II. Stream Condition Inventory Attributes and Protocols

A. Stream Condition Inventory Attributes

The 18 stream condition attributes in this technical guide are shown in Table 1. Nine attributes are measured throughout the entire reach selected for SCI measurements, known as the sensitive reach, and nine are measured in the survey segment (the same length as the sensitive reach on reaches shorter than 1,000 m, or a randomly selected portion of sensitive reaches that are longer than 1,000 m). Section IIIA provides a definition and description of SCI stream reaches, and the rationale for attribute measurement locations.

SCI attribute measurement is described in this technical guide as a four-pass sequence along a stream reach although attributes can be measured in any sequence. See Section IIIB for a full description of the SCI pass procedure.

Table 1 - SCI Attributes

Location of Measurement	Attributes	Core/Optional	Pass Number
Sensitive Reach	Macroinvertebrates	Core	1
	Particle Size Distribution	Core	1
	Stream Temperature[1]	Core	1
	Large Woody Debris (LWD)	Core	1
	Bankfull Stage	Core	2
	Cross-section	Core	2
	Water Surface Gradient	Core	2
	Width-to-depth Ratio	Core	2
	Entrenchment	Core	2
Survey Segment	Habitat Type	Core	3
	Pools	Core	3
	Pool Tail Surface Fine Sediment	Core	3
	Streambank Stability	Core	4
	Stream Shading	Core	4
	Streamshore Water Depth[2]	Core	4
	Streambank Angle[2]	Core	4
	Aquatic Fauna	Core	4
	V^*_W[3]	Optional	N/A[2]

[1] Thermographs must be in streams prior to July 1st

[2] Measured only in low gradient stream reaches (<2%) with fine textured streambanks.

[3] V^*_w is a very intensive inventory and should be done after passes 1-4 are completed.

Of the 18 SCI attributes, 17 are core attributes and one is an optional attribute. Measurement priorities are described below:

Core Attributes – These should be measured on every SCI stream reach. Data for each attribute can be collected in a relatively short period and the data gathered strengthens each individual stream comparison, as well as interpretations at larger scales. Measurement of gradient is essential to facilitate comparison with other stream reaches in the regional database.

Optional Attribute – This should be included when it meets specific monitoring objectives.

V^*_w – This attribute has been shown to be a reliable measure of sediment deposition in pools in some geologic and channel types. It is an optional SCI attribute primarily because its application is limited to certain channel types and geology. V* requires a greater intensity of data collection than other SCI attributes. If monitoring questions focus on tracking fine sediment in appropriate geology and channel types then V^*_W should be considered.

B. Stream Condition Inventory Protocols

The protocols for the18 SCI attributes are described in the order in which they are recommended for surveying in the SCI pass sequence.

Macroinvertebrates

(Core Attribute)

Importance:

Macroinvertebrates have been demonstrated to be very useful as indicators of water quality and habitat condition (Rosenberg and Resh 1993). They are sensitive to changes in water chemistry, temperature, and their physical habitat. Most benthic macroinvertebrates have aquatic life stages lasting several months to several years, they are relatively abundant, and are easy to collect. These attributes contribute to the usefulness of macroinvertebrates as indicators of aquatic condition.

In recent years, the Pacific Southwest Region has developed the protocol described below to provide a consistent approach for collection of benthic macroinvertebrates. During this period a model was developed for use in the region utilizing data collected from numerous reference streams across the region (Hawkins, 2003). The model provides a consistent way to interpret macroinvertebrate data at the site, watershed, and regional scales. This model is one of several methods to analyze and interpret information from macroinvertebrate samples.

Objectives of This Measurement:

Gain a biological assessment of water quality and habitat condition. Bioassessment using macroinvertebrates provides a measure of biological integrity, as mandated by the Clean Water Act.

A secondary objective is to collect data to characterize the stream in terms of factors important to macroinvertebrates. This data improves the interpretative value of the macroinvertebrate data and facilitates comparison of data from reference streams with similar characteristics.

A key element in this characterization is water chemistry, as indicated by alkalinity and conductivity. Alkalinity primarily results from the presence of bicarbonates, carbonates, and hydroxides, which together shift the pH to the alkaline side of neutrality (i.e. pH> 7.0). Specific conductance is a measure of the resistance of a solution to electrical flow (resistance to electrical flow increases with the purity of water).

How Many Measurements to Take:

Macroinvertebrates:

Take two 0.1 square meter samples from four riffles (a total of eight samples composited into a single sample).

Particle Count:

Take four counts of 100 particles as described in the Particle Size Distribution protocol.

Water Chemistry:

Take two samples (conductivity and total alkalinity).

Where to Take the Measurements:

Macroinvertebrates:

Identify riffles during reach reconnaissance that are representative of the reach, using the riffle identification criteria described below.

Select the first four riffles upstream from the start of the sensitive reach that are representative of the reach, using the riffle selection criteria described below.

Riffle identification criteria:

- Flow: Turbulent
- Depth: Shallower than pools or runs (portions of substrate typically extend above the water surface).
- Morphology: Uniform to convex profile.
- Dimension*:* Riffles are often irregularly shaped, and vary in length and width. Some portion of the riffle is the dominant habitat across the channel width. Riffles may extend across the wetted width, but typically include features such as edgewater, bars and runs.
- Substrate: Varies from gravel to boulder depending on size of watershed and channel gradient. Typically coarser than that found in pools and runs.
- Gradient: Steeper than runs or pools. Some reaches may contain both low and high gradient riffles. High gradient riffles are relatively steeper and have larger substrate than low gradient riffles.

Riffle selection criteria:

- Length: Select riffles that are representative of the reach. For example, if the typical length is about 10 m with a range of 5 to 15 m, do not select a 2 m long riffle for sampling. In streams where riffles representative of the reach are very long, (i.e., greater than five times the wetted width) break the riffle into sample units that are two times estimated average wetted channel width, separated by one estimated average wetted channel width. Minimum riffle length and width is the size of 2 macroinvertebrate samples (2 square feet, or .62 m^2). This condition is usually only found in very small streams.
- Width: Select riffles that are representative of the reach, similar to the criteria for length.
- Substrate: Select riffles that are representative of the substrate size of riffles in the reach. For example, if nearly all riffles are mid-to-small gravels do not select a large cobble/small boulder riffle.
- Gradient: Select low gradient riffles if the reach has both low and high gradient riffles.

<u>Water Chemistry:</u>

Measure conductivity and total alkalinity at the furthest downstream riffle selected for macroinvertebrate sampling.

How to Take the Measurements:

<u>Macroinvertebrates:</u>

All samples are collected using a 500µm mesh net. Mesh size is critical, as it directly impacts the size and abundance of organisms collected.

Sampling begins at the first selected riffle at the downstream end of the sensitive reach. Remember that the area suitable for macroinvertebrate sample collection may not encompass the entire wetted riffle habitat unit. Include only those portions of the riffle that meet the sample criteria described above. Do not include edgewater, runs, or other areas that do not meet the criteria. Also, consider water depth. If riffles representative of the sensitive reach have depth less than the macroinvertebrate sampler, do not include areas deeper than the sampler in the sample area (sampler efficiency is reduced when depths exceed that of the sampler). Use Form 2 to sketch the selected riffle and the area within each riffle suitable for macroinvertebrate sample collection.

Use a ten-sided die, stopwatch, or random number table (see Appendix D) to randomly select two pairs of single digit numbers (1-9). To reduce edge effects, 0's are discarded if selected. The first number of each pair, multiplied by 10, is the percent upstream along the suitable area's length. The second number, multiplied by 10, is the percent of the stream width from the left edge of the sample area, looking downstream. The second pair of numbers is used in the same way to select the second macroinvertebrate sample location. The intent of this procedure is to randomize the selection of sample locations within the area of the riffle suitable for macroinvertebrate sampling.

Beginning at the most downstream site in the first riffle, place the opening of the net perpendicular to and facing the flow of water. Move substrate material as necessary to create a flush contact between channel substrate and the bottom of the sampler. Disturb the substrate in front of the opening of the net such that about .125 m^2 is disturbed; this is the width of the net by approximately .4 m (16”). Many samplers have a frame that lies in front of the net and outlines the sample area. Carefully remove, rub clean and inspect all large rocks in this area to ensure removal of all macroinvertebrates. After all of the larger rocks have been removed, rake or disturb the smaller rocks and sands to a depth of approximately .1 m (4”) for approximately 60 seconds.

If necessary, empty the contents of the net into a 14 L (five gallon) bucket. Repeat the sampling procedure above at the second randomly selected site for the first fast-water habitat. Empty the contents of the second sample into the bucket. Repeat the process for each of the three remaining riffles. A total of eight samples will be collected. All nets will be emptied into a single bucket, resulting in a single composite sample.

After all eight net samples are in the bucket, carefully remove large pieces of debris and rocks. Wash each piece of debris, inspect carefully and remove any invertebrates before disposal. Place remaining material from the bucket into one plastic jar. Sample material can be agitated (swirled) and dumped through a soil sieve with mesh size 500 um or less to remove organisms and reduce sample volume, as necessary. Carefully inspect material left in the bucket to see than no macroinvertebrates remain. Completely cover the sample material in the jar with 95% ethanol.

Samples must be mailed for laboratory analysis. Label samples and ship them to The BugLab at Utah State University. Note that two sample labels must be sent with each sample – one inside and one outside the sample jar. The inside label must be prepared in pencil on water resistant paper, and the outside label must be written in permanent marker. In addition, a sample form must be sent to the lab with each sample (Form 2, page 1), or the form available from the BugLab may be used). Detailed information on labeling and shipping is available from the BugLab, as follows:

The BugLab
Department of Aquatic, Watershed, and Earth Resources (AWER)
Utah State University
Logan, Utah 84322-5210
Phone: 435-797-3945
http://www.usu.edu/buglab/

Water Chemistry:

Measure conductivity at the center of the stream and record in µS/cm. Collect a sample at the same location and measure total alkalinity.

References

Rosenberg and Resh 1993

Karr and Chu 1998

Particle Size Distribution

(Core Attribute)

Importance:

Streambed materials are key elements in the formation and maintenance of channel morphology. These materials influence channel stability, resistance to scour during high flow events, and also act as a supply of sediment to be routed and sorted throughout the channel. The amount and frequency of bedload transport can be critically important to fish spawning and other aquatic organisms that use stream substrate for cover, breeding, or foraging.

Particle size distribution can change over time as a result of management activities and/or natural disturbances. Detecting change is important for making decisions related to managing aquatic communities and ecological processes.

Objective of This Measurement:

Detect status and change of streambed particle size distribution.

How Many Measurements to Take:

Conduct a particle count of 100 particles in each of the four riffles sampled for macroinvertebrates, for a total count of 400 particles in the sensitive reach.

Where to Take the Measurements:

Take the particle count in the four riffles sampled for macroinvertebrates (see Macroinvertebrate protocol). Measure and record the distance upstream from the start of the sensitive reach to the lower end of each riffle, and the length of each riffle.

Measurement is conducted on the stream bottom so that the streambed is sampled without incorporating bank materials. The stream bottom is the area of the stream that is practically bare of vegetation caused by the wash of waters of the stream from year to year. It is therefore at a level less than bankfull stage and excludes streambanks.

