Stream Stability Assessment Guidelines for Nonpoint Source (NPS) Grant Applicants

All applications for Section 319 NPS grants or Clean Michigan Initiative NPS grants addressing stream engineering projects (bank stabilization, channel relocation, etc.) should consider assessing stream stability to improve both the quality of their project and the competitiveness of their application. Recommended assessment procedures are described below.

1.0 Introduction.

This document describes five tools for assessing stream channel stability: one set of qualitative, picture-based indicators and four more quantitative tools. It is directed primarily at: (a) grant applicants who are applying for monies to execute a channel restoration or bank stabilization project to help in assessing whether the cause of the problem is local or large-scale in nature, and (b) grantees writing watershed management plans who need to assess the scope of channel stability problems. These tools are for preliminary assessment and problem identification but are not intended for design purposes.

Stream channel stability refers to the capacity of a stream channel to transport its water and sediment inputs without changing its dimensions (width, depth, cross-sectional area, and slope). This simple definition obscures a couple of complicating factors:

- Stream bank and bed mobility is a natural phenomenon, and stable streams differ from unstable streams primarily in the rate of bank and bed mobility.
- Unnaturally high rates of bank and bed mobility can have multiple causes, ranging from small-scale, local causes like unrestricted livestock access or all-terrain vehicle traffic, to large-scale, regional causes like a watershed-wide increase in impervious pavement.

Assessing the scale of a stream stability problem is important for choosing whether, and what, corrective best management practice (BMP) should be installed. Stream channel stability problems with small-scale causes can be addressed by removing the cause; fencing out the livestock or blocking ATV trails, for example, followed by an appropriate local BMP such as bank stabilization. Conversely, permanently fixing large-scale stream stability problems requires large-scale solutions, increasing regional storm water retention or infiltration, for example.

Further, choosing the proper BMP to match the scale of the stream stability problem has ecological and economic implications. Applying small-scale BMPs such as bank stabilization to stream reaches impacted by large-scale degradations is at best a “band-aid” approach in which the BMP is likely to fail in a few years. Worse, inappropriate BMPs can actually exacerbate stream channel problems; for example, “hard” bank stabilization BMPs such as sheet pile or extensive rip rap installed in a stream reach impacted by a large-scale watershed development can deflect stream energy downstream, increasing erosion at the next unprotected stream meander bend.

Since a mismatch between the scale of the cause of a stream channel problem and a proposed solution is at best ineffective and could even make the problem worse, applicants proposing major stream treatments such as bank stabilization, meander restoration, or installation of instream structural BMPs like sand traps or cross-vanes, should assess the scale of the cause(s) of the problem to be solved.

Documenting local causes like livestock access is usually straightforward, while identifying large-scale causes is more challenging. By far the most common large-scale cause of stream channel instability in Michigan is changing land use practices, which alters the hydrologic regime of the stream, primarily by increasing the frequency and magnitude of post-storm peak flows and/or lowering base flows. Hydrologic alteration often results in changes in channel geomorphology; for example, increased width and/or depth or decreased sinuosity. Hydrologic alteration can be assessed using measures of bank condition and channel morphology. The next section in this document provides guidance on determining bankfull conditions, a common step in site assessment. The rest of this document describes five recommended hydrologic and geomorphic tools for assessing stream stability. The interpretations that are recommended by the Department of Environment, Great Lakes, and Energy (EGLE) for the results of these tools is also described. The five stream stability assessment tools are discussed in order of increasing complexity.

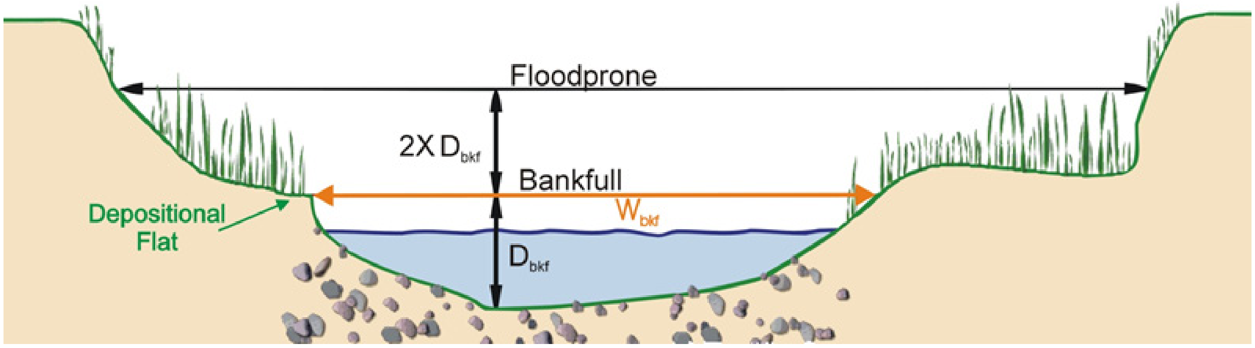
2.0 Field Determination of Bankfull Elevation and Bankfull Width.

