose and scope of this monitoring method.

As noted by Bunte and Abt (2001), using different methods to sample substrate at the same location may yield different results. Thus, trend over time should be based upon the same technique applied to each sampling event.

The guidelines on bed-material sampling provided by Bunte and Abt (2001) include an excellent summary of the literature and serve as the principal base reference for this protocol. With respect to repeatability, this statement by Bunte and Abt (2001) is especially appropriate for substrate sampling:

> Operator training is extremely important. When selecting particles from a predefined streambed location, or even when measuring particle sizes in a preselected sample of rocks, there is less variability between the results of experienced operators than between those obtained by novices. Field personnel need to be trained to perform procedures accurately, to avoid bias, and to use equipment that reduces operator induced error.

Fast-moving and/or deep water presents additional challenges. Observers should exercise caution when sampling cross sections associated with fast water (i.e., water flowing > 1.5 m per second). Fine particles can become easily washed away when collecting from the substrate, causing inaccuracies.

As summarized by Bunte and Abt (2001), sources of error in pebble counts may result from observer variability. The most common error is to favor larger-sized particles when sampling substrates with fine particles lodged between larger particles. Rather than collect the fines, the observer selects the larger particle, often out of convenience. The systematic method described here helps to reduce this error by requiring the observer to collect the sample directly beneath the given point of measurement. Still, the substrate may be difficult to see and the use of the index finger to touch the substrate and then select what is touched is recommended, even though the sample may miss small interspaces and the associated fine fraction located between large particles. For this reason, percent fines (i.e., particles < 6 mm) and the lower percentile particles (***D_{16}* and *D_{30}***, 16th percentile and 30th percentile particles, respectively) may be underestimated.

Despite known bias towards larger particles and away from fines, there was better observer agreement (i.e., repeatability) at the authors' test sites on percent fines (coefficient of variation or CV = 6%) than on median particle size (CV = 29%). This agreement is likely because median particle sizes are calculated from size classes (slots in the template) that represent broader ranges as particles increase in size, and fines are measured in small slots that are closer to the actual size of the particle. Additionally, most of the test sites were located on low-gradient streams where the frequency of encountering larger particles that mask fines in their interspaces is low. Typically, sand and gravel with dispersed cobbles dominated these sites and allowed for less bias in collecting the smaller particles from the substrate.

With respect to accuracy, as summarized in Bunte and Abt (2001), a 100-count particle-size sample is usually too low to compare particle-size distributions over time. The authors' testing indicated that adequate sample sizes range between 74 and 384 (with an average of 229) to estimate the mean within 5% at 95% confidence (see MIM Data Instructions Guide, Estimating Sample Size). The range of sample sizes varied according to heterogeneity of the substrates at the test sites. Small sample sizes of 74 were indicated at a site with relatively homogeneous substrate, and large sample sizes were indicated at heterogeneous, bimodal, or highly variable sites.

Relationship to Other Indicators: Substrate-size distributions and fine-sediment abundance are related to greenline composition, streambank alteration, streambank stability and cover, and GGW. In tests conducted by the authors, the ***D_{84}*** (84th) percentile particle size was moderately positively correlated with stubble height (correlation coefficient = +0.43; authors' unpublished data). Greenline vegetation dominated by high stability plants promotes bank stability and capture of fine sediments to build streambanks and floodplains. In contrast, greenline vegetation dominated by low stability plants can lead to bank instability and generation of excess sediment. Unstable banks that exhibit fractures, slough, slump, and near-vertical erosional faces commonly correspond to DMAs with higher GGW, corresponding channel widening, decreased water velocity, and increased channel deposition.

Procedure: Streambed particles are measured along transects across the stream at every other sample location (or 20 or more total transects), evenly spaced along the entire length of the DMA. Generally, substrate transects are located at even-numbered quadrats in the upstream direction of the survey, therefore, substrate is first sampled at the second sample point. Where substrate is especially heterogeneous or where additional precision is desired, collect substrate data at every sample point in the upstream direction. Collect and measure the diameter of 10 pebbles at each transect. Samples are collected within the active channel only (which means between the scour lines). Never sample a particle above the scour line.

Step 1. Determine the interval length to obtain 10 evenly spaced particles in the cross section. Use a measuring rod or laser rangefinder to determine the width of the ***active channel*** (the active channel is located between the ***scour lines*** of the stream). Where scour lines are indistinct, measure the channel bed, which is bounded by the points where the channel bed (relatively flat) meets the streambank (the sloped surface above channel bed). Divide this width by 10. Alternatively, count the number of heel-to-toe steps across the active channel width, divide by 10 to determine the interval length. Collect the first sample at one-half this interval length, and all subsequent samples at the interval length, so that the last particle selected is not directly on the scour line (Figure 65).

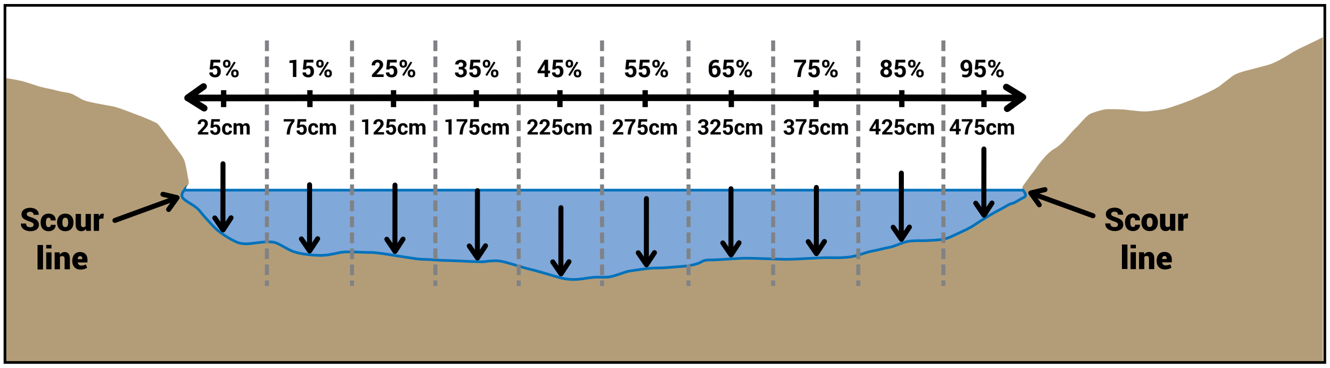

Figure 65. Collecting substrate in the active channel. Measure the width of the active channel (i.e., from scour line to scour line, see dark horizontal line) and collect 10 equally spaced samples from the channel bed at the mid-point of each sample interval (i.e., at 5%, 15%, 25%, 35%, 45%, 55%, 65%, 75%, 85%, and 95% of the distance across the active channel). Exclude the width of islands or parts of the channel that are above the elevation of the scour lines.

For very small and narrow streams, collect 5 samples on each of 2 crossings (i.e., cross once, move upstream 0.5 m, then cross again) (Figure 66). If after 2 passes, the sample is still short of 10 particles, follow the instructions in step 4 below to obtain additional samples.

- When the transect crosses a multiple-thread channel or flows around islands, total the active channel width of all active channels (including bifurcated flow around islands) and divide by 10 to determine the interval length (Figure 67). Distribute sample collection proportionately across the width of all active channels (Figure 67). Baseflow channels convey water at and below the scour line; they do not include overflow channels that can form on the floodplain or above the scour line as a consequence of high-magnitude flood events.

  Do not sample particles on the streambanks or islands that are above the scour line.

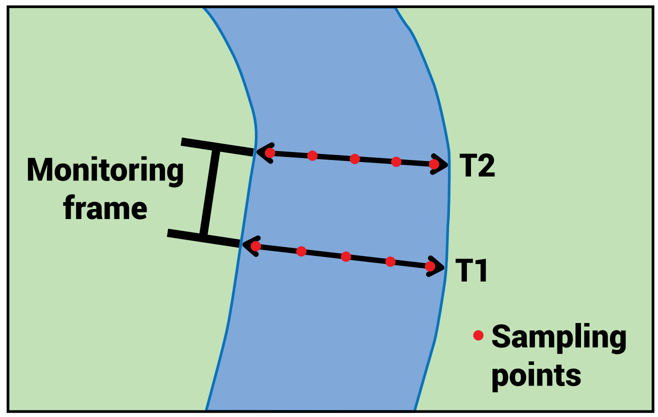

Figure 66. Collecting substrate in narrow channels. In narrow channels, collect 5 equally spaced particle samples along the default transect (T1), then proceed upstream 0.5 m to collect 5 remaining particles along a second transect (T2). Because the MIM monitoring frame is 0.5 m long, the substrate transects (T1 and T2) can be aligned with each end of the monitoring frame, provided the frame is oriented parallel to streamflow.

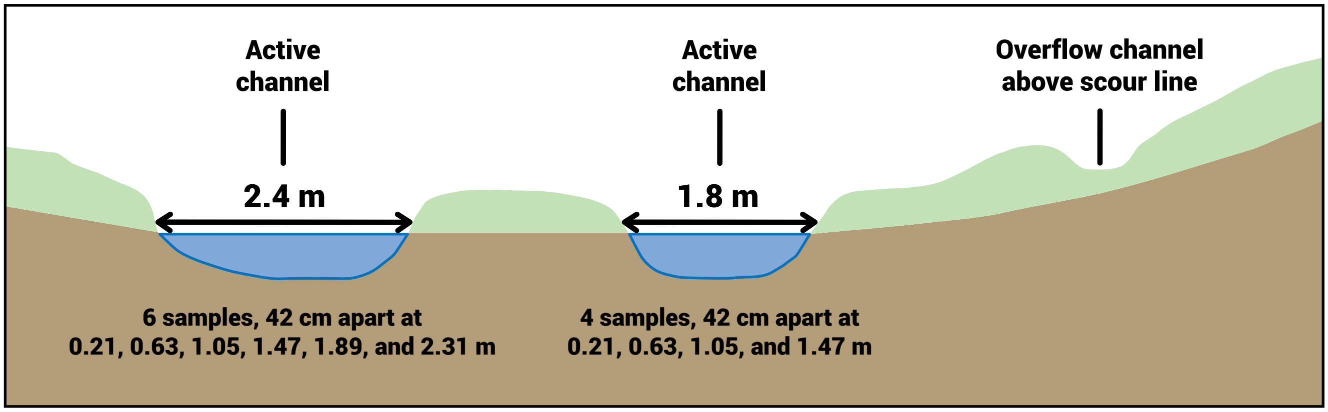

Figure 67. Collecting substrate around multiple-thread channels or islands. Add the active channel width from each side of the island and below the scour line. Distribute the samples proportionately to the width of each channel. In this example, two channels have an active channel width of 4.2 m. Sixty percent of the active channel width is in the left-side channel and 40 percent in the right-side. Samples are spaced approximately one-tenth of the total active channel width apart (0.42 m).

Step 2. Determine the first sample location and begin sampling particles. Start the cross-channel transect at one-half the interval length, and then collect all subsequent particles at the full interval length. For example, if the width of the active channel at the sample location is 5 m, the sampling interval is 0.5 m, and the first sample is collected at 0.25 m (½ x 0.5 m) from the scour line. All subsequent samples are collected at 0.5-m intervals, and the last sample, or particle number 10, should be approximately 0.25 m from the scour line on the opposite side of the channel (Figure 65).

- Stand downstream of the transect to avoid disturbing the streambed (if possible). To locate the sampling point, place the index finger at that point, and **without looking at the streambed**, reach into the stream and obtain the first particle in the substrate that touches the index finger. It is especially important to collect a fine particle if it is the first particle encountered. Under-sampling fine particles is a known issue with this indicator. If the side of the finger touches a larger particle and the center of the finger can extend further down to the bed, select the lower particle touched by the center of the finger. With the finger on the bed, use the thumb in combination with the index finger to capture the fine particle and bring it out of the stream for measurement.
- Collect samples at equal spacing across the channel. Because water depth and water velocity affect particle size, and because depth and velocity change across the channel, the entire width of the active channel must be sampled at each transect. If pacing, measure to the starting point (i.e., 0.25 m as above) with the rod, collect the first sample there, and then pace at approximately 0.5-m intervals from that location to the other sample points across the channel.
- Make sure the samples are all collected from the active channel (i.e., from scour line to scour line). Do not collect samples above the scour line; this area technically represents streambanks or islands, not the streambed. Do collect from parts of the channel beneath undercut banks. If the channel bed is partly or completely dry, continue to collect samples uniformly across the channel from scour line to scour line.
- Do not sample large particles if any part of the particle extends above the scour line elevation (Figure 68).
- Depositional features (e.g., ***point bars***) that are not covered by vegetation and located below the scour line are considered streambed material and should be included in the sample.

Figure 68. Excluding particles when measuring substrate. Boulders on the streambed that protrude above the scour line (which coincides with water surface in this image) and are not measured as part of the substrate.

- When collecting other greenline-based data prior to establishing the substrate transect, avoid trampling the streambed at the location where the substrate samples will be collected. However, in reaches where trampling the channel bed cannot be avoided due to the presence of a soft substrate dominated by silt and clay, collect substrate data before trampling the streambed and before collecting the greenline-based indicators. Repeated trampling of a soft channel bed can result in changes to particle sizes and depth of pools. In very small streams with soft, unconsolidated substrate, it is also possible to modify pool depths with trampling. In such cases, complete the entire thalweg survey first, and while proceeding upstream in that survey, locate and measure substrate at cross sections before sampling the other indicators.

There are several practical ways to measure the active channel width and to determine the sample interval for substrate measurements, including use of the 2-m measuring rod and pacing using boot length or step length. Generally, for narrow channels (defined here as channel widths ≤ 4 m from scour line to scour line), the 2-m measuring rod can be placed along the scour line and the intervals measured directly from the rod.

For channels wider than 4 m, it can be cumbersome to simultaneously hold a measuring rod in place while measuring sample intervals and collecting substrate particles, especially if the current is strong. A tape stretched tautly across the channel from scour line to scour line can be more practical.

Finally, as long as the sampling process minimizes bias and strives to collect samples equally distributed across the channel, another approach is to step or pace sampling points across the channel. For example, an individual with a 30-cm-long wading boot (Figure 69) could pace heel to toe and collect samples every 0.3 m across a 3-m-wide channel. For a 4.5-m-wide channel, the samples would be collected 0.45 m apart, alternating between the toe and the instep of the boot. As always, look away from the channel bed and minimize bias by pointing the index finger straight down to collect each sample at the designated point.

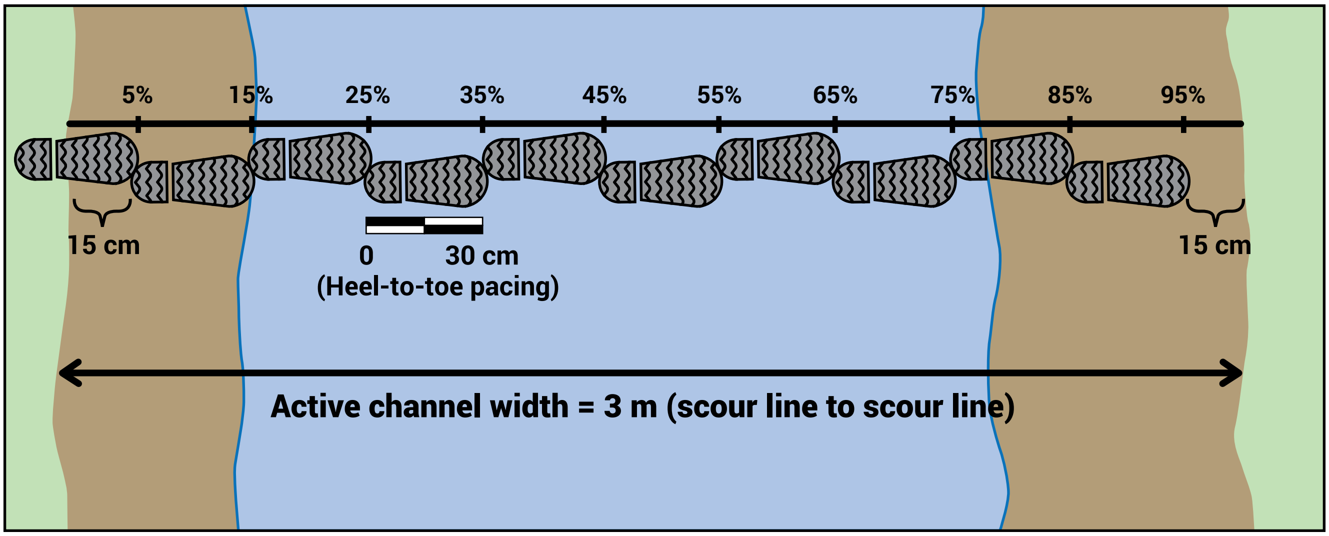

Figure 69. Collecting substrate measurements in swift-moving water. In fast water, it can be impractical to use a measuring rod to locate sampling points. A pace technique can be employed to locate equally spaced sampling points in an unbiased method.

Step 3. Measure the diameter of samples collected. Align the longest axis (a-axis; Figure 64) of the particle perpendicular to the gravelometer (Figure 70.A). Pass the particle through the smallest slot in the gravelometer or template possible (Figure 70.B). If a template is not used, measure the middle width (intermediate or b-axis) of the particle in millimeters.

- A gravelometer is highly recommended to reduce observer subjectivity. They are shown to increase precision and accuracy over rulers because of reduced bias and observer error, and elimination of parallax error (Bunte and Abt 2001). Gravelometers are designed to measure the intermediate or b-axis of particles. They are inexpensive and greatly increase speed and accuracy of measurements. Openings in the gravelometer match the Wentworth scale (Wentworth 1922) and can be used to estimate the particle-size class or phi scale based on Krumbein and Sloss (1963; Table 10).
- If a small particle falls into the fines category, is touched in between larger particles, and the observer is unable to collect it, the particle size can be estimated (e.g., < 2 mm or < 6 mm). Substrate sampling inherently under samples fine sediments given the nature of particle interstices and the ability of a finger to isolate and pick up individual particles < 10 mm in diameter. Make a concerted effort to point finger vertically toward substrate and pick up the first particle touched; be especially sensitive to the general difficulty of picking up small particles that might be located between larger particles.
- Do not measure the same particle twice. If the particle is so large that the sample interval falls on it more than once, measure only the first time encountered and follow the instructions in step 4 to obtain a replacement sample.
- When a particle is too large to pick up or embedded or cemented into the channel, measure the smallest visible length, which is likely the b-axis. Most particles will rest like a shingle on a channel bed with the smallest axis (the c-axis) oriented vertically. Assume the c-axis is not accessible or visible and that the smallest axis visible is the b-axis. Flag the sample as an estimate in the data sheet.
- For particles that exceed the largest opening in the gravelometer (the 180 mm opening), measure the intermediate axis using the millimeter scale along the edge of the gravelometer (Figure 70.A). If the particle exceeds 300 mm, the gravelometer will have to be flipped to determine the cumulative length of the intermediate axis (or b-axis).

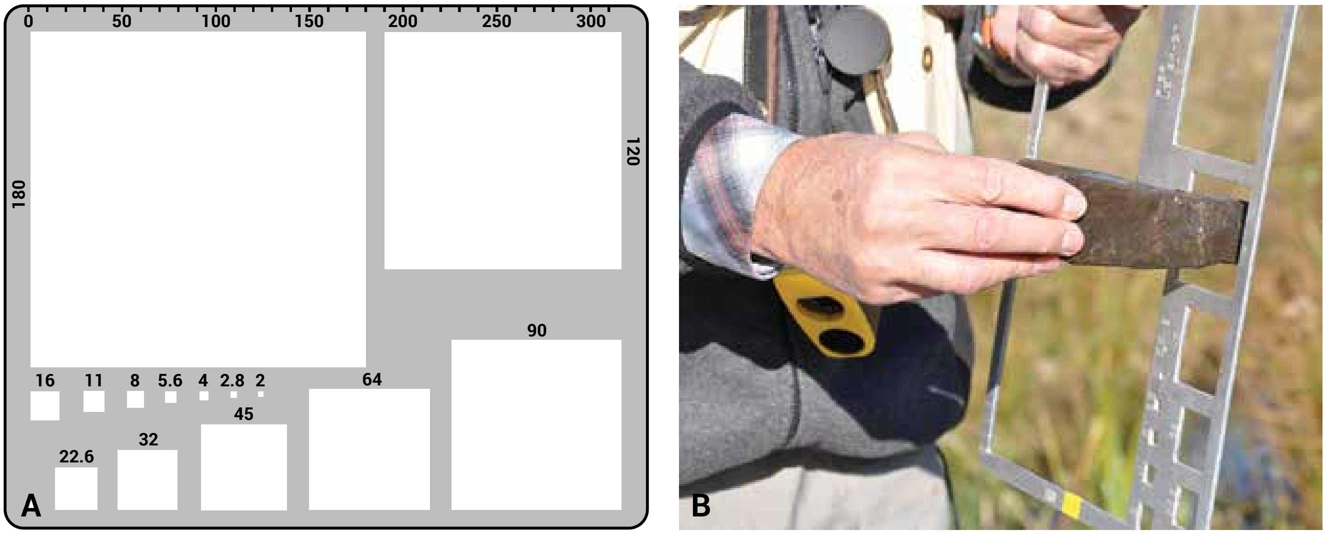

Figure 70. A. A gravelometer with openings from 2 mm to 180 mm and a ruler on the long (top) edge up to 300 mm. B. Align the a-axis (longest particle axis) perpendicular to the gravelometer and pass particle through the smallest opening possible to determine particle size.

