Draft 2010 Trust Fund Geomorphic Protocols: Pebble Counts

Recommended Equipment

Representative pebble count datasheet printed on Rite-in-the-Rain paper
Active bed riffle pebble count datasheet printed on Rite-in-the-Rain paper
Sand gauge reference cards (1 per surveyor)
Metric ruler (with mm markings) (1 per surveyor)
Metal hand tally counter (clicker) (1 per surveyor)
Clipboard
Pencil

Representative Pebble Count Instructions

1) Walk the entire study reach, paying attention to the distribution and lengths of riffles, runs, pools, and glides within the reach
2) 10 transects (perpendicular to flow) within the reach will be sampled for pebbles. Determine the number of riffle, run, pool and glide transects needed based on the proportion of the reach they occupy (for example, if the reach is 40% riffle, 20% run, 30% pool, and 10% glide, one would sample 4 transects in riffles, 2 in runs, 3 in pools, and 1 in a glide).
3) Identify bankfull on both sides of the channel at your first transect location and determine the sampling interval (sample at equal increments across the entire bankfull channel).
4) Begin the pebble count below the bankfull elevation. Do not include bankfull particles if the channel width is small as 20% of samples (2 out of 10) may skew the particles that make up the boundary of the channel. Often, a 5% bank sample is taken (one sample every other transect). To avoid bias of selecting larger particles, the observer should look away from the channel bed and select the first particle touched by the tip of index finger at observer's toe.
5) Measure the length of the intermediate axis in millimeters and mark a dot in the correct column and row on the data sheet. (The intermediate axis is neither the longest nor the shortest of the three mutually perpendicular sides of the particle). If the particle is linear-shaped, average the axes. If the particle is very small and a measurement cannot be taken (e.g., sand or silt), sand gauge reference cards can help the surveyor classify the particle appropriately.
6) Sample each transect moving perpendicular to the stream banks until 10 random particles equally spaced across the transect have been measured. Repeat this procedure until 10 random particles at each of 10 different transects have been measured in proportion to the bed features of the reach for a total of 100 particles assessed. A metal hand tally counter/clicker can be used to help keep track of counts.
7) The field QC Officer must perform QC checks on all datasheets. The field QC officer should tally up counts in each cell of the datasheet to ensure that a total of 100 particles were measured and recorded.
8) Record data using the Ohio Department of Natural Resources Reference Reach Spreadsheet (available free from http://www.dnr.state.oh.us/tabid/24137/Default.aspx), or other transferable program.

Active Bed Riffle Pebble Count Instructions

1) Repeat Steps 5-8 from the Representative Pebble Count Instructions (above), only sampling on the active bed of the riffle cross-section (100 particle counts).

Related References

Harrelson, C.C, C.L. Rawlins, and J.P. Potyondy. 1994. Stream channel reference sites: An illustrated guide to field technique. Gen. Tech. Rep. RM-245. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Ohio Department of Natural Resources (ODNR), Division of Soil and Water Resources – Stream Morphology. 2010. *STREAM Modules*. http://www.dnr.state.oh.us/tabid/24137/Default.aspx

Rosgen, D.L. 2008. River Stability Field Guide. Wildland Hydrology. Pagosa Springs, CO.

Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions of American Geophysical Union.

Draft 2010 Trust Fund Geomorphic Protocols: Cross Sections

Recommended Equipment

Cross-section datasheet printed on Rite-in-the-Rain paper
Clipboard
Pencil
Self-leveling laser level and audible receiver
Tripod
Top-setting, telescoping survey rod
300-foot measuring tape
Bank pins
Survey caps
Small sledgehammer
Wooden stakes
Flagging
Hammer and aluminum nails
Bright-colored spray paint
GPS unit
Digital camera
Hand shears

Cross-Section Instructions

1) Within the reach, choose a representative riffle area and representative meander bend/pool area to install the two cross-sections. The areas should be free from direct anthropogenic alterations and reflective of local geology such that the stream is able to adjust its banks under its current flow regime. The riffle location should be chosen along a relatively straight stretch of the stream when possible. Locate cross-sections across the middle of each feature. Establish the cross-sections perpendicular to the direction of flow.

2) Before measuring the cross-section, install and label rebar monuments and top with rubber survey caps. Monuments should be located sufficiently back from the top of bank to prevent them from being lost due to bank erosion. Monuments should be geo-referenced with GPS and flagged. Record GPS coordinates at the cross-section monuments on the cross-section data sheet. Flagged wooden stakes installed behind each pin enable location of monuments on re-visits.

3) Setup the surveying instrument in a location where the entire cross-section can be viewed. The instrument should be placed at an elevation higher than the highest feature required for the survey. Ideally, only one instrument setup will be required to survey the entire cross-section; however, determining the width of the flood-prone area may require multiple instrument setups due to dense foliage.

4) Stretch the tape across the channel (**zero on left bank facing downstream**) making sure the tape is perpendicular to the direction of flow. The zero end of the tape should be secured directly above the left bank pin and the tape should be taut and secured behind the right bank pin. If a survey of the reach longitudinal profile is also being conducted, record the station along the longitudinal profile where the cross section tape crosses the longitudinal profile tape.

5) Survey the top of the rebar pin installed on the left bank. Place the rod firmly on top of the pin and hold it as steady and vertical/plumb as possible while moving the receiver up/down until the audible tone indicates a proper reading. Once the elevation is determined, the rod operator should call out to the recorder the reading from the rod in hundredths of feet. Record this as station 0 (zero) and the corresponding elevation in hundredths of feet on the datasheet, making note that it is on top of the left end pin. Move the rod beside this pin level with the ground elevation and take another reading. Record this as station 0 as well, making note that it is beside the left end pin.

6) Continue surveying across the cross-section obtaining rod readings at major breaks in bed elevation. Typically, 15 to 20 points are necessary including key features such as top of left bank (TOB-L), left bankfull (LBF), left edge water (LEW), Thalweg (THL), right edge water (REW), right bankfull (RBF) and top of right bank (TOB-R). Other significant depositional features or breaks in slope should also be surveyed. See Rosgen (1996) and *Identifying Bankfull Stage in Forested Streams in the Eastern United States* video produced by the USDA Forest Service (2003)for additional guidance in determining bankfull elevation. Record the distance on the tape (station), the corresponding rod height and feature notes on the cross-section datasheet. Record station measurements in tenths of feet and rod heights in hundredths of feet.

7) If banks are severely undercut or slumping, an additional measuring device (e.g., measuring rod or yard stick) can be used as a base for the main surveying rod. Hold the auxiliary rod horizontally against the bank at the first location of undercut, and perpendicular to the main survey rod, keeping it as level and steady as possible. Rest the main survey rod on top of the auxiliary rod, making note of the distance of the base of the main rod along the auxiliary rod (reading 1) and the stationing of the main rod on the survey tape where they cross (reading 2). Move the receiver on the main rod up/down until the audible tone indicates a proper reading and record the elevation. Then determine stationing for the undercut by subtracting reading 1 from reading 2. Then move the entire setup down to the next point of measurement on the undercut bank and repeat until the bank is no longer undercut.

8) At the end of the cross-section, record an elevation reading beside the rebar pin installed on the right bank, making note that it is beside the right end pin. Move the rod on top of the pin and record the elevation of the pin (*keeping the station the same*), making note that it is on top of the right end pin. Top of pin elevations can be used in conjunction with or as benchmark elevations to match up survey data from year to year.