Accurately measuring bankfull elevation is a key step in natural channel design and is used in several of the tools described in this document. Bankfull elevation can be measured anywhere along the stream channel (along riffles, pools, or runs) where consistent bankfull indicators are present (Figure 1). Bankfull width, in contrast, should only be measured at a riffle or along a straight run in sand bed streams that lack riffles (Figure 1).

Identifying bankfull elevation is usually straightforward in stable streams with no to moderate incision (a.k.a. entrenchment), and recommended field indicators include:

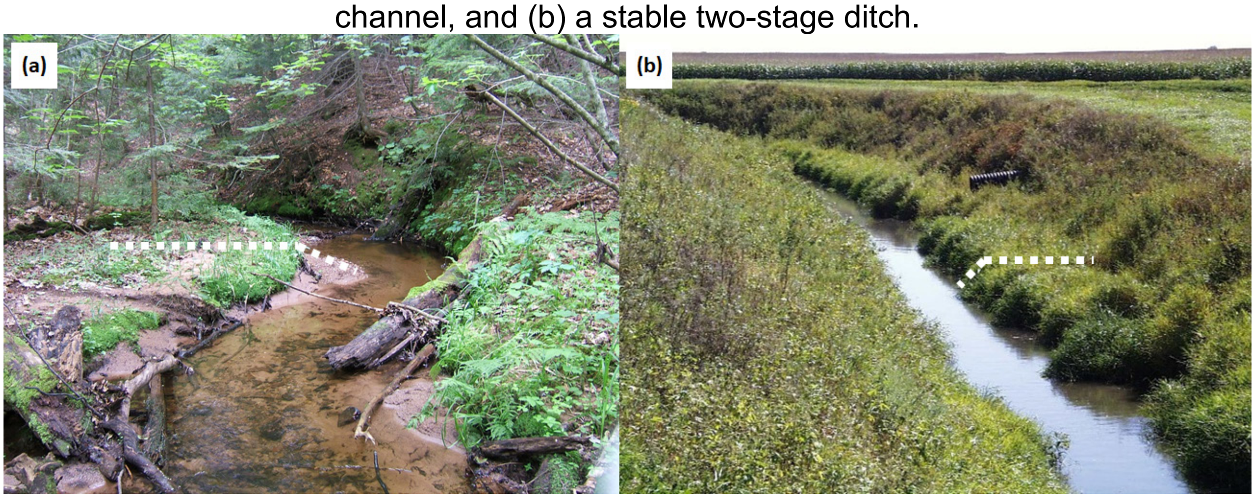
- The top of the first depositional flat above the waterline along the channel margin, especially if freshly deposited sand is present.
- The top of point bars or mid-channel bars or islands, especially towards the upstream end of these features.

Figure 1. Diagram Showing Identification of Bankfull Depth (D_{bfk}), Bankfull Width (W_{bkf}), and Floodprone Width.



Vegetative indicators, sometimes used in the arid West, are not recommended for Michigan streams. An exception is sedge wetland streams where the best bankfull indicator is the lowest elevation between adjacent sedge hummocks. Various field indicators of bankfull elevation are discussed in the literature, and these are reviewed in the Michigan Stream Team's protocol (Michigan Stream Team, 2010). However, in most stable Michigan streams, a floodplain break or an inflection point are the most reliable bankfull field indicators as discussed above (Figure 2).

Figure 2. Examples of Field Indicators of Bankfull Height in Stable Streams.
Note: The dashed white line shows the floodplain break for both: (a) a natural stream channel, and (b) a stable two-stage ditch.



Identifying bankfull elevation in incised streams (including excavated ditches) can be quite difficult or even impossible. The primary recommended bankfull field indicator in incised streams is the top of natural floodplain benches or natural mid-channel bars, whose maximum elevation is usually well below the overall top of the stream bank. If bankfull indicators cannot be identified in an incised channel, it is recommended that either measurements be made at a local reference reach near the project site or in a nearby watershed or bankfull dimensions be determined using regional reference curves.

Where bankfull elevation field indicators are present, it is recommended that multiple measurements of bankfull elevation be taken over a stream reach with a length of at least 20 stream widths or 2 stream meanders. Typical precision of multiple bankfull elevation measurements is approximately ±20%; greater variation usually indicates that older, higher-elevation terraces have been confused with bankfull flats.
Bankfull elevation measurements in the vicinity of road/stream crossings should be made with caution; atypical erosion and deposition can occur near culverts and bridges. Also, it is never appropriate to estimate bankfull width from aerial photographs.