- When algae are present on the substrate (Figure 71), be especially mindful to distinguish and differentiate algae from fine sediment; do not sample algae. Sample the inorganic or mineral substrate below the organic growth.

Figure 71. Measuring substrate when dried algae cover the substrate. Dried algae may form a mat covering the substrate. Although obvious when the channel is dry, inundated algae can be mistaken for fine sediment; measure inorganic substrate only.

- Return all particles back to the channel. Many macroinvertebrates rely on coarse particles for part of their life cycle. Throwing these particles with macroinvertebrates on a dry streambank needlessly harms an important component of the aquatic environment.
- If the water is too deep to practically acquire substrate particles, use visual clues, sound, and the 2-m measuring rod to probe the channel bed at the calculated intervals across the channel to estimate particle sizes. Flag estimated particle sizes in the data sheet. It

may be possible to differentiate sand, fine gravel, coarse gravel, fine cobble, coarse cobble, boulder, and bedrock by a combination of visual clues, sound, and feel. For example, silt and clay may appear as plumes of turbid water generated from walking or probing the channel bed. Sounds might also distinguish particle classes. Silt and clay should generate almost no sound, sand and fine gravel should have a scratchy sound on a depth rod, and coarser material might generate a ringing sound and the measuring rod might bounce off the coarser particles when the channel bed is probed. Finally, walking on the channel bed might provide a feel of the dominant particle sizes, but finer material trapped in the interstices of larger particles might be difficult to assess by this method.

For estimating particle sizes in deep water, **flag the sample as an estimate** and use the sample-class sizes in Table 11.

Table 11. Particle size classes for use when estimating particle size.

Particle Size Class	Representative Size (mm)
Clay and Silt	2
Sand	2
Very Fine–Fine Gravel	4
Medium–Very Coarse Gravel	32
Small Cobble	90.5
Large Cobble	181
Small–Medium Boulder	512
Large–Very Large Boulder	2048
Bedrock	4097

Step 4. Make sure 10 samples are collected per transect. If a transect produces fewer than 10 samples, then move upstream 0.5 m and collect the remaining samples evenly across the active channel. For example, if large particles (large cobbles or boulders) are encountered in the transect, ensure that they are not sampled more than once. If the chosen interval results in hitting a particle a second time in the transect, do not record that particle size, and continue with the original sample interval to the other side of the channel. When the first transect yields fewer than 10 samples, move upstream 0.5 m (or more if necessary to avoid the same large particles in the original transect) and space the remaining samples evenly across the active channel at the new location. Two or more passes may be required for some small streams (Figure 66).

Step 5. Indicate the stream habitat feature (pool or riffle). Note whether the substrate transect traversed a pool or riffle. Select pool (P) for any comparatively deep, flat water, or riffle (R) for any comparatively fast-moving water. For the purposes of the MIM protocol, it is not necessary to further divide stream habitat features into more discreet units, such as glide or run. The pool category is intended to include both pool and glide, and the riffle category is meant to include both riffle and run.

Timing: Substrate is easiest to sample when the streamflow is low. The low-water season is preferred over periods of bankfull or near-bankfull flows. Preferably, sample when streamflow is at or below the scour line. To evaluate trend over time, sampling should occur every 3–5 years based on management priorities. Sampling should also be done after large flow events, when fines may be flushed from the channel and substrates undergo the greatest changes. Alternatively, if the watershed or channel are highly degraded, large flow events may result in a large influx and net accumulation of fine sediment.

6.2.7 Residual Pool Depth and Pool Frequency

Purpose: Pools provide important aquatic structure or habitat for fish and other aquatic organisms. Pools also provide information on the channel-bed morphology, which is an indication of channel stability and the ability of a channel to process sediment and dissipate stream energy. The most reliable and reproducible way to measure pool depth is to measure residual pool depth (Lisle 1987), which is a metric independent of water-surface stage or stream discharge. Consequently, residual pool measurements can be made at any discharge and can detect trend from year to year. This method measures water depth along the deepest part of the channel and calculates the difference in depth between the pool bottom (or maximum depth of pool) and depth of the ***riffle crest*** (or pool tail; Figure 72). That difference, maximum pool depth minus depth of riffle crest, is the residual pool depth.

Water or wetted width and maximum depth measurements described in Burton et al. (2008) are not included in the MIM protocol; testing and review of results found these measurements are of questionable value for monitoring trend through time. Both water width and thalweg depth are streamflow dependent; therefore, monitored changes may largely reflect stage differences rather than management effects. In addition, pool length is not included in the MIM protocol as studies found poor crew agreement, particularly in locating the head of the pool (Poole et al. 1997; Peterson and Wollrab 1999; Archer et al. 2004).

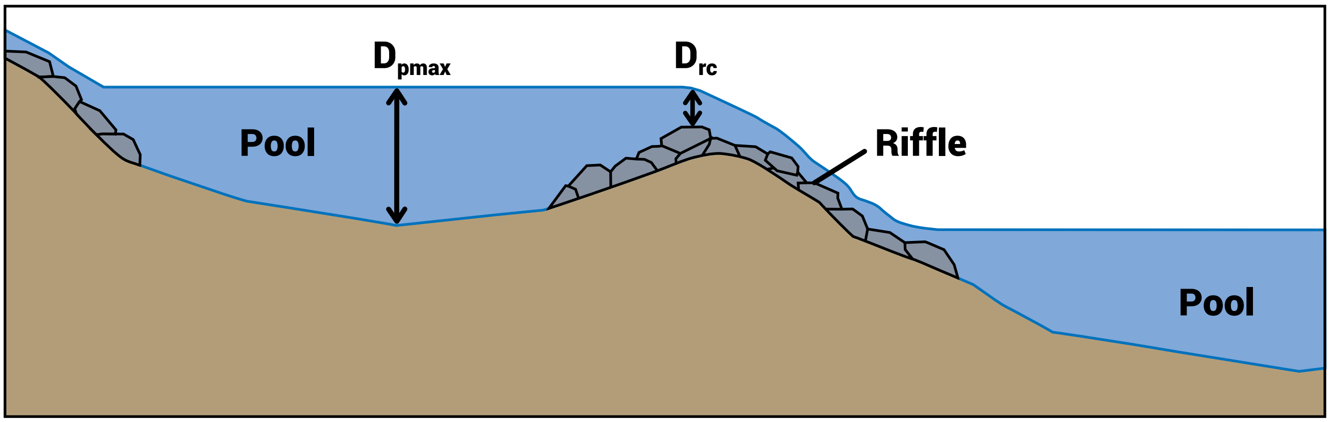

Figure 72. Calculating residual pool depth. Residual pool depth is calculated by subtracting the depth at the riffle crest (D_{rc}) from the maximum pool depth (D_{pmax}). Vertical scale is exaggerated to make individual depth features more apparent.

Background: Because pools are vital to the rearing and production of fishes, pool depth has been an important component of stream habitat measurements. For example, Mossop and Bradford (2006) found a positive correlation between mean maximum residual pool depth and the density of Chinook salmon in 16 tributary reaches to the Yukon River in Canada. As described previously, livestock grazing can result in the breakdown of streambanks and the loss of stabilizing vegetation. These impacts can lead to secondary effects within the channel, such as the formation of wider and shallower channels (Clary et al. 1996; Clary 1999; Clary and Kinney 2002; Kauffman and Krueger 1984; Magilligan and McDowell 1997; Powell et al. 2000) and the accumulation of fine sediments in pools (Whittaker and Davies 1982; Coats et al. 1985; Platts et al. 1989; Montgomery and Buffington 1998).

Assumptions and Limitations: The residual pool depth method appears to work well in gravel/cobble, gravel, gravel/sand, sand, silt, and clay bottom streams. However, cobble- and boulder-dominated substrates can create complex pool structures; the results of field testing have found poor repeatability among observers in these substrates. In coarse-textured substrates, scouring often results in the development of small “pocket” pools that can be missed by some observers. The ability to consistently identify pools decreases as the substrate becomes coarser, particularly when the substrate is dominated by coarse cobble and boulders. Observers have difficulty consistently identifying qualifying pools when pocket pools are common.

Also, very small streams, or those with intermittent streamflow, may not develop good pool structure. Caution is advised when using and interpreting this indicator in these types of streams.

Pool depth is inversely related to gradient. That is, pools generally tend to become shallower and shorter in steeper gradient systems than in lower gradient systems (Wohl et al. 1993). Recognize that as channel gradient increases above 4%, many streams transition from riffle-pool beds to run-dominated beds, especially if these steeper reaches coincide with coarser bed material.

Relationship to Other Indicators: Residual pool depth is related to streambank cover and stability as well as GGW and particle-size distribution. As summarized in the literature (Powell et al. 2000), as the channel margins become less stable, greenline-to-greenline or channel width will usually increase. Such an increase will usually be associated with a decrease in channel depth. This reduction in channel depth is often caused by a decrease in the ability of the stream to scour the bed and may also be associated with a higher sediment load and greater proportion of fine particles in the channel (Montgomery and Buffington 1998).

Procedure: Residual pool depth and frequency is calculated by measuring the length of the ***thalweg*** and the water depths of ***riffle crests*** and ***pools***.

- Pools are defined as any depression in the bed of the stream resulting in relatively low water velocity and often as relatively flat-water surfaces when measured at low streamflow (usually occurring mid- to late summer). Such streamflow should be well below the bankfull stage but sufficient to completely fill pools and to maintain surface flow between pools. In this protocol, a qualifying pool must be at least one-half the channel width to avoid ambiguous “pocket” pools. In addition, two pool metrics are calculated: all pools and ***quality pools***. All pools are the average residual pool depth from all the pools observed and measured in the DMA. Quality pools include only pools that are at least 6 cm deeper than their corresponding riffle crest. Any residual pool that is < 6 cm is eliminated in the calculation of quality pools. The quality pool notation removes some of the observer variability and subjectivity associated with shallow and poorly formed pools.

- It is customary to measure residual pool data last, after all the greenline-based indicators have been collected. However, if the channel bed is soft (e.g., an unconsolidated, silty, or muddy substrate), reverse the workflow and collect substrate and residual pool data before the greenline-based indicators. The mere act of walking on a soft channel bed can either create or deepen pools and can destroy or modify riffle crests. Repeated trampling of a soft channel bed can result in changes to particle sizes and water depths.

- Residual pool measurements should not be made by this wading method if the DMA is not truly wadeable. When pools exceed about 1.25 m depth, the residual-pool indicator can be omitted and the presence of deep (>1.25 m) pools should be noted in the data forms. At depths > 1.25 m, pools are generally not a management concern and are unlikely to be a limiting factor of resource conditions.

Step 1. Identify the riffle crest. Beginning at the downstream marker of the DMA, proceed upstream and identify the first riffle crest (pool tail). The riffle crest is best identified when looking upstream. It is the top of the riffle or upstream end of shallow, rippling water. It coincides with the point where water exits or spills from a pool (Figure 73). To qualify as a pool, it must be at least one-half the width of the active channel. Small pocket pools are not counted. The distance from the lower marker in the DMA to the first riffle crest is not measured.

An effective technique is to have one individual wade in advance to measure the maximum or thalweg depths of the channel at both the riffle crests and in pools. The second observer follows and measures the distances between riffle crests and pool bottoms.

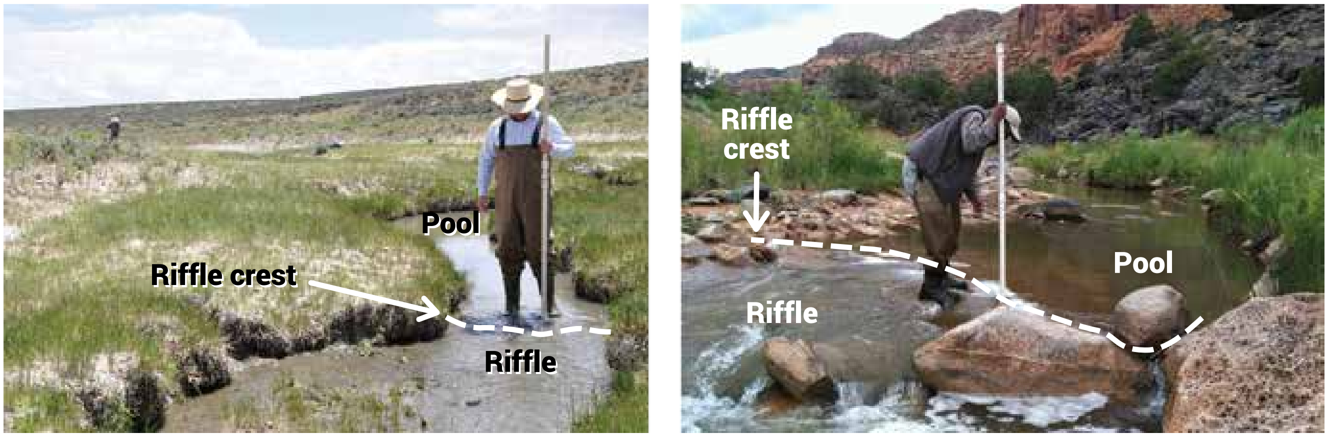

Figure 73. Identifying the riffle crest. The riffle crest in these photos represents the point where water spills from the pool (relatively deep water with a flat or smooth surface) and into a riffle (relatively shallow water with a more turbulent surface).

Note: Pools are separated by riffle crests. Do not subdivide a large pool into two or more pools because of a channel bedform that is not a true riffle crest or "spill" point out of a pool (Figure 74).

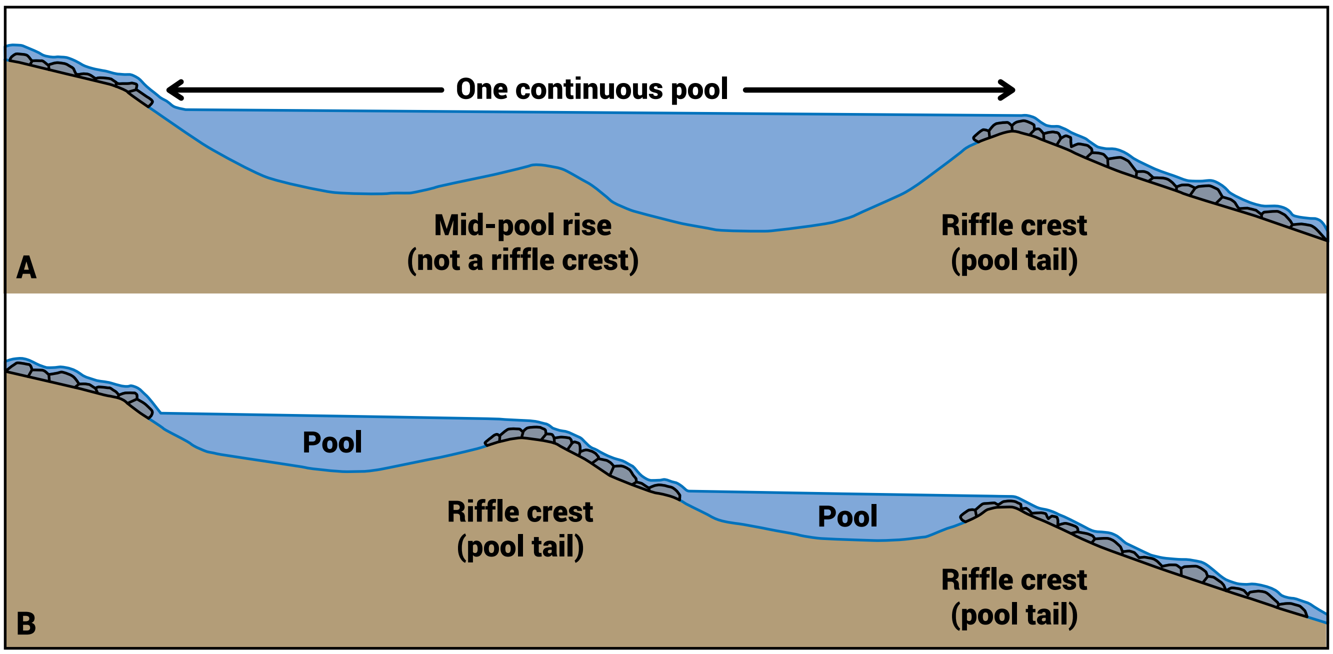

Figure 74. Example showing difference between mid-pool rise and riffle crest.
A. A single pool with one pour point controlled by the riffle crest and a mid-pool rise.
B. Adjacent pools, each of which is controlled by a riffle crest. Vertical scale exaggerated to better illustrate bed morphology.

Step 2. Determine the thalweg depth of the riffle crest. Measure and record the thalweg depth of the riffle crest to the nearest hundredth of a meter (0.01 m) with the measuring rod. The depth measurement is made in the thalweg or deepest part of the channel in the stream cross section.

Note: Orient the measuring rod vertically when making depth measurements. In fast-moving water, the water surface will form a high-pressure ridge on the upstream side of the measuring rod and a low-pressure depression on the downstream side of the measuring rod. For consistency, measure the water depth on the side of the rod to average the hydraulic ridge and depressions (Figure 75).

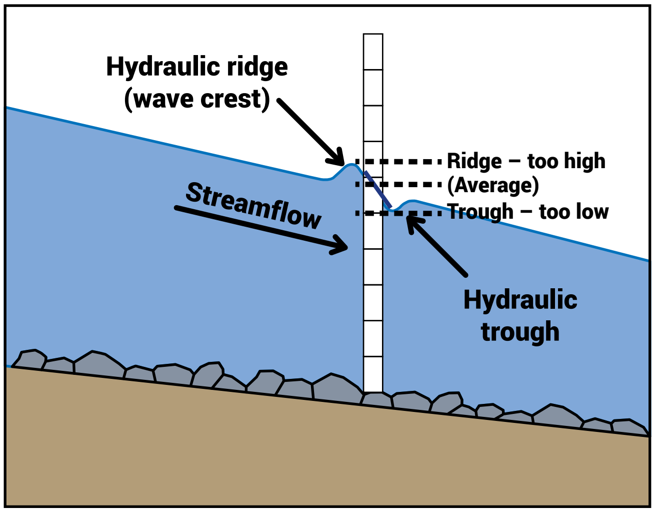

Figure 75. Measuring pool depth in high velocity water. Fast-moving water can force water to pond as a ridge or wave crest on the upstream side of the depth rod and to form a depression or trough on the downstream side of the depth rod. If the depth measurement is not made consistently in high-water settings, the monitor could introduce several centimeters or more of error to each measurement. For consistency, measure the water surface on the side of the depth rod to average the upstream ridge and downstream trough.

Step 3. Locate the pool upstream from the riffle crest and find the deepest point. This is best accomplished by wading up through the pool to feel depth changes and by probing with the 2-m measuring rod.

Step 4. Measure the horizontal distance from the riffle crest to deepest point in pool and the maximum pool depth. Follow the thalweg and proceed upstream to find the maximum pool depth. Record the horizontal distance from the riffle crest to the maximum pool depth to the nearest decimeter (0.1 m). Measure and record the maximum depth of the pool to the nearest hundredth of a meter (0.01 m). Horizontal distance along the thalweg is measured with a 2-m measuring rod, metric tape, or laser rangefinder. Depths are measured with a 2-m measuring rod or other survey instrument with resolution of 0.01 m (1 cm).

- When tracing the thalweg, make sure to carefully measure distances around meander bends. Do not truncate thalweg length by measuring across meander bends. Carefully measure the length of the thalweg into, through, and out of meanders.
- When a channel bifurcates around a bar or island, **follow the main channel**, which will visually contain most streamflow. If in doubt, walk both sides of an island to determine which channel contains the thalweg (i.e., the deepest trace of the channel). Note which channel was measured; draw a sketch so subsequent monitoring can account for changes in channel conditions.

Step 5. Continue measuring horizontal distance and water depths to the top of the DMA. Continue measuring and recording water depths at each riffle crest and each pool bottom. Continue measuring and recording the horizontal distances from the riffle crests to the maximum pool depth and conversely from the maximum pool depth to the next riffle crest in an upstream direction to the top of the DMA. As you near the upstream end of the DMA, pay attention to the location of the riffle crests.

If a riffle crest is within the DMA, proceed to the next pool bottom (even if it is beyond the upstream DMA marker). If the riffle crest is upstream of the top DMA marker, then stop and do not make any additional measurements.

Step 6. Measuring residual pool depth and pool frequency in dry or non-flowing channels (optional method).

- Residual pool depth is conventionally measured in perennial streams during baseflow conditions when water is exiting pools through riffle crests. There are some important fisheries in intermittent streams (e.g., streams with winter-spawning steelhead that dry up during summers), where information on residual pools may be desired. If water is no longer flowing over riffle crests, a “no-flow” alternative method can be used to measure residual pool depth.

  To use this method, extend a level line (a mason line, measuring tape, or 2-m measuring rod) from the lowest point in the riffle crest to the maximum pool depth and measure the vertical drop from this horizontal reference (Figure 76). A level (inset photo, Figure 76) placed on a taut mason line, tape, or measuring rod will ensure the line (or rod) is horizontal. Record “0” for the depth at the riffle crest, the depth of the pool bottom, and the distances between pool features.

Timing: The residual pool depth and pool frequency indicators help document stream channel function and recovery over time. Because the recovery process may be relatively slow, it is recommended that the method be repeated every 3–5 years. The method is relatively easy and requires about one-half hour per DMA.