9) Determine the bankfull depth by subtracting the recorded bankfull elevation from the recorded thalweg elevation. Determine the flood-prone elevation by subtracting twice the calculated bankfull depth from the recorded thalweg elevation. Use this elevation to measure the flood-prone area width (width of the channel at an elevation that is two times the maximum bankfull depth). If this elevation was covered during the cross-sectional survey on both the right and left side of the stream, measure the distance between the location of these two points, recording it as the width of the floodprone area. Else, move the rod upslope from both the left pin and right pin online with the cross section until this elevation is reached. Mark the locations on each bank and measure the distance between these two points, recording it as the width of the floodprone area.

10) Take four photographs of each cross section and record the photograph number, time stamp, and location information on the datasheet. Take one photograph from above the cross-section

looking downstream, one from below the cross-section looking upstream, one from the left bank looking at the right bank, and one from the right bank looking at the left bank.

11) While the measuring tape is still deployed and level is still set up, the field QC Officer must make sure that all measurements have been recorded in the field and photographs taken. The field QC Officer must perform QC checks on all datasheets. All field datasheets should be filled out as accurately and completely as possible. Any errors found should be marked through with a single line, with a date and the corrector's initials noted beside the marked-out data.

12) Plot cross-section using the Ohio Department of Natural Resources Reference Reach Spreadsheet (available free from http://www.dnr.state.oh.us/tabid/24137/Default.aspx), or other transferable program.

Related References

Anne Arundel County, MD. 2008. SOP for Stream Cross Sectional Measurement, Revision No. 1. Prepared by: Christopher J. Victoria. February 8, 2008. Annapolis, MD

Ohio Department of Natural Resources (ODNR), Division of Soil and Water Resources – Stream Morphology. 2010. *STREAM Modules*. http://www.dnr.state.oh.us/tabid/24137/Default.aspx

Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

Rosgen, D.L. 2008. *River Stability Field Guide*. Wildland Hydrology. Pagosa Springs, CO.

USDA Forest Service. 2003. Identifying Bankfull Stage in Forested Streams in the Eastern United States. Video available online http://www.stream.fs.fed.us/publications/bankfull_east.html

Draft 2010 Trust Fund Geomorphic Protocols: Longitudinal Profile

Recommended Equipment

Longitudinal Profile datasheet printed on Rite-in-the-Rain paper
Clipboard
Pencil
Self-leveling laser level and audible receiver
Tripod
Top-setting, telescoping survey rod
300-foot measuring tape
Bank pins
Survey caps
Small sledgehammer
Wooden stakes
Flagging
Hammer and aluminum nails
Bright-colored spray paint
GPS unit
Digital camera
Hand shears

Longitudinal Profile Instructions

1) Locate the reach starting and ending points. Reach length should include at least two meander wavelengths, 20 bankfull widths, or a minimum of 300 feet. Reach must encompass locations chosen for riffle and meander bend/pool cross-sections. Reach should start and end at the top of a stable channel feature. If possible, the feature type of the start point should be the same as the feature type for the end point. For the best calculations of slope, the start and end points should be at the top of a riffle.

2) Before measuring the profile, install and label rebar or concrete monuments to serve as benchmarks. Install 2 monuments (one on either bank) at the downstream end of the profile and top with rubber survey caps. Install at least 1 monument on a bank at the upstream end of the profile and top with rubber survey cap. Monuments should be located sufficiently back from the top of bank to prevent them from being lost due to bank erosion. Monumented benchmarks should be geo-referenced with GPS and flagged. Flagged wooden stakes installed behind each rebar pin enable location of monuments on re-visits.

3) Setup the instrument with a clear line of sight to both downstream monuments, and where as much of the monitoring reach as possible is visible. Choose instrument locations carefully to minimize the number of times you need to reposition. The instrument should be placed at an elevation higher than the highest feature required for the survey. Tripod legs should be spread sufficiently to ensure a stable base, and the feet should be pressed firmly into the ground.

4) At the downstream end of the reach, stretch a measuring tape across the channel between the monuments so that the tape crosses the starting point. Record the locations of the monuments on a datasheet using a site sketch and record the distance on the tape of both monuments and the start point.

5) Beginning at the downstream starting point, secure the end of a 300-foot measuring tape and position the tape along the centerline of the channel (if flow permits) or along edge of water to obtain stream length stationing, keeping the tape as tight as possible to eliminate slack. Record how the tape was laid out (center of channel versus water's edge) on datasheet to enable repeatability in future assessments. Subsequent tapes should be run in the same manner with the start point of the new tape matching up with the end point of the previous tape to ensure consistent stationing.

6) Place the rod firmly on top of each downstream benchmark and hold it as steady and vertical/plumb as possible while moving the receiver up/down until the audible tone indicates a proper reading. Once the elevation is determined, the rod operator should call out to the recorder the reading from the rod in hundredths of feet. Record the values in the backsight (BS) column on the datasheet.

7) Place the rod at the thalweg at station 0 on the tape. Place the rod firmly on the bed material and hold it as steady and vertical/plumb as possible while moving the receiver up/down until the audible tone indicates a proper reading. Once the elevation is determined, the rod operator should call out to the recorder the reading from the rod in hundredths of feet.

8) At the same location, record the water depth reading off the rod in hundredths of feet. Also record the station and feature type in the notes column. Features should be recorded as follows: Top of Pool (TOP), Maximum Depth of Pool (MDP), Top of Glide (TOG), Top of Riffle (TOR), Top of Run (TON).

9) Continue the same sequence moving upstream to the top of major bed features (e.g. pool, glide, riffle, run) and to the deepest part of pools and repeat the same measurements at the new stations. When compound features occur (double/triple pools, etc.) they should be noted accordingly. Location along the profile (station) should be recorded in hundreds of feet + tens of feet. hundredths of feet (for example, the station one-hundred ninety five and five-tenths (195.5) should be recorded as 1+95.5).

10) At the top of each riffle and at any other locations where bankfull features are confidently recognizable, place the rod at a bankfull indicator and determine the elevation recording it on datasheet as BKF. See Rosgen (1996) and *Identifying Bankfull Stage in Forested Streams in the Eastern United States* video produced by the USDA Forest Service (2003)for additional guidance in determining bankfull elevation. Also, whenever a bankfull elevation is recorded, record a corresponding top of low bank elevation. Place the rod on top of the lowest bank (i.e., the bank that would overtop first in the event of an out of bank flow) and determine the elevation recording it as TOB-R (for right bank) or TOB-L (for left bank). (Note that all language referring to bank location within the survey reach are oriented facing downstream (i.e., "left bank" is the bank on the left side when facing the downstream direction and vice versa). If the top of the low bank is slumping due to partial bank collapse or other reason, the TOB reading should be taken further back where the bank is stable.

11) At cross-section intersection locations, note the distance (station) on the longitudinal profile tape in tenths of feet. Take a measurement on top of both cross-section end point monuments to obtain common elevations of the cross-section and longitudinal profile.

12) If the entire profile is not able to be surveyed from the initial location of the level due to distance and/or visual obstructions, a turning point will be needed, and must be taken prior to moving and

re-setting the laser. The turning point should be taken from a location that provides a stable elevation that will not shift between shots (e.g., large rock boulder, tree stump, concrete benchmark, firmly packed soil, etc.). The point collected using the first laser setup is recorded as the foresight (FS). Repeat Step 3 for laser setup at a new location with clear views of the turning point and the next section of stream to survey, then re-shoot the turning point. This will be recorded as the backsight (BS).