Riffles are the preferred sampling location for detecting change since they have a relatively homogenous particle size composition. This reduces sampling variability and makes it more likely to detect change than by sampling different habitat types (i.e. pools, runs). The objective of this procedure is to compare riffle particle size distribution over time and between reaches.

The riffle particle count may be suitable for reach characterization. Although the riffle D50 is likely to be different than a count across habitat types, it will usually be in the same particle category. Where a reach characterization across habitat types is desired, a different protocol should be employed.

How to Take the Measurements:

At each riffle, locate ten equally spaced transects perpendicular to the main axis of the channel. Proceed across the transect and count 10 particles at evenly spaced intervals. The minimum distance between sample points should not be less than the size of the largest particle in the riffle. (Note: where an anomalously large particle is present use the largest dominant particle size in the riffle. For example, if a riffle is 70% gravel and 30% cobble but has one very large boulder, use the largest cobble as the minimum spacing guide).

Record each particle on the data form in the “wet” or “dry” column to denote whether it is within or outside the wetted width of the channel at the time of the particle count. This allows analysis of the particle size distribution for the macroinvertebrate sample (in the wetted area) as well as the entire channel. To select an individual particle for measurement, reach down over the tip of the boot while averting the eyes. Collect the first particle touched by the tip of the index finger. Use a gravel template to measure the intermediate axis size class of the particle. A class-defined ruler may be used if a gravel template is unavailable but care should be taken to determine the correct size class. Sizes larger than 180 mm, or particles that cannot be extracted from the streambed, need to be measured with a ruler. For gravel-bed streams, tally particles smaller than 2 mm in size into a class defined as "<2 mm" because particles smaller than this are difficult to representatively sample. If a large proportion of the count (approximately more than 50%) is less than 2mm in size, volumetric sampling is suggested.

The particle count procedure varies for very small streams. Some reaches may be so narrow that 10 particles cannot be collected between streambanks while maintaining intervals greater than the largest particle size between sample points. In steeper, small stream systems, suitable riffle substrate for macroinvertebrate collections may be limited. Collection of macroinvertebrate samples may disturb (and remove) some or most of the substrate, making subsequent particle counts impossible. In these cases, the following technique will be employed. At each macroinvertebrate site (typically pool tails rather than true riffles) alternatively collect 12 or 13 particles for measurement using the following systematic approach. Within the macroinvertebrate sampler frame, superimpose an imaginary 3x4 grid. At each of the grid sample points, select a particle as per the "toe point" method. Wash the particle as per the macroinvertebrate collection procedure, then place the rock in a bucket for subsequent measurement. If 13 particles are to be collected, select the 13^{th} particle from the center of the sample area. By collecting 12 particles from four samples and 13 particles from four samples, a total of 100 particles are collected from the eight macroinverterbate sample locations. Measure and record the length of the intermediate axis of all particles collected.

<u>Vendor Information – Gravel Template</u>

Federal Interagency Sedimentation Project (FISP)
US SAH-97 Gravelometer
Phone (601) 634-2721
www.stream.fs.fed.us (go to Stream Notes October 1997)

References:

Bunte and Abt 2001

Harrelson 1994

Potyondy 2003

Wolman 1954

Stream Temperature

(Core Attribute)

Importance:

Water temperature strongly influences the function of biological systems, and individual organisms and species. Stream temperature has impacts on health, behavior and survival of aquatic organisms. Manipulation of riparian vegetation that provides shade is a key management concern.

Objective of This Measurement:

Thermographs are used to collect and record stream temperatures during low-flow long day length periods, when maximum temperatures are likely. The objective of the measurement is to determine mean maximum temperature for the period July 1-August 31. Temperature range for this time period can also be derived. Maximum temperatures are determined for comparison with project or forest standards, or state water quality objectives.

Note: Forest or project standards may have objectives for temperatures other than this low flow period, including minimum (winter) temperatures. If such site-specific objectives for timing have been developed, they should be substituted for the July 1-August 31 sampling period.

Additional Note: Forests may also elect to collect "spot" temperature data with hand held thermometers or other means. This approach may be valuable, especially as a site-specific reference. This data does not lend itself to rigorous monitoring level comparisons between streams or over time, and therefore is not stored in the Regional database. Thermograph technology has developed to the point where they are very inexpensive relative to the amount of information acquired.

How Many Measurements to Take:

Take a minimum of 1, 468 measurements (hourly for 62 days).

Where to Take the Measurement:

At a run or riffle, anywhere where the flow is mixed (versus in a pool where stratification might occur).

How to Take the Measurement:

A recording thermograph is used for this measurement. Program the thermograph to take measurements at intervals of one hour (this is the minimum sampling intensity, most thermographs will take more frequent measurements over a 62 day time scale).

Install the thermograph prior to July 1, and retrieve it after August 31. Mean daily maximum temperatures (for the thermograph) are calculated for the 62 day period July 1-August 31. As with the measurement interval, the 62-day period is a minimum, most thermographs will record temperature over a much longer time period.

Note: If the thermograph is installed at the same time macroinvertebrate sampling is conducted, stay out of the water while setting the thermograph, or do the macroinvertebrate sampling first.

Large Woody Debris (LWD)

(Core Attribute)

Importance:

Large wood is important to the morphology of many streams. It influences channel width and meander patterns, provides for storage of sediment and bedload, and is often most important in pool formation in streams. Large wood is also an important component of instream cover for fish, as well as providing habitat for aquatic insects and amphibians. Large wood influences on stream ecology vary with size of the stream and size of the wood (small wood is easily transported in large systems).

Objective of This Measurement:

To characterize the woody debris in the sensitive reach that is influencing the stream channel. If the objective is to measure large woody debris (LWD) as a cover component, more extensive information should be collected although some inferences could be drawn from the tally in this protocol.

How Many Measurements to Take:

Conduct a count of all large woody debris and root wads within the sensitive reach that meet dimensions described below. Preliminary results from testing of these protocols confirmed the work of others demonstrating that LWD distribution is clumped, and that long reaches are necessary for an accurate description.

Where to Take the Measurement:

Count all pieces of wood lying within the sensitive reach that has any portion within the bankfull width of the channel. This includes logs suspended above the channel.

How to Take the Measurement:

Walk the sensitive reach counting wood longer than one-half bankfull width. Wood must be downed with a portion lying within bankfull stage.

Single Pieces – Tally each piece that meets the criteria in the paragraph above. There is no need to record the length or diameter of each piece. Sum the number of pieces on the form. Use the comment section to note if any of the large wood counted is part of stream enhancement structure.

Aggregates - Aggregates are defined as four or more pieces of woody debris in contact where each piece meets the minimum length requirement and has some portion occurring within bankfull width. Tally all the pieces in the aggregate meeting the minimum size criteria that can be feasibly and safely identified (some aggregates may be large enough to obscure individual pieces from view or safe access). Record the number of pieces in each aggregate on the aggregate line, and sum the total number of pieces.

Tally root wads as single pieces whether they occur alone or are within an LWD aggregate. A root wad is defined as the root mass of a tree whose trunk length is approximately equal to or shorter than the diameter of the root wad. Root masses with longer tree boles should be tallied as LWD.

Beaver dams should not be tallied with the LWD count. They should be noted as comments on the data form.

References:

Knopp 1993

Platts et al. 1987

Sedell et al. 1988

Bankfull Stage

(Core Attribute)

Importance:

The bankfull stage corresponds to the discharge at which channel maintenance is often the most effective. This discharge is a major factor in shaping channels sensitive to disturbance by management activities, such as gravel bed streams. The bankfull stage discharge is associated with a momentary maximum flow that has a recurrence interval of about 1.5 years (Dunne and Leopold, 1978).

Objective of this Attribute:

Identify bankfull stage in order to determine associated channel characteristics such as bankfull width, bankfull depth, and bankfull width-to-depth ratio. The location of bankfull stage is also important for stream classification.

How to Identify this Attribute:

The determination of bankfull stage should focus on the identification of the flat depositional surface adjacent to the stream channel that corresponds to the elevation of the floodplain. Depositional surfaces are most readily observed on low gradient streams but may be less evident in steep streams or in recently incised channels. When floodplains are not well defined, other indicators can serve as surrogates to identify bankfull stage. These include vegetation, changes in sizes of bank materials, and water stain or lichen lines on substrate. However, these must be used with care since specific indicators vary with stream type and geographical region. Vegetation, in particular, may exhibit regional differences. For example, the base of alders is an indicator of bankfull stage in some ecosystems, while willows indicate bankfull stage in others. Some perennial herbaceous plants that provide streambank stability, such as sedges, may extend below bankfull stage.

By using the presence of depositional surfaces as the conceptual underpinning, the identification of bankfull stage links directly back to the basic definition of bankfull discharge established by Leopold and Wolman (1964) which states, “Bankfull discharge is defined as that water discharge when stream water just begins to overflow into the active floodplain; the active floodplain is defined as a flat area adjacent to the channel constructed by the river and overflowed by the river at a recurrence interval of about two years or less.”

Note: It is important that bankfull stage is correctly identified. To do so, a length of approximately 20 channel widths should be selected in the sensitive reach where representative bankfull stage locations can be identified and marked with survey flags. Locating bankfull stage should be done in fastwater habitat units using field indicators and, when available, regional curves of bankfull dimensions.

The USDA video and DVD for identification of bankfull stage is a helpful reference (USDA 1995).

Where to Identify this Attribute:

Identify bankfull stage at the following sites:

1) Start of sensitive reach (to determine large woody debris minimum length tally)
2) Particle size distribution transects
3) Cross-section locations
4) Width-to-depth/entrenchment locations

References:

Dunne and Leopold 1978
Harrelson et al. 1994
Leopold and Wolman 1964
USDA 1995

Cross-section

(Core Attribute)

Importance:

Channel cross-section measurements express the physical dimensions of the stream perpendicular to flow. They provide fundamental understanding of the relationships of width and depth, streambed and streambank shape, bankfull stage and floodprone area, etc. All of these are important attributes of channel condition and indicators of the health of aquatic and riparian ecosystems. Cross-section measurements also serve as essential criteria for stream classification. Monumented cross-sections are used to determine channel condition and trend since they can be monitored repeatedly.

Objectives of This Measurement:

Measure channel cross-section to determine indicators of channel condition. These include width/depth ratio, bank angle, channel shape, floodprone area, etc.

Measure cross-sections to establish permanent monitoring sites to determine change in channel condition over time.

How Many Measurements to Take:

Measure up to three cross-sections per sensitive reach, each within fast water habitat units. If there are more than three candidate sites for cross-sections within the sensitive reach, randomly select three. If there are three or fewer candidate sites measure them all. (In reaches with more than three candidate sites, the ones not selected for cross-sections will become candidates for width-to-depth and entrenchment measurements).

Where to Take the Measurement:

Identify candidate sites during the first pass along the sensitive reach. Flag and number each candidate site and record its distance from the start of the sensitive reach. Candidate sites are fast water habitat units in straight sections typical of the sensitive reach. Candidate sites must have clear bankfull stage indicators. Do not use pools as candidate sites.

Measure the cross-section at the widest point in the selected candidate site.

How to Take the Measurement:

The standard SCI method is described below and shown in Figure 1. It is designed to use lightweight gear so that cross-sections can be easily measured at remote sites as well as more accessible sites. It utilizes permanent site marking stakes, a string line and level, a measuring tape, engineering survey flags, and a depth rod. Alternately, a survey level and rod can be used following standard surveying techniques such as described in Harrelson, 1994.