Where stream reaches have deep pools, measurement of residual pool depth will be most practical during low-flow conditions, provided this coincides with the optimal time to collect other indicators. In intermittent streams, it is easier and faster to collect residual pool measurements while there is still streamflow over the riffle crest. However, the alternative no-flow method in step 6 can be used to calculate residual pool depth and frequency (Figure 76).

Figure 76. Measuring residual pool depth and pool frequency in a dry channel. Anchor or hold a tape, tag line, or mason line to the thalweg of the riffle crest (indicated by black arrow) and extend it to the pool bottom. Use a line level (example, upper right inset photo) to make sure the line is taut and horizontal. Measure the residual pool depth with a depth rod at the point the horizontal line intersects the rod (see person holding depth rod).

7. Abbreviations and Acronyms

AIS – Aquatic invasive species

BLM – Bureau of Land Management

D_{xx} – particle size at which a specified percent of the particles has a smaller diameter. The xxth percentile diameter ranges from 1 to 99. For example:
- D_{16} – particle size at which 16% of the particles have a smaller diameter (D)
- D_{30} – particle size at which 30% of the particles have a smaller diameter (D)

DMA – Designated monitoring area

GGW – Greenline-to-greenline width

GPS – Global Positioning System

ID – Interdisciplinary, as in interdisciplinary team

IRMP – Integrated riparian management process

MIM – Multiple indicator monitoring

NRCS – Natural Resources Conservation Service

PFC – Proper functioning condition

PIBO – PacFish/InFish Biological Opinion; an interagency biological opinion and the monitoring protocol that resulted from that biological opinion

PIBO-EM – PacFISH/InFISH Biological Opinion Effectiveness Monitoring

PLANTS – Plant List of Attributes, Names, Taxonomy, and Symbols, an online database operated by USDA, NRCS

SMART – In reference to land-management objectives, which should be: **S**pecific, **M**easurable, **A**chievable, **R**esults-oriented, and **T**ime-fixed (Adamcik et al. 2004)

USDA – United States Department of Agriculture

USDI – United States Department of the Interior

USFS – United States Forest Service

UTM – Universal Transverse Mercator

8. Glossary

Absolute cover: The percentage of the ground (surface of the plot or stand) that is covered by a species or group of species (Klein et al. 2007). Absolute cover of all species or groups if added in a stand or plot may total greater or lesser than 100% because it is not a proportional number (Klein et al. 2007).

Active channel: The active channel is a short-term geomorphic feature formed by prevailing stream discharges, is narrower than the bankfull channel and is defined by a break in bank slope that also typically is the edge of permanent vegetation. It occurs at and below the scour line (Lawlor 2004).

Available woody species: Woody shrubs and trees in which at least one half of the leaders are available for browse by large herbivores (e.g., cattle, sheep, horses, burros, deer, elk, and moose). The concept of availability differs by animal, as taller animals can browse to a higher level (Table 5).

Bankfull stage (or level): The elevation of the bank where flooding begins. The bankfull level is associated with the streamflow that just fills the channel to the top of its banks and where water usually begins to overflow onto the floodplain. This streamflow level is often associated with moving sediment, bar formation, and generally, the work that forms the morphological characteristics of the stream channel (Wolman and Miller 1960).

Bench: A relatively flat area, more or less parallel to the stream, which may be a depositional bar, floodplain, or terrace.

Critical DMA: A critical designated monitoring area (DMA) is not representative of a larger area but is important enough that specific information is needed at a particular site. Critical DMAs are monitored for highly localized management objectives and to address site-specific monitoring questions. See also **DMA**, **reference DMA**, and **representative DMA**.

Current year's leader or twig growth: That portion of the stems of woody plants that reflects the current year's growth or that extends from the terminal buds of 2-year-old growth. Leaders represent the dominant trunk of a branch or stem; twigs represent the terminal parts of the branch or stem.

Cutbank: The outside or concave bank at a curve or bend in a stream channel. Cutbanks are typically steep and vertical to nearly vertical faces of streambank. Cutbank morphology is result of net erosion on the streambank. Cutbanks may contain alluvium or may be formed in non-fluvial material. See additional information at point bar.

Designated monitoring area (DMA): A DMA, for the purposes of this protocol, is a permanently marked segment of stream or vegetated drainageway that has been selected for monitoring. It refers to the specific sampling location that extends at least 150 m along the stream. Longer segments may be needed for monitoring larger streams (i.e., streams with average GGW > 7.5 m). For larger streams, the length of the DMA is set to 20 times the GGW, which should be at least two meander wavelengths (Gordon et al. 2004). For example, a DMA on a stream segment with an average GGW of 8.3 m will be 166 m (8.3 m x 20) in length. See also **critical DMA**, **reference DMA**, and **representative DMA**.

D_{xx}: The particle size at which a specified percent of the particles has a smaller diameter. The xxth percentile diameter ranges from 1 to 99. For example:

D_{16} – particle size at which 16% of the particles have a smaller diameter (D)

D_{30} – particle size at which 30% of the particles have a smaller diameter (D)

Ephemeral system: A stream system that flows only in direct response to precipitation. It receives no water from springs and does not have a long, sustained supply of water from melting snow or other surface sources. Its stream channel is always above the water table. The term ephemeral may be arbitrarily restricted to streams or stretches of streams that do not flow continuously during a period of as much as 1 month (Meinzer 1923). An ephemeral stream does not exhibit the typical biological, hydrological, and in some cases physical characteristics associated with the continuous or intermittent availability of water (Nadeau 2011). The MIM protocol is not designed for use on ephemeral streams or ephemeral reaches.

False banks: False banks are sections of bank that have broken off (i.e., **slump block**) from a high bank, terrace, or streambank and have become reattached to the streambank. False banks are stable features and do not have fractures, stream scour, or streambed between the former block (now a section of bank) and the bank or terrace. They may or may not be vegetated to the base of the terrace wall, but they must be stable (i.e., unlikely to move during high flow events). If a false bank is present, the greenline is located at the edge of the vegetation above the water's edge or scour line (Figures D.29–D.30).

Fines: Substrate particles that are ≤ 6 mm in diameter.

Floodplain: The relatively flat area adjacent to a stream or lake that experiences occasional or periodic flooding. Dunne and Leopold (1978) defined the floodplain as the flat area adjoining a river channel, constructed by the river in the present climate, and overflowed at times of high discharge.

Foliar cover: The amount of live plant parts, leaves, twigs, stems, and branches that covers the ground surface expressed as a percentage. Foliar cover is the shadow cast if the sun was directly overhead.

Fracture: A visible crack at or near the top of the streambank that has created a gap, but which has not led to separation of a block of the streambank (see **slump**). In the MIM protocol, a fracture must be at least one-fourth of the length of the MIM monitoring frame (≥12.5 cm) to qualify as a fracture feature. See Figures H.4 and H.5 for additional examples of fractures.

Geomorphology: The study of the age and evolution of landforms and the processes that form them.

Hoof shear: A broken part of the streambank caused by the weight of a hoof or foot stepping on the streambank and causing it to break down. Shearing is often the most obvious form of streambank disturbance caused by animals. See Figures E.6 and E.7.

Hydrophyte/Hydrophytic: Hydrophyte literally means "water loving." Many hydrophytic vegetation species have adapted to growing in low-oxygen (anaerobic) conditions associated with prolonged saturation or flooding. Other hydrophytes grow in oxygenated soils that have an abundance of readily plant-available moisture during much of the growing season. Plants with wetland indicator ratings of OBL, FACW, and FAC (see **wetland indicator status**) are considered hydrophytes.

Intermittent system: A stream system that flows only a certain time when it receives water from springs or gradual and long, continued snowmelt. The intermittent character of a stream is generally due to fluctuations of the water table whereby part of the time the streambed is below the water table and part of the time it is above the water table. The term intermittent may be arbitrarily restricted to streams or stretches of streams that flow continuously during periods of at least 1 month (Meinzer 1923). An intermittent stream may lack the biological and hydrological characteristics commonly associated with continuous conveyance of water (Nadeau 2011). The channel may or may not be well defined.

Key Graminoids: Grass and grass-like plants that are relatively palatable to grazing animals, relatively abundant, important for stream/riparian function and habitat, and serve as indicators of environmental and management changes. Available key graminoids are plants that are accessible to grazing animals. Unavailable key graminoids are those that are completely inaccessible to grazing animals (e.g., located beneath dense woody overstories, on rock outcrops, or on steep slopes).

Key species: Plant species that are relatively abundant, important in the plant community and important for stream/riparian function and habitat. They are relatively palatable to livestock (or other ungulates of interest) and serve as indicators of change.

Logical inference: A reasonable deduction or induction based on analogies and comparisons. For example, one might use quantitative monitoring data from a single representative DMA in combination with supplemental information (e.g., photo points, riparian assessments [e.g., PFC], riparian inventories, pasture inspections, and field notes) to make informed inferences about similar (commonly larger) areas (e.g., the sensitive complex within which the representative DMA is located).

Obvious streambank alterations: Those alterations to the streambank that are easily seen, clear to the eye, not to be doubted, or plain (Thorndike and Barnhart 1993).

Point bar: Point bar is an alluvial deposit that forms by accretion on the inside, or convex, bank at a curve or bend in a stream channel. Point bars typically have a low bank angle and are the result of deposition along the inside of a meander bend where streamflow velocity and transport capacity are low. See also **cut bank**.

Pool: A depression or deeper part of a stream channel that usually has slower moving water. In the MIM protocol, a pool must occupy at least ½ of the width of the active channel. Also see **quality pool**.

Pool tail: The downstream boundary of a pool, also known as **riffle crest**.

Quality pool: Quality pools must have a residual pool depth > 6 cm. Because juvenile trout and salmon have a breadth averaging approximately 6 cm, such pools are available for resting and feeding and more likely to be important for these aquatic biota. Quality pools are identified in the Data Analysis Module and not while sampling in the field.

Reference DMA: A type of DMA selected to obtain reference information useful for identifying potential natural conditions or determining initial desired condition objectives for a similar riparian complex. See also **critical DMA**, **DMA**, and **representative DMA**.

Representative DMA: A monitoring site in a riparian complex that is representative of a larger area. This is the most common type of DMA used by land managers. This type of DMA should be selected by an experienced ID team, should be in a complex that represents and is accessible to the management activities of interest, should be located on a site that is sensitive to disturbance, and should be capable of responding to the management activity of interest. See also **critical DMA**, **DMA**, and **representative DMA**.

Residual pool depth: Residual pool depth is a calculation of pool depth from two measurements of water depth, one in the thalweg at the riffle crest and one at the deepest part of a pool upstream of the riffle crest. Residual pool depth = maximum pool depth minus riffle crest depth. Residual pool depths can be measured independently of stream discharge, which is important in detecting trends. See also **pool**, **quality pool**, and **riffle crest**.

Riffle: That part of a stream that is locally steeper and shallower than adjacent reaches and at low flow has relatively faster, shallower water causing choppiness on the water surface. Also see **riffle crest**.

Riffle crest: The point at the downstream end of a pool where water flows into the start of a riffle. A riffle crest is the upstream end or top of a riffle and the downstream end of a pool where water exits or spills out of the pool and into a riffle. Riffle crest is also known as **pool tail**.

Riparian complex: The overall geomorphology, substrate characteristics, dominant soil family, stream gradient, hydrology, vegetation patterns along the stream (Winward 2000; USFS 1992; Herrick et al. 2009), and land uses.

Scour line: The elevation of the ceiling of undercut banks at or slightly above the summer low-flow elevation, or on depositional banks, the lower limit of sod-forming or perennial vegetation. The scour line has roughly the same elevation above the water surface elevation throughout the entire DMA so that where it is not apparent on the streambank, its position can be inferred.

Sensitive riparian complex: A complex that is quick to detect or respond to management changes, more susceptible to management actions, and more vulnerable to risk.

Seral stage (successional status): Ecological status is also referred to as successional status, successional stage, or seral stage and refers to the relative position of individual plants or plant communities in relation to climax. This is related to the tendency of a plant to occur either earlier or later in a successional progression and is based on its response to disurbances and its relative shade tolerance and persistence.

Slough (sluff): This applies to streambanks where loose, disaggregated soil or sod material has been shed or cast off and has accumulated either on an inclined slope or at the base of a vertical or nearly vertical streambank. In the MIM protocol, slough must be at least one-fourth of a MIM monitoring frame in length (12.5 cm) to qualify as a slough feature. Slough commonly forms from ungulate trampling on the streambank as well as by the freeze-thaw cycles, wetting and drying, and other processes that form dry ravel. See Figures H.7, H.9, and H.11 for examples of slough.

Slump (slump block): A block or chunk of soil/sod that has separated from the streambank and has obviously been displaced downward. In the MIM protocol, a slump feature must be at least one-fourth of a MIM frame in length (12.5 cm) to qualify as a slump feature. Slumps blocks may be the size and direct consequence of an ungulate hoof print that has noticeably displaced part of the streambank or may be large chunks of an undercut streambank that have collapsed. See Figures H.4, H.6, and H.14 for examples of slumps.

Stratification: Process of using specific criteria to sort stream reaches (riparian complexes) into groups (i.e., strata). All reaches in a specific group share similar characteristics.

Streambank: As a geomorphic concept, the streambank is the part of the bankfull channel that extends from the scour line to the bankfull stage. In channels where a bankfull stage or floodplain are not apparent or developed, the upper limit coincides with the normal high-water mark. In the context of streambank stability and cover, the streambank extends from the scour line to the lip of the first bench. The first bench may be lower than, equal to, or higher than the bankfull stage depending on the fluvial setting.

Streambank alteration: Streambank disturbance caused by animals (e.g., elk, moose, deer, cattle, sheep, goats, horses, and burros) walking along the streambanks or the margins of the stream. The animals' weight can cause shearing that results in a breakdown of the streambank and subsequent widening of the stream channel. Streambank alteration also exposes bare soil, increasing the risk of erosion of the streambank. Animals walking in the channel margins may increase the amount of soil exposed to the erosive effects of water by breaking or cutting through the vegetation and exposing roots and/or soil. Excessive trampling causes soil compaction, resulting in decreased vegetative cover, less vigorous root systems, and more exposure of the soil surface to erosion. Streambank alteration can also be caused by human foot traffic and by vehicles or other land-use activities. See Appendix E, for examples of streambank alteration.

Stream gradient: The slope or amount of vertical drop along the stream channel per unit horizontal distance. It is usually expressed as a percentage.

Terrace: An abandoned floodplain that is not flooded regularly or frequently by mean annual floods and only possibly on rare occasions associated with extremely large floods. A terrace has a level surface and is located upslope of (i.e., above) the active floodplain.

Thalweg: The line connecting the lowest or deepest points along a streambed, vegetated drainageway, or wet meadow.

Trampling: Animal-caused depressions in the soil surface or soil compaction along the streambank or crossing the channel.

Wetland indicator status: Wetland indicator status ratings represent a consensus determination from botanical literature and the best professional judgment of wetland ecologists. A wetland indicator status rating is assigned to each plant species to represent the estimated probability, or frequency, with which it was thought to occur in wetlands. Wetland indicator status ratings include five categories (from Lichvar et al. 2016), listed from most likely to least likely to occur in wetlands:

- Obligate wetland plants (OBL) almost always occur in wetlands.
- Facultative wetland plants (FACW) usually occur in wetlands but may occur in non-wetlands.
- Facultative plants (FAC) occur in wetlands and non-wetlands.
- Facultative upland plants (FACU) usually occur in non-wetlands but may occur in wetlands.
- Upland plants (UPL) almost never occur in wetlands.

Also see **Hydrophyte/Hydrophytic**.

Winward greenline stability rating: A relative value based on general rooting characteristics. Plants with deeper, denser, and stronger roots and rhizomes are assigned a high stability rating. Those with shallow, sparse, or weak roots are assigned a low stability rating. Detailed rating criteria are provided in Appendix G.

Woody riparian species: Woody riparian species are hydrophytic trees and shrubs. Hydrophytic plants have a wetland indicator status rating of facultative, facultative wetland, or obligate wetland.

9. Appendices

Appendix A. Stratification and Identification of the Sensitive Complex for MIM DMAs

As part of the MIM protocol, practitioners must delineate and stratify riparian areas to identify sensitive complexes appropriate for locating representative DMAs. Users should rely on a combination of GIS layers, existing assessment and monitoring data, field and aerial photography, and the collective, local knowledge of interdisciplinary team members.

Many administrative units have already delineated and stratified riparian areas as part of a systematic effort to conduct stream assessments (e.g., the proper functioning condition protocols) (BLM 2015, BLM 2020), or to conduct prior riparian monitoring. MIM users should consult office records and/or GIS databases to determine if riparian areas have already been delineated and stratified for their unit.

The process of delineating and stratifying riparian areas is described in many sources, including USFS 1992, BLM 2015, and BLM 2020. A simplified set of instructions is provided here, along with a general worksheet to facilitate and document the process of stratifying reaches into riparian complexes.

1. Identify the population of stream reaches. Delineate stream reaches using a GIS stream layer. This could be derived from an existing National Hydrographic Dataset (NHD) layer, or from aerial imagery that identifies perennial and intermittent stream reaches. Differentiate perennial and intermittent reaches, if known. Exclude ephemeral reaches, as these do not generally support riparian vegetation and are inappropriate for management of riparian resources or values.

2. Note the Strahler stream order.

3. Break reaches up initially by allotment boundaries (or similar management boundaries, as appropriate). For management of public lands, remove reaches that traverse private lands or lands administered by other entities.

4. Use a valley-bottom mapping tool to determine coarse valley properties, such as valley type (e.g., Rosgen valley type, Rosgen 1996), average valley width, and average valley gradient.

5. With hydrology GIS tools, calculate stream gradient. Initially, reaches can be stratified by broad gradient bins that conform to Rosgen stream types (i.e., < 0.5%, 0.5–2%, 2–4%, 4–10%, and > 10%). If finer resolution is needed, determine more appropriate bins for stream gradient and document rationale.

6. Determine dominant or median particle size of the channel substrate. General bins are appropriate initially (i.e., silt and clay, sand, fine gravel, coarse gravel, pebble, cobble, boulder, bedrock).

7. Characterize the dominant plant communities by reach. This might be done initially by reviewing aerial imagery and then refined based on local knowledge or field visits. Some initial bins might include hydrophytic graminoids, hydrophytic trees, hydrophytic shrubs, mixed hydrophytic graminoids and shrubs, mesic graminoids, mesic trees, mesic shrubs, mixed mesic graminoids and shrubs, upland graminoids, upland trees, upland shrubs, and mixed upland graminoids and shrubs. Additional modifiers or groups might be made with respect to annual plants, depauperate plant communities, native or nonnative species, and invasive or noxious species.

Stratification Worksheet

Stream name: ______________________ Allotment/Pasture: ______________________

Hydrology

Flow permanence (check one):

Perennial __________ Intermittent __________ Ephemeral (not suited to MIM) __________

Strahler's stream order (check one): 1st _____ 2nd _____ 3rd _____ 4th _____ ≥ 5th _____

Geomorphology – Valley and Channel

Entrenchment ratio ________ = ________ (Flood-prone width) / ________ (Bankfull width)

Width: Depth ratio __________ Sinuosity (channel length/valley length) __________

Substrate (circle one): silt/clay sand gravel cobble boulder bedrock

Channel gradient (circle one): < 0.5% 0.5–2% 2–4% 4–10% > 10%

Rosgen stream type (circle one): Aa+ A B C D DA E F G

Rosgen valley type (circle one): I II III IV V VI VII VIII IX X XI

Soil

Dominant soil family(ies)	
Riparian ecological site(s)	

Plant Communities (Existing)

Greenline vegetation community(ies)	
Dominant understory species	
Dominant overstory species	

Complex name and description (current condition and potential):

Appendix B. Special Situations—DMAs

This appendix contains specific information related to natural or human-induced disturbances that may influence establishment of or continued use of existing DMAs, or recommendations on the timing of monitoring.

DMAs affected by beaver dams (or stream-installed infrastructure like beaver dam analogs or post-assisted linear structures): The MIM protocol can be applied to existing DMAs that have been influenced by construction of beaver dams after their establishment. In addition, DMAs can be established on reaches with active beaver dams but generally only if they are relatively small and infrequent ponds and lotic features are still intact for most of the DMA. The presence and number of dams in the DMA and the extent of beaver-ponded water should be described in the narrative section. Beaver dams may affect the ability to collect:

- Residual pool depth – If pools are too deep to safely wade, note the presence of such pools in the narrative section.
- GGW – If ponded condition has led to the formation of a complicated system of bifurcating, anastomosing, or standing water conditions that have flooded the greenline, note this condition in the narrative section. Changes in GGW will reflect the expansion or contraction of beaver influences and not the effects of management, so tracking GGW in these situations is not informative to management.
- Substrate – If ponded conditions have created pools greater than an arm's length in depth, substrate may be difficult to access and record reliably. An alternative is to note the extent of pool habitat and to collect substrate data only from riffles, which provides information on the scouring capacity of the stream through beaver-dammed reaches. Collecting substrate data using the pool-tail method is not recommended as beavers commonly create a mud ramp at the pool tail to reinforce the beaver dam and to improve stream flow over the dam during high streamflow events.
- Woody riparian species age class – This can be a complicated indicator to interpret as a high water table may prevent the establishment of some woody species. Also, beaver may alter the population of woody species considerably in just a few years.

