

Modified Bank Erosion Hazard Index (BEHI) Protocol

1.0 Introduction

Watershed management practices throughout the Cleveland Metroparks attempt to determine the volume, source, and rate of stream bank erosion to assist in stream, riparian and habitat restoration, and management recommendations. Bank Erosion Hazard Index (BEHI) is a fluvial geomorphic assessment procedure used to evaluate the susceptibility of stream bank erosion on a section of stream, based on a combination of several erodibility variables. The BEHI assessment is comprised of several metrics that take into account major physical attributes of streambanks. These metrics include:

1. Riparian root depth
2. Root density
3. Bank angle
4. Surface protection
5. Bank material
6. Stratification

The BEHI assessment assigns a numerical value for each metric which corresponds to an overall BEHI rating (very low, low, moderate, high, very high, extreme) for a particular stream bank. The following procedure, figures, and attachments are used throughout the Cleveland Metroparks to determine the susceptibility of stream bank erosion on a section of stream, based on the BEHI assessment.

2.0 Procedure

2.1 Streambank Identification

Identify a uniform section of bank (either left or right bank). This section could be differentiated by a drastically different slope of the bank, different bank material, break in vegetation etc. There is not a minimum or maximum length of bank. Extremely long sections can be separated into smaller sections to assist with the assessment; however, it is not necessary.

2.2 Pre-Screening BEHI Questionnaire

When a uniform section of bank is identified, proceed to the "Pre-Screening BEHI Questionnaire" sheet (**ATTACHMENT A**), to determine if a BEHI evaluation of that bank is necessary. A brief description of each question is provided below.

Toe Protection:

Does the bank exhibit less than or equal to 50% protection at the toe? The toe is located at the base of the bank where it meets the water; on average the bottom 6-8 inches of the bank. Protection includes embedded boulders, embedded large woody debris, and rooted vegetation. Bedrock counts as toe protection; however, if you are able to break or pull pieces of the bedrock this does not count as toe protection. For example, very weathered shale does not exhibit the same characteristics as sandstone bedrock, therefore, should not be treated as such.

Undercut Bank:

Does 50% or more of the bank exhibit an undercut of 0.5 feet or more? Undercut banks have a higher risk of bank failure due to gravitational force and shear stresses.

Stratified Bank:

Does 50% or more of the bank exhibit stratification? Stratification is a clearly defined horizontal break in geology and may cause zones of preferential erosion within the banks that have more than one strata. One layer of the stratification must be composed of an erodible material (sand, gravel, or matrix).

Bank Height:

Does 50% or more of the bank have a bank height of 10 feet or more with 50% or more soil exposure? Often times this is indicative of an incised channel with a loss of the riparian buffer. Examples of this can be seen in West Creek where the stream was rerouted, leaving very high shale banks void of vegetation.

Root Exposure:

Does 50% or more of the bank exhibit roots lacking bank material (soil)? An excess of hanging roots in the stream can be indicative of active erosion because the roots were once anchored in the bank material.

Bank Exposure:

Is 50% or more of the bank void of rooted vegetation? Rooted vegetation holds the bank material in place and helps protect the bank from erosive forces.

If the bank is exhibiting two or more of the questions listed above, there is a significant chance that stream bank erosion is occurring and/or will occur; therefore, a BEHI evaluation of the bank is necessary. If the bank is not exhibiting two or more do not proceed with the BEHI evaluation because the bank is experiencing little to no erosion (i.e. very low to low BEHI rating). Continue this procedure for each uniform section of the bank.

2.3 BEHI Evaluation

If erosion is occurring and/or will occur a BEHI evaluation and data collection is necessary. A brief description of the data recorded on the "BEHI Evaluation Data Sheet" (**ATTACHMENT B**) is provided below.

Bank Number:

This is the number of the bank you are on. For example, 1 is the first bank you are assessing that day, 2 is the second bank you are assessing, 3, 4, 5...etc.

GPS Coordinates:

Take GPS coordinates at the most upstream (where the water is flowing from) and most downstream (where the water is flowing to) points of the bank. Stand as close to the bank as possible to ensure accuracy.