Establish a horizontal measuring line across the channel between permanent end-point markers of sufficient stability, elevation, and distance from water's edge so they will not be washed out over time. End-point markers should be higher than two times maximum bankfull stage depth, preferably on a terrace or high bank (twice maximum bankfull stage depth approximates a 50-year flood). End-point markers are designated left pin (LP) and right pin (RP). The left pin is on the left bank facing downstream.

The horizontal measuring line must be a level, tight string line. The height of the string line on the end-point markers must be noted on the form so that future cross-section measurements are made at the same elevation. Place a measuring tape alongside the string line for reading distances at which depth measurements are taken across channel. Always start measurements at the left bank facing downstream.

Prior to taking depth readings, bankfull stage must be identified and marked. It must be the same elevation on both banks (the height from the string line down to bankfull stage must be identical). Bankfull stage cross-sectional area should be consistently similar at cross-section sites in the reach. If not, bankfull stage may not have been correctly identified. Compare the bankfull stage cross-sectional area measurements in the field as sites are measured to assure consistency.

Begin cross-section measurements at the left pin and end at the right pin. Take depth readings with rod at intervals representing 5-10 percent of total width measured, at all locations of significant slope changes across the channel, at bankfull stage, and at water's edge. Intervals may be at fixed widths where channel shape remains similar, but will be non-uniform across full width measured since certain points must be identified. As an example of the number of depth measurements to take, if a channel width is 10 m, 10% intervals yield 10 depth measurements and 5% intervals yield 20. Examples of significant slope changes in the channel include noticeable breaks between streambed and streambank, channel bars, terrace edges, large boulders, and undercut banks.

In the case of undercut banks, measure the depth at the top and bottom of the undercut and enough undercut widths to accurately depict the shape of undercut (see Figure 1). Record the depth and undercut widths on the datasheet. To determine the distance from the left bank, subtract the undercut width from the distance from left stake at the top of the undercut (TUC). It is important to record the cross-section point in the proper sequence so that the cross-section may be graphed. The sequence should be ordered so that a continuous line may be drawn from point to point depicting the cross-section profile. Plot the cross-section in the field and sketch the channel profile. Identify bankfull stage, water surface elevations, end-points, and undercut banks. Confirm the data accuracy and verify enough measurements were collected to provide a precise profile.

Make all measurements to the nearest 0.01 m.

Once depth measurements are completed, the measurements associated with cross-sections can be made. Gradient and entrenchment are measured using separate protocols. Width/depth ratio is calculated from data collected at the cross-section.

Permanent Identification:

- Cross-sections must be referenced with permanent monuments wherever monitoring change in stream morphology over time is desired. Permanent references include the following:
- Benchmarks – A benchmark should be a permanent feature near the cross-section and include a distance and bearing to the cross-section end-point markers. It should also include an elevation from the benchmark to the end-point markers. Refer to standard surveying protocol (Harrelson 1994). It is also helpful to take a bearing from one end-point marker to the other.
- Cross-section end-point markers – It is essential to install markers that will remain in place permanently. Rebar (about 1 m by 0.015 m sunk into the ground with only a short piece above ground) is a standard marker. Shorter rebar (i.e., 18”) can sink into the ground as time goes on, or can be pulled out. Other marker options include angle iron or T-stakes. Wilderness cross-section markers may have to be unobtrusive, but are still essential since remeasurement is impossible without a permanent marker. End-point markers must be of sufficient stability, sufficient elevation, and distance from water’s edge so they will not be washed out over time.
- Photographs – Photos are a key tool for relocating the cross-section site and showing change over time. Even with benchmarks and the cross-section’s known distance upstream from the start of the sensitive reach, they often provide the best clue to relocating cross-section markers. At a minimum, four photo angles should be used:

upstream, downstream, and left and right banks. Additional photos are recommended if there are important details of the site to display, such as the end-point pins and the bankfull stage flags. All photos of cross-sections should be taken with the string line and/or tape in place for better depiction of the location.

- Georeference – GPS units can be used to identify the cross-section location. However, GPS accuracy limitations are such that GPS will not find the precise spot where end-point pins are located. Georeferencing, however, is a good tool for locating the cross-sections so they can be mapped. If cross-sections are georeferenced, the start and end-points of the sensitive reach should also be georeferenced.

Cross-section Remeasurement:

Remeasurement of cross-sections should be done over time when it is expected there may be changes in channel morphology. Frequency of remeasurement depends on a number of environmental and management variables. These can include change in management practices in the watershed upstream of the cross-section, staffing, and changes in channel form due to large storm events. However, it is recommended that cross-sections be remeasured frequently enough to respond to the management questions for which they were established. As a guide, a range of 2-5 years is recommended. More frequent measurements may be considered if measurable annual change is expected, or a large natural event has affected the watershed.

Procedure for remeasuring cross-sections is the same as for their establishment. However, the following points should be considered:

If the existing end-point markers are missing or appear to have been moved (i.e., bent or partially pulled up), establish new ones at the same site and consider it a new cross-section.

If the existing end-point markers were established lower than two times maximum bankfull depth, consider site factors to determine if they should be relocated higher (such as whether the present location appears to be subject to washing out). It is advisable to have the end-point markers above two-times maximum bankfull depth if practical to minimize them being dislodged or lost. When relocated higher, the original cross-section data are still usable if the existing end-point markers are in place. The only change is that additional height and width are added.

References:

Harrelson et al. 1994

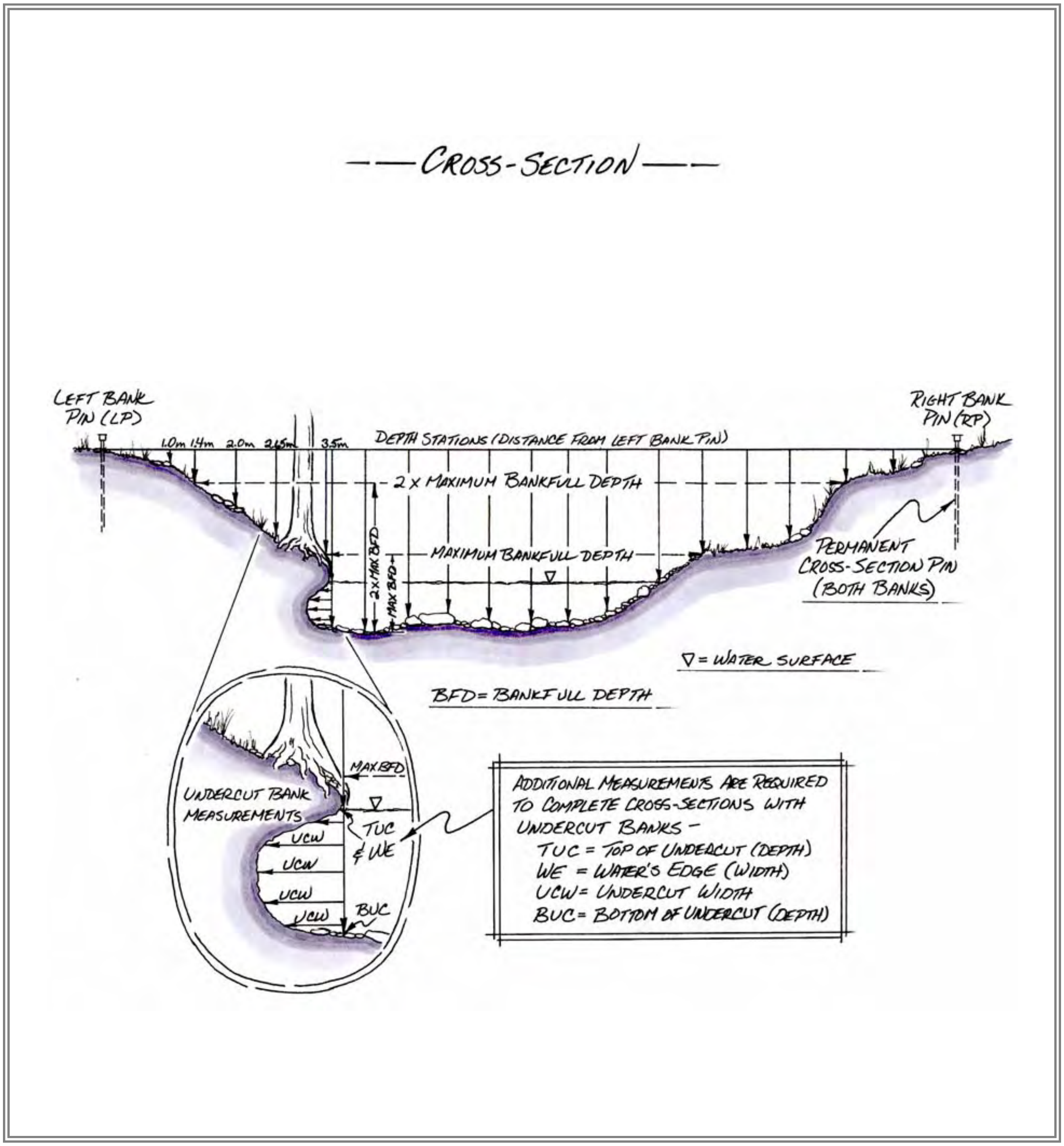


Figure 1 – Cross-section

Water Surface Gradient

(Core Attribute)

Importance:

Gradient of the stream surface is an essential element of many stream classification systems and a primary attribute for stratifying sensitive reaches in the R5 SCI database. In addition, knowledge of gradient helps provide understanding of the geomorphological processes shaping the channel.

Gradient must be measured in order to compare the reach with other reaches in the SCI database, and to help classify the reach stream type.

Objective of This Measurement:

To determine the water surface gradient in percent slope.

How Many Measurements to Take:

Three, one at each channel cross-section.

Where to Take the Measurement:

Gradient is measured at the channel cross-section location for a distance upstream and downstream that incorporates at least one pool-riffle or step-pool sequence. If such sequences are not present, measure the longest possible distance in order to represent the average gradient in the area of the cross-section*.*

How to Take the Measurement:

Distance between end-points upstream and downstream from the cross-section should be as long as practical. End-points should be located on the same channel feature (e.g. pool tail) and include as many pool-riffle or step-pool sequences as is practical. At least one pool-riffle or step-pool sequence must be included. In the case of streams where these sequences are not present or not easily identifiable, locate end-points that are as representative as possible of average gradient. Measure the distance, or "run," between the gradient survey end-points along the thalweg. Determine the water surface elevation change, or "rise," between the end-points. Divide rise by run and multiply by 100 to calculate gradient.

A hand level and tripod is the minimum tool for measuring gradient. More sophisticated surveying instrumentation such as a laser level may be used if available and practical. Do not use a monopod for mounting an instrument since it cannot be held steady. Lightweight camera tripods can be adapted to firmly hold a hand level. The lightweight tripod and hand level are often more practical in wilderness or other remote stream reaches.

If the end-point is difficult to see (i.e., vegetative obstructions, stream curvature, distance too far), the gradient measurement should be collected in increments. The gradient survey may be taken sighting upstream or downstream; if increments are needed to complete the survey, the instrument must be relocated or turned in place and sighted in the opposite direction.