In contrast, the following indicators should be generally applicable in beaver-affected reaches:

- Greenline composition and cover – This indicator can document establishment of hydrophytic plant species along the greenline in dammed and well-watered reaches.
- Woody species height classes – Woody species provide shade, so some understanding of how beavers are affecting the woody shade component of the reach can be informative.
- Stubble height and streambank alteration – These annual-use indicators are generally appropriate along the greenline even when it is the result of beaver-ponded conditions.
- Woody riparian species use – Although beavers may harvest some of the available woody plants, it is still possible to evaluate the level of woody use by livestock and other ungulates.

In situations where dams have failed and have exposed extensive patches of a vegetation-free channel in once inundated pools, delay monitoring from 1 to several years so vegetation can respond to changes in hydrology.

If an existing DMA has been flooded by one or more beaver dams, consider the size and extent of the ponding to determine if the DMA should be shifted.

Do not shift the DMA location when:

- The total extent of beaver ponds is less than one-third of the DMA (and the remaining two-thirds is clearly not ponded),
- More than one-third of the DMA is ponded but the ponds are narrow.
- The pools, GGW, and substrate would not be collected in the ponds as described above.

Shift the DMA upstream or downstream within the same complex, as little as possible, but when:

- The total extent of beaver ponds at the DMA is greater than one-third of the DMA.

If shifting the DMA upstream or downstream within the identified complex is not possible because of the presence of a complex boundary, go back to the stratification and DMA selection exercise and randomly select a new DMA in another sub-complex or complex. Any shifts or relocation of DMAs should be well documented so that successors understand what was done and why (see Data Instructions Guide, Calibrating DMA Shifts and Relocations).

Recent floods. Infrequent, high-magnitude streamflow events can leave thick deposits of sediment on streambanks or can physically scour vegetation from the greenline, creating conditions that are difficult to associate with and interpret relative to management impacts. To differentiate the impacts of climatic events from those of management, delay monitoring from 1 to a few years after an infrequent, high-magnitude streamflow event so vegetation can reestablish or grow through streambank sediment. In many post-flood situations, it might be only a matter of a few months in the growing season for riparian vegetation to emerge through recent sediments and recolonize streambanks.

Recent fires. Many riparian areas are adept at surviving wildfires with little to no lasting effects to riparian vegetation. Generally, the higher soil moisture of streambanks and the higher water content of riparian vegetation provides some buffer to the effects of wildfire. However, intense wildfires can and do burn over riparian vegetation. In addition, wildfires that burn the contributing watershed can produce high runoff events that can scour channels or deliver large amounts of sediment to the stream channel. Many riparian woody plant species are rhizomatous or display sprouting characteristics following denudation from fire. Consequently, to differentiate the geomorphic and vegetation responses to fire from management effects, delay monitoring by 1 to a few years after a fire.

Flow-regulated streams. Streamflow may be affected by regulated flow for flood control, water supply, hydropower, or irrigation purposes. Understand the nature of flow regulation and how the seasonal alteration of flow might affect monitoring. Identify a window of optimal monitoring when streamflow conditions permit safe wading and the ability to collect the MIM indicators. Avoid periods of flooded greenlines or conditions that preclude the collection of residual pool depths. If the flow regulation follows a predictable seasonal or annual cycle, make sure to collect repeat data at the same seasonal progression to better interpret conditions that might reflect trends related to the effects of management.

Acquisition of streamflow data in regulated streams can help with interpretation of monitoring data. Preferably, all streamflow discharge data should be acquired, not just the current year's data.

Appendix C. Equipment Specifications

MIM Monitoring Frame

The MIM monitoring frame is 42 cm x 50 cm (Figure C.1). Each half of the MIM frame is the equivalent of a Daubenmire frame (20 cm x 50 cm). The materials used to construct the MIM monitoring frame are summarized in Table C.1.

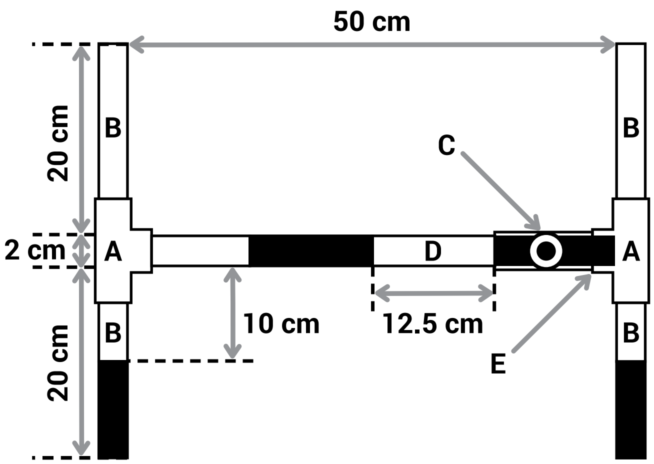

Figure C.1. Schematic of MIM monitoring frame. Labels A through E refer to parts listed in Table C.1. MIM handle parts F, G, and H (optional) are pictured in Figure C.4.

Monitoring frames may be constructed of various materials. Below are instructions for a simple and inexpensive frame constructed of PVC pipe and fittings. Schedule 40 PVC is rigid and does not warp as much as lighter pipe. These instructions can be adjusted as needed to work with other materials. **PVC fittings vary in dimensions by manufacturer** so carefully measure each part, dry fit the parts, and adjust the dimensions of cut parts, if necessary, before glueing parts together.

To construct a monitoring frame using ½-inch PVC pipe:

1. Cut pipe to the appropriate lengths (Table C.1). Dry fit cut parts with fittings and adjust pipe lengths, as necessary. Remember, PVC cement cures rapidly (within a few seconds). There are no second chances. **Note:** Some adhesives use a two-step process requiring an application of PVC solvent and then PVC cement; others use a one-step process. Follow the instructions of the adhesive used.

Table C.1. Parts list for a MIM monitoring frame. Schedule 40 PVC is recommended.

Item	Part Label	Number of Parts	Length	
			inches	cm
½” tee (slip-slip-slip fitting)	A	2	4	10
PVC pipe, ½” (internal diameter)	B	4	7.75	19.7
½” tee, with female-threaded riser (slip-slip-threaded fitting)	C	1	4	10
PVC pipe, ½” (internal diameter)	D	1	16.9	43
PVC pipe, ½” (internal diameter)	E	1	1.25	3.2
PVC pipe, ½” (internal diameter)	F (handle)	1	39	100
½” male-threaded coupler (slip-threaded fitting)	G (on handle)	1	1.5	4
Optional: ~½” diameter wooden dowel (diameter ≤ internal diameter of part G)	H	1	2.5	6
Optional: polyurethane adhesive, water-based expanding	NA	1	—	—

2. Apply PVC cement to one end of pipe (part B) and a 3-way tee (part A, Figure C.2) and slide them together. Repeat the procedure on the opposite end of the tee. Repeat the process on the second tee (part A) to create a second end to the frame.

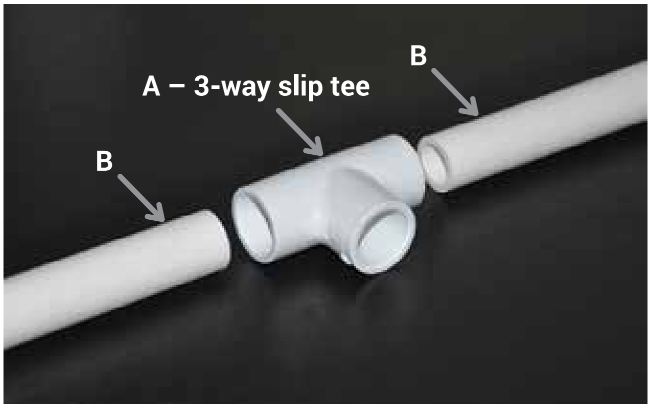

Figure C.2. The ends of the frame are constructed with a slip tee (part A) and ½″ PVC pipe.

3. Apply cement to a new tee (part C, ½″ tee with two slip and one threaded coupler, Figure C.3) and to the end of part E (short pipe). Apply cement to the other end of part C and insert the center pipe (part D).

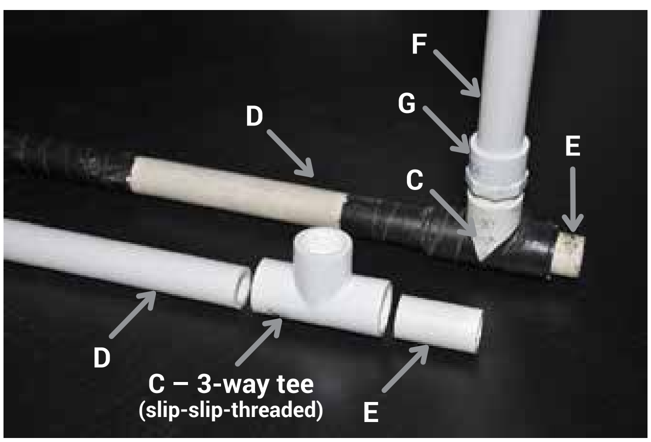

Figure C.3. Front: individual parts for center bar of MIM frame. Back: an assembled center bar with a handle screwed into the threaded coupler.

4. The center bar (parts D, C, and E) can be glued or dry fitted to the two end pieces (parts A and B) to make the frame. Slide the parts together, making sure the threaded tee is perpendicular (90 degrees) to part A so that a handle can be affixed and used properly.

5. Construct the handle by cementing the male-threaded coupler (part G) to one end of the pipe (part F, Figure C.4).

   Note: Part C is a tee with one threaded joint, it is designed to attach to the threaded coupler (part G). Alternatively, slip tee (like part A) could be used instead so that the handle (part F) fits directly into the top of part A thereby omitting part G (see Figure C.4). Although the alternative is simpler to construct, we have found that dry fitting the handle into a slip joint often results in the frame falling off the handle. This is why we prefer a threaded joint to connect the handle to the frame (Figure C.3).

6. (Optional) For added strength and durability, glue a 6-cm-long wooden dowel (part H) into the male-threaded coupler (Figure C.4). Glue the dowel into the male-threaded coupler and leave 1–2 cm protruding. The diameter of the dowel should match the internal diameter of the male-threaded coupler. A **moisture-activated, expanding polyurethane adhesive** is best for this operation as the expanding adhesive will provide the best adhesion of wooden dowel to the PVC part.

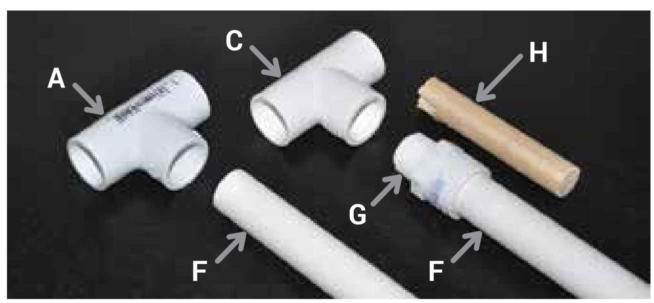

Figure C.4. The handle (Part F) can be connected to the frame in two ways. If a threaded tee (part C) is used to construct the center bar, then attach the handle (part F) to a male-threaded coupler (part G). Alternatively, if a slip tee (part A) is used to construct the center bar, then the handle (part F) can be inserted directly into the slip tee (part A). Optional: the weakest part of the handle is the threaded coupler (part G). Gluing a wooden dowel (part H) inside the threaded coupler (part G) can greatly strengthen this weak point.

7. Screw the handle (part F) into the frame (part C) and mark the handle in 1-inch or 2-cm increments, beginning at ground level (Figure C.5). Proceed up the handle for 1 m. Cut off excess pipe at the 1-m mark.

The markings on the frame and handle provide references for observers to project lines and estimate the amount of vegetation in the quadrat. Electrical tape wrapped around the pipe is a good material for marking the alternating colors. Tape does not come off PVC pipe as easily as some paints.

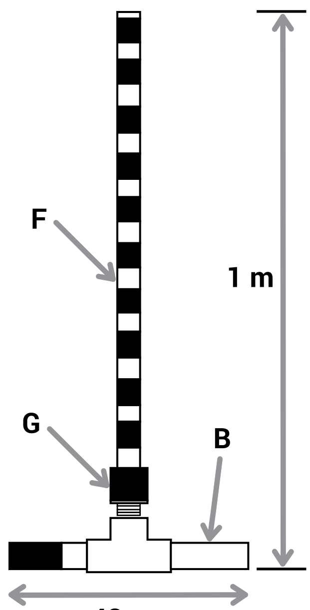

Figure C.5. Schematic of monitoring frame handle.

Measuring Rod/Field Staff

A 2-m measuring rod (or field staff) is used extensively in the implementation of MIM. It can assist in demarcating the dimensions of various quadrats, in determining height classes of shrubs and trees, in measuring the depth of pools and riffle crests, in obtaining photographs from a standardized height, in measuring GGW or the sampling interval, and other uses. The rod can be constructed from various materials; it can be made from a single piece of pipe or wooden dowel, cut to 2 m in length.

Instructions for constructing a breakdown rod of PVC (with a threaded coupler at its midpoint) are as follows (refer to Table C.2 for a list of parts and dimensions):

1. Cut a 1-inch diameter, schedule 40 PVC pipe into two, 94-cm-long lengths (Table C.2, part A). **Note:** PVC couplers and pipe caps vary in dimensions by manufacturer. Carefully measure each part, dry fit the parts, and adjust the length of each part A, if necessary, before all parts are glued together.

2. Glue one slip fitting (part B) onto one end of each pipe. Insert a pipe cap (part C) into each slip fitting (part B, Figure C.6). Be sure to seat each cap fully onto the slip joint or the assembled length of the measuring rod may not be 2 m.

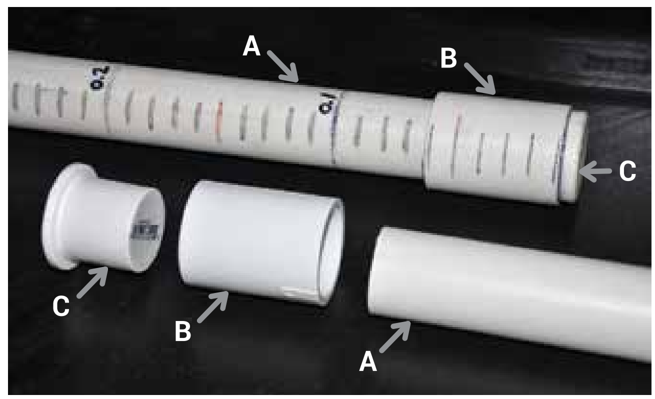

Figure C.6. End pieces of the 2-m rod. 1” PVC pipe (part A) is inserted into a slip fitting (part B). An end cap or plug (part C) is inserted into the other end of the slip fitting (part B). In the background is the assembled product.

3. Glue a male-threaded pipe coupler (part D) to a PVC pipe (part A, Figure C.7). Be sure to seat the coupler fully onto the pipe or the assembled length of the measuring rod may not be 2 m. Optional: the weakest part of the rod is the threaded coupler (part D). A wooden dowel (part F) inserted inside the threaded coupler (part D) can greatly strengthen this weak point. The diameter of the dowel should match the internal diameter of the PVC coupler. A **moisture-activated, expanding polyurethane adhesive** is best for this operation.

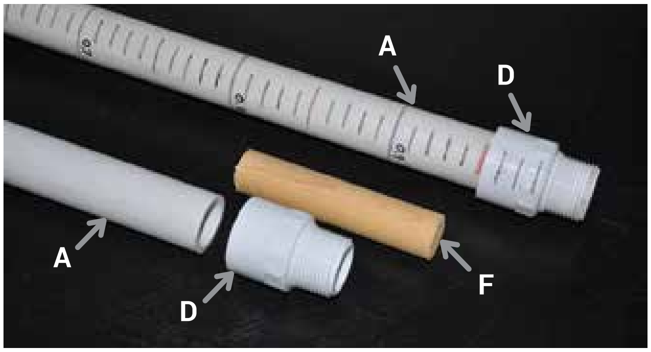

Figure C.7. Construction of the male-threaded part of the 2-m rod. Attach male-threaded coupler (part D) to 1-inch diameter PVC pipe (part A). Optional: insert and glue wooden dowel (part F) inside threaded coupler (part D) to strengthen coupler. In the background is an assembled piece of the rod.

4. Glue a female-threaded pipe coupler (part E) to a PVC pipe (part A, Figure C.8). Be sure to seat the coupler fully onto the pipe or the assembled length of the measuring rod may not be 2 m. Once assembled, use a meter stick to mark centimeter intervals and decimeter intervals on the measuring rod.

5. Use a fine-toothed hand saw or band saw to scribe a groove completely around the entire circumference of the pipe to mark each decimeter (10 cm) interval (see Figures C.7 and C.8).

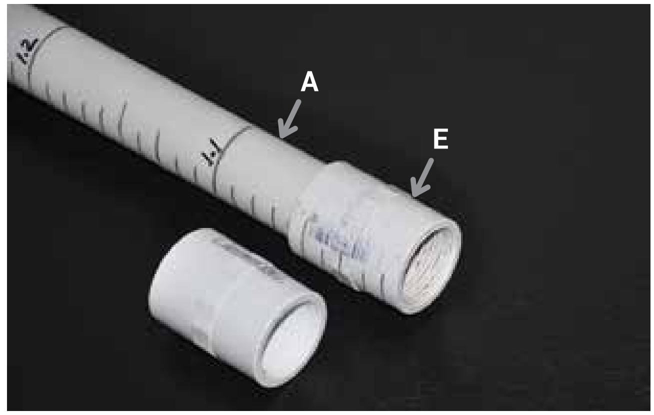

Figure C.8. Construction of the female-threaded part of the 2-m rod. Attach female-threaded couple (part E) to 1-inch diameter PVC pipe (part A).

6. Scribe a 2-cm-long cut at each centimeter with a fine-toothed hand saw or band saw. A longer cut may be made for each 5-cm interval to facilitate reading of measurements.

7. Darken the scribed marks with a permanent marker or paint and label 10-cm intervals (see Figures C.7 and C.8).

8. Apply plumber's tape to the threads to facilitate disassembly.

Table C.2. Parts list for a 2-m-long field staff or measuring rod. Schedule 40 PVC is recommended.

Item	Part Label	Number of Parts	Length	
			inches	cm
1-inch diameter PVC pipe	A	2	28.5	94
1-inch diameter slip fitting (slip-slip)	B	2		
1-inch diameter PVC pipe cap/plug	C	2	–	–
1-inch diameter PVC male-threaded pipe coupler (slip-threaded)	D	1	–	–
1-inch diameter PVC female-threaded pipe coupler (slip-threaded)	E	1	–	–
Optional: wooden dowel, 0.75-inch diameter Note: dowel needs to fit snuggly into part D	F	1	4	10
PVC solvent	NA	1 can	–	–
PVC cement	NA	1 can	–	–
Plumber's tape	NA	1 roll	–	–
Optional: polyurethane adhesive, water-based expanding (to glue wooden dowel into part D)	NA	1 tube	–	–

Appendix D. Greenline Examples

Appendix D contains examples of greenlines that one may encounter in the field. In each figure, the greenline is delineated with a white, dashed line.

Figure D.1. The greenline is the first relatively continuous line of live perennial vegetation above the scour line or water's edge (can include roots, embedded rock, or anchored wood).

Figure D.2. When the first vegetation above the water's edge is composed of perennial herbaceous vegetation, greenlines follow the relatively continuous line of live perennial vegetation with at least 25% foliar cover.

Figure D.3. The greenline must be aligned roughly parallel to the stream. Therefore, the greenline cannot exceed 75 degrees from the alignment of the streamflow or scour line and maintains a relatively continuous (although interrupted) linear, nonoverlapping progression along the bank. Where eddy pools exist, ensure that the greenline maintains a linear, nonoverlapping progression along the bank.

Figure D.4. The greenline must have at least 25% cover with no bare patches greater than 10 cm x 10 cm. Bare patches are any combination of rocks smaller than 15 cm, litter, annual plants, dead plants that do not qualify as anchored wood, or nonvascular plants. The soil on the left side of the frame (see shaded polygon) is a bare patch greater than 10 cm x 10 cm. Therefore, the monitoring frame is not on the greenline.

Figure D.5. Frequently the greenline is near the bankfull stage. The greenline cannot exhibit bare patches exceeding 10 cm x 10 cm. Bare patches are any combination of rocks smaller than 15 cm, litter, annual plants, dead plants that do not qualify as anchored wood, or nonvascular plants. The greenline here is located upslope of discontinuous vegetation patches that are closer to the waterline because that vegetation has < 25% foliar cover, with a bare patch of pebbles that exceeds 10 cm x 10 cm.

Figure D.6. The greenline cannot exhibit bare patches exceeding 10 cm x 10 cm. Bare patches are any combination of rocks smaller than 15 cm, litter, annual plants, dead plants that do not qualify as anchored wood, or nonvascular plants. Trampling by hoofed animals may create bare patches and cause the greenline to move away from the stream.

Figure D.7. In this image, the greenline can be at the water's edge, or on a terrace covered with upland vegetation.

Figure D.8. Sometimes, as pictured here, the greenline is on the edge of the terrace.

Figure D.9. Nonvascular plants such as moss and lichens (pictured here) are not considered part of the greenline. This moss would be considered a "bare patch" and the frame would be moved back away from the channel.

Figure D.10. Rock A is > 15 cm (intermediate axis), embedded, and is above the scour line, therefore, it is not considered a bare patch. Active erosion exists on the streambank side of rock B. The greenline is located as shown by the dashed white line.