3.0 Tool 1 – Qualitative Indicators of Channel Stability.

Qualitative observations of channel stability can provide supporting evidence for conclusions drawn from the more quantitative assessment techniques described below. Several examples of useful qualitative observations of channel instability or stability are described in Sections 3.1 and 3.2, respectively.

3.1 Examples of Qualitative Indicators of Channel Instability

Multiple unvegetated mid-channel bars or **side bars,** or **braided channels** often indicate excessive sedimentation (aggradation), although they can also be caused by local flow restrictions, like undersized or blocked culverts (Figure 3). Mid-channel bars due to excessive sediment loads are often accompanied by locally over-wide channels. Natural mid-channel bars can occur where channel slope changes.

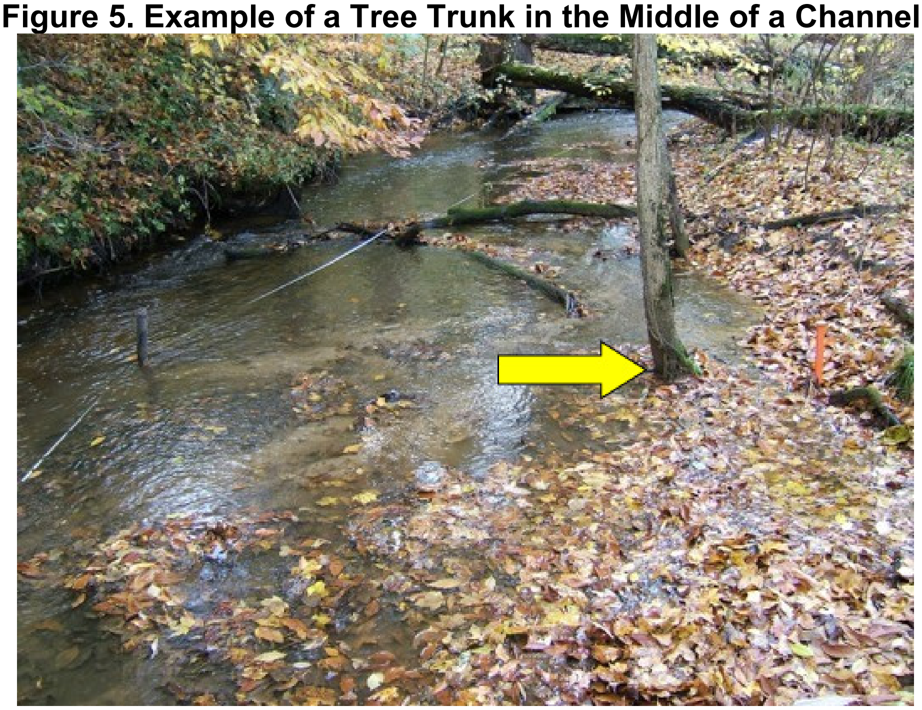
Figure 3. Example of an Unvegetated Mid-Channel Bar.

Leaning trees on both sides of the channel in straight reaches can indicate channel widening or incision (Figure 4). Observation of arching vs. straight tree trunks can provide insight into the speed of channel widening; trees can compensate for slow channel widening by arching back towards the bank. Note that leaning trees on only the outside of channel meanders may be due to natural bank erosion and mobility.

Figure 4. Example of Leaning Trees Along a Channel.

Tree trunks in the middle of the channel can be caused by excessive sedimentation or other causes of channel widening (Figure 5).

Figure 5. Example of a Tree Trunk in the Middle of a Channel.