There are two recommended general instrument locations for measuring gradient – In-stream and Off-stream:

<u>In-stream Sighting:</u>

To measure gradient with a single sighting (where the entire gradient "reach" can be observed without obstruction), the observer at the instrument places the tripod in the thalweg and attaches the level to the top of it (see Figure 2). The observer records the height of the instrument sight line and the height of the water surface above the streambed. The observer at the instrument sights through the level to an observer with a measuring rod at the other end-point of the survey. The observer at the rod notes the height on the rod that is level with the height of the instrument. The observer at the rod records this height and the height of the water surface above the streambed.

To calculate the gradient reach rise, first subtract the water-surface height from the height of the instrument. At the rod end, subtract the water-surface height from the level height observed from the instrument. For example, when sighting upstream, if the instrument height is 1.5 m above the streambed and the water-surface height is 0.2 m, the difference is 1.3 m. If the rod level height is 1.1 m and its water-surface height is 0.3 m, the difference is 0.8 m. The water-surface slope elevation change between the survey end-points is 0.5 m (1.3 m - 0.8 m), or the rise. Note: for single in-stream sightings, viewing upstream is usually easier because it is easier to read the rod end when level height is lower than at the instrument.

To complete the gradient calculation, divide the rise by the run (the distance along the thalweg between the downstream and upstream measuring points) and multiply by 100 to obtain percent gradient. Using the above example over a 50 m length between end-points, 0.5 m/50 m x 100 = 1% gradient.

To measure gradient with a double in-stream sighting (upstream and downstream), place the instrument in the gradient reach where both end-points can be viewed without obstruction. Point the instrument at one end-point (i.e., back sight) and record level height on the rod and water height at the rod. Turn the instrument to the other end-point (i.e., foresight) and, with the rod relocated at that end-point, record level height on the rod and water height at the rod. Calculate the gradient reach rise and run in the same manner as described above to complete the gradient measurement.

<u>Off-Stream Sighting:</u>

Gradient measurements and calculations are done in the same manner as double in-stream sighting. The difference is that the instrument is placed outside the stream, often on a nearby floodplain or terrace. This method is most commonly done with a survey level so it is not subject to falling in the water.

Common to both sighting locations and methods is obtaining rise and run measurements. In some cases the single in-stream sighting may be the quickest. In other cases in-stream or off-stream double sighting, or even a series of double sightings may be the most practical (such as where visual obstructions or a transit is already on site).

Reference:

Harrelson et al. 1994

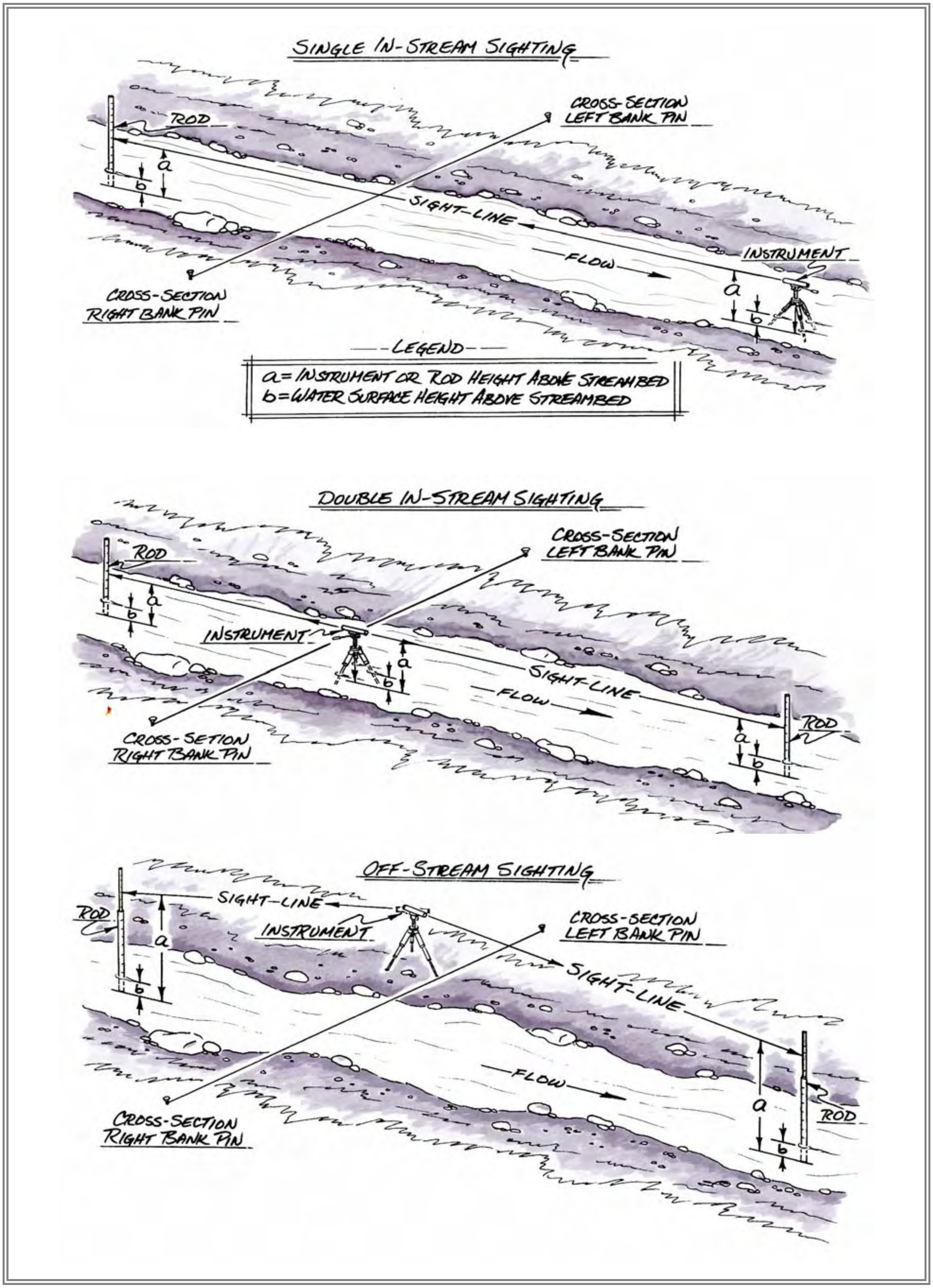


Figure 2 – Water Surface Gradient

Width-to-depth Ratio

(Core Attribute)

Importance:

Stream width-to-depth ratio is a key indicator of channel condition. A low width-to-depth ratio generally indicates good conditions for aquatic flora and fauna and riparian vegetation. Low width-to-depth ratios result in deeper water for aquatic species and a higher water table to support growth of riparian and meadow vegetation.

Objective of this Measurement:

Characterize stream morphology and aquatic habitat.

How Many Measurements to Take:

Take three measurements at the cross-sections and up to five additional measurements (depending on available candidate sites). For example, if there are seven remaining candidate sites after the cross-sections have been selected, randomly select five additional sites for width-to-depth measurements. If there are fewer than five remaining, measure them all.

Where to Take the Measurement:

Randomly select up to five sites from among the remaining cross-section candidate sites after the three cross-section sites have been selected. Candidate sites are in fast water habitat units in straight sections typical of the sensitive reach. Do not take width-to-depth measurements in other habitat types (i.e., pools).

How to Take the Measurement:

Width-to-depth measurements are taken at the same time as entrenchment measurements.

Once bankfull stage has been identified, stretch a measuring tape between bankfull stage flags. Starting at bankfull stage on the left bank, take a minimum of 10 depth measurements before reaching bankfull stage on the right bank. Include the thalweg, water's edge, and major slope changes in the channel cross-section. Take depth measurements at intervals that result in a representative sample of bankfull depths.

Make all measurements to the nearest 0.01 m.

Bankfull stage cross-sectional area should be consistently similar at width-to-depth sites in the reach. If not, bankfull stage may not have been correctly identified. Compare the bankfull stage cross-sectional area measurements in the field as sites are measured to assure consistency.

To calculate the mean depth, the total number of depth measurements should be divided by n+1, in order to account for the zero depths at the streamshore. For example, if 10 depth measurements are taken, divide the sum of those 10 depth measurements by 11.

Document the presence of undercut banks (UC) in the notes column on the data sheet but disregard computing undercuts when measuring width-to-depth ratio. It is beyond the scope of this attribute to assess undercut area and in, most cases, undercuts have a negligible effect on the width-to-depth ratio.

References:

Bauer and Burton 1993

Platts 1987

Rosgen 1996

Entrenchment Ratio

(Core Attribute)

Importance:

Stream discharges greater than bankfull strongly influence the character of the channel. The interaction of these flows with the channel floodplain plays a major role in sediment transport and storage, streambank stability, and channel morphology.

Entrenchment ratio is defined as the ratio of flood prone width to bankfull width as measured at twice the maximum bankfull depth. This measure is intended to quantify channel confinement.

Objective of this Measurement:

Characterize stream morphology and aquatic habitat.

How Many Measurements to Take:

Take three measurements at the cross-sections and up to five additional measurements (depending on available candidate sites). For example, if there are seven remaining candidate sites after the cross-sections have been selected, randomly select five additional sites for entrenchment measurements. If there are fewer than five remaining, measure them all.

Where to Take the Measurement:

At each cross-section and up to five sites randomly selected from among the remaining cross-section candidates.

How to Take the Measurement:

Entrenchment measurements are taken at the same time as width-to-depth measurements.

Double the maximum bankfull stage depth that was determined during the width-to-depth measurement, and measure flood prone width at this elevation using a level tape. Flood prone width may be nearly identical to bankfull width in gullied or very steep streams, or several hundred meters in low gradient streams in wide valleys. In wide valleys where tape measurements may be difficult, estimate the flood prone width by pacing. Avoid visual estimates over long distances since they can be substantially inaccurate. Once the flood prone width is measured, divide by bankfull width to derive the entrenchment ratio. Record the entrenchment ratio on the data form.

Make all measurements to the nearest .01 m.

References:

Rosgen 1996

Habitat Type

(Core Attribute)

Importance:

At the broadest resolution level, fluvial geomorphologists recognize fast water (riffles, runs, etc.) and slow water (pools) as the two primary stream habitat unit types. These units are an important core attribute because they are the base stratification of habitats that support aquatic life.

Forest management can alter the character of fast and slow water habitat units by changing the amount of sediment, water, and LWD contributed to streams. Excessive sediment can smooth channel gradient by filling pools. Removal or reduction in woody debris reduces sediment storage and eliminates local hydraulic variability that influences habitat unit development. Habitat types change throughout streams based on gradient and valley form. Over time these changes are based on stream flow or changes in hydrologic character.

Objective of This Measurement:

To describe the spatial distribution and characteristics of fast and slow water habitat units.

How Many Measurements to Take:

Take measurements equal to the number of fast and slow water habitat types in the survey segment.