Pictures:

Take pictures at both the upstream and downstream points on the bank. Attempt to capture the main features of the bank in the pictures. More pictures may be taken to capture features on the bank or in the channel (i.e. stratification, large woody debris (LWD) jams, etc.). Record the picture numbers for reference.

Bank:

Bank refers to the side of the stream you are assessing (i.e. left or right bank). The left and right bank is determined when facing downstream; left and right respectively.

Bank Length/Height:

Bank height is measured from the toe of the bank to the top of the bank. The top of the bank can be determined by the first definable break in slope, generally lying parallel to water flow. Bank length measures the length of bank between the most upstream and most downstream points on the bank.

Questions answered "yes" to:

Refers to the initial evaluation questions which were answered with a “yes” Write the question numbers only.

BEHI Metrics:

A brief summary of each BEHI metric is provided below.

Material Description:

The composition of the bank material is noted in order to account for erosive variables that occur due to differential erosion susceptibilities attributable to sediment size. Record all the materials found along the bank section that is being evaluated. Stream banks can be a mix of materials. For example, a bank may have “shale at the toe, and silty, sand with trace gravel above” “Silty, sand” indicates more sand than silt and “trace gravel” indicates a small amount of gravel. “Sandy silt” indicates more silt than sand. A brief description of the different material types is provided below.

Material types:

- Clay – very fine grained material; no visible particles; sticky and difficult to wash off of your hands (i.e. clay pottery).
- Silt – very fine grained material; has visible particles; easier to wash off of your hands than clay.
- Sand – can range from very fine to vary coarse grained material; can feel sand grains.
- Gravel – ranges from 2 to 64 mm.
- Cobble – ranges from 64 to 256 mm.
- Boulders – greater than 256 mm.
- Shale – bedrock that can be solid or “weathered” and easily broken apart.

Stratification:

Stratification adjustments, described in detail below, are made to account for zones of preferential erosion that occur within banks that have more than one strata. An example of a stratified bank can be seen in **FIGURE 1**.

Riparian root depth:

The ratio of the average root depth of plants to the study bank height, expressed as a percentage, to estimate the adherence of bank material by vegetation. Failure of the bank due to undercutting can occur if the root depth does not reach the full bank height. Often times a horizontal line where most roots stop growing can be seen. Do not consider roots that are void of bank material (i.e. hanging roots). Consider the vegetation on top of the bank (trees will have deeper root growth compared to grasses).

Visually estimate the root growth depth vertically from top to bottom. For example, if roots are growing in the top half of the bank, the root depth would be 50%. If there are roots growing from the top of the bank to the toe, the root depth would be 100%. Take an average percentage of the root depth along the entire section under evaluation. See **FIGURE 2** for a root depth to bank height comparison.

Root density:

A visual assessment of the amount of bank composed of root material, expressed as a percentage (i.e. density of roots within the bank). Do not consider roots that are void of bank material. Small, fibrous roots can be very dense and provide greater soil retention compared to large, tap root systems. See **FIGURES 3 and 4** for a fibrous root and tap root comparison.

Bank angle:

The bank angle is the angle from the lower bank at the waterline during base flow to the top of the bank. Steeper bank angles are estimated to have a higher risk of mass failure of the bank due to gravitational force and shear stresses.

An extremely undercut bank can have an angle up to 120 degrees. It helps to place a measuring stick at a 90 degree angle to the water in order to estimate angles. Take an average of the bank angle along the entire section under evaluation. For example, if the section is mostly 90 degrees with a small section that has 120 degree undercut, the recorded degree would be approximately 100 degrees. An example of an undercut bank can be seen in **FIGURE 5**.

Surface protection:

Surface protection is the amount of stream bank covered and protected by woody debris, rooted vegetation, embedded boulders, revetment, bedrock, etc. This is measured as the percentage of streambank not exposed to erosive forces (i.e. the percentage of bank that is protected from the toe to the top of the bank). **FIGURE 6** shows a bank with embedded boulders acting as surface protection.

Distance to infrastructure:

Note the distance to the nearest infrastructure (i.e. bridges, culverts, roads, utilities, houses etc.), the time it took to get there, and if it is public or private.

Qualitative Indicators:

Circle any of the following qualitative indicators that are present.