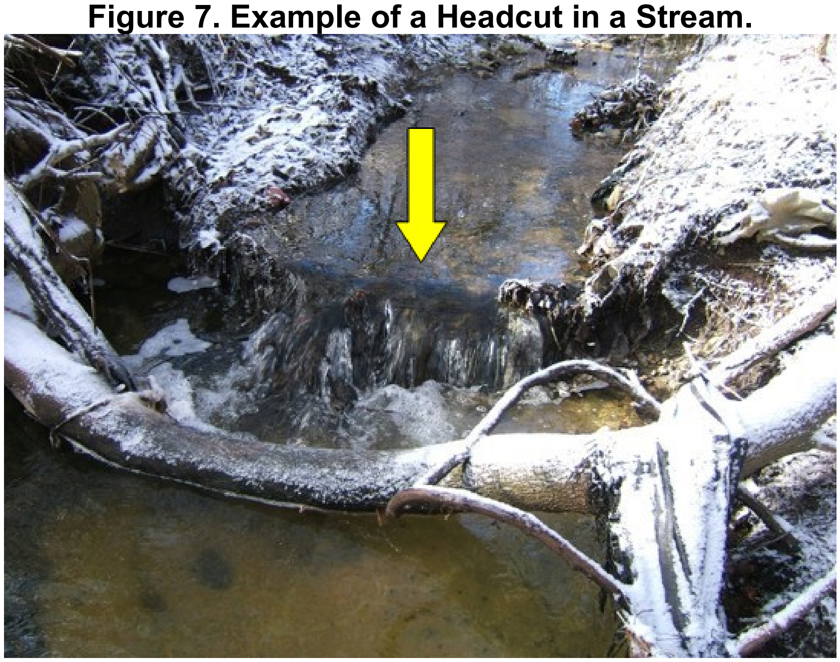


Exposed infrastructure (for example, sewer pipes, buried electrical wires, or street drains) is a sign of widening and/or incising channels (Figure 6).

Figure 6. Example of Exposed Infrastructure in a Channel.

Headcuts, or **nickpoints**, are points of channel incision where the channel bed elevation rapidly adjusts to a natural or human-induced disturbance (Figure 7). Headcuts range from over-steep riffles to small waterfalls and can rapidly migrate upstream, destabilizing channels far from the original disturbance. If observed at or near the mouth of a small tributary, another headcut has already migrated upstream in the larger stream.

Figure 7. Example of a Headcut in a Stream.



Exposed tree roots on both sides of the bank indicate channel widening (Figure 8).

Figure 8. Example of Exposed Tree Roots Along a Stream Channel.

Slumping banks (mass-wasting erosion) indicate erosion at the bank toe, often due to channel widening (Figure 9). (This stream near Ann Arbor is so over-wide that the low flow wetted channel, which is to the left, is not even visible in the picture.)

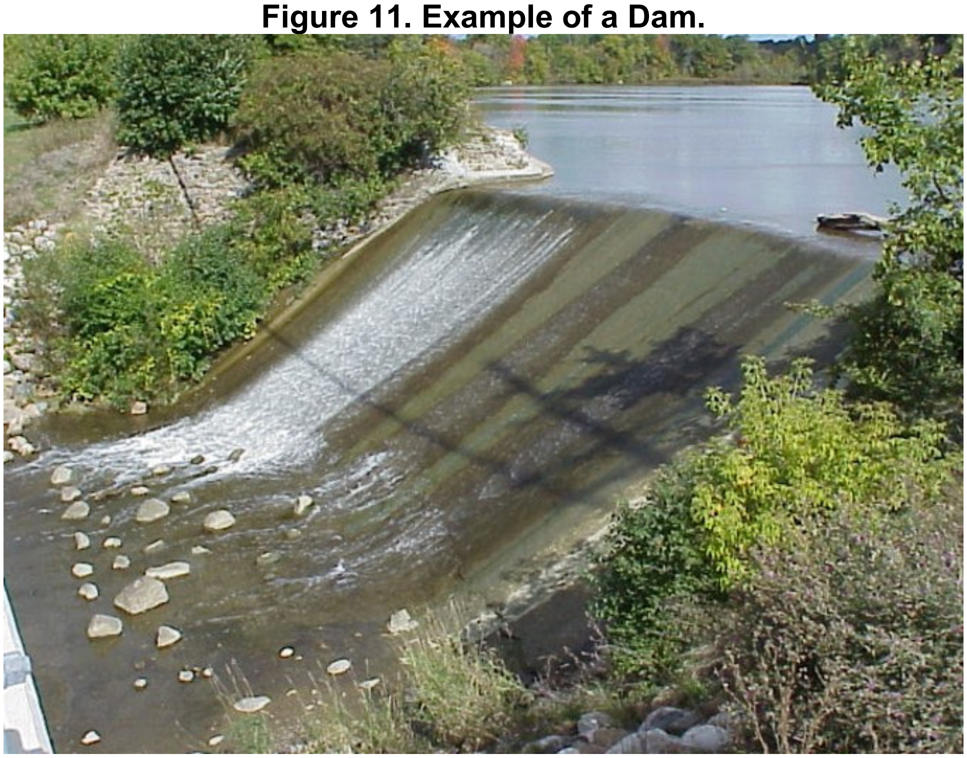
Figure 9. Example of Slumping Banks.

Failed bank stabilization BMPs (Figure 10). Arrows show bank toe rip rap from a previous, unsuccessful stabilization project. This site is downstream from a small dam, which produced sediment-starved, highly erosive "hungry water."

Figure 10. Example of Failed Bank Stabilization BMPs.

Proximity to dam (Figure 11). "Hungry water" downstream of dams can cause channel incision and/or widening.

Figure 11. Example of a Dam.



3.2 Examples of Qualitative Indicators of Channel Stability.

Herbaceous vegetation (grasses, sedges, wildflowers, emergent aquatic macrophytes, and mosses) **at the low flow water line** indicate channel stability (Figure 12).