13) To complete the survey at the top end of the reach, record the feature, thalweg elevation and water depth at the last station. Then place the rod firmly on top of the upstream monumented benchmark and hold it as steady and vertical/plumb as possible while moving the receiver up/down until the audible tone indicates a proper reading. Once the elevation is determined, the rod operator should call out to the recorder the reading from the rod in hundredths of feet. Record this value on the datasheet. Top of pin elevations from the upstream and downstream monuments can be used to match up survey data from year to year.

14) While the measuring tape is still deployed, take photographs moving along the reach, recording the profile stations (in feet) where photographs are taken, the photograph number and time stamp, and a description of the photograph as well.

15) While the measuring tape is still deployed and level is still set up, the field QC Officer must make sure that all measurements have been recorded in the field and photographs taken. The field QC Officer must perform QC checks on all datasheets. All field datasheets should be filled out as accurately and completely as possible. Any errors found should be marked through with a single line, with a date and the corrector's initials noted beside the marked-out data.

16) Enter the data and plot the longitudinal profile using the Ohio Department of Natural Resources Reference Reach Spreadsheet (available free from http://www.dnr.state.oh.us/tabid/24137/Default.aspx), or other transferable program.

Related References

Anne Arundel County, MD. 2012. Picture Spring Branch Longitudinal Profile Procedure, Revision No. 0. Prepared by: Christopher J. Victoria. April 10, 2012. Annapolis, MD

Ohio Department of Natural Resources (ODNR), Division of Soil and Water Resources – Stream Morphology. 2010. *STREAM Modules*. http://www.dnr.state.oh.us/tabid/24137/Default.aspx

Rosgen, D.L. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

Rosgen, D.L. 2008. *River Stability Field Guide*. Wildland Hydrology. Pagosa Springs, CO.

USDA Forest Service. 2003. Identifying Bankfull Stage in Forested Streams in the Eastern United States. Video available online http://www.stream.fs.fed.us/publications/bankfull_east.html

Standards for Rosgen Bank Erosion Hazard Index

1. PURPOSE

The Bank Erosion Hazard Index (BEHI) is a field method to evaluate bank erodibility potential at a typical study bank or a study bank length. Several bank characteristics are measured including top of bank and bankfull height, rooting depth, root density, bank angle, percent bank protection, bank composition, and bank material stratification. This information, used in conjunction with field estimated near bank shear stress (NBS) ratings, allows one to predict bank erosion quantities and rate of erosion using existing bank erodibility curves developed by Rosgen for Yellowstone and Colorado (Rosgen 2001). A bank erodibility curve is a graph that relates combinations of BEHI and NBS ratings with actual erosion rates. Repeated measurements at monumented cross sections for representative conditions allow for validations of quantities and rates.

Surveyors should also read and understand the Near Bank Shear Stress (NBS) Standards prior to using these standards in the field as the BEHI and NBS are generally conducted at the same time.

The purpose of this standard is to document methods for collecting and recording field data.

2. METHODS

The methods, procedures, and definitions presented within this protocol are drawn from several sources, including:

- Brady, N.C. 1990. The nature and properties of soils. Tenth edition. Macmillan Publishing Co., NY.
- Rosgen, D. L. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, Colorado.
- Rosgen, D.L. 2001. A practical method to predict stream bank erosion. In: U.S. Subcommittee on Sedimentation. Proceedings of the federal interagency sedimentation conferences, 1947 – 2001.
- Rosgen, D.L. 2003. Wildland Hydrology. 2003. River Assessment and Monitoring Field Guide.

3. DEFINTIONS

- Duripan: mineral soils, in the form of a hard pan, and strongly cemented by silica.
- Fragipan: mineral soils in the form of a brittle pan, usually loamy textured, and weakly cemented.
- Hemic soil materials: organic soils with an intermediate degree of organic material decay.

4. FIELD EQUIPMENT

- Field Forms: (1) Rosgen Reach BEHI and NBS Field Form and (2) Rosgen - XS BEHI Bank Profile Field Form.
- Completed geomorphic map, sketch, or aerial photograph with mylar overlay.
- Survey rod, pocket rod, and clinometer.
- Digital camera.

5. BEHI CALIBRATION, MEASUREMENTS, AND REVIEW

When several workers are assessing a watershed, they should initially work together to familiarize themselves with the existing bank conditions and calibrate their observations. The BEHI requires and examination of the amount of bank material susceptible to erosion processes, such as, freeze/thaw, rotational failure, mass wasting, water piping, etc. Take measurements in feet and tenths-of-feet, degrees, and percentages. Prior to completing the BEHI for the reach or cross section, the observer(s) should review the BEHI data and consider if the results are representative of the bank conditions.

6. BEHI FIELD PROCEDURES

Surveyors will conduct two types of BEHI assessments: 1. Reach BEHIs to predict sediment contributions from bank erosion, and 2. Cross section BEHIs to validate bank erosion rates. The field methods for selection are discussed separately below. In some situations, such as an entrenched stream, it may be necessary to assess bank conditions on each side of the stream.

1. <u>Reach BEHI Assessment</u>

   a. Assess all stream banks prone to erosion, excluding banks with significant deposition or stable concrete revetment (*i.e.*, no indications of erosion along the revetment).

   b. Partition the study banks based on different combinations of BEHI and NBS conditions (*e.g.*, study bank with one BEHI rating but two NBS conditions should be assessed as two separate study banks).

   c. Note the study bank locations on an aerial photograph with mylar overlay, site sketch, or a geomorphic map.

   d. Evaluate BEHI conditions for the entire length of study bank

   e. Draw a typical bank profile in the space provided in the field form, with illustrations of rooting depth, bank protection, bank composition, and bank stratification.

   f. Photograph the study bank with a surveyor or survey rod in the foreground as reference.

   g. Identify reach BEHI location and length on the geomorphic map.

   h. If a repeat survey, use the same reach BEHI bank map labels, if BEHI and NBS conditions are the same.

   i. Use the same reach BEHI bank map labels and add a sequential letter if additional bank labels are required (*e.g.*, Bank 9, Bank 9A, and Bank 9B).

2. <u>Cross Section BEHI Assessment</u>

   a. Surveyors should conduct the cross section BEHI assessment following the completion of each cross section survey.

   b. BEHIs at monumented cross sections should represent the various BEHI and NBS combinations found in the study reach in order to validate bank erosion predictions.

   c. Assess the study bank directly in line with the cross section.