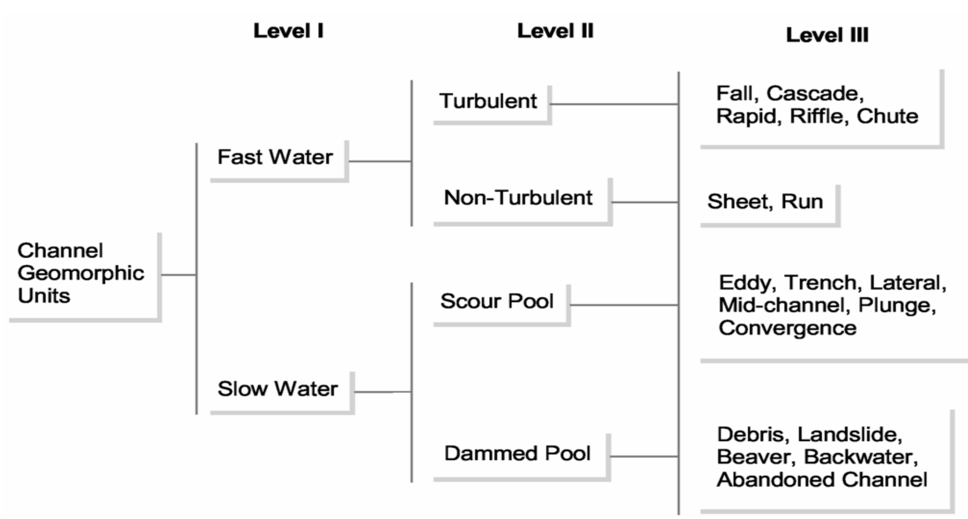
Where to Take the Measurement:

Measurement is taken continuously throughout survey segment.

How to Take the Measurement:

Using a string machine, begin measurement from the start of the survey segment noting lengths of slow and fast water. Record start and stop distance for each habitat unit. See Pools attribute for description of pools.

Finer levels of resolution can be used based on the following:



Reference:

Hawkins et al. 1993

Pools

(Core Attribute)

Importance:

Pools are an important component of habitat for aquatic organisms. They are important for different reasons to different aquatic species and may provide deep water and cool summer temperatures, winter refuge, and areas for rearing of fish and amphibians. They are also important components and indicators of channel morphology. Residual pool depth is measured to characterize pools in the survey segment because it reduces variability in pool depths that result from differences in stage.

Objectives of This Measurement:

Quantify the number of pools in the survey segment.

Determine range of residual pool depths within the survey segment. Residual pool depth is the difference between maximum pool depth and pool tail depth.

Document whether wood is a factor in pool formation.

How Many Measurements to Take:

Measure every pool in the survey segment.

Criteria for Determining Pools:

- Flow: Slow or no velocity during summer low flows.
- Morphology: Hydraulic control at pool tail, usually a concave longitudinal profile.
- Dimension: Dominant feature occupies most of stream width and includes thalweg (backwater and sidewater pools are not measured). Length is greater than wetted width. Depth is greater than non-pools. Maximum depth is more than twice pool tail depth. (Exceptions to these criteria can be found. These units should be considered pools if criteria described above are present).

Where to Take the Measurement:

Measure pool depth at the deepest point.

Measure pool tail crest depth. This is the deepest point in the channel cross-section at the downstream end of the pool where the water breaks from smooth to turbulent flow. See Figure 3.

How to Take the Measurements:

Use the staff rod to measure the pool at its deepest point, to the nearest .01 m. Use the tape or string machine (hip chain) to measure the length of the pool. Record this information on the data form.

Also note if the pool is formed by wood.

Reference:

Kershner et al. 2004

USDA 1994

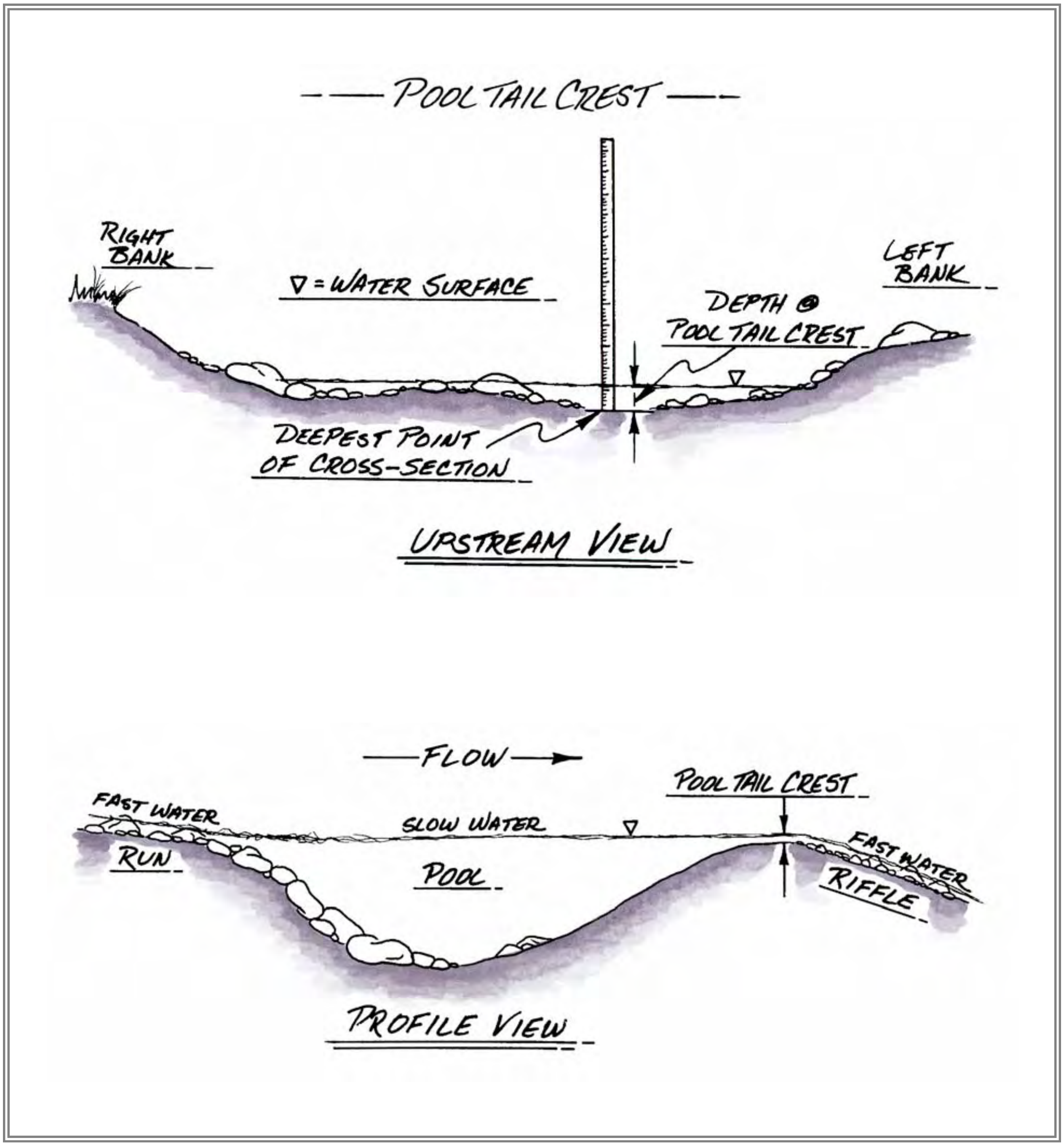


Figure 3 – Pool Tail Crest

Pool Tail Surface Fine Sediment

(Core Attribute)

Importance:

Watershed and streambank disturbance often result in increased sediment input to streams. Increased fine particles in the stream substrate can impair aquatic food production and decrease survival of young salmonids. Salmonid mortality is increased when water interchange between streams and redds is reduced by fine sediment and by filling interstitial spaces resulting in barriers to movement of alevins. Particles of 2 mm or less are the principal barriers, although particles up to 8mm have resulted in increased mortality.

Objective of This Measurement:

To quantify the percentage of fine sediment less than 2 mm on the pool tail substrate.

How Many Measurements to Take:

Three grid measurements are conducted at each pool tail within the survey segment. The grid is a 14-inch square frame with 49 line intersections and one corner (50 points total). Counts are made of percent fines at the intersections and one identified corner.

Where to Take the Measurement:

At each pool tail, stand on the pool tail crest. Define the extent of each pool tail unit by estimating a zone that incorporates the downstream 10% of the total pool length. It will lie within the wetted stream width. Within the area defined, make three random tosses of the grid. See Figure 4. The first measurement is in the thalweg within that 10% zone; the second measurement midway is upstream between thalweg and left wetted edge; and the third measurement is midway upstream between thalweg and right wetted edge.

Exception: Placing the sampling grid 10% of the distance upstream of some pool tail crests could result in measurements that may not be reasonably called pool tail substrate. Pool tails are usually a depositional feature, dominated by fine to cobbl-sized substrate. Where such conditions do not exist, avoid measuring pool tail surface fines.

How to Take the Measurement:

Count and record the number of intersections lying above substrate 2 mm or less. A viewing tube, dive mask, etc. can aid in viewing the grid by breaking the water surface turbulence.

Each point represents 2% fines. Multiply the points per toss by two and record on Form 8.

<u>Special Cases:</u>

Aquatic vegetation - In some streams, aquatic vegetation may be growing or otherwise cover parts of the area to be sampled by the grid, making its use difficult or impossible. If that is the case, an alternative procedure for that pool tail is employed. At such a location, the pool tail area is defined. Transects are then run across the area, with a particle selected at the toe point of each stride. If the particle falls into the <2 mm size class, it is tallied. This procedure is continued until 100 particles have been selected. Transects and strides should be staggered such that the entire pool tail area is sampled equally. The tallied number of particles under 2 mm represents the percent surface fines estimate for the pool tail.

- Small streams - If three tosses will not fit in the area defined by wetted width and the 10% pool length zone, take two tosses, or only one if possible. Do not overlap tosses.