Figure 12. Example of Herbaceous Vegetation at Low Flow Conditions.

Self-sustaining populations of **sensitive fish species**, including sculpins, certain darters, and <u>nonmigrating</u> salmonids, indicate channel stability (Figure 13). (Migrating salmonids can be temporarily found in highly unstable streams, during spawning season.)

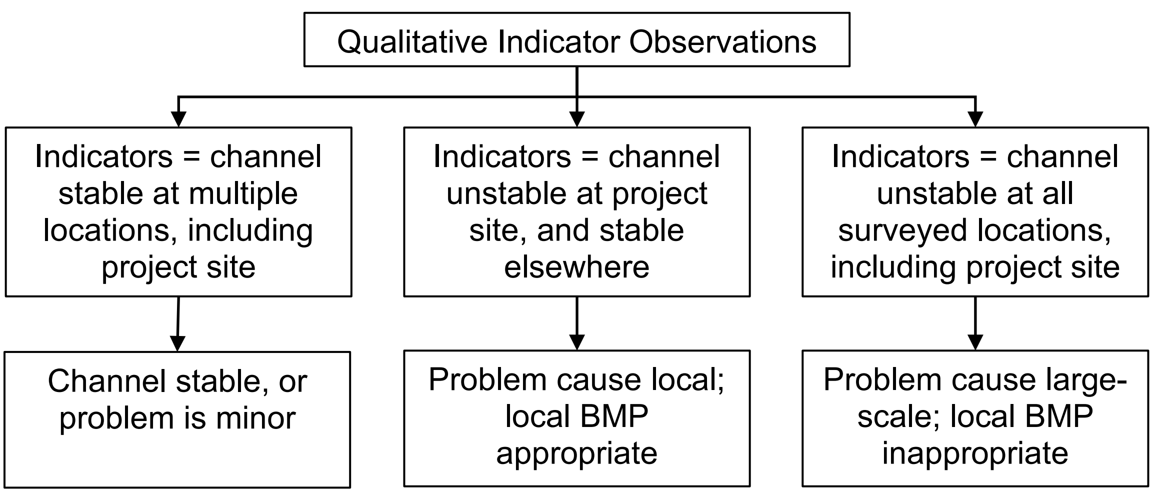
Figure 13. Example of a Sensitive Fish Species.

Aquatic moss growing on submerged rocks indicates minimal sedimentation and mobilization of the stream bottom materials (Figure 14). This is not necessarily true for attached filamentous algae like *Cladophora*, which grow more quickly than aquatic mosses and can therefore cope with limited channel bed mobility.

Figure 14. Example of Aquatic Moss.

In practice, qualitative observations of channel stability should be made at the project site and at multiple locations in the vicinity of the project site. The data collected should be interpreted per Figure 15.

Figure 15. Interpretation of Qualitative Bank Stability Observations.



Reporting requirements: If qualitative indicators are used to assess stream stability for an NPS grant application, a description of the presence or absence of indicators at the project site and at multiple locations in the vicinity of the project site should be included with the application.

4.0 Tool 2 – Bank Assessment for Nonpoint source Consequences of Sediment (BANCS) Supported by Ribbon Test and Erosion Pins.

A quantitative assessment of stream bank stability can be rapidly performed using the BANCS model (Rosgen et al., 2014). This model includes two bank erosion estimation tools:

1. Bank Erosion Hazard Index (BEHI)
2. Near-Bank Stress (NBS)

Further detail describing these methods and the data collection sheets for BANCS can be found in Rosgen's River Stability Field Guide (2014) and are available upon request from NPS staff.

BEHI - BEHI evaluates the susceptibility to erosion for multiple sources and assigns scores to several aspects of bank condition. An overall score can be used to inventory stream bank condition over large areas and/or prioritize eroding banks for remedial actions. The BEHI procedure consists of seven metrics (Figure 16):

1. Ratio of bank height to bankfull height
2. Ratio of riparian plant root depth to bank height
3. Weighted root density, in percent
4. Bank angle, in degrees
5. Surface protection, in percent
6. Bank material
7. Stratification of bank material

The BEHI variables are each calculated and converted to a BEHI rating. These ratings are divided into five categories of bank erosion potential (low, moderate, high, very high, and extreme) and have values between zero and ten. The numerical BEHI ratings are totaled and adjusted according to bank material and stratification of bank material. These ratings are used with NBS ratings to obtain annual erosion rate values. Figure 17 shows examples of two different streams (rural and urban), and Table 1 shows an example of how the BEHI score and rating would be determined for each of these streams.