Figure D.11. Anchored wood includes dead woody material that is not likely to move during high flows, has no evidence of erosion behind it, and is above the scour line. Here, the greenline follows the top edge of the anchored log.

Figure D.12. This diverse greenline includes vegetation, embedded rock, and anchored wood. Segment A is embedded rock and segment B is anchored wood. Both rock and wood are above the scour line.

Figure D.13. The base of this live pine tree is the greenline at this sample point, as it is woody overstory (i.e., at least 0.5 m tall). Here, there is just enough herbaceous vegetation for a greenline to the left of the photo (> 25% foliar cover) but not to the right of where the line ends. Therefore, the frame had to be moved back to the base of the tree. The greenline is not visible to the right of the tree.

Figure D.14. The bases of both live woody plants (willow in background and alder in foreground near frame) are considered the greenline because they are at least 0.5 m tall (i.e., they are woody overstory). Understory does not need to be present (25% foliar cover is not required and bare patches are acceptable).

Figure D.15. When mature trees and shrubs are present and there is no understory beneath the canopy, if the quadrat is under the canopy of the overstory trees, the greenline is located by drawing a line connecting the base of the trees/shrubs on the stream side.

Figure D.16. In this photo, mature trees and shrubs are present and there is no understory beneath the canopy. If the quadrat is under the canopy of the overstory trees (as is the case here), the greenline is located by drawing a line connecting the base of the trees/shrubs on the stream side.

Figure D.17. Exposed live shrub or tree roots of overstory woody plants rooted in the ground above the scour line are part of the greenline (roots below the scour line are not part of the greenline). These are roots of overstory plants and the bare patch rule does not apply. Roots below the frame in this photo are not in contact with the streambank. The frame is placed where the roots are in direct contact with the bank.

Figure D.18. Exposed live shrub or tree roots at or above the scour line are part of the greenline.

Figure D.19. In this photo, high water has obscured the vegetation, streambank, and channel characteristics needed to obtain accurate measurements. Sampling should not be done when the greenlines are flooded.

Figure D.20. Here, the greenline follows the vegetation line at the water's edge. Note the bullrush (*Schoenoplectus* spp.) growing in shallow water. The greenline is behind the bullrush, where the margin of the stream intersects the streambank.

Figure D.21. Watercress (*Nasturtium officinale*) is a floating plant that grows on the surface of the water and therefore would not be part of the greenline. However, it should be noted in the remarks section of the data forms.

Figure D.22. Brookgrass (*Catabrosa aquatica*) is a short-lived perennial grass that grows both in the water and on the streambank. It is only considered part of the greenline if it exhibits foliar cover at or above the waterline. In this photo, the brookgrass is growing in the water; not enough (i.e. < 25% foliar cover) is rooted on and covering the bank above the water line to be considered the greenline.

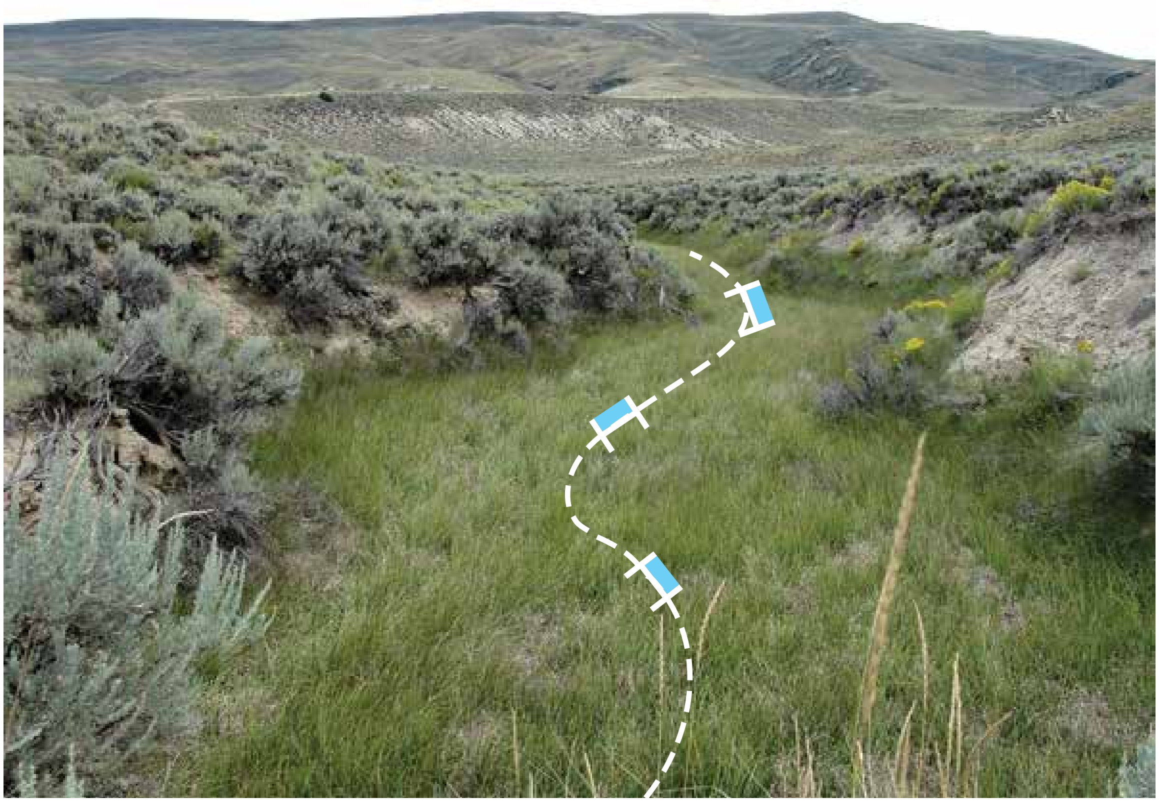

Figure D.23. This photo depicts a vegetated drainageway. The greenline follows the thalweg upstream and upslope to the top of the DMA. The center bar remains on the thalweg at the sample points, but the composition, woody height, and stubble height quadrats (blue rectangles) alternate from left to right of the center bar as shown (the other quadrat procedures are done using both sides of the frame).

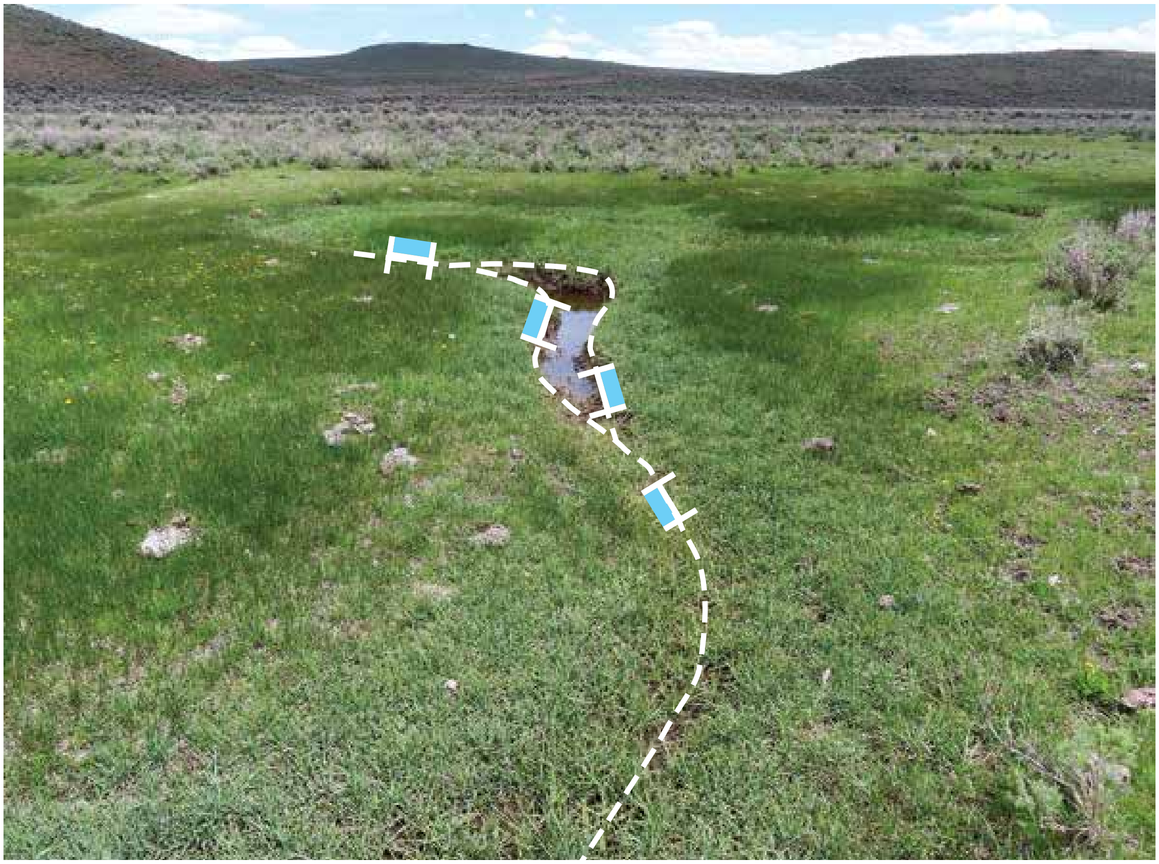

Figure D.24. A vegetated drainageway alternates with scoured channel sections. The greenline follows the thalweg until the scoured section is encountered, then it follows the channel margin per regular greenline rules. Beyond the scoured section, the greenline follows the thalweg again. In the scoured channel sections, the frame alternates between the left and right side of the channel at each sample point (as shown).

Figure D.25. A slump block with a narrow fracture. The greenline is behind the fracture.

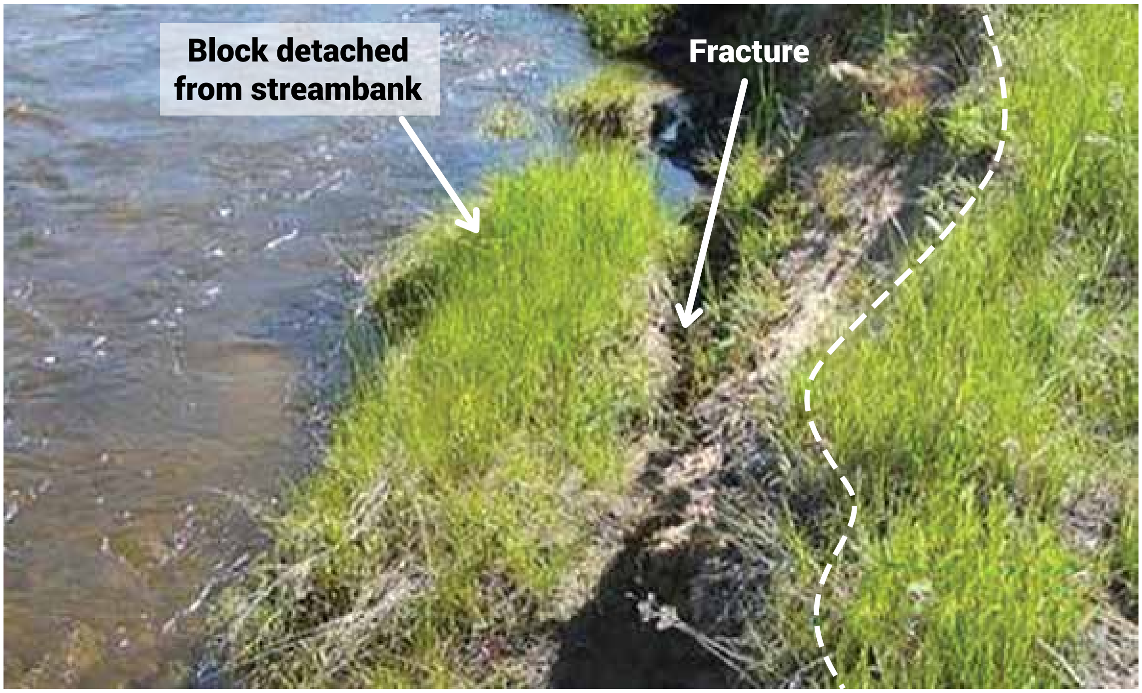

Figure D.26. The slump block is detached from the terrace wall. There is a fracture between the slump block and the terrace wall and there is a high potential for erosion behind the block. The greenline is located behind the fracture, along the terrace wall.

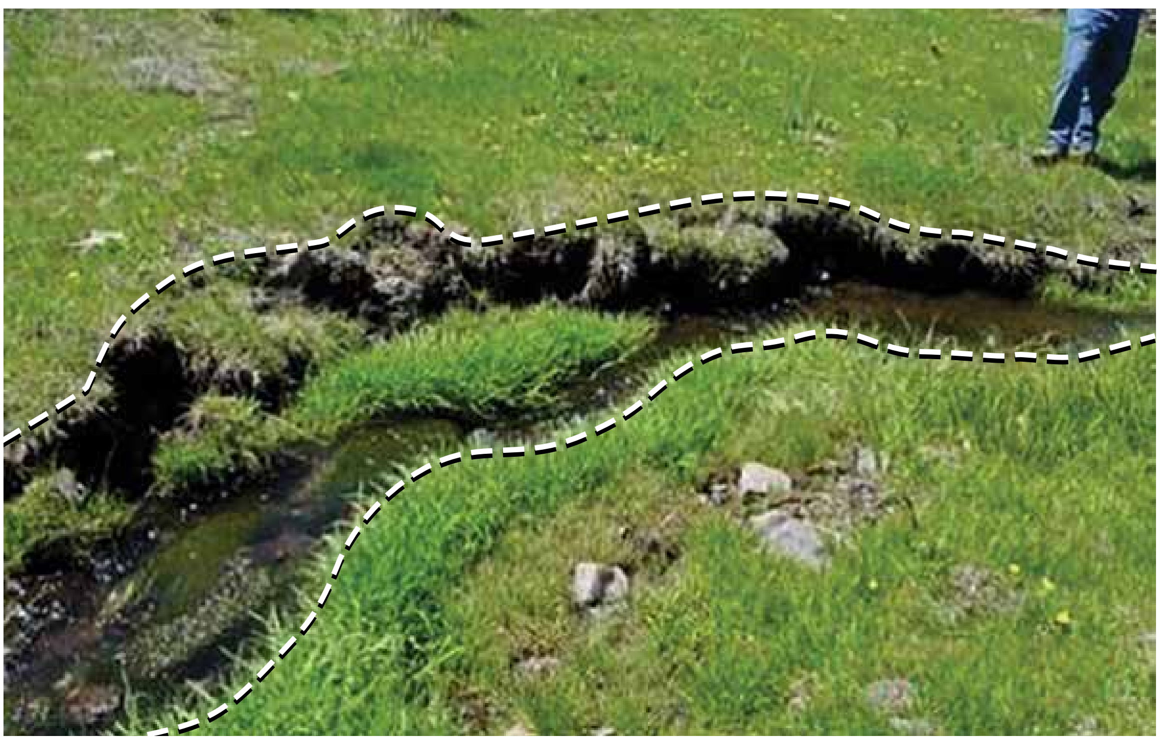

Figure D.27. Here, the greenline follows the continuous line of vegetation behind the slump blocks. Note that there are blocks that have fallen into the stream and blocks that are broken from the bank but have not fallen into the stream. Also note that vegetated slump blocks are considered islands when there is water or scour path between the block and the streambank.

Figure D.28. In this photo, vegetation is not well established between the slump block and the vertical bank, and there is scour between the block and the bank. Therefore, this block is considered an island.

Figure D.29. False banks are sections of bank (slump blocks) that have broken off from a high bank or terrace and have become reattached. They may also be places where slough material has accumulated at the base of terrace walls and has become vegetated. This false bank (see arrow) is vegetated back to the terrace wall, there is no fracture or erosion behind it, and it is a stable feature. The greenline follows the water's edge where the greenline rules are met.

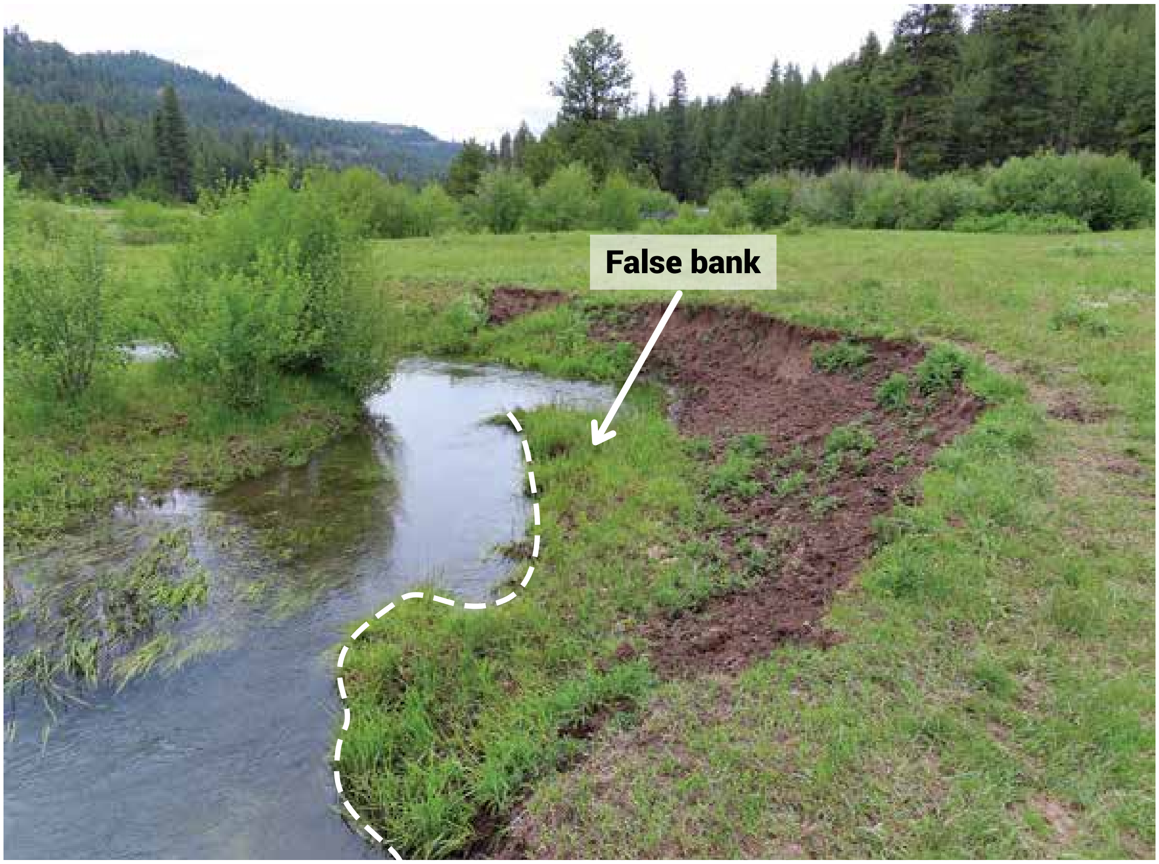

Figure D.30. Some false banks are subject to annual trailing/trampling impacts behind them; as a result, they may be sloped back to the edge of the terrace with considerable bare ground. If there are no fracture features or stream erosion behind them, they are stable and not considered slump blocks. The greenline is at the edge of the vegetation above the water's edge where the greenline rules have been met.

Figure D.31. Vegetation patches marked A are considered islands because they are above the scour line and the scoured channels marked B do not have perennial vegetation growing across them.

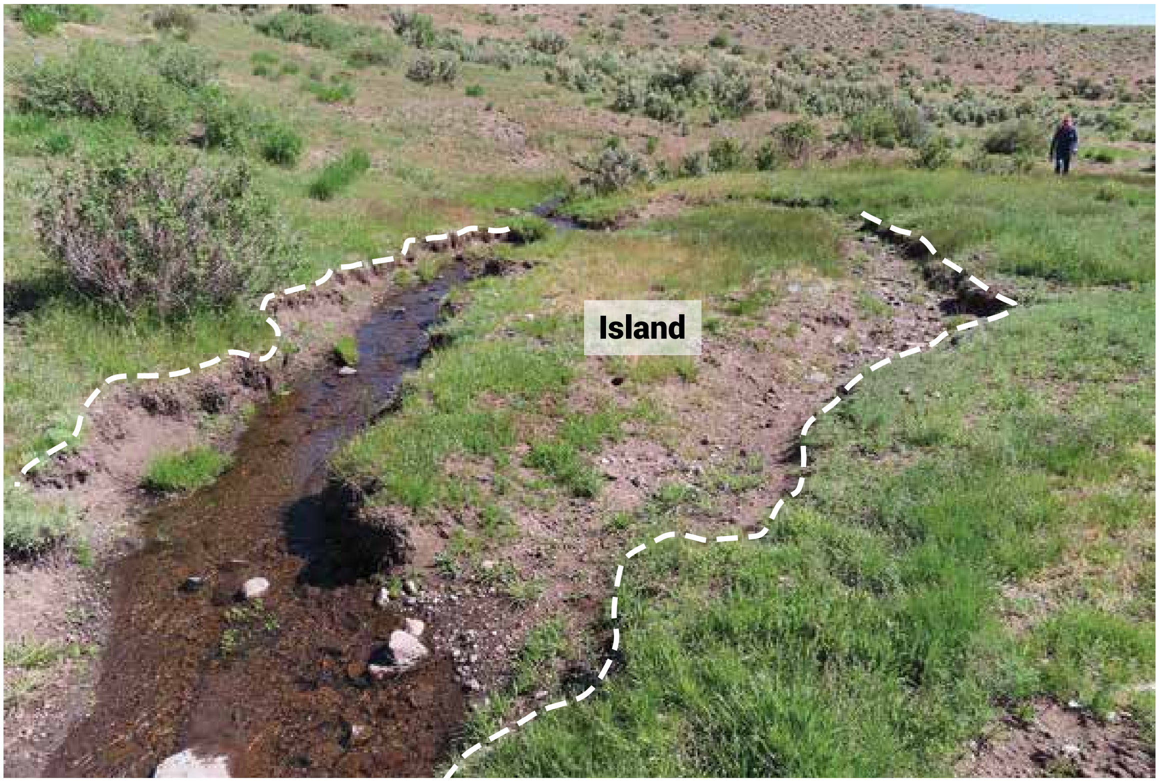

Figure D.32. An island surrounded by an active channel and a scoured side channel. The side channel is considered scoured because it does not have at least 25% foliar cover of live perennial vegetation across the entire width of the channel for at least 50 cm in length (one frame length). Also, its bed is below the scour line of the main channel (which is conveying water at this flow stage). Therefore, this is an island and the greenline follows the outside margin of the scoured side channel.