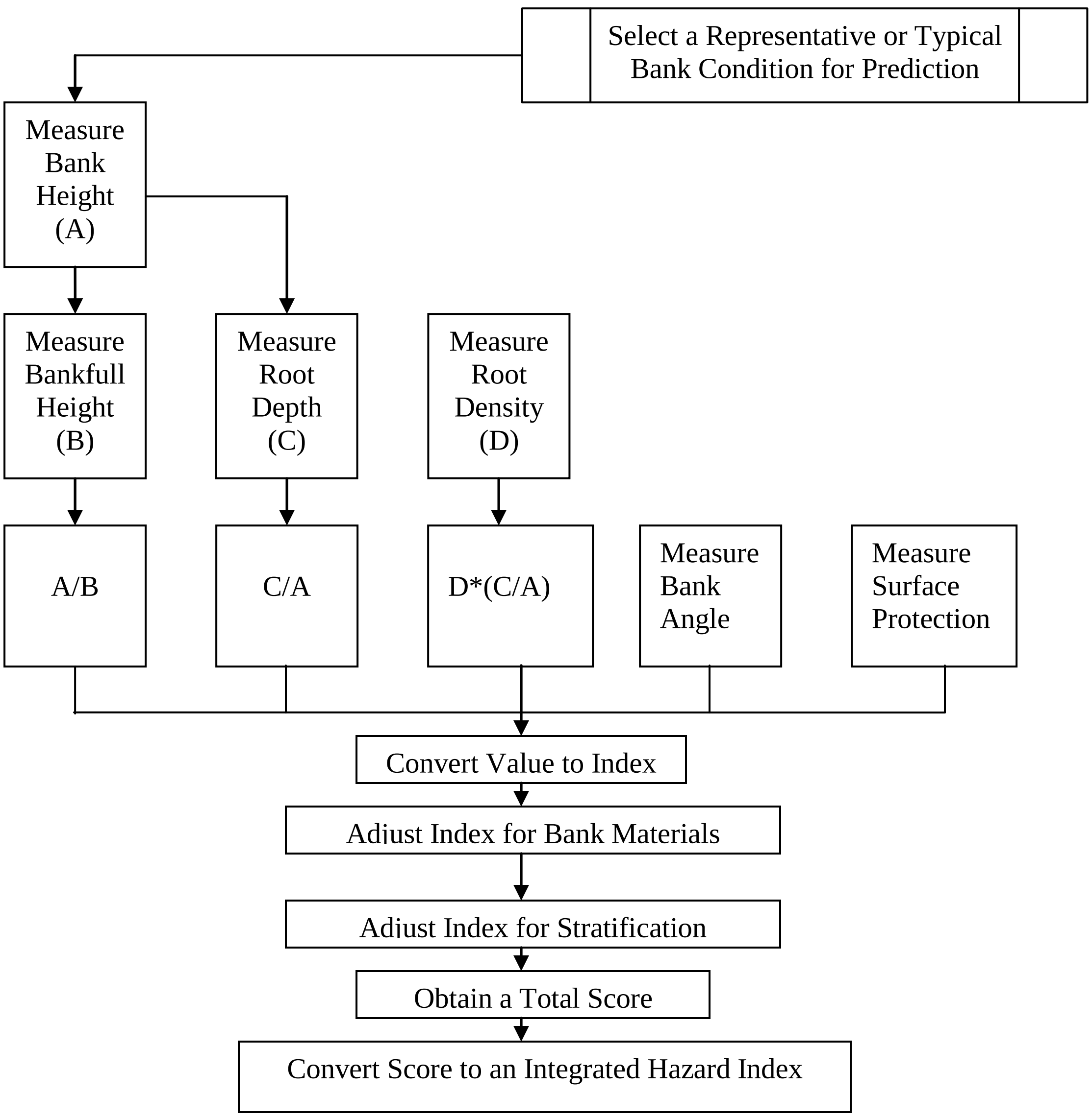
d. Avoid evaluating upstream and downstream influences, such as boulder diversions or protection, when assessing the study bank.

e. Photograph the study bank with surveyor or survey rod in the foreground as reference.

For study bank BEHIs, the assessment location and BEHI characteristics (*e.g.*, top of bank to bankfull height ratio, rooting depth-bank height ratio, *etc.*) should represent average bank conditions in the study reach. For example, if the bank angles within a study reach ranged from 50^o to 60^o the average bank angle would be 55^o for the study reach.

BEHI CRITERIA AND PROCEDURES

The flow diagram below (from Rosgen 2003) outlines the general BEHI procedure and relationship between variables. Figure 1 provides a graphic display for general measurement and Figure 2 is the BEHI Index and Value chart. Outlined below are the seven BEHI criteria and procedures for measurement. In some cases, specific examples from the mid-Atlantic region are provided for explanatory purposes.



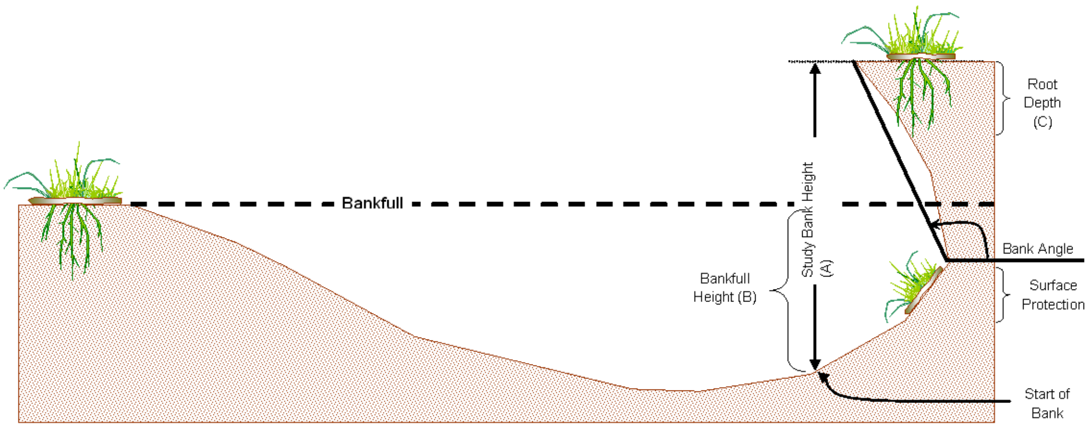


Figure 1. BEHI Variables (Rosgen 2003).

Bank Erosion Hazard Index							
		Bank Erosion Potential					
Erodibility Variable		*Very Low*	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
Bank Height/ Bankfull Height	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth/ Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials
Bedrock (Bedrock banks have very low bank erosion potential)
Boulders (Banks composed of boulders have low bank erosion potential)
Cobble (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, do not adjust)
Gravel (Add 5-10 points depending on percentage of bank material that is composed of sand)
Sand/Silt/Clay loam (Add 5 points, where sand is 50-75% or the composition)
Sand (Add 10 points if sand comprises > 75 % and is exposed to erosional processes)
Silt/Clay (+ 0: no adjustment)

Stratification
Add 5-10 points depending on position of unstable layers in relation to bankfull stage

Total Score

Very Low	*Low*	*Moderate*	*High*	*Very High*	*Extreme*
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Figure 2. BEHI Value and Index table (Rosgen 1996).

Top of Bank Height to Bankfull Height Ratio

a. Measure the top of bank and bankfull heights from the bank toe (Figures 1 and 3).

b. For BEHIs at a cross section survey, determine the top of bank and bankfull heights from the survey data.