Figure 16. Flowchart and Diagram Describing the BEHI Metrics. Adapted from River Stability Field Guide (Rosgen et al., 2014)

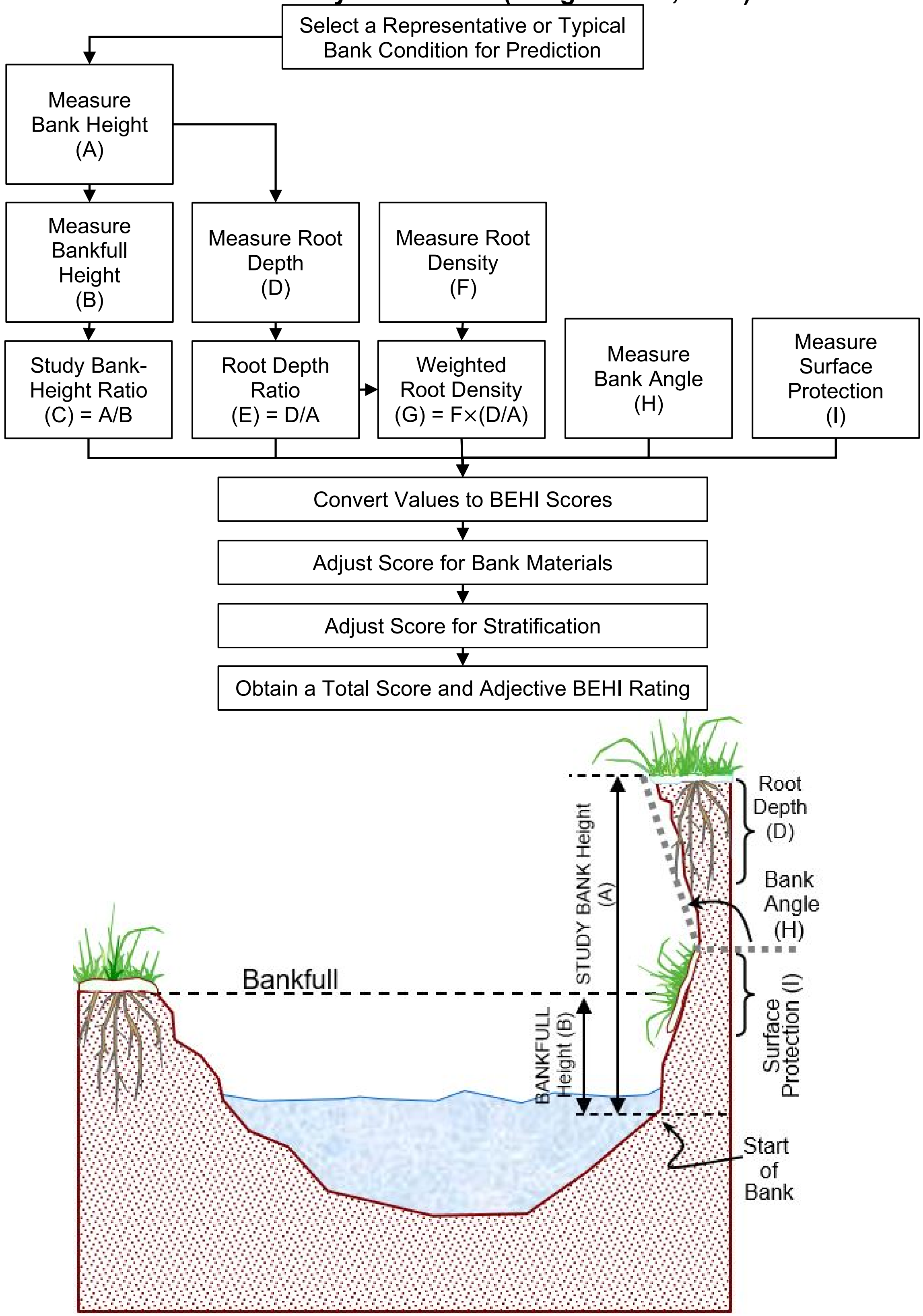


Figure 17. Examples of a Rural Stream (a) and an Urban Stream (b).