References:

Bauer and Burton 1993

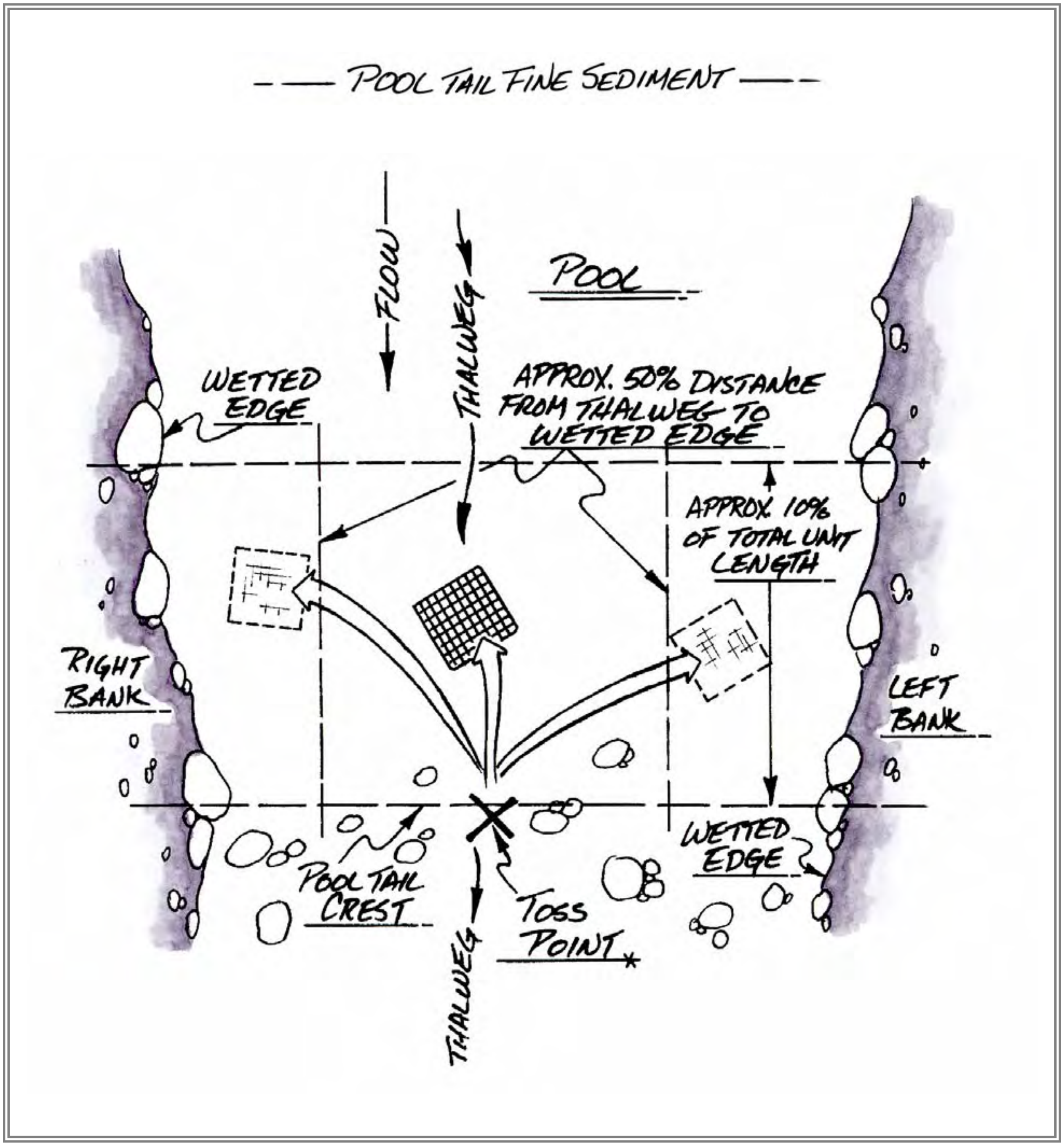


Figure 4 – Pool Tail Fine Sediment Measurement Area

Streambank Stability

(Core Attribute)

Importance:

Channel stability is a key indicator of channel condition. Stable streambanks are essential for achieving desired stream channel morphology. Stable banks maintain or help restore low width-depth ratio which in turn helps maintain a high water table, vegetative productivity and favorable habitat for aquatic and riparian dependent wildlife. In many low gradient channels, unstable banks are a major erosion source.

Objectives of This Measurement:

Calculate streambank stability of the sensitive reach.

How Many Observations to Make:

Make 100 observations (50 each bank). Sample points are located at each channel transect.

Where to Take the Measurement:

Streambank stability is a measure of cover that protects streambanks against erosion. Streambanks lie immediately adjacent to the edge of the streambed and are susceptible to the erosive force of water during high flows. Cover consists of perennial vegetation, rock, down wood, or similar erosion resistant material. Cover most commonly occurs above the bankfull stage of stream channels. However, vegetative cover can exist below this level. For example, live plants often grow slightly below bankfull stage along low gradient streams with fine textured streambanks. Where a cover component occurs below bankfull stage record it since it contributes to bank stability.

Streambank stability is measured by observing cover within a plot on the surface of the streambank (Figure 5). The plot is .30 m (12”) wide, perpendicular to flow and extends the length of the streambank as defined below.

How to Take the Measurement:

Identify the base of the streambank. It is the point of greatest slope change between the streambed and streambank.

Locate the point on the streambank where vegetative cover is first encountered above the streambed or at bankfull stage, whichever occurs first. Begin the stability plot at that point and extend it upwards as follows:

For channels less than 2% gradient with fine textured streambanks, to the crest of the first convex slope above bankfull stage. This is usually a terrace or an alluvial fan (see Figure 5).

For channels greater than 2% gradient with coarser textured streambanks, to the crest of the first convex slope above bankfull stage or twice maximum bankfull depth, whichever occurs first. Record the following streambank stability class for each plot:

- Stable - Stable streambank plots have 75% or more cover of living plants and/or other stability components that are not easily eroded, and have no indicator of instability.
- Vulnerable - Vulnerable streambank plots have 75% or more cover but have one or more instability indicators.
- Unstable - Unstable streambank plots have less than 75% cover and may have instability indicators. Unstable streambanks are often bare or nearly bare banks composed of particle sizes too small or uncohesive to resist erosion at high flows.

Remember that there are 100 plots that make up the average bank stability for the reach. Do not spend a lot of time determining individual plot condition. Once familiar with this rating system, streambank stability plots can be rated accurately and quickly. Record the numeric value (1 = stable, 2 = vulnerable or 3 = unstable) on Form 9 and move on to the next plot.

Cover Components:

Live Plants - (1) Perennial herbaceous species, such as grass-sedge-rush; (2) woody shrubs (willows, etc.); (3) broadleaf trees (cottonwood, aspen, alder, etc.); (4) conifer trees, and (5) plant roots that are on or near the surface of the streambank and provide substantial binding strength to the substrate beneath.

Rock - Boulders (>256mm), bedrock, and cobble/boulder aggregates when combined as a stabilizing mass.

Down Wood - Logs that are firmly embedded into stream banks.

Erosion Resistant Streambank Soil – In very limited cases, hardened conglomerate or highly cohesive clay/silt stream banks.

Instability Indicators:

Fracturing, blocking, or slumping – This includes cracks near the top of the streambank (often parallel with flow), slumping banks without cracks, and blocks of soil/plant material, which have fallen off or have been pushed down the bank. Usually associated with streams with gradients <2% and fine-textured banks.

Mass Movement - this includes stream bank failure from deep-seated landslides and gravity erosion of oversteepened slopes adjacent to the channel. Mass movement is usually associated with streams with >2% gradient.

Calculating Streambank Stability:

Tally the number of stable plots recorded. Divide the number of stable plots by the number of total plots and multiply by 100 to obtain percent streambank stability. For example, if a 100 plot survey segment has 85 stable plots, dividing by 100 and multiplying by 100 = 85% streambank stability. Vulnerable plots are not classified as stable because they have instability indicators.

References:

Bauer and Burton 1993

Rosgen 1996

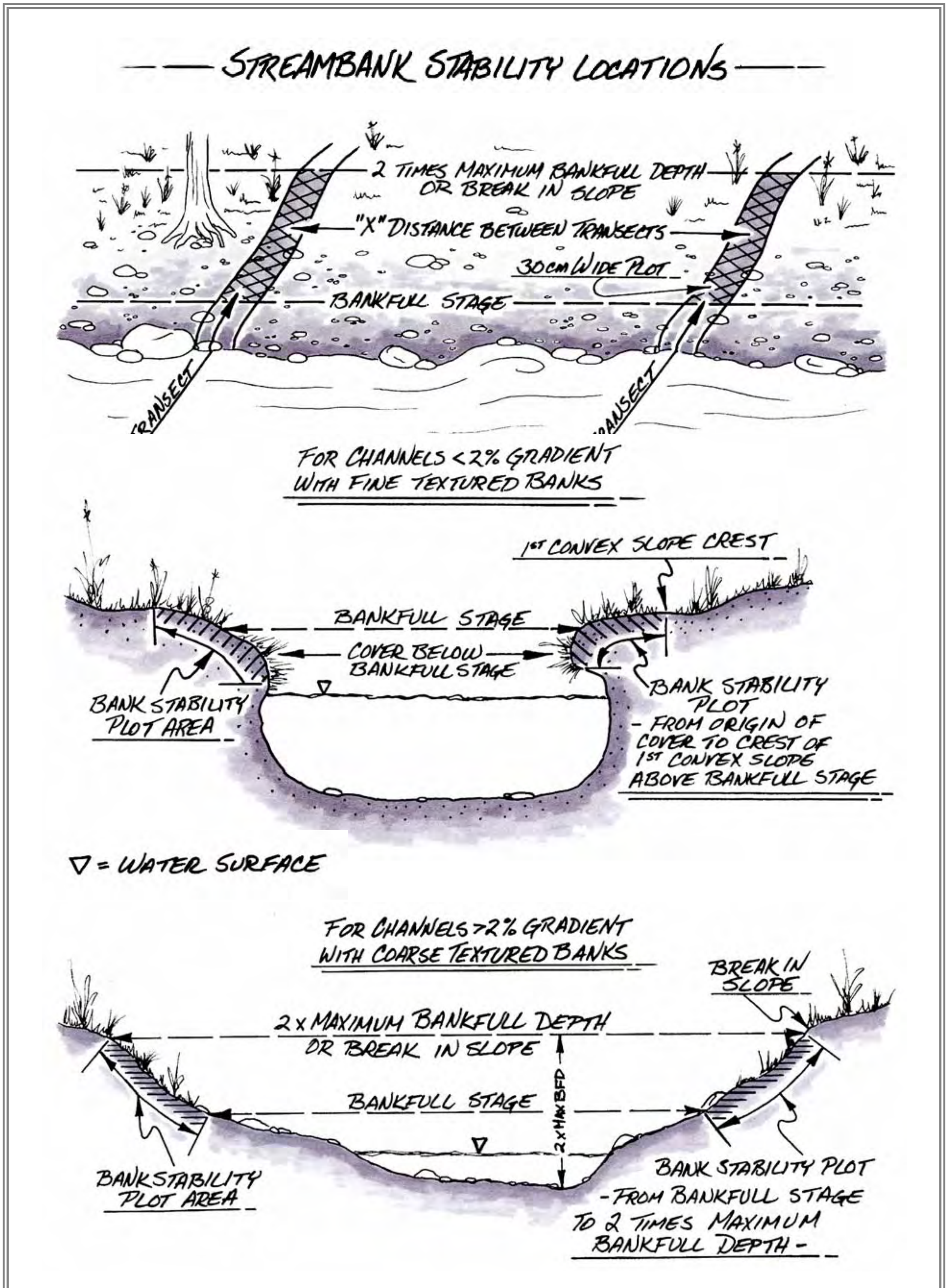


Figure 5 – Streambank Stability

Stream Shading

(Core Attribute)

Importance:

Stream temperature has impacts on the health, behavior, and survival of aquatic organisms and is strongly influenced by streamside shading. Streamside vegetation is a primary source of energy to most streams. Manipulation of riparian vegetation that affects shade to aquatic systems is a key Forest Service management concern.

Objective of This Measurement:

Determine the average canopy cover in the survey segment.

How Many Measurements to Take:

Fifty, one at each transect.

Where to Take the Measurement:

At mid-wetted width of the channel, approximately 0.3 m (12") above water surface.

How to Take the Measurement:

Stream shading is measured using a Solar Pathfinder. At each sample location, level the instrument facing south at a height of approximately 0.3 m above the water surface. Before taking measurements, make sure that the declination on the pathfinder is correct, and that the path for the appropriate latitude is on the pathfinder. Look for the reflection of the sky and objects providing shade (trees, ridges, etc.) on the instrument dome, as viewed from no more than 15 degrees from vertical, at a distance between 0.3 (12") and .45 m (18").