Figure D.33. A peninsula (not an island). This area is not completely surrounded by an active scoured channel. There is greater than 25% live foliar perennial cover for 50 cm in length across the channel at the top of the side channel (see arrow). Therefore, this is not an island but a peninsula. The greenline is as shown.

Figure D.34. When no greenline is present within 6 m from the scour line (or water's edge if the scour line is under water), there is no greenline. The frame is then placed at the edge of the first bench above the scour line (or water's edge) and only streambank alteration and streambank stability and cover are recorded.

Appendix E. Streambank Alteration Examples

The figures in Appendix E provide common examples of streambank alterations.

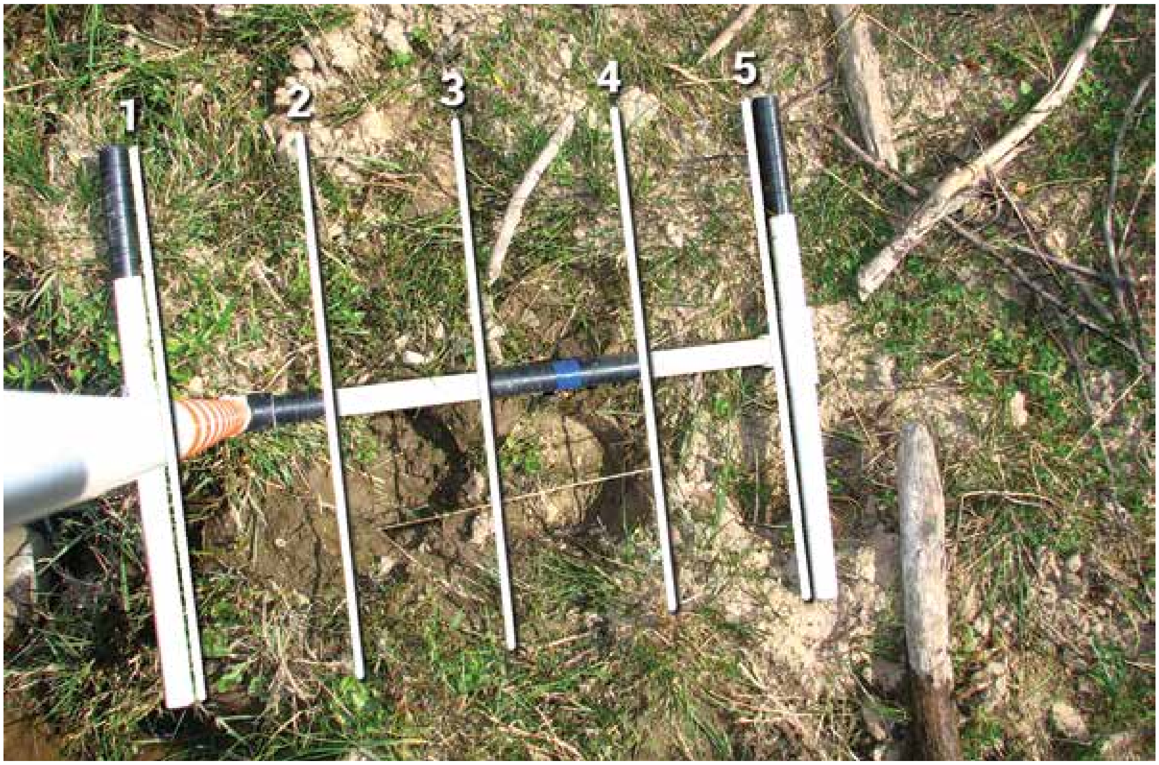

Figure E.1. A monitoring frame is centered on the greenline and the number of observation lines (0 to 5) that intersect streambank alterations (trampling, shearing, or compacted trails) are counted and recorded.

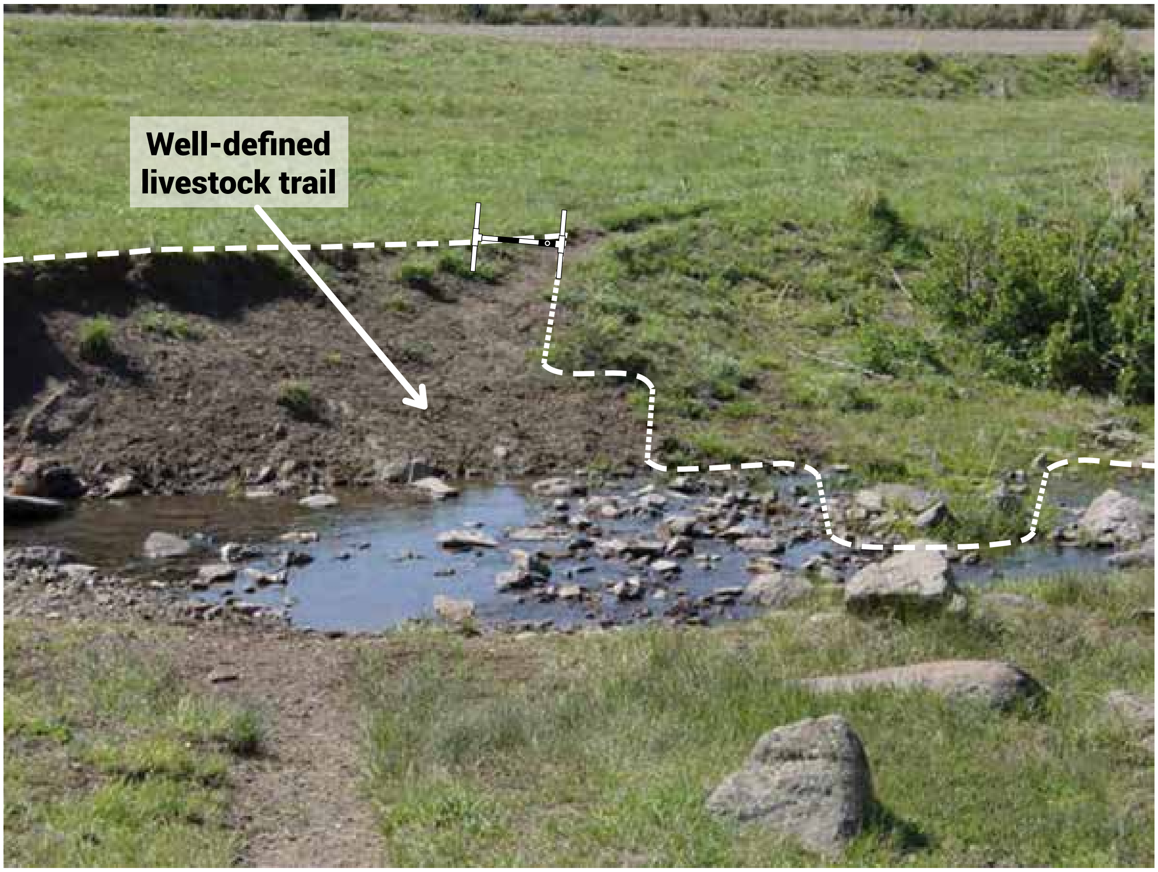

Figure E.2. A compacted and unvegetated cattle trail intersects the greenline and sampling location. All 5 observation lines intersect the cattle trail, and the number of alterations is 5.

Figure E.3. Hoof shear has created a vertical face that intersects lines 1, 2, 3, and 5. Line 4 has a pug, or deep vertical hoof print. All 5 lines intercept an alteration, so 5 alterations are recorded.

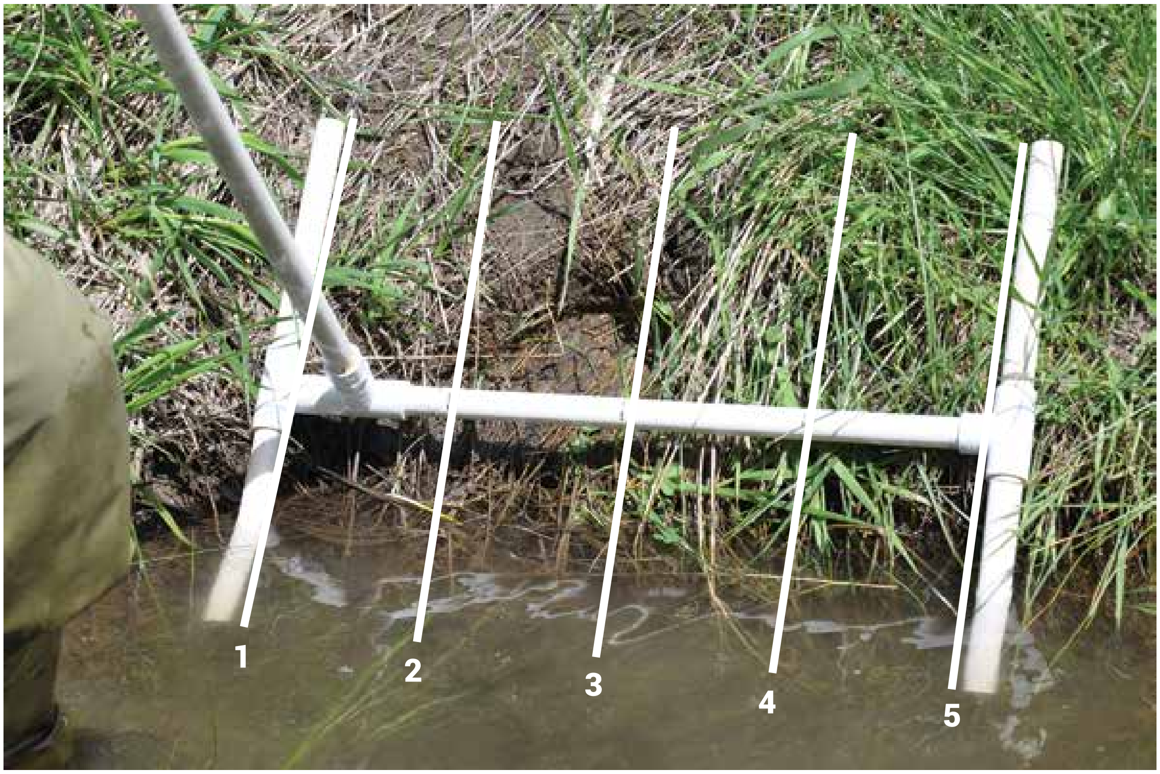

Figure E.4. Another indication of current year's disturbance is the trampling of live vegetation into the soil depression that intersects observation lines 2 and 3. Blades of green grass are obviously pushed and embedded on the soil surface providing an indication of current year's disturbance, so 2 alterations are recorded.

Figure E.5. This frame falls along a compacted and unvegetated trail. Although there are no depressions greater than 13 mm, the compacted trail intersects all 5 observation lines on the near half of the frame, so 5 alterations would be recorded.

Figure E.6. Hoof shear commonly forms a vertical face on the streambank with a hoof print at the base of the shear. This plot would be recorded as having 2 alterations for hoof shears on lines 3 and 4.

Figure E.7. Close up view of hoof shears on vertical face of bank. Notice the “tooled” look to the soil face.

Appendix F. Common Rhizomatous and Low-Growing (Dwarf) Riparian Shrub Species

Table F.1. Common rhizomatous riparian shrubs. This list includes the common riparian shrub species that are recorded for woody riparian species use and woody riparian species age class. In general, all subordinate taxa of the listed species should also be considered rhizomatous shrubs.

Scientific Name	Code	Common Name
Dasiphora fruticosa	DAFR6	shrubby cinquefoil
Gaultheria shallon	GASH	salal
Phyllodoce breweri	PHBR4	purple mountainheath
Prunus virginiana	PRVI	chokecherry
Ribes aureum	RIAU	golden currant
Rubus parviflorus	RUPA	thimbleberry
Salix eriocephala	SAER	Missouri River willow
Salix exigua	SAEX	coyote/sandbar willow
Salix polaris	SAPO	polar willow
Salix sessilifolia	SASE3	northwest sandbar willow
Salix taxifolia	SATA	yewleaf willow
Spiraea douglasii	SPDO	rose spirea
Spiraea tomentosa	SPTO2	steeplebush
Vaccinium vitis-idaea	VAVI	lingonberry

Table F.2. Common low-growing (dwarf) riparian shrubs. In general, all subordinate taxa of the listed species should also be considered dwarf shrubs.

Scientific Name	Code	Common Name
Andromeda polifolia	ANPO	bog rosemary
Arctostaphylos rubra	ARRU	red fruit bearberry
Empetrum nigrum	EMNI	black crowberry
Gaultheria hispidula	GAHI2	creeping snowberry
Gaultheria humifusa	GAHU	alpine spicywintergreen
Gaultheria miqueliana	GAMI2	Miquel's spicywintergreen
Gaultheria ovatifolia	GAOV2	western teaberry
Harrimanella stelleriana	HAST3	Alaska bellheather
Kalmia microphylla	KAMI	alpine laurel
Kalmia polifolia	KAPO	bog laurel
Ledum palustre	LEPA11	marsh Labrador tea
Linnaea borealis	LIBO3	twinflower
Loiseleuria procumbens	LOPR	alpine azalea
Rhododendron lapponicum	RHLA2	Lapland rosebay
Salix arctica	SAAR27	arctic willow
Salix arctophila	SAAR6	northern willow
Salix brachycarpa	SABR	shortfruit willow
Salix chamissonis	SACH	Chamisso's willow
Salix commutata	SACO2	undergreen willow
Salix eastwoodiae	SAEA	Eastwood willow
Salix fuscescens	SAFU	Alaska bog willow
Salix nivalis	SANI8	snow willow
Salix ovalifolia	SAOV	oval-leaf willow
Salix planifolia	SAPL2	diamondleaf willow
Salix reticulata	SARE2	netleaf willow
Salix rotundifolia	SARO2	least willow
Salix setchelliana	SASE4	Setchell's willow
Salix sphenophylla	SASP2	wedgeleaf willow
Salix wolfii	SAWO	Wolf's willow
Vaccinium cespitosum	VACE	dwarf bilberry
Vaccinium myrtilloides	VAMY	velvetleaf huckleberry
Vaccinium oxycoccos	VAOX	small cranberry
Vaccinium uliginosum	VAUL	bog blueberry

Appendix G. Plant Ratings

The plant list used in MIM was developed from multiple sources. This list is not comprehensive. Users should add plants or update plant information when additional plants are found in the project area, or as new data become available.

Wetland Status

The “The National Wetland Plant List: 2016 Wetland Ratings” (Lichvar et al. 2016) is used to establish the wetland ratings of each plant species.

Modified Winward Greenline Stability Rating

The concept of greenline stability ratings is based on how well each plant species resists the erosive force of water at the fluvial interface and therefore can stabilize streambanks. Plants with shallow, weak, and/or limited root masses, or taproots tend to have a diminished ability to protect streambanks and thus have a low greenline stability rating. Plants with deep, strong, and/or massive root systems (e.g., many rhizomatous plants) protect streambanks and have a higher greenline stability rating. The literature is generally lacking in comprehensive riparian and wetland plant species characteristics, such as the extent of root systems and belowground biomass (Boyd and Svejcar 2009). Winward (2000) and Lorenzana et al. (2017) are the two primary sources for the greenline stability ratings used in MIM. Various authors, including the authors of this document, provided professional opinions for species where information is lacking (see Table G.1).

Ecological Status Rating

The ecological status rating for individual plant species was determined from many riparian vegetation classifications from the Western United States. These references are listed in Section 10, References Used to Develop Plant Lists. Ecological status is sometimes referred to as successional status, successional stage, or seral stage and refers to the relative position of individual plant species or a plant community in relation to climax. This is related to the tendency of a plant to occur either earlier or later in a successional progression and is based on its relative shade tolerance and persistence. Since riparian areas associated with streams are dynamic, plants of all seral stages may be present in a late seral riparian community. Winward 2000 and the U.S. Forest Service’s Fire Effects Information System (USFS 2010) provided much of the information used to determine the successional status of plants.

The ecological status ratings for individual plant species must be differentiated from the ecological status rating metric displayed for a site. The ecological status rating for a site is a summary metric that is calculated using individual ecological or successional status ratings and a weighted average of all plants recorded on the DMA according to their percent composition.

Many woody riparian species (most species of willow, cottonwood, alder, dogwood, and birch) require bare ground or freshly deposited sediment for seeds to germinate and establish (USFS 2010). These plants also tend to live a long time (50 years or more). Even though they are early seral for establishment, they are long lived. Therefore, they are considered late seral for the MIM protocol.

Table G.1. The modified Winward (2000) Greenline Stability Rating.

Reference	Criteria	Modified Winward Greenline Stability Rating for Individual Plant Species
Winward 2000	**Winward Greenline Stability Rating**	
	1 to 3	Low (2)
	4 to 6	Medium (5)
	7 to 10	High (8.5)
Crowe and Clausnitzer 1997	**Streambank Erosion**	
	Poor = Low	Low (2)
	Fair = Moderate	Medium (5)
	Good = High	High (8.5)
	Excellent = High	High (8.5)
Authors' Criteria	**Modified Winward Greenline Stability Rating** - A relative value based on general rooting characteristics assigned by the authors or other referenced publications.	
	Forbs	
	Taproot and/or most roots, shallow (< 15 cm)	Low (2)
	Fibrous roots, usually up to 30 cm	Medium (5)
	Rhizomatous roots, little indication of extensive fibrous roots	Medium (5)
	Rhizomatous roots, with extensive fibrous roots	High (8.5)
	Graminoids	
	Annual, biennial, and short-lived perennials	Low (2)
	Stoloniferous, caespitose, tufted, or short slender rhizomatous perennials (< 1 m tall)	Low (2)
	Slender or thin creeping rhizomes	Medium (5)
	Long, stout, well-developed creeping rhizomes	High (8.5)
	Woody Species	
	Taprooted species	Low (2)
	Short shrubs (< 1 m tall) with shallow root systems	Low (2)
	Shallow to moderate root systems	Medium (5)
	Rhizomatous root system, generally shallow (< 31 cm)	Medium (5)
	Root crown with spreading roots	High (8.5)
	Widespread root systems	High (8.5)

The ecological status rating classes for individual plant species are:

Early Seral (E) – All annual and short-lived (living < 5 years) perennial plants tend to be replaced by plants that live longer. All weeds and shallow-rooted perennial species that tend to be tolerant of grazing and other uses are classified as early seral.

Mid-Seral (M) – Perennial plants, mostly forbs that are not shade tolerant and tend to have fibrous root systems. These plants are usually replaced in a riparian community by long-lived plants.

Late Seral (L) – Plants that usually exist in the most stable riparian plant communities. They tend to stabilize streambanks and develop extensive root systems.

Assigning Values to Plants not in the MIM Data Forms

Individual plant species ratings for 1) Wetland Indicator Category, 2) Ecological Status, and 3) Modified Winward Greenline Stability Rating are provided for in the MIM data platform. However, not all plants that may be encountered at a MIM DMA in the Western United States are included. Therefore, there is a frequent need to assign plant ratings to plants at a DMA. The following are common resources where this information can be found.

Wetland Indicator Categories: “The National Wetland Plant List: 2016 Wetland Ratings” (Lichvar et al. 2016). The USDA NRCS PLANTS Database (2022) also provides wetland indicator categories for many plants.

Ecological Status and Modified Winward Greenline Stability Ratings:

- Winward (2000) provides ecological status and greenline stability ratings for many riparian systems in the Intermountain West (this publication provides ratings only for community types however, not individual plant species ratings).
- The U.S. Forest Service Fire Effects Information System (USFS 2010) provides detailed information regarding the autecology (individual plant ecology) of many plants, which includes botanical characteristics and successional pathways.
- Lorenzana et al. (2017) includes ecological status ratings and greenline ratings for many riparian-wetland plants in the Pacific Southwest region of the U.S. Forest Service lands. Although this publication was written for that region, the ecological status and greenline ratings are generally transferable to other regions. Note that this publication presents ecological status in three, non-mutually exclusive functional types (competitor, intermediate, and ruderal). The crosswalk to seral stages is generally: Competitor = late seral; intermediate = mid-seral, and ruderal = early seral.
- Table G.1 provides the authors’ criteria for assigning modified Winward Greenline Stability Ratings for plants.
- Many riparian-wetland vegetation classifications provide information on successional pathways that can be used to assign ecological status. Note that Crowe and Clausnitzer (1997) were used in Table G.1.