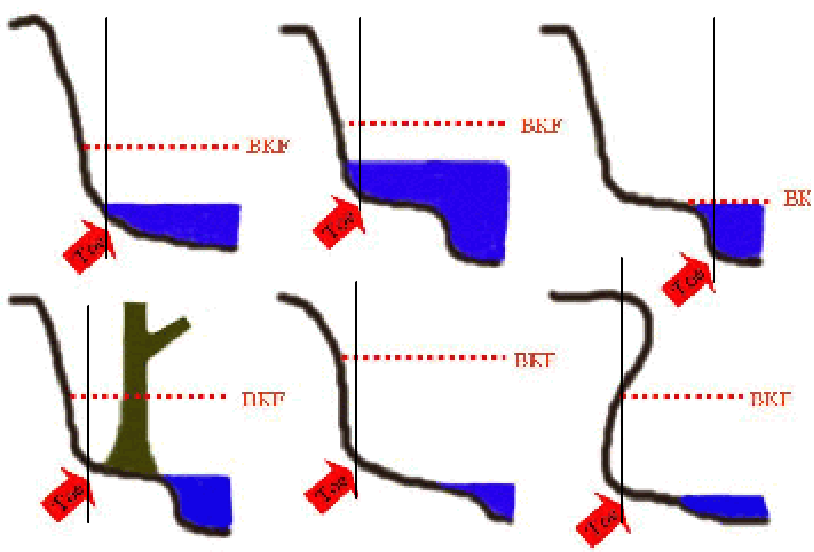
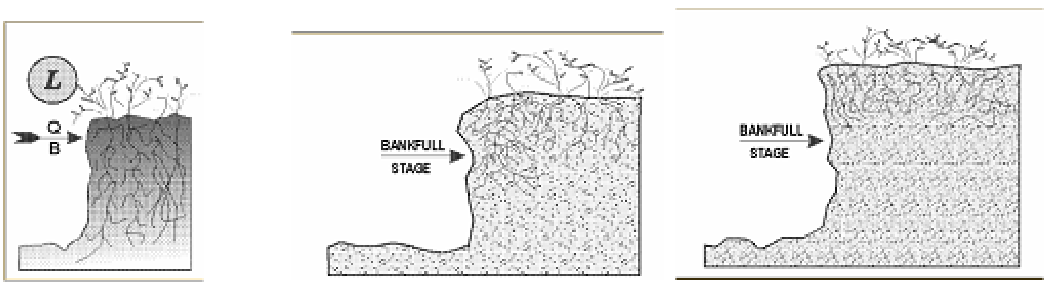


Figure 3. Bank toe location examples.

1. Rooting Depth to Top of Bank Height Ratio

Rooting depth to bank height ratio is a measure of rooting depth in relation to the top of bank height (Figure 4). For example, if the bank is gently sloped to the toe and covered with grasses, the rooting depth is only the depth of the vegetation, in relation to the height of the bank. Rooting depth is highly variable and depends on vegetation type and soil conditions. Familiarity with annual and perennial growth for a particular region and an understanding of how conditions may change seasonally is essential. Rooting depth is often species and location dependent. Table 1 provides average root depths for various vegetation types; however, one should look for evidence in the field of rooting depths for the particular vegetation growing at the study sites.

Table 1. Average Root Depths (adapted from Colorado State University cooperative extension newsletter).			
Vegetation Type	Root Depth (ft)	Vegetation Type	Root Depth (ft)
Annuals	0.16 - 0.25	Shrubs	0.67 - 1.00
Perennials	0.33 - 0.83	Trees	0.83 – 1.5
Turf grass	0.50 - 0.67		



Low *Medium* *High*

Figure 4. Examples of low, medium, and high BEHIs for rooting depth (Rosgen 1996).

a. Where the upper bank is accessible (but not at the cross section location), clear the soil to expose the roots and assess the root depth. If the upper bank is not accessible, look for areas with exposed roots or use Table 1 to determine rooting depths.

b. Where the tree and/or tree roots extend down the bank, the extent of the roots down the bank (*i.e.*, the height of the root ball) is the rooting depth (Figure 5).

c. It is important to consider soil conditions (*e.g.*, duripan, fragipans, and hemic soil materials) that will affect rooting depths. Duripans and fragipans tend to retard rooting depths. Hemic soil materials tend to promote rooting depth because of its high organic matter.

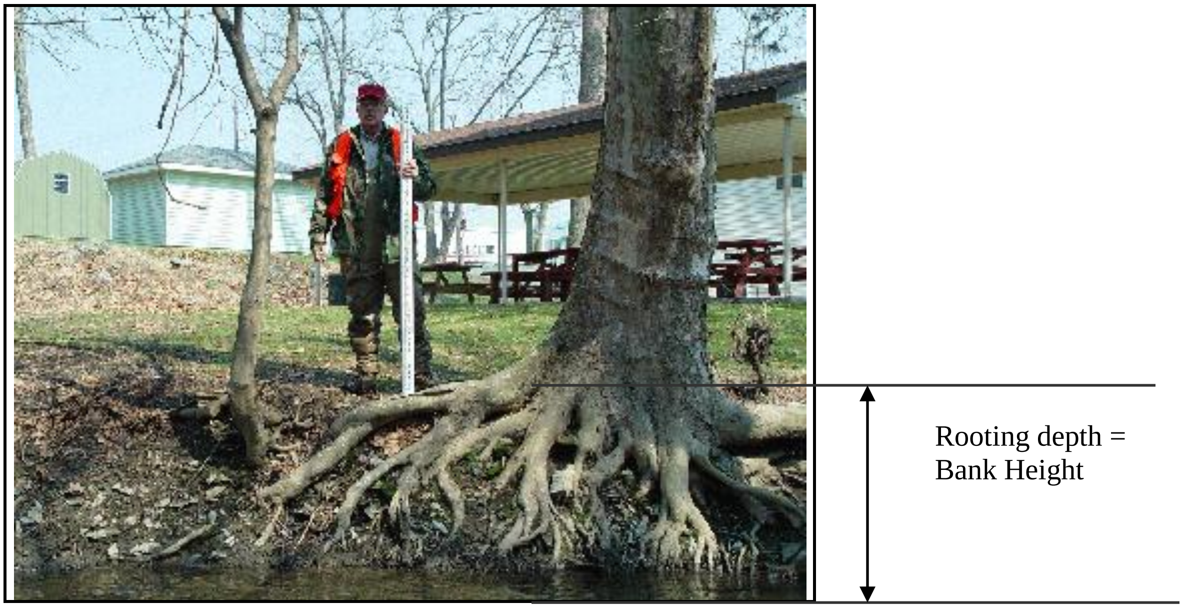


Figure 5. Tree roots extending down the stream bank.

3. Weighted Root Density

   Weighted root density is a percentage of root density within the rooting depth. This is an ocular estimate, (*e.g.*, if the bank as a 60 percent density but only on 1 percent of the bank, then root density is less than 5 percent (extreme category)). Similar to rooting depth, root density is highly variable and depends on vegetation type and soil conditions.

   a. Where the upper bank is accessible, clear the soil (except at the cross section) to expose the roots and assess the root density.

   b. When estimating root density, it maybe helpful to compress the surface area of the root and visualize what percent that area comprises of the total rooting depth area (Figure 6).

   c. If the upper bank is not accessible, look for areas with exposed roots to determine root density.

   d. It is important to note soil conditions (see 2.d. above).

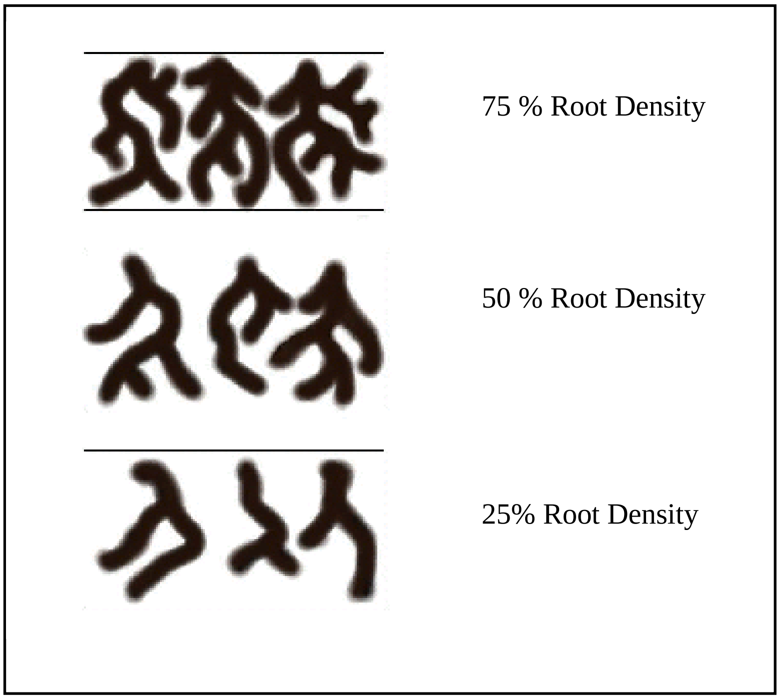


Figure 6. Root density examples.