Use the August sun path. Add the shaded sections along the sun path to yield the percent shade for each sample. When totaling the shade numbers, observe the portion of each section that is shaded. Consider fractions of individual sections, i.e. if half of a "6" section is shaded, record "3"; if 2/3 of "3" section, record "2," etc. Document the total number on Form 9. See Figure 6.

Tips for Using Pathfinder:

Glare from the sun can severely affect the observer's ability to read shade values. It may be helpful to hold a clipboard or hand above the pathfinder in a position that reduces glare while still allowing shade to be observed.

<u>Vendor Information – Solar Pathfinder</u>

Solar Pathfinder
3680 HWY 438
Centerville, TN 37033
(931) 593-3552
http://solarpathfinder.com

Reference:

Platts et al. 1987

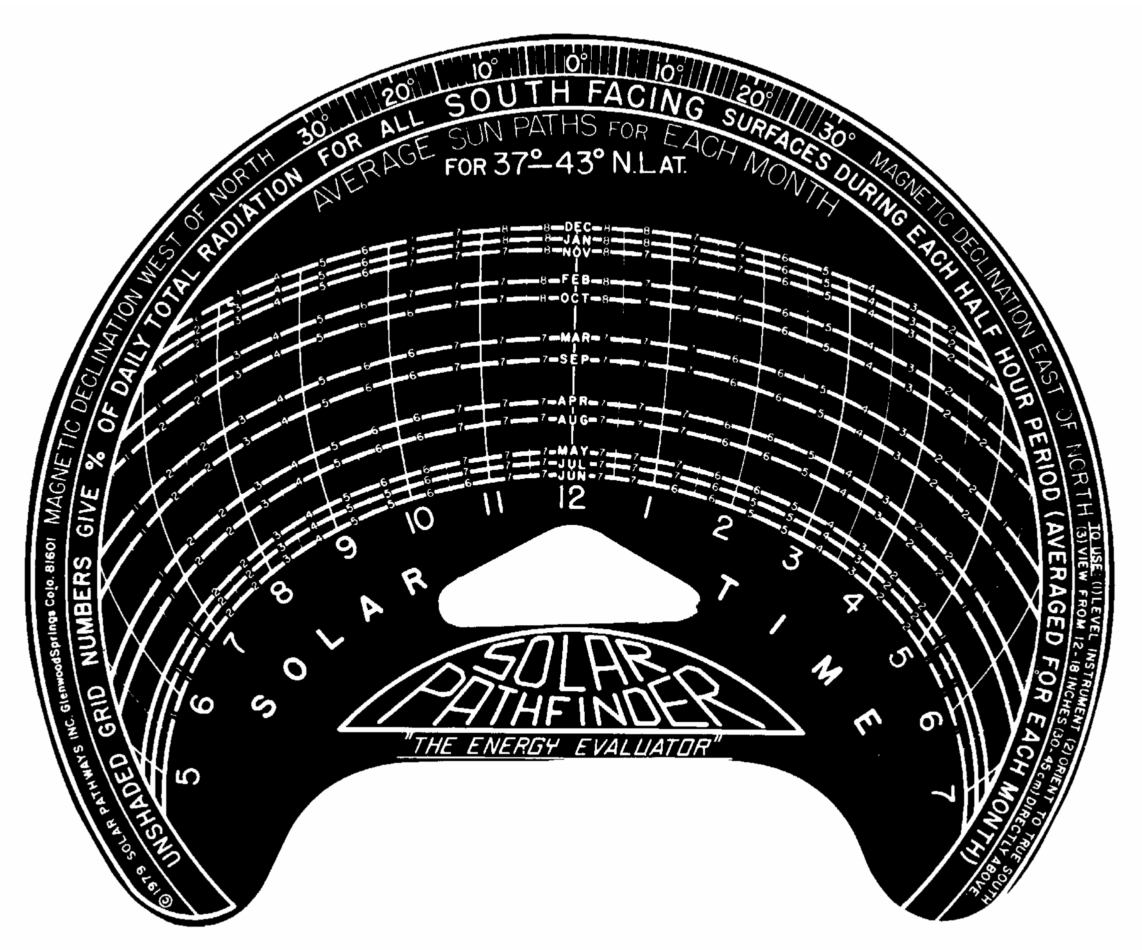


Figure 6 – Solar Pathfinder Sun Path

Streamshore Water Depth

(Core Attribute)

Importance:

This attribute is an important indicator of channel morphology in low gradient streams (<2%) with fine textured banks. Streamshore water depth is closely related to other indicators of channel conditions (bank angle and undercut bank) of channel conditions that provide cover and resting areas for aquatic species. Platts, et al. (1987) note that streamshore depth is critical for young-of-the-year salmonids.

Objective of This Measurement:

To quantify the average streamshore depth in the survey segment.

How Many Measurements to Take:

One hundred: one measurement at both shore edges on each of the fifty transects.

Where to Take the Measurement:

At the edge of water on each shore, at each of the fifty transects (two measurements per transect, one on each side of the stream).

Note: this attribute is measured only on streams where the gradient is less than 2% and the stream has fine textured streambanks.

How to Take the Measurement:

Measure the water depth at water’s edge (see Figure 7).

If the bank angle is equal to or less than 90 degrees, the water depth will be greater than zero. The staff or rule should be held vertically, and water depth measured to the nearest .01 m.

If the bank angle is greater than 90 degrees, the water depth will be recorded as zero. For bank angles greater than 90 degrees, do not record water depths observed in micro-recesses at water’s edge since they are not representative of the dominant bank angle.

References:

Platts et al. 1987

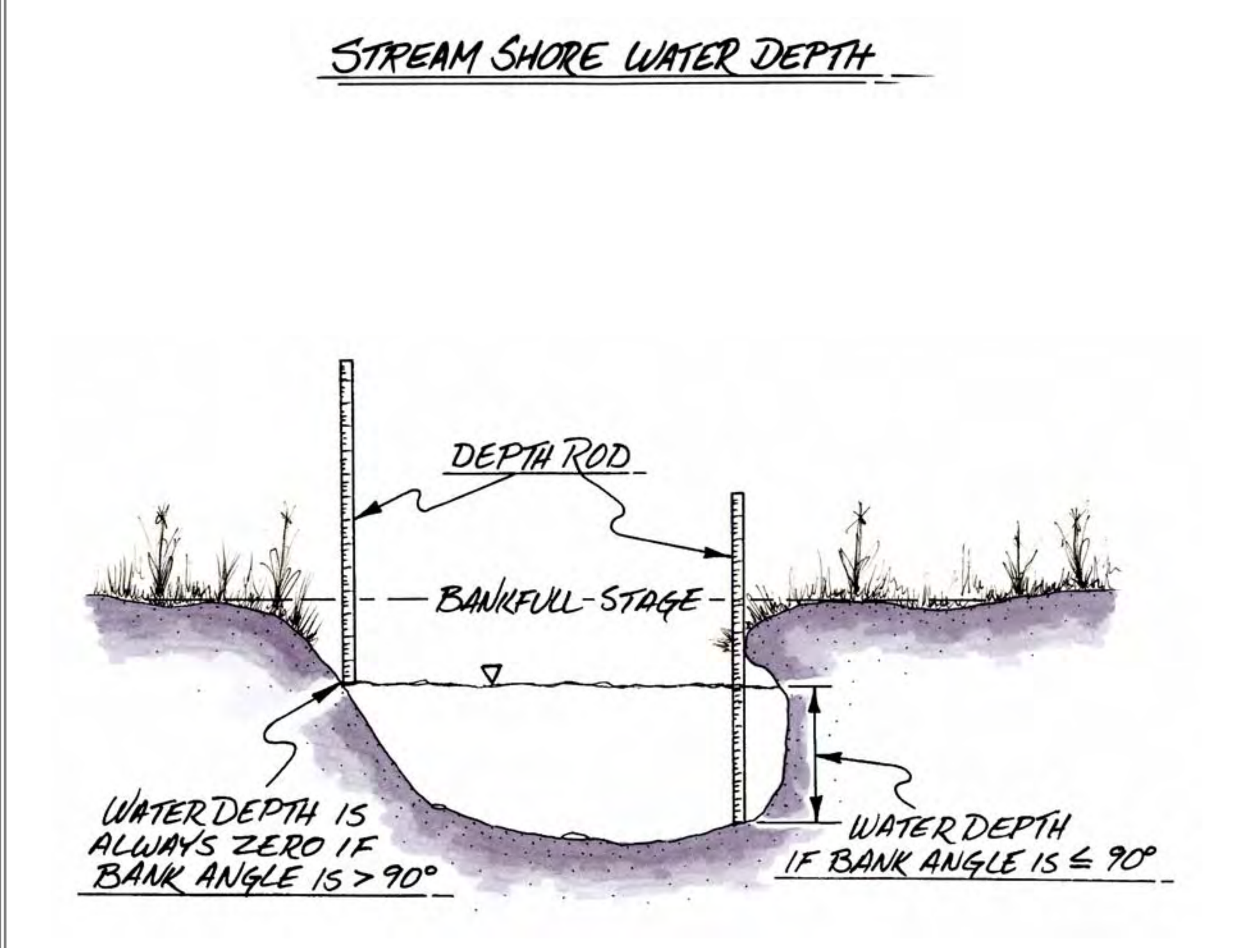


Figure 7 – Streamshore Water Depth

Streambank Angle

(Core Attribute)

Importance:

Bank angle is an important factor in aquatic habitat on many stream reaches. It influences shading, vegetation potential, bank stability, etc. Streambanks that are vertical or undercut provide more habitat value than banks sloping away from the streambed. Undercut banks provide excellent cover for fish, and are recognized as a component of healthy streams.

Objective of This Measurement:

To quantify bank angle and the frequency of vertical and undercut banks in the survey segment.

How Many Measurements to Take:

One hundred: one measurement at both shore edges on each of the fifty transects.

Where to Take the Measurements:

On the left and right bank at each channel transect.

Note: this attribute is measured only on streams where the gradient is less than 2% and the stream has fine textured streambanks.

How to Take the Measurement:

Bank angle is the measure of the dominant angle of the streambank between the bottom of the bank and bankfull stage. The bottom of the streambank is the point of greatest slope change between the streambed and the bank.

To measure bank angle, lay the depth rod on the streambank perpendicular to flow between the bottom of the streambank and bankfull stage (see Figure 8). Measure the angle that represents the greatest length between the bottom of the bank and bankfull stage (e.g., the dominant angle). Place a clinometer on the top of the depth rod and record the angle. If the bank slopes away from the streambed, the bank angle will be greater than 90 degrees. To obtain the actual bank angle for these banks, subtract the value on the clinometer from 180 (i.e., the clinometer reading is 30; 180 - 30 = 150). If the bank is vertical or undercut, the bank angle will be equal to or less than 90 degrees, respectively, and can be read directly from the clinometer.

If the bank is inaccessible at a transect (i.e. transect crosses a very deep pool with bedrock banks, extremely dense vegetation or a debris jam) estimate the bank angle. Circle estimated values on the data sheet and make a note in the comments why it was estimated.