- Unvegetated mid-channel bar/braided channel – depositional features that are not attached to the sides of the channel; often found in the middle of the channel with water flow on all sides.
- Exposed tree roots on both sides
- Leaning trees on both sides
- Exposed infrastructure – utility, pipeline, sewer, etc.
- Downstream of a dam
- Slumping stream banks
- Failed “Best Management Practices” (BMP’s) – revetment walls, culverts, gabion baskets, etc.
- Headcuts – erosional feature on stream bed where there is a sudden vertical drop.
- Perched tributaries – a stream feeding/flowing into a larger stream that is raised (perched) above the stream bed it is flowing into.

Notes:

Take note of bank/stream specifics. For example, bank on the outside of a meander bend, a large woody debris jam, a culvert in the middle of the stream, strong petroleum odor, etc.

2.4 BEHI Scoring

For each BEHI metric described above estimate a percentage based on the **entire bank**, then use the “BEHI Score Chart” (**ATTACHMENT C**) to record the score for that percentage on the data sheet. There are two adjustments that can be made, which are described below.

Bank material adjustment:

Bank material adjustments can be made based on the erodibility of the material. **Up to** 10 points can be subtracted for material that does not have a high rate of erodibility (i.e. cobble). **Up to** 10 points can be added for extremely erodible materials (i.e. sand). A mixture of material (i.e. sand with some gravel or silty, sand with trace gravel) is more often found in stream systems so an average score would be more appropriate (i.e. add 6 points instead of 10). This is not a mandatory adjustment.

Stratification adjustment:

Stratification adjustments can be made if increased erosion is occurring due to the stratified layers. If the bank is stratified, **up to** 5 points can be added for a single layer of stratification (two different geologic layers). **Up to** 10 points can be added for multiple layers of stratification (three different geologic layers). Only adjust for stratification if at least one layer of material is erodible (sand, gravel, matrix). Consider where the stratification layers are in relation to the water (i.e. stratified layers that are 50 feet above the

water may not have an erosive effect. A stratified layer near the toe of the bank may have an extremely erosive effect). An average score may be necessary, especially when considering how erodible the materials are and where the stratified layer is in relation to the water. This is not a mandatory adjustment.

As this procedure is completed a consensus for each individual metric should be reached (within +/- 10). This assists with consistency and helps to reduce errors and observer biased calls. Add all scores together to determine the overall BEHI rating (low, moderate, high, very high, extreme) for the bank assessed. After a final BEHI rating is obtained think about the following questions. Does your rating make sense? Does the bank look like it is eroding at a rapid rate or not at all? It may be necessary to return to some of the metric scores and discuss reasoning for certain calls and make adjustments. Continue this procedure for both left and right banks along the stream channel.