4. Bank Angle
   Bank angle is a measure of the angle-of-repose of the bank. Figure 7 provides five common bank angle scenarios.

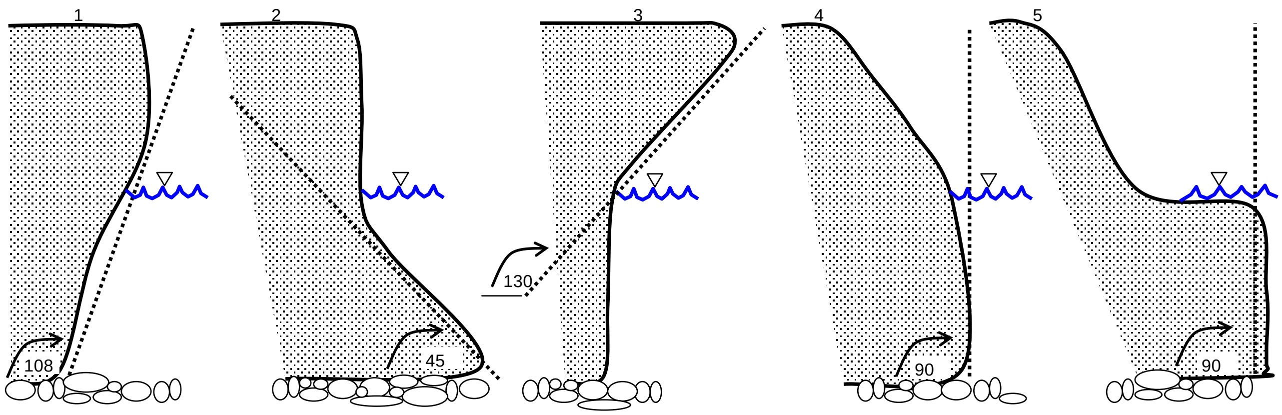


Figure 7. Bank angle scenarios (perspective: cross-section view)(Rosgen 2003).

a. In general, measure the angle of steepest slope or slope most prone to failure, at bankfull.

b. If possible, place a survey rod on the slope face.

c. Using a clinometer, place the base of the clinometer on the survey rod and measure the angle. If using a compass with a clinometer, remember to set the bezel so that the clinometer reads 0^{o} when the compass base is flat and 90^{o} when it is vertical.

5. <u>Surface Protection</u>

Surface protection characterizes bank conditions (*e.g.*, boulders, vegetation) that attenuate erosional forces along the bank. Surface protection is a percentage measurement of the surface area of the bank protected from erosion. The surface protection can be vegetation, debris, rootwads, etc.

a. Determine areas along the bank that have surface protection.

b. Determine the protected percent of the total bank height.

c. For banks vegetated with vines, brambles annuals, and/or moss, determine the vegetated percent of the bank. It may be easier to determine the percent of exposed soil, and calculate the remaining vegetated percentage (Figure 8).

Figure 8. Herbaceous bank vegetation.

d. To determine bank protection for banks vegetated with shrubs and trees, determine the percent of the bank influenced by the root fan (Figure 9). Soil exposed within the area of the root fan is less a consideration with woody vegetation.

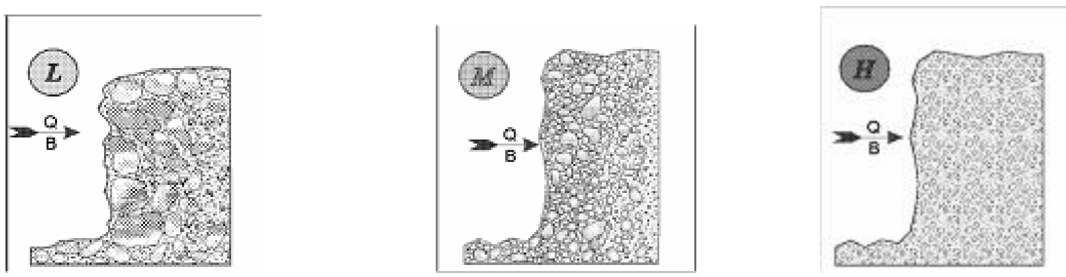
Figure 9. Woody bank vegetation.

e. When evaluating suspended logs, and trees and boulders in the channel, determine the percent of the bank protected at the near bank (Figure 10).

Figure10.Suspended log bank protection.

6. <u>Bank Material Adjustment</u>

Bank material adjustment characterizes the composition and consolidation of the bank (Figure 11).



(0 points) (5 points) (10 points)

Figure 11. Examples of low, medium, and high erodibility bank material composition (Rosgen 1996).

a. Determine the general bank composition. Stream flow may influence surface appearance, if necessary, remove the surface layer of soil.

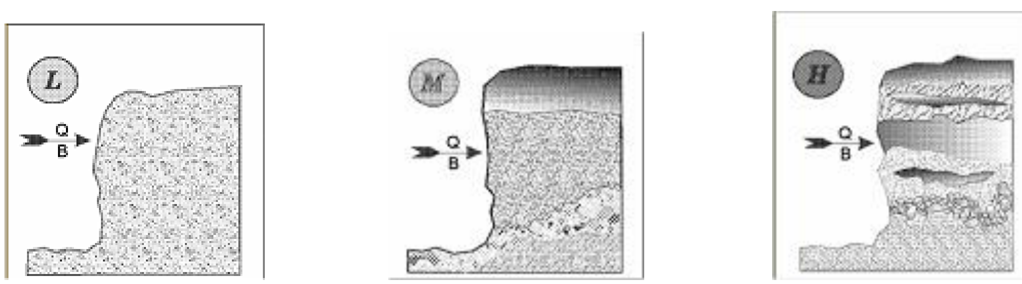
b. Adjust the overall BEHI score using values from Table 2.

Table 2. Bank Material Adjustment	
Bank Material	**BEHI Rating Adjustment**
Bedrock	BEHI for bedrock banks are "very low erosion potential".
Boulders	BEHI for boulder banks are "low erosion potential".
Cobble	Subtract 10 points. No adjustment if sand/gravel composes greater than 50 percent of bank.
Sand/Silt/Clay Loam	Add 5 points, if composition is 50 – 75 percent sand.
Gravel	Add 5-10 points depending on percentage of bank material composed of sand.
Sand	Add 10 points if sand comprises greater than 75 percent and is exposed to erosional processes.

Table 2. Bank Material Adjustment	
Bank Material	BEHI Rating Adjustment
Silt/Clay	Subtract up to 20 points depending on percentage of bank material composed of clay. *Note: this is a new adjustment

7. Bank Stratification Adjustment

Bank stratification adjustment characterizes unstable soil horizons that are prone to erosion in relation to the bankfull stage (Figure 12). There are several processes of bank erosion to consider when evaluating bank stratification adjustments: fluvial entrainment, rotational failure, soil piping, and freeze/thaw.