As noted, users should update ratings as new information becomes available.

Appendix H. Streambank Stability and Cover Examples

The following series of photographs provides annotated views of streambank stability and cover features.

Figure H.1. A. The scour line is delineated by the lower limit of sod-forming vegetation and the ceiling of undercut banks. B. The scour line coincides with the trim or erosion line on bare banks. This erosion line marks the water stage during baseflow conditions and coincides with the ceiling of undercut banks elsewhere in the DMA.

Figure H.2. A cutbank to the left is erosional (E), uncovered (U), with a vertical eroding bank (E). The opposite bank is depositional (D) and covered (C). The top of the first bench is indicated by the black dashed line. The top of the first bench marks the top of the streambank stability and cover quadrat.

Figure H.3. During stream recovery, stabilizing riparian vegetation may establish on the streambank, where it can trap sediment and form an inset floodplain. The lip of the first bench (black dashed line) is the top of the new floodplain. A new floodplain has developed creating the first bench above the scour line. The bank from scour line to floodplain is erosional (E), covered (C), and absent (A).

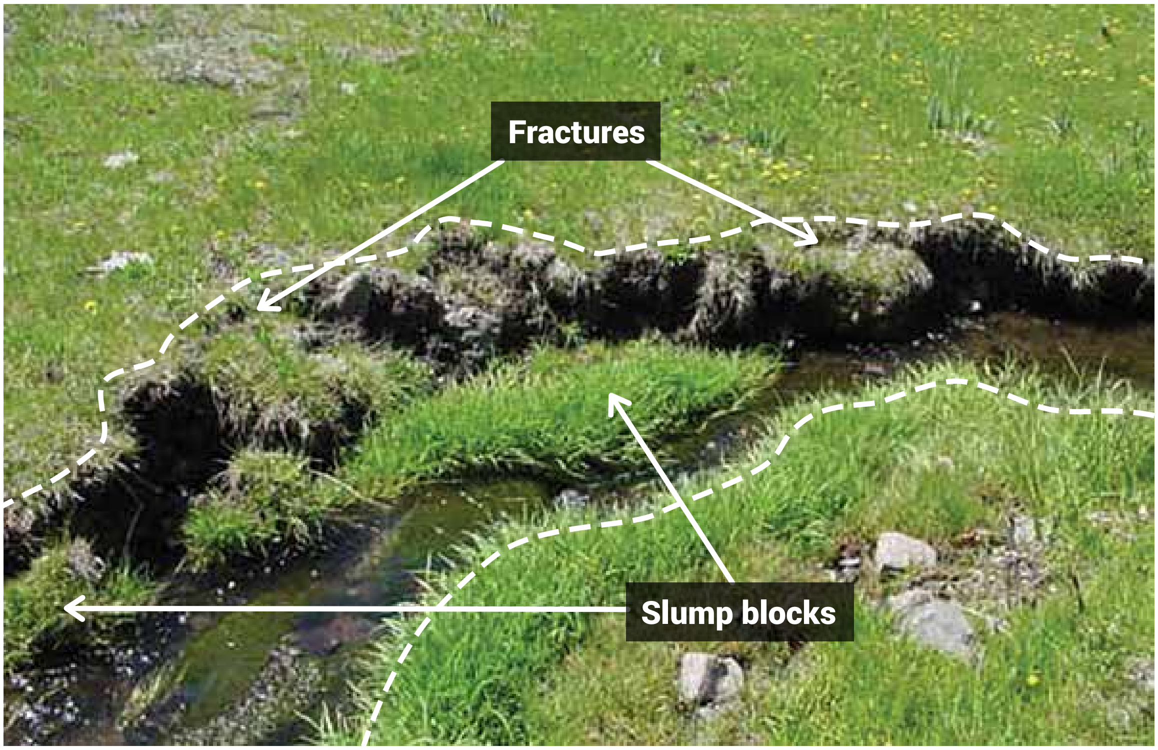

Figure H.4. Erosional features help determine the stability of a streambank. Slump blocks that are detached from the streambank and isolated in the channel are not considered part of the streambank. Fractures must be obvious at the top of the streambank or on the bench.

Figure H.5. In this photo, the right bank is erosional (E), covered (C), and fractured (F). Left bank is depositional (D) and covered (C).

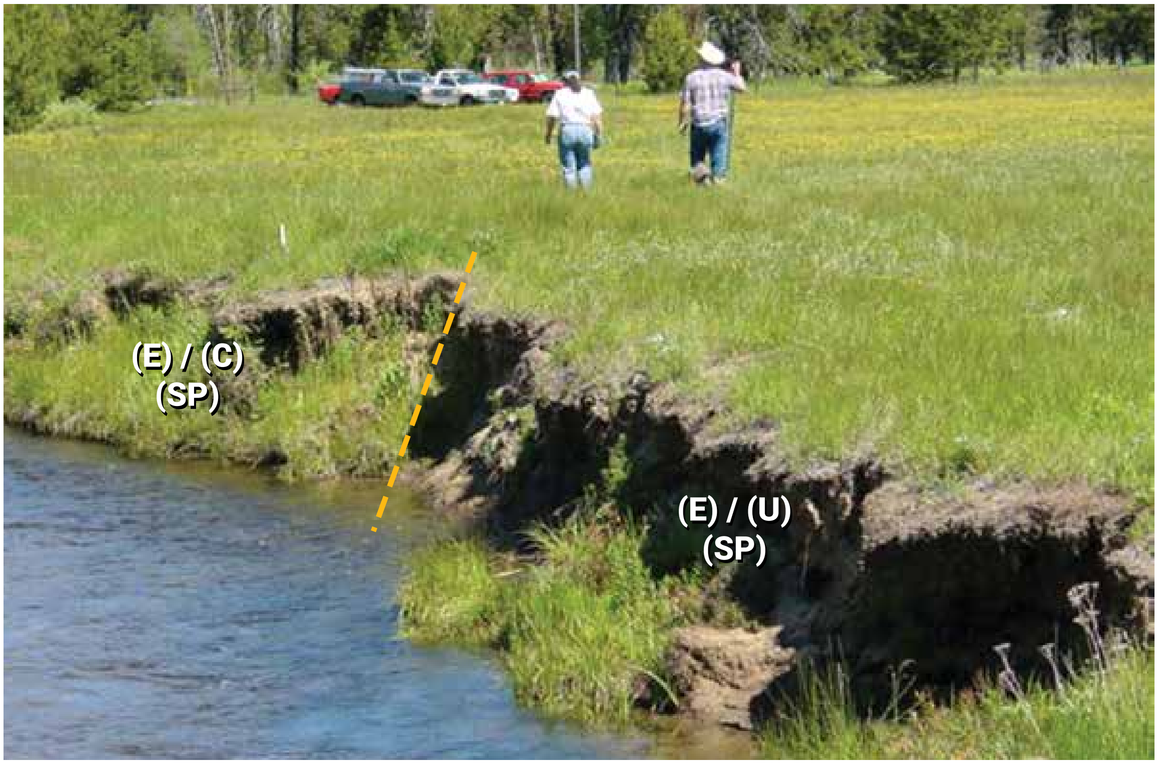

Figure H.6. The stream in this photo is flowing at the scour line. The streambank on the right side of the orange dotted line is recorded as erosional (E), uncovered (U), and slump (SP). The streambank on the left side of the dotted line is erosional (E), covered (C), and slump (SP).

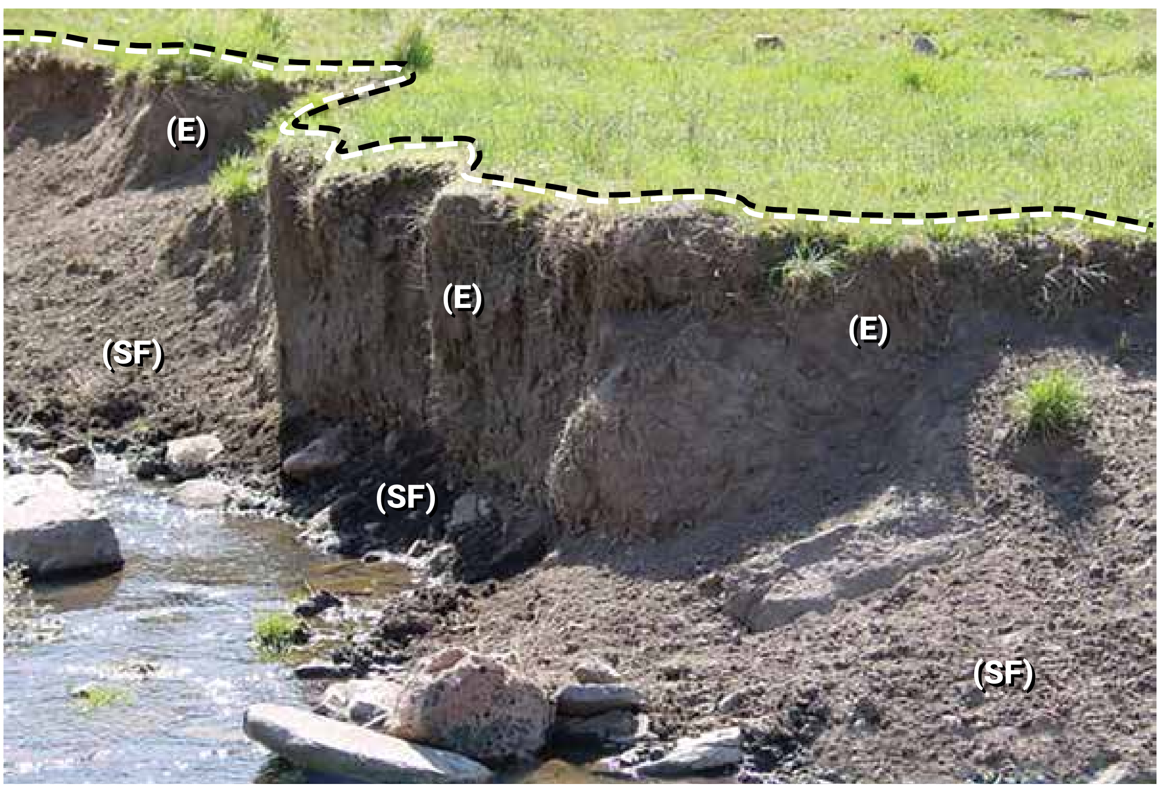

Figure H.7. This is an uncovered, erosional bank with both erosional (E) and slough (SF) features. The nearly vertical bank faces contain eroding (E) features, whereas as the disaggregated bits of soil accumulating at the base of the vertical banks constitutes the slough (SF). It is not uncommon to have more than one instability feature in the streambank stability quadrat. In this case, the instability feature could be listed as either eroding (E) or slough (SF).

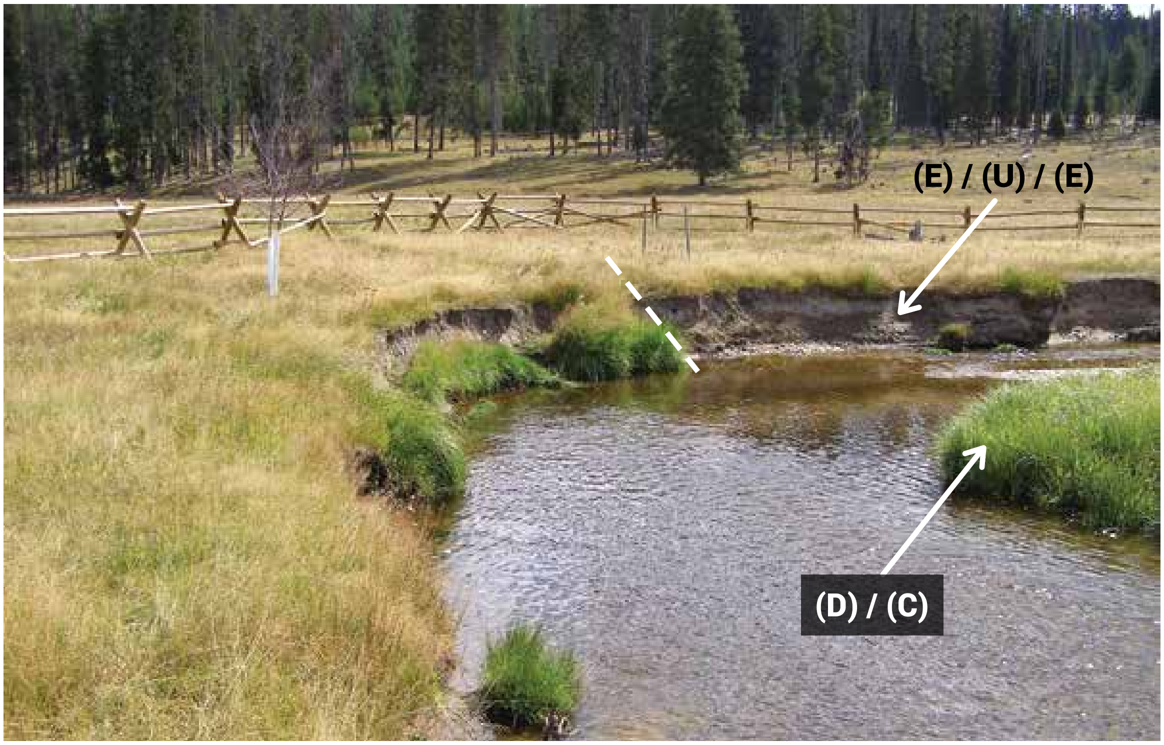

Figure H.8. The streambank on the left side of the stream, to the right of the dashed line, is an erosional bank (E) that is uncovered (U) and eroding (E). The right streambank is depositional (D) and covered (C).

Figure H.9. The left bank in this photo is erosional (E) and uncovered (C) with no vegetation, rock, or wood. The lower two-thirds of the bank has accumulated loose aggregates of soil, or slough (SF), which likely will be removed from the bank during high streamflow.

Figure H.10. In this image, there is a small hoofprint (outlined with a white dashed line) that has flattened vegetation into the bank, but no slump or slough is associated with it; therefore, there is no indicator of instability and erosional (E), covered (C), and absent (A) are recorded.

Figure H.11. The water surface is at the scour line in this photo. The bank in the background is erosional (E), covered (C), and absent (A). The bank in the foreground is erosional (E) and uncovered (U). The upper part of the bank is nearly vertical and eroding (E), while the lower part of the bank has an accumulation of slough (SF). It is not uncommon to have more than one instability feature in the streambank stability quadrat. In this case, the instability feature could be listed as either eroding (E) or slough (SF).

Figure H.12. The stability and cover plot extends vertically up the bank from the scour line (blue dashed line) to the edge of the first bench (dark dashed line). The frame rests on erosional, covered (E/C) bank (white dashed line, greenline). Immediately right and left of the frame, the bank is erosional (E) and uncovered (U). The vertical, uncovered streambanks would be evaluated as eroding (E) and covered bank as absent (A).

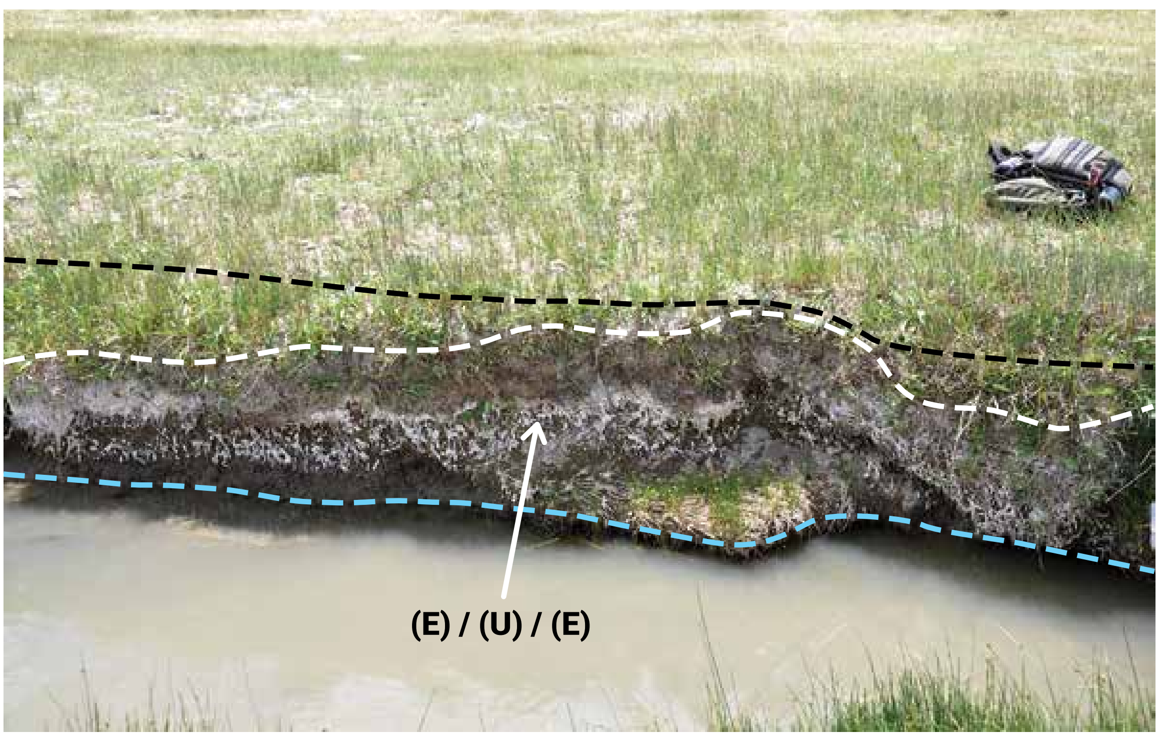

Figure H.13. The scour line (blue dashed line) is delineated by the ceiling of undercut banks and is about 2 cm above the water surface. The bank is vertical and mostly uncovered across the entire view. This bank would be evaluated as erosional (E) and uncovered (U) and eroding (E). The greenline (white dashed line) coincides with the lower limit of perennial, sod-forming vegetation and the top of the bank is marked by a black dashed line.

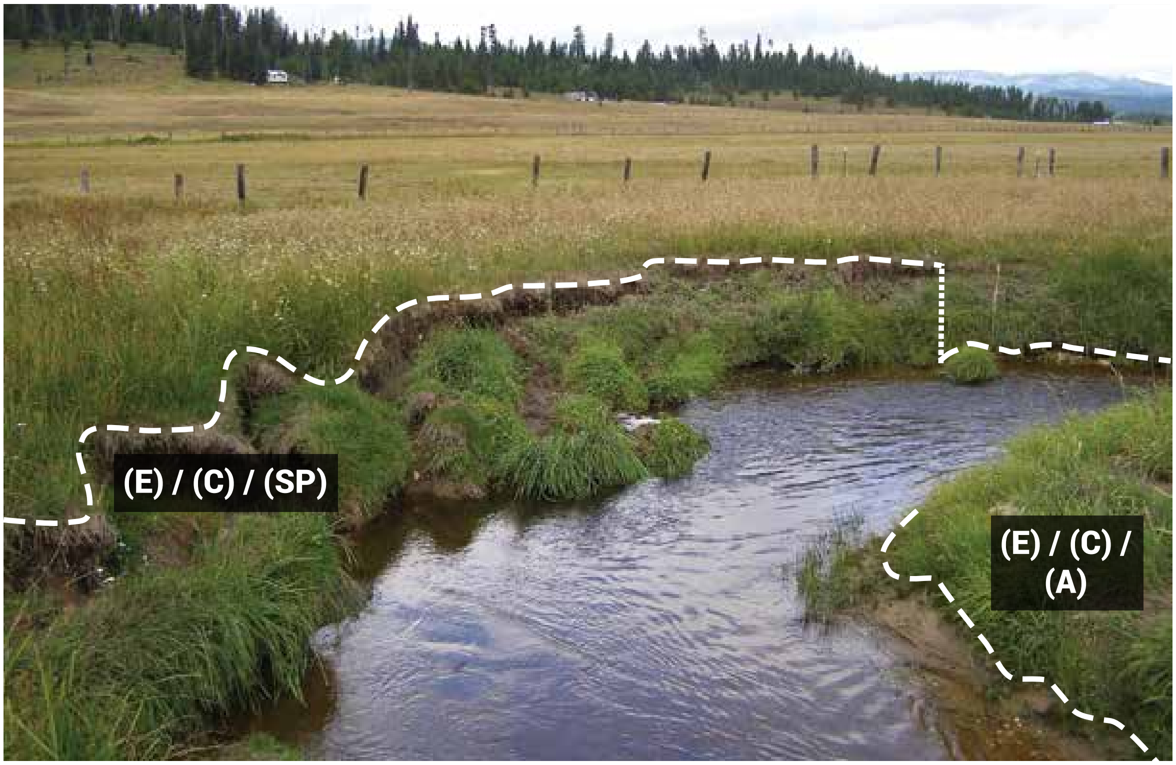

Figure H.14. The left bank has collapsed along nearly the entire view. This is an erosional bank, but the slump blocks are generally in place and vegetated. This bank would be evaluated as erosional (E) and covered (C) and the erosional features along most of the bank would be slump (SP) except for a small segment without slump blocks on the far right-hand side of the view, which would be evaluated as absent (A).