Figures

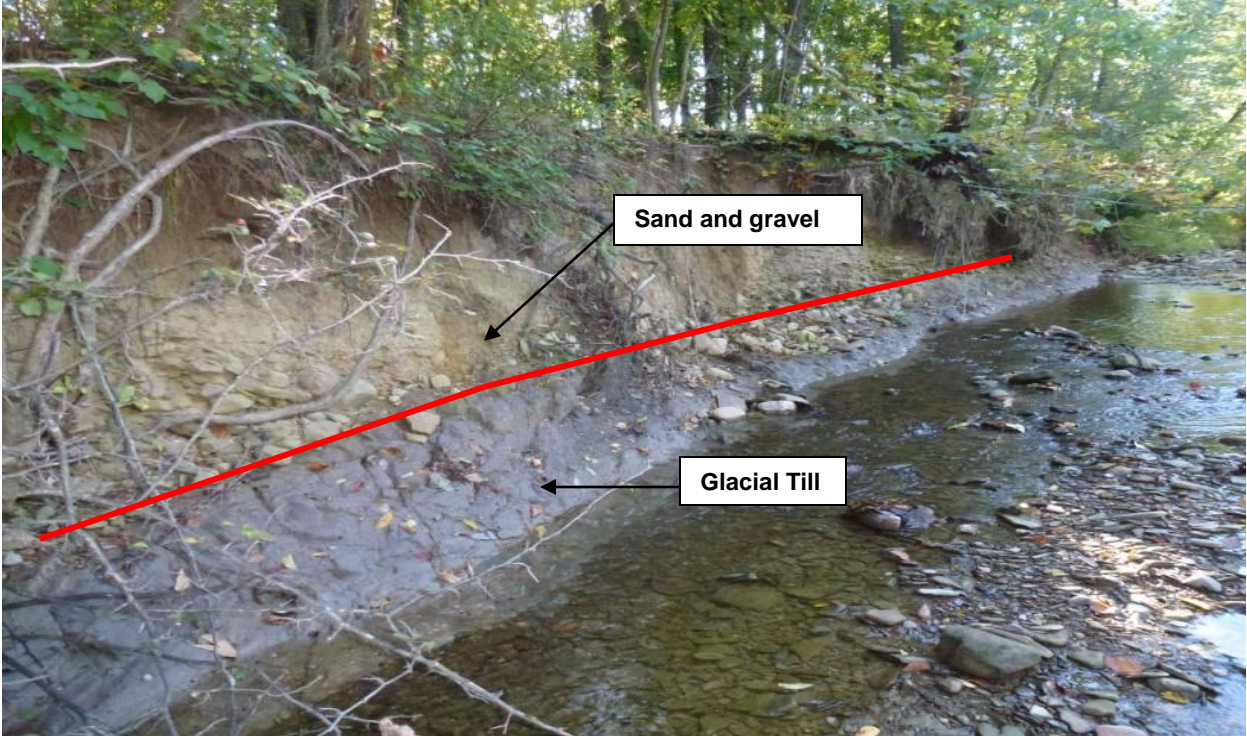


Figure 1: A clearly defined layer of stratification with glacial till at the toe and sand/gravel layer above.



Figure 2: Root depth to bank height comparison. The roots do not extend into the shale layer beneath the top soil.

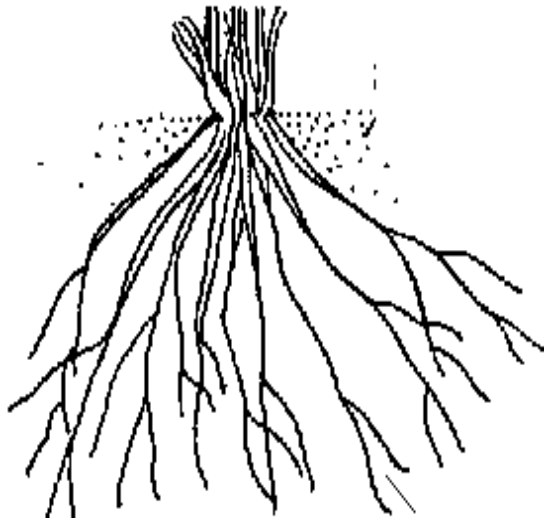


Figure 3: A fibrous root system.

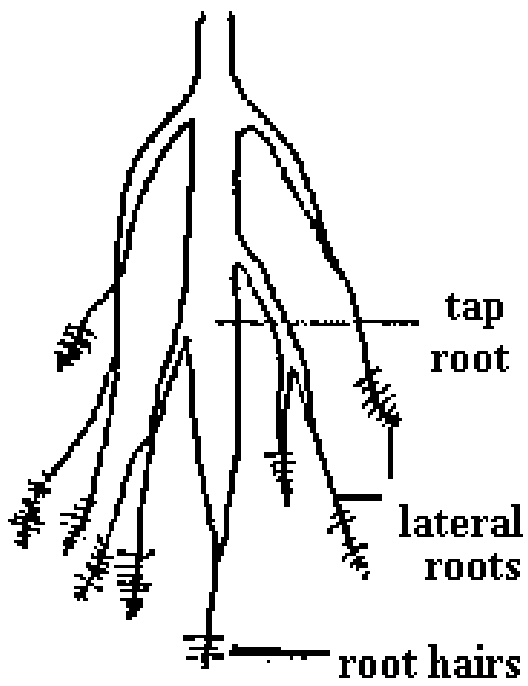


Figure 4: A tap root system.



Figure 5: A bank with an extreme undercut.



Figure 6: Boulders embedded in the stream bank, acting as surface protection.

Attachments

Pre-Screening BEHI Questionnaire

If the bank in question is exhibiting 2 or more of the following then proceed with the BEHI protocol. If the bank is not exhibiting 2 or more do not proceed with the BEHI protocol because the bank is exhibiting little to no erosion (i.e. very low to low BEHI rating).