(0 points) (5 points) (10 points)

Figure 12. Examples of low, medium, and high erodibility soil stratification (Rosgen 1996).

a. Observe the bank profile and soil horizons along the bank.

b. Identify any zone(s) where water concentrates, and area(s) of rotational failures and soil piping.

c. Evaluate the horizon’s consolidation by attempting to dislodge the bank materials. Stream flow may influence surface appearance, if necessary, remove the surface layer of soil.

d. Adjustment values depend on the location of horizons prone to erosion, for example, if the bank has a gravel lens in the lower third of the bank add 10 points. Add 5-10 points depending on position of unstable layers in relation to bankfull stage.

8. PHOTOGRAPHIC DOCUMENTATION

Photographic documentation is required for each BEHI assessment. The photograph should represent bank conditions assessed for the BEHI. Reach BEHIs may require multiple photographs, while site BEHIs may require only one photograph.

1. If possible, incorporate a reference (*e.g.*, survey rod) into the photograph.

2. If necessary, take the photograph at an oblique angle to accentuate bank conditions.

3. Record the camera number, photograph number, and photograph description on the BEHI data sheet.

Standards for Estimating Near-Bank Stress

1. PURPOSE

Estimation of Near-Bank Stress (NBS) rating is a field method, developed by Dave Rosgen, to estimate bank stress associated with bankfull flows. The use of stream pattern, shape, and depositional areas provides a rapid method to estimate NBS for a study reach for general assessment and initial predications. When used with Bank Erodibility Hazard Index (BEHI) scores, the NBS ratings allow one to predict bank erosion rates. If the objective is to quantify bank erosion rate, a more intensive level of assessment is required (*i.e.*, validation).

Rosgen (2003) provides seven levels of estimating and/or quantify near-bank stress (Figure 1). The method selected must incorporate an understanding of stream processes. For example, if a tight radius in a bend is having greater influence than the local stream slope, the radius of curvature/bankfull width is a better predictor.

The purpose of this standard is to document field methods for estimating NBS.

2. METHODS

The methods and procedures presented within this protocol are drawn from:

- Rosgen, D.L. 2001. A practical method to predict stream bank erosion. In: U.S. Subcommittee on Sedimentation. Proceedings of the federal interagency sedimentation conferences, 1947 – 2001.
- Rosgen, D.L. 2003. Wildland Hydrology. 2003. River Assessment and Monitoring Field Guide.

3. FIELD PROCEDURE

1. Use the Estimating near-bank stress Field Form (Figure 1).
2. For reach-level assessment, use near-bank stress estimation based on channel pattern, depositional feature, and cross section shape (Level I Reconnaissance) (Figure 2).
3. Select, from Figure 2, the cross section that best represents the study reach cross section.

4. Consider the following factors when determining the NBS rating:

    - The maximum depth location will influence the NBS rating. For example, a cross section with the maximum depth located in the middle has a lower NBS rating than a cross section with the maximum depth located in the outer one third of the stream.

    - Chute cutoff return flows and split channels converging against study banks (Figure 3) will cause a disproportionate energy distribution in the near bank region and NBS ratings will be extreme.

    - Depositional features such as transverse bars and/or central bars (Figure 3) will also create a disproportionate distribution of energy in the near bank region and NBS estimate ratings should be adjusted upward due to high velocity gradients. For central bars, estimate both outside banks.

    - Evaluate the individual channels of a braided reach separately based on the distribution of energy in the near bank region.

    - If the stream slope directly upstream of a study bank is steeper than the average reach slope, adjust the NBS rating upward.

U.S. Fish & Wildlife Service

Chesapeake Bay Field Office *Annapolis, MD*

Stream Habitat Assessment and Restoration Program

Figure 1. Estimating near-bank stress Field Form

Stream: Location: Date: Crew:

Level I	1	Transverse and/or central bars - short and/or discontinuous. NBS = High/Very High Extensive deposition (continuous, cross channel). NBS = Extreme Chute cutoffs, down-valley meander migration, converging flow (Figure X). NBS = Extreme			
Level II	2	Radius of Curvature Rc (feet)	Bankfull Width W_{bkf} (feet)	Ratio Rc/W	Near-Bank Stress
	3	Pool Slope S_p	Average Slope S	Ratio S_p/S	Near-Bank Stress
	4	Pool Slope S_p	Riffle Slope S_{rif}	Ratio S_p/S_{rif}	Near-Bank Stress

Dominant Near-Bank Stress

Level III	5	Near-Bank Max Depth d_{nb} (feet)	Mean Depth d (feet)	Ratio d_{nb}/d	Near-Bank Stress				
	6	Near-Bank Max Depth d_{nb} (feet)	Near-Bank Slope S_{nb}	Near-Bank Shear Stress τ_{nb} (lb/ft^2)	Mean Depth d (feet)	Average Slope S	Shear Stress τ (lb/ft^2)	Ratio τ_{nb}/τ	Near-Bank Stress
Level IV	7	Velocity Gradient (ft/s/ft)		Near-Bank Stress					

Converting Values to a Near-Bank Stress Rating

Near-Bank Stress	Method Number						
	1	2	3	4	5	6	7
Very Low	N/A	>3.0	< 0.20	< 0.4	<1.0	<0.8	<1.0
Low		2.21 - 3.0	0.20 - 0.40	0.41 - 0.60	1.0 - 1.5	0.8 - 1.05	1.0 - 1.2
Moderate		2.01 - 2.2	0.41 - 0.60	0.61 - 0.80	1.51 - 1.8	1.06 - 1.14	1.21 - 1.6
High	N/A	1.81 - 2.0	0.61 - 0.80	0.81 - 1.0	1.81 - 2.5	1.15 - 1.19	1.61 - 2.0
Very High		1.5 - 1.8	0.81 - 1.0	1.01 - 1.2	2.51 - 3.0	1.20 - 1.60	2.01 - 2.3
Extreme		< 1.5	> 1.0	> 1.2	> 3.0	> 1.6	> 2.3

Methods for Estimating Near-Bank Stress

1. Transverse bar or split channel/central bar creating NBS/high velocity gradient: **Level I - Reconnaissance.**
2. Channel pattern (Rc/W): **Level II - General Prediction.**
3. Ratio of pool slope to average water surface slope (S_p/S): **Level II - General Prediction.**
4. Ratio of pool slope to riffle slope (S_p/S_{rif}): **Level II - General Prediction.**
5. Ratio of near-bank maximum depth to bankfull mean depth (d_{nb}/d_{bkf}): **Level III - Detailed Prediction.**
6. Ratio of near-bank shear stress to bankfull shear stress (t_{nb}/t_{bkf}): **Level III - Detailed Prediction.**
7. Velocity profiles/Isovels/Velocity gradient: **Level IV - Validation.**