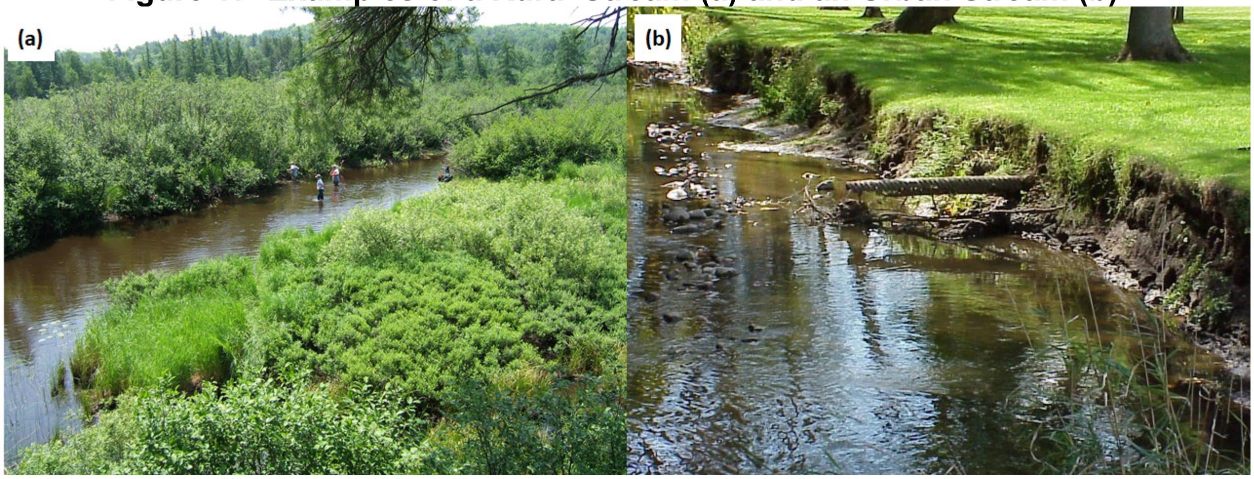


Table 1. Examples of BEHI Results

BEHI Metric	Stream Type			
	Rural Stream		Urban Stream	
	Measure	Score	Measure	Score
Ratio of bank height to bankfull height	≈1	1	≈2	8
Ratio of riparian plant root depth to bank height	≈95%	1	≈20%	7
Weighted root density	≈90%	1	≈20%	7.3
Bank angle	≈30°	2.4	≈80°	6
Surface protection	≈90%	1	≈20%	7
Bank material	Loam	0	Loam	0
Stratification of bank material	None	0	None	0
BEHI Score	6.4		35.3	
BEHI Category	Very Low		High	

NBS – Annual stream bank erosion rate prediction must include the NBS assessment associated with energy distribution against stream banks (Rosgen et al., 2014). There are seven different method options for determining NBS:

Level I	1. Channel pattern, transverse bar, or split channel/central bar creating NBS or high velocity gradient
Level II	2. Radius of curvature to bankfull width
	3. Pool slope to average water surface slope
	4. Pool slope to riffle slope
Level III	5. Near-bank maximum depth to bankfull mean depth
	6. Near-bank shear stress to bankfull shear stress
Level IV	7. Velocity profiles/isovels/velocity gradient

Levels I-IV are associated with the level of detail of the assessment (Level I being the most broad and rapid and Level IV being the most complex and time-consuming). The levels are not necessarily synonymous with reliability of prediction.

Ribbon Test - Stream bank appearance is not the only factor in assessing bank erosion hazard; however, bank soil cohesiveness is also important. For example, a high, steep, bare bank of sandy soil is much more erodible than an identical bank composed of clayey soil. A quantitative assessment of bank material cohesiveness is the ribbon test (Figure 18). The ribbon test is very simple and can be performed in a few seconds, as described below:

1. Put a ping-pong-sized ball of moist stream bank soil in palm of hand.
2. Roll soil into a cigar-shape between palms, then roll out between thumb and forefinger into ribbon 1/8” to 1/4” thick and as long as possible.
3. Compare to Table 2.

Figure 18. Example of a Stream Bank Soil Ribbon.

Table 2. Interpretation of Ribbon Test Results

Ribbon Length (cm)	Approx. % Clay	Soil Type/Texture	Qualitative Erosion Potential
None	≥ 50% sand	Sand	High
Flakes, not ribbon	0 – 20	Sandy silt/silt loam	High
< 5	20 – 40	Clayey sand/sand clay loam	Moderate
5 – 7.5	40 – 50	Silty clay	Low
> 7.5	> 50	Clay	Low

In practice, BANCS assessments and the ribbon test should be performed at the project site and at multiple locations in the vicinity of the project site. The data will be interpreted per Figure 19.