1. Does the bank exhibit less than or equal to 50% protection at the toe.
 - The toe is located at the base of the bank where it meets the water; on average the bottom 6-8 inches.
 - Protection includes: boulders, rocks the stream can not move (has to be larger than the largest size of rock on depositional bars), large woody debris embedded in bank, rooted vegetation.
 - Bedrock counts as toe protection however, if you are able to break/pull pieces this does not count as toe protection. For example, in this area you will often find weathered shale which does not function the same way as bedrock.
2. Does 50% or more of the bank exhibit an undercut of 0.5 feet or more?
3. Does 50% or more of the bank exhibit stratification?
 - Stratification is a clearly defined break in geology (i.e. change in material type).
 - One layer of the stratification must be of erodible material: sand, gravel, matrix (combination of sand, gravel), weathered shale.
4. Does 50% or more of the bank have a bank height of 10 feet or more with 50% or more soil exposure?
 - Often times this is indicative of an incised channel (i.e. large shale walls).
5. Does 50% or more of the bank exhibit roots lacking bank material (soil)?
6. Is 50% or more of the bank void of rooted vegetation?

Attachment A: Pre-Screening BEHI Questionnaire.

Bank Number:							
GPS up:			GPS down:				
Picture Numbers:						Bank:	
Bank Height:			Bank Length (ft):				
Questions answered yes to:							
Material Description:							
Circle One:							
Bedrock: no score adjustment; low BEHI, move on (unless able to pull apart w / hand: add 5)							
Boulders: no score adjustment; low BEHI, move on							
Cobble: minus 10; fill out table							
Gravel: add 5; fill out table							
Sand: add 10; fill out table							
Silt/Clay: no adjustment; fill out table							
<i>*If a mixture of materials, consider how the material behaves. (i.e. sand and gravel might add 7, sand and silt may be no adjustment.)</i>							
Stratification Adjust if layers of erodible material (i.e. sand/gravel, not bedrock/clay). Also consider where layers are in relation to water.							
No Layer:		Single Layer: add 5		Multiple Layers: add 10			
Overall average of the bank							
Root Depth/Bank Height	Score	Root Density	Score				
Bank Angle	Score	Surface Protection	Score	Total Score:			
				*add all scores including adjustments			
Distance to Infrastructure (ft):				Type (eg. Bridge, culvert, rd, utility):			
Accessibility:							
Time:	Private:	Public:	Walk or Drive:				
Qualitative Indicators: Circle all that apply							
Unvegetated mid channel bar/braided channel		exposed infrastructure		failed BMPs			
exposed tree roots on both sides		Downstream of dam		headcuts			
leaning trees on both sides		slumping stream bank		perched tributaries			
Notes:							
Very Low : 4		Low :8-15.5		Mod:16-23.5		High:24-31.5	
				Very High: 32-36		Extreme: >37	

Attachment B: BEHI Evaluation Data Sheet.

BEHI SCORES							
Root Depth	Score	Root Density	Score	Bank Angle	Score	Surface Protection	Score
100	0	100	0	120	10	100	0
95	1.5	95	0.5	115	9.75	95	0.5
90	2	90	1	110	9	90	1
85	2.25	85	1.5	105	8.75	85	1.5
80	2.5	80	2	100	8.5	80	2
75	2.75	75	2.5	95	8.25	75	2.5
70	3	70	2.75	90	8	70	3
65	3.25	65	3.25	85	7	65	3.25
60	3.5	60	3.5	80	6	60	3.5
55	3.75	55	4	75	5.5	55	4
50	4	50	4.25	70	5	50	4.25
45	4.25	45	4.5	65	4.5	45	4.5
40	4.75	40	5	60	4	40	5
35	5.25	35	5.5	55	3.75	35	5.5
30	6	30	5.75	50	3.5	30	6
25	6.5	25	6	45	3.25	25	6.5
20	7	20	7	40	3	20	7
15	7.75	15	8	35	2.75	15	8
10	8.5	10	8.5	30	2.5	10	9
5	9	5	9	25	2.25	5	9.5
0	10	0	10	20	2	0	10
				15	1.75		
				10	1.5		
				5	1		
				0	0		

Attachment C: BEHI Score Chart.