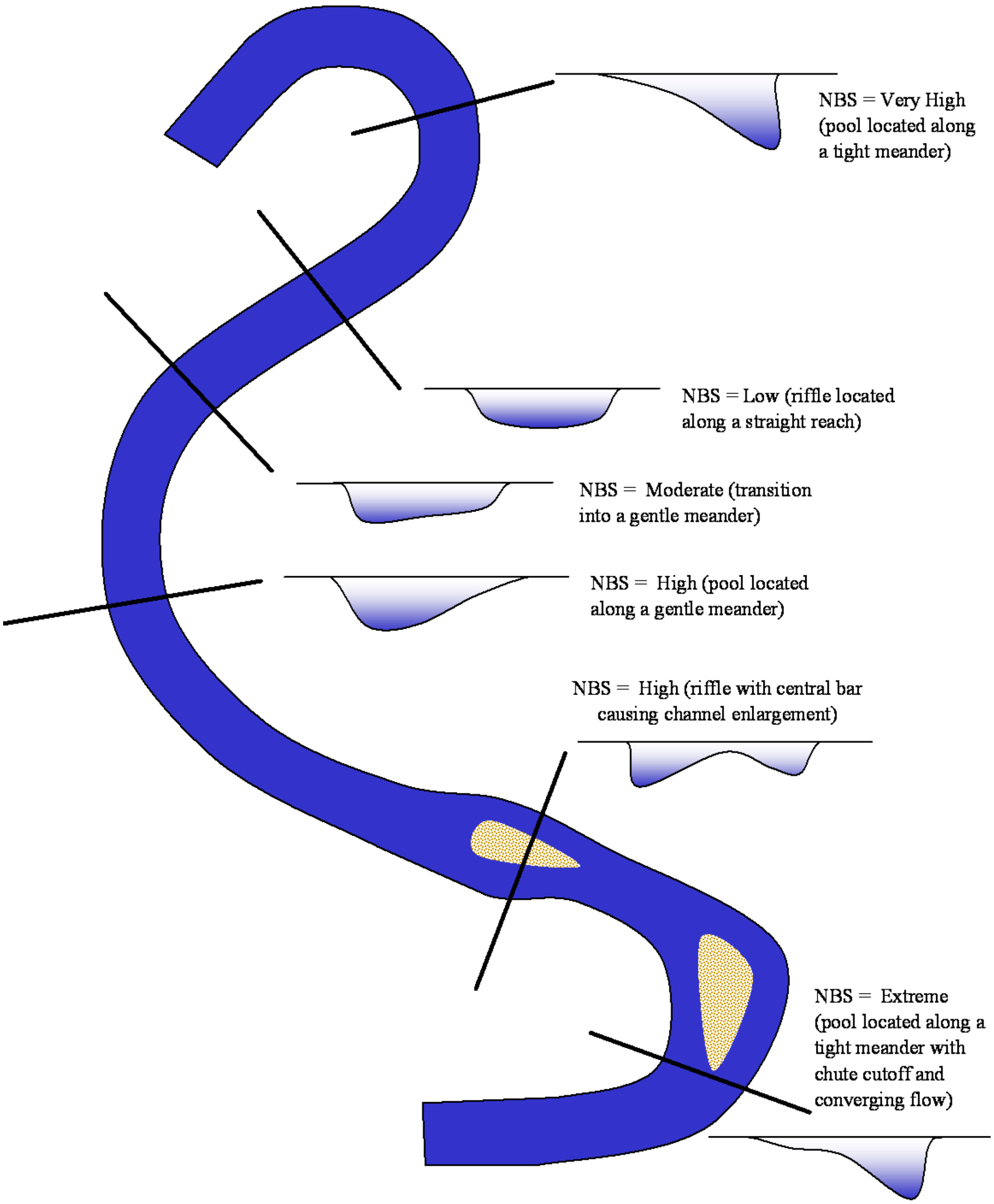


Figure 2. Near-bank stress estimation based on channel pattern, depositional features, and cross-section shape (Level I Reconnaissance) (Rosgen 2003).

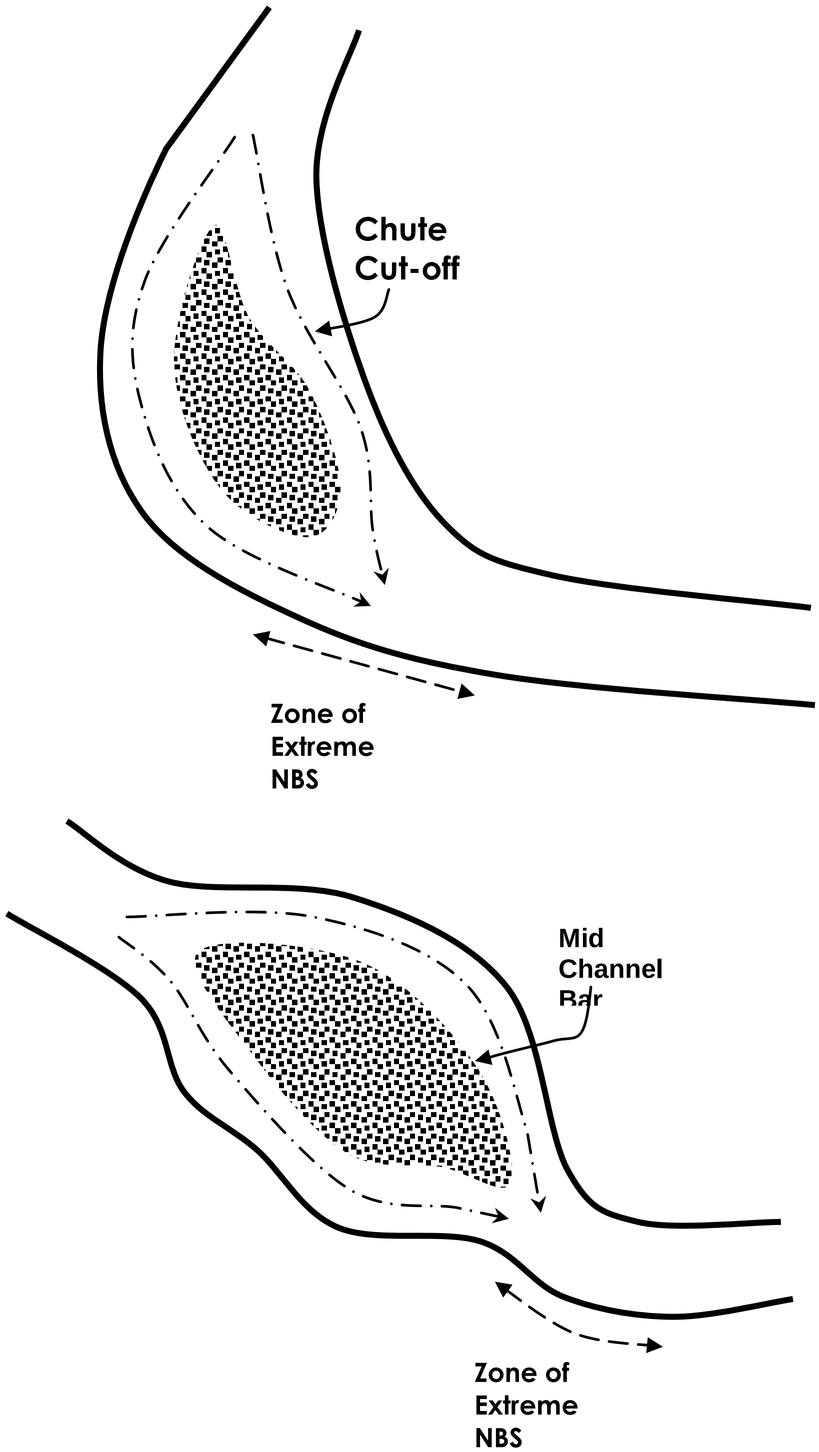


Figure 3. Examples of converging flows from chute cutoffs and central bars (Rosgen 2003).