Reference:

Platts et al. 1987

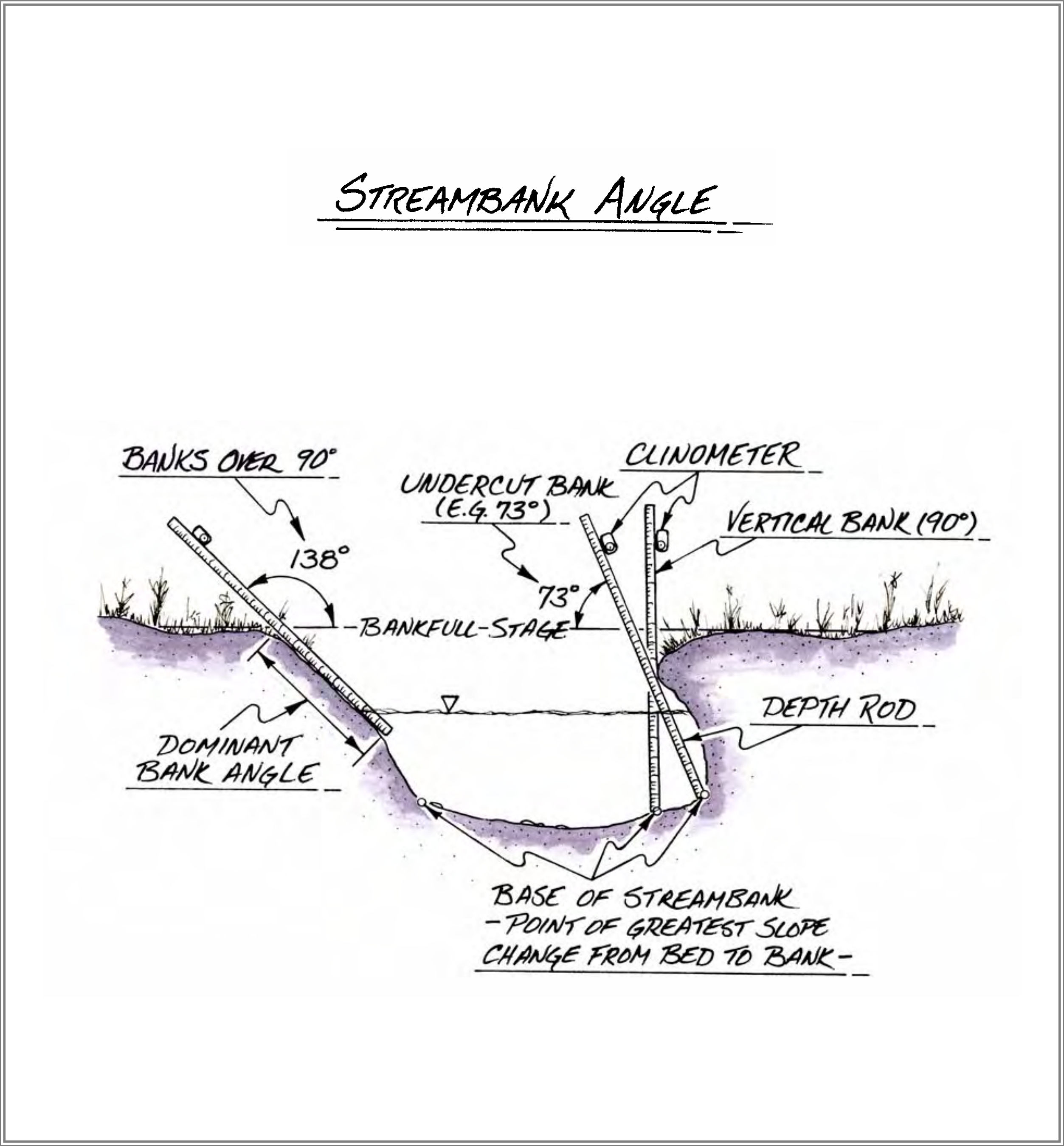


Figure 8 – Streambank Angle

Aquatic Fauna

(Core Attribute)

Importance:

Surveys such as SCI are sometimes the only record of the presence of aquatic species. With the increasing number of species of concern (TES species, mollusks, etc.) and increasing occurrences of exotic species (zebra mussel, mud snails, bullfrogs, etc.), having surveyors look for aquatic species and noting their presence is important in understanding frequency and distribution patterns.

This attribute is intended to identify the basic aquatic biota present in the stream, and may identify the need for more intensive biological surveys. Communication with other agencies is important in order to make surveyors aware of any key species that may be present, as well as make appropriate identification keys available.

Objective of This Measurement:

Document presence of aquatic fauna.

How Many Measurements to Take:

Take one at each transect. In addition, note any key species observed throughout the sensitive reach.

Where to Take the Measurements:

One at each transect in the survey segment, and throughout the sensitive reach.

How to Take the Measurement:

At transects: Note any species seen within eyesight of each transect. Carefully look around boulders and near the shore to cover all microhabitats at each transect. Record the four-letter species code for herptofauna (Appendix E) or the numeric code for fish species (Appendix F). Do not leave blank spaces on the form – use a dash or write “none.”

Between transects: Throughout the sensitive reach note any species observed during any of the survey passes. Record observations unrelated to transect measurements on Form 10. Note the location of the observation, the species name and relevant information, and take photos if possible.

V^*_W

(Optional Attribute)

Importance:

Pools are important habitat components for fishes and other aquatic organisms. Accelerated inputs of fine sediment are known to affect pools by reducing their volume, particularly during periods of low discharge. V* is a measure of the relative volume of fine sediment in a pool. The weighted mean value of V* for a reach, V^*_W, is a sensitive indicator of a channel's response to the volume of fine sediment delivered from its watershed.

Objectives of This Measurement:

For a given reach, determine the weighted mean value of the relative volume of fine sediment in pools (V^*_W). This can be used to assess stream condition, monitor trends over time, or detect and evaluate the effects of discrete sediment sources within a watershed.

Use and Limitations of V^*_W:

V^*_W is a very sensitive indicator of fine sediment in pools. However, its usefulness is limited to channels in which significant volumes of fine sediment can be deposited in pools. Therefore, it is not typically used in volcanic and metamorphic terrains.

V^*_W is an optional attribute because it is time consuming, typically requiring a three-person crew one to three days to characterize a single reach. Forests should therefore use discretion prior to measuring this attribute.

Hilton and Lisle (1993) should be consulted for additional information on uses and limitations.

Equipment:

The minimum equipment required is two tapes, chaining pins, and a graduated rod long enough to measure water depth plus fines depth in the deepest part of the pools to be measured. A palmtop computer with Excel is also highly recommended for selecting transect locations, entering data, calculating V*, calculating V^*_W, and computing the standard error for V*w in the field. This can be done quickly and easily using the "fips.xls" and "varv.xls" spreadsheets available at http://www.fs.fed.us/psw/topics/water

How Many Observations to Make:

The number of pools evaluated in a reach typically ranges from 6-20. If values in a given reach are relatively similar (V* for all pools differs from the mean by less than 20%), measurements should be taken in 6-10 pools. Where values vary moderately (V* for all pools is within 20-30% of the mean), measure 10-15 pools. Up to about 20 pools are needed in reaches where V* is highly variable (V* for some pools differs from the mean by more than 30%).

At each pool, measurements of water depth and fine sediment depth are taken at 4-10 cross-sections, depending on the complexity of the pool and the desired accuracy of the measurement. At each of cross-section, measurements are made at 7-16 locations.

Where to Take the Measurements:

Measurements of water and fine sediment depths are taken at various points at cross-sections in pools. For this attribute, measurable pools are defined as areas of the channel that have significant residual depths (i.e., the deepest part of the pools is greater than two times the depth of water flowing out of the pools), have relatively flat water surfaces during low flows, and occupy most of the channel (i.e., the thalweg and at least have the width of the low flow channel). These criteria can be modified, as long as they are repeatable and consistent across all reaches that are compared. Pools with unclear boundaries should be avoided.

How to Take the Measurements:

The following text is intended only to summarize the methods for measuring and calculating V^*_w. The more detailed protocol described in Hilton and Lisle (1993) should be consulted prior to taking these measurements.

Conduct a reconnaissance survey of the reach to identify pools that meet the definition provided above and number them while proceeding along the channel. During this survey, determine what constitutes fine sediment for this particular channel and the estimate the variability of V* between pools. Based on this variability and the desired accuracy, randomly select 6-20 pools for measurement[1].

The grain-sizes that constitute fine sediment for a particular channel is determined by evaluating the distribution of particle sizes and patterns of sediment deposition in the channel. Fine sediment in a reach is defined as material that is distinctly finer than the bed surface (median particle size of fine sediment is 10% of the median particle size of the bed surface) and can be distinguished from underlying coarser sediment by probing with a metal rod. For most channels, deposits with a median grain-size less than 11mm can be considered fine sediment, but this can increase to 16mm for channels with large surface particles and high transport capacity.

For each selected pool, measure riffle-crest depth and define the pool boundaries. Water depth at the riffle crest is measured at 5-20 evenly spaced locations across the thalweg. Water depths and fine-sediment depths are measured in the “scoured residual pool,” which is the residual pool that would result if all the fine sediment were removed.

Volumes of water and fine sediment are calculated from measurements of water and fine-sediment depths along a series of cross-sections in the pool. These measurements are made as follows:

Stretch a tape along the length of the pool, from the upstream end to the furthest point on the riffle crest or along the longest dimension of the pool. This tape must be straight, since bends will distort the volume calculations. If the pool is so irregular that a bend cannot be avoided, divide the pool into sections and measure each separately.

Draw a sketch map of the pool, showing the locations of the upstream end of the pool, riffle crest, areas of fine-sediment deposition, and major feature of the pools, such as logs and outcrops.

Decide on the number of cross-sections and the distance between depth measurements. The appropriate sampling intensity depends on the complexity of the pools and the desired accuracy. The number of cross-sections typically varies between 4 and 10 and the number of measurements at each cross-section ranges from 7-16, depending on the length of the cross-section.

Use the “fip.xls” spreadsheet to determine the locations of cross-sections and the depth measurements along each cross-section.

Run a tape perpendicular to the length-wise tape at each cross-section. Measure water depth and thickness of any fine sediment present at each measurement point with a graduate rod. Fine-sediment depth is determined by probing with the rod until a change in resistance is felt as it strikes coarse material. A small sledge is useful for probing deep deposits. The cross-section begins at the edge of the course pool where water depth plus fines depth becomes greater than riffle-crest depth. Enter the total water depth and fines

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[1] *The exact number of pools needed to obtain the desired accuracy will be quantitatively confirmed prior to leaving the field.*

depth data at both edges of the pool and at regular intervals across the pools into “fip.xls.” If a fines deposit deep enough to be included in the course pool extends above the water surface, record height above the water surface as a negative water depth.

After completing all measurements at the pool, use the spreadsheet to compute the total water volume, fine sediment volume, and V*. Copy the water volume and fine sediment volume into the “varv.xls” spreadsheet and move on to the next pool. Repeat the steps above.

When all pools have been measured, use “varv.xls” to estimate the total and mean pool water volumes for the reach, total and mean fine sediment volumes, V^*_W, and the standard error for V^*_W. Compare the standard error of V^*_W to the desired accuracy. If the error exceeds the desired accuracy, measure V* in additional pools until the desired accuracy is attained.

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Lisle and Hilton 1991

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