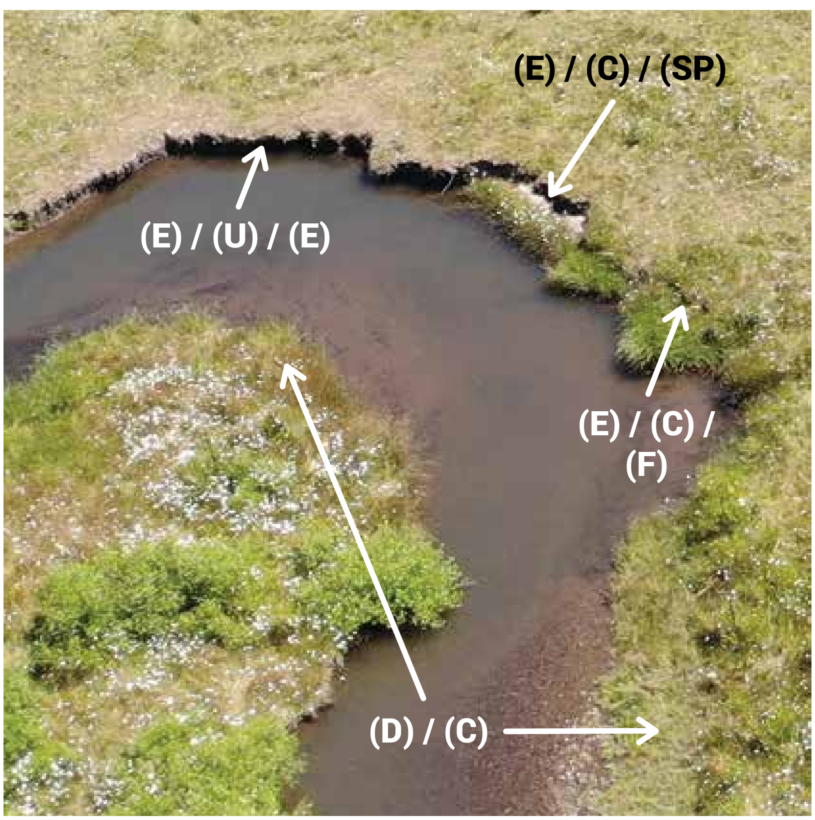

Figure H.15. A low-elevation aerial view illustrates multiple types of banks and erosional features in close proximity to one another. Depositional banks are common on point bars. Notice the gradual slope from top of point bar into shallow water. Erosional banks are most common everywhere else along the channel.

Appendix I. Greenline-to-Greenline Width (GGW) Examples

The following figures provide numerous examples demonstrating how to determine GGW in a variety of field situations.

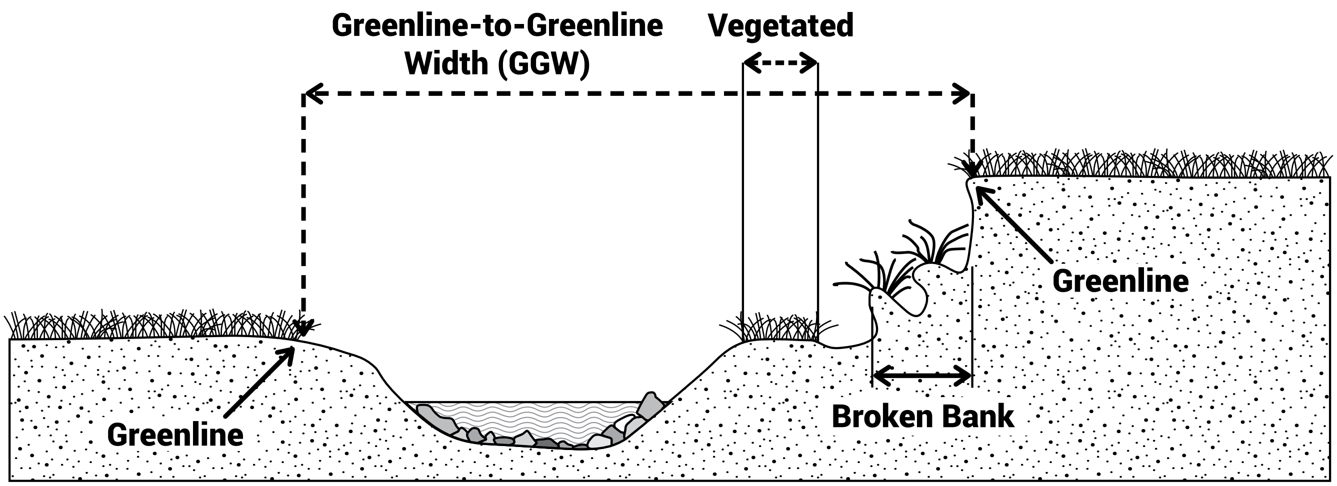

Figure I.1. The GGW is the horizontal distance between the greenlines on each side of the stream, measured perpendicularly to the flow of the stream. It is the unvegetated/uncovered stream channel. When vegetation (at least 25% foliar cover on slump blocks or islands) or covered portions (embedded rock or anchored wood) are encountered along the GGW, the vegetated or covered (embedded rock or anchored wood) portion is excluded from the total GGW. Only the unvegetated/uncovered portion of the width is recorded.

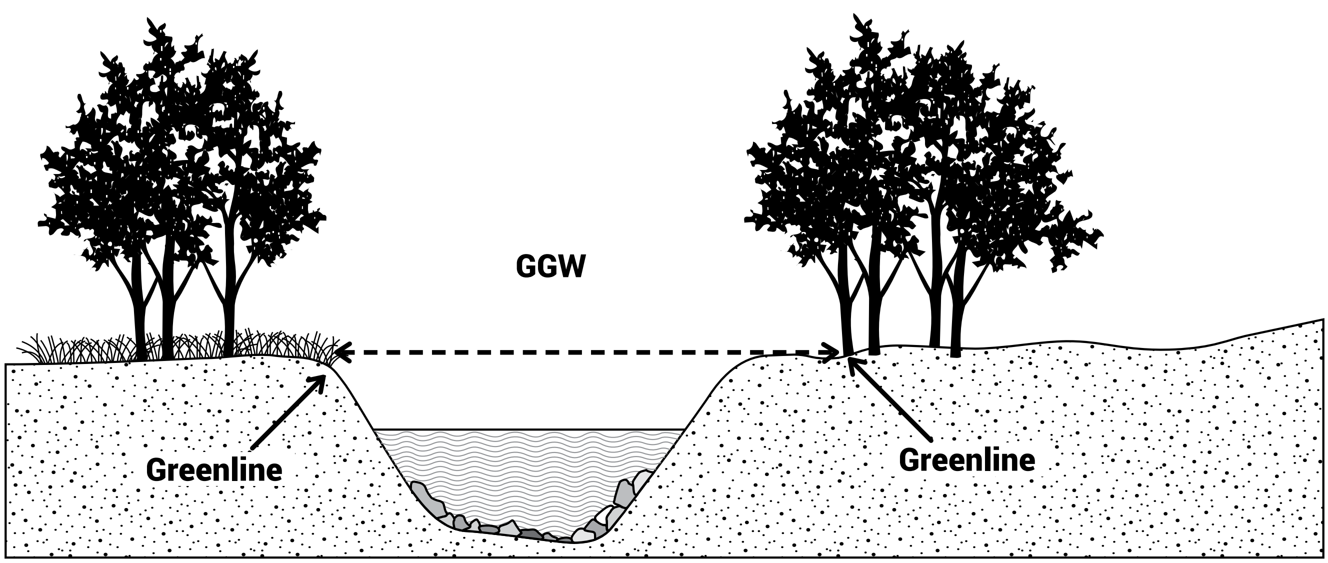

Figure I.2. GGW is measured perpendicularly to streamflow and from the rooted base on the vegetated greenline (left bank) to the rooted base of the woody plants on the greenline on the opposite side of the unvegetated stream channel (right bank).

Figure I.3. In this image, the GGW is measured from the corner of the frame that is at the “start” or downstream end of the quadrat. This convention is especially important when the frame has been rotated so that it is not oriented parallel to streamflow.

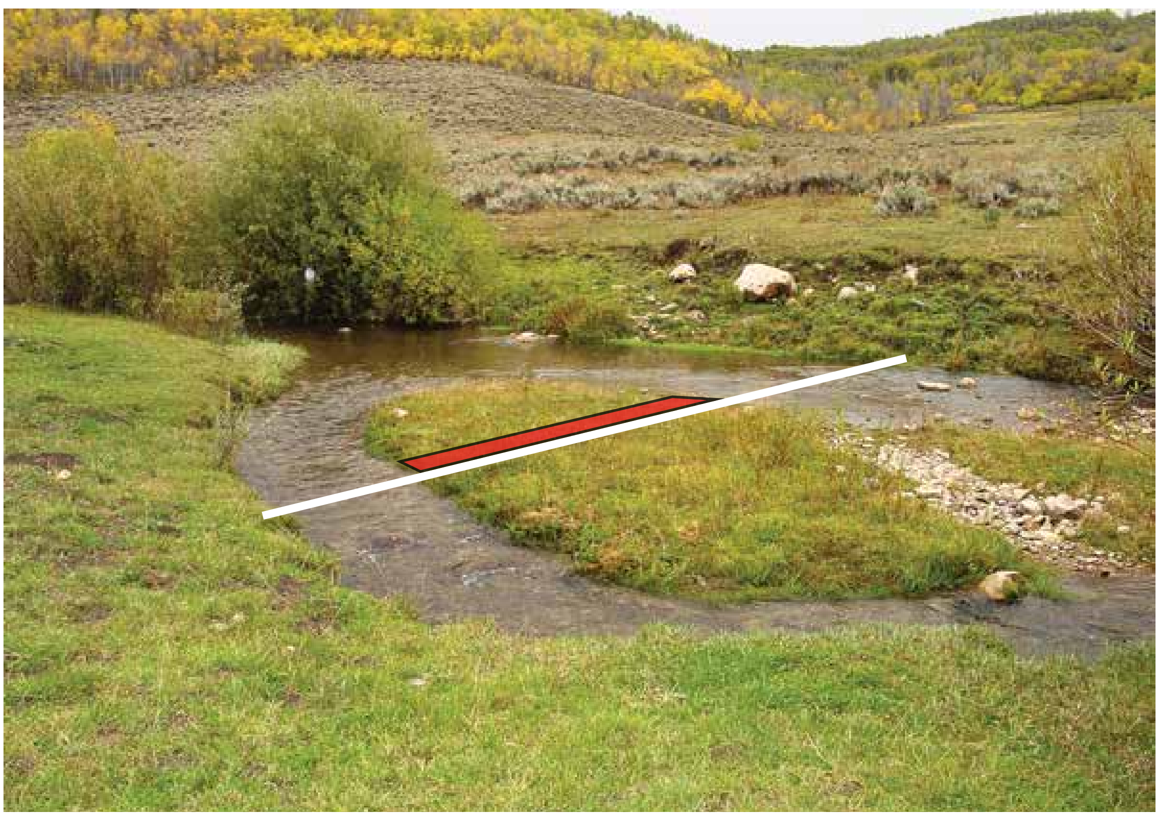

Figure I.4. When measuring GGW, exclude any qualifying cover (vegetation, embedded rock, or anchored wood) that is above the scour line and occurs in a 50-cm-wide band adjacent to (and upstream of) the GGW transect (depicted here as red shaded box). Because GGW is measured in an upstream direction, the qualifying cover (red shaded box) must also be on the upstream side of the GGW transect (white line).

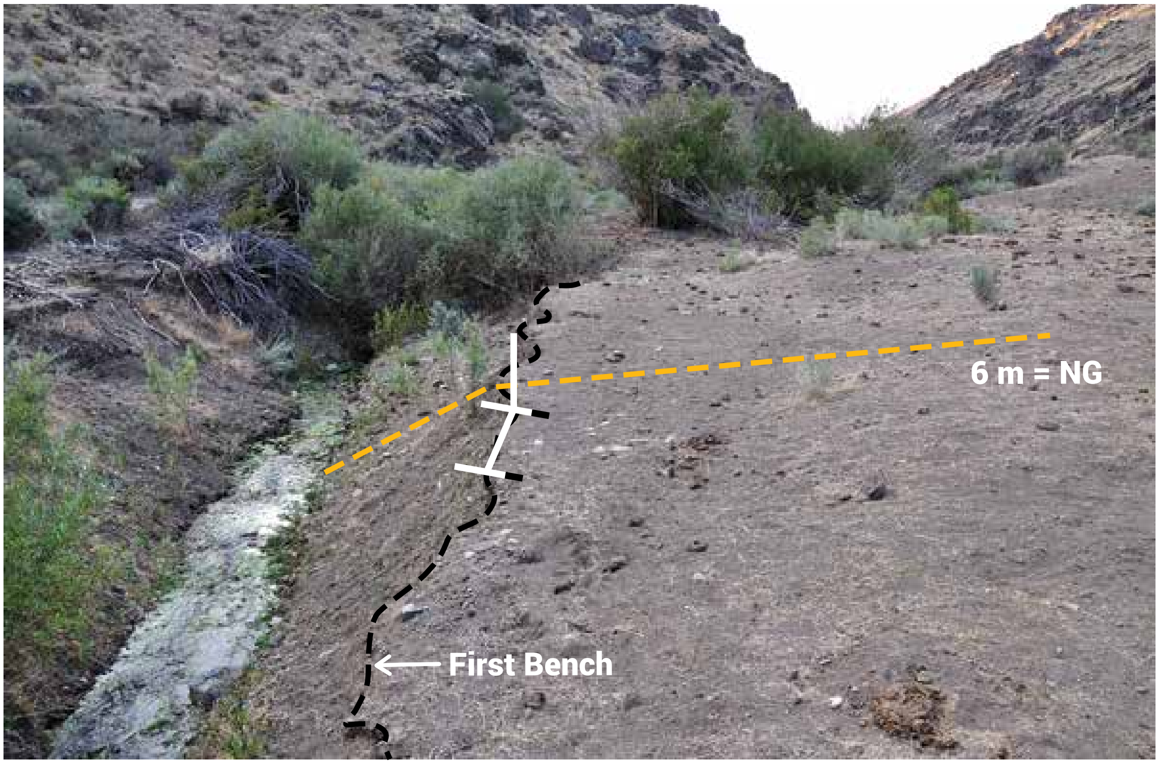

Figure I.5. An extensive patch of bare ground creates a situation where no greenline (NG) exists within 6 m of the scour line or edge of the active channel. When no greenline exists at the sampling point, leave GGW blank and place the monitoring frame at the lip of the first bench (black dashed line) to measure or observe other indicators (i.e., streambank alterations and streambank stability and cover).

Figure I.6. When a greenline is not encountered within 6 m slope distance (orange dashed line) of the scour line (or edge of the active channel), the GGW is not measured—leave this indicator blank for this sampling point. The monitoring frame (red quadrat) is placed on the first bench (black dashed line) to measure other indicators (i.e., streambank alteration and streambank stability and cover).

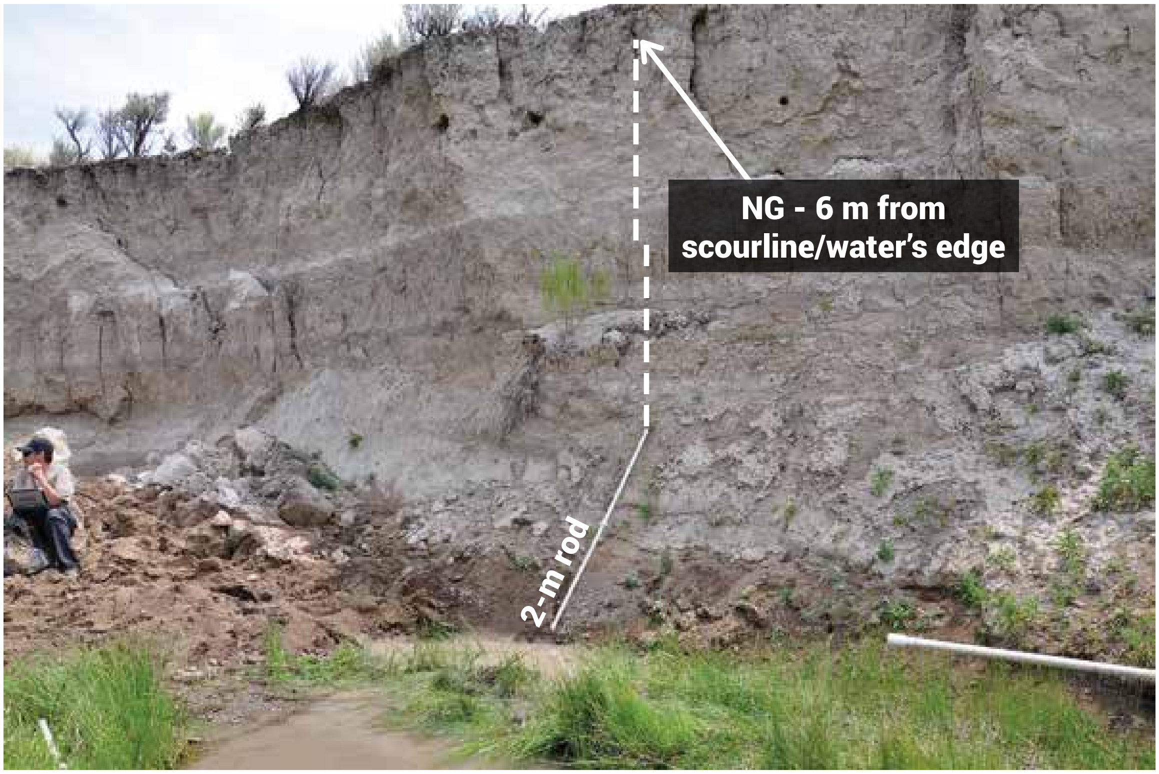

Figure I.7. Although GGW is the horizontal distance between greenlines on each side of the stream, the distance measured to determine if no greenline (NG) occurs is based on ground, or slope, distance from the scour line or edge of the channel. Here, a 2-m rod is positioned with one end on the scour line and is aligned vertically up the face of a tall cut bank. The same 2-m increment is projected (white dashed line) to the 6 m distance from the scour line. It is impractical to locate the frame at the 6 m mark (vertical face). Because the 6-m mark falls on an inaccessible vertical face, the other indicators are estimated.

Figure I.8. In a continuous vegetated drainageway, in which vegetation spans the entire channel and there is no unvegetated span, GGW is not recorded. An orange dashed line traces the thalweg, which serves as the greenline of the vegetated drainageway. A monitoring frame is placed along the thalweg to read indicators.

Figure I.9. Along a vegetated drainageway with discontinuous "necklace" pools, scour channels, or inundated flow paths, measure GGW at all sample locations. The greenline (dashed white line) follows the thalweg through the vegetated drainageways, and GGW is recorded as "0" in these sample locations. Through the pools, the greenline follows the water's edge; GGW (white double arrows) is measured across the pool, perpendicular to streamflow or to the longitudinal axis of the pools if streamflow is not evident.

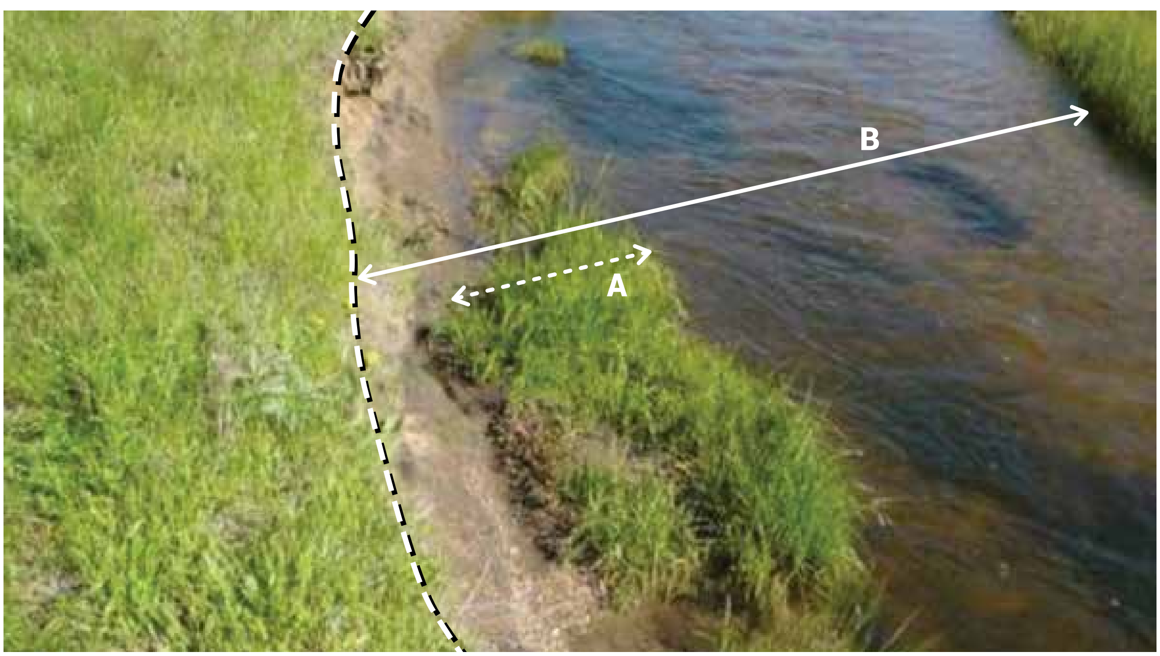

Figure I.10. The greenline (white dashed line) is located on the top of the left bank. A vegetated slump block (A) rests at the foot of the streambank. GGW is the total horizontal length of B, less the horizontal length of the vegetated slump block (A).

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