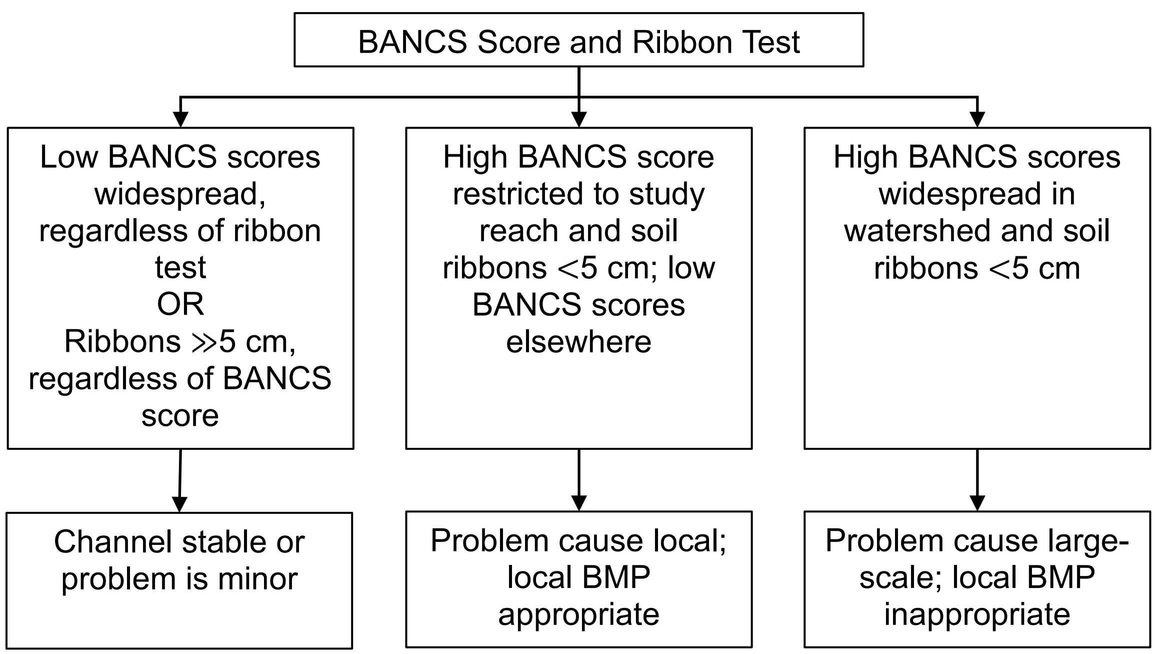
The BANCS procedure does have pros and cons. Pros include:

- Requires a low level of effort to perform assessment (1 day = multiple locations).
- Results help to prioritize reaches for implementation.
- Provides adequate reach information to estimate erosion rate.
- Provides a standardize approach to watershed-wide assessment of erosion.

While cons include:

- Natural bank erosion in an active floodplain can be mistaken for unnatural, excessive erosion.
- Training is required.
- It can be difficult to select a “representative” reach.
- Need to use regional reference curves and bankfull indicators to correctly identify bankfull.
- Validation of erosion rate should be measured with erosion pins over a minimum of one year.

Figure 19. Interpretation of BEHI and Ribbon Test Scores.



Erosion Pins – The most accurate measurement of erosion rate at a specific location can be obtained by installing bank and toe pins and measuring the amount of sediment lost over time. BANCS will result in an estimate of erosion rate. The estimated rate can be validated by comparing it to the actual measurement at erosion pins at least once per year. Further detail describing stream bank erosion and the data collection sheets for bank profiles can be found in Rosgen's River Stability Field Guide (2014) and are available upon request from NPS Program staff.

The toe pin is installed offset from the bank. An elevation rod is set on the toe pin with corresponding horizontal measurements taken to intercept the bank. A resurvey at the toe pin location allows for a detailed computation of a change in bank profile yielding lateral erosion rate.

Bank pins (smooth steel rods, four feet long or longer if needed) are driven horizontally at various positions in the stream bank. The amount of exposed pin upon resurvey following runoff events or annually is measured as the amount of lateral erosion at that site. Bank pins are not used if sod mats overhang the bank as the erosion pins help stabilize the bank. Bank pins are generally not used in banks composed of a cobble/gravel/sand matrix due to the physical disturbance during their installation. In these cases, only a bank profile is obtained.

Reporting requirements: If BANCS evaluations are used to assess stream stability for an NPS grant application, the scores from the project site and multiple locations in the vicinity of the project site should be included with the application.

5.0 Tool 3 – Hydrologic Flashiness Index.

The Richards-Baker Flashiness Index (R-B Index; Baker et al., 2004) is an expression of stream discharge variability, or hydrologic flashiness. Significantly increasing values of the R-B Index over time correspond to increasing variability in stream flashiness, which is interpreted as a strong indication of hydrologic instability (refer to Baker et al., 2004 for details of this calculation). United States Geological Survey (USGS) discharge data are required to calculate the R-B Index; consequently, its results can only be applied to stream reaches within a reasonable distance of a USGS gage station. Note that "reasonable distance" will be project-specific and should be discussed with the appropriate NPS Program engineer. EGLE has calculated and graphed the R-B Index trends for 308 locations throughout Michigan. The results are compiled in a report titled, "Application of the Richards-Baker Flashiness Index to Gaged Michigan Rivers and Streams," which was last revised in 2012 but is currently being updated. This report includes a map of the gages used and may be found at the "Nonpoint Source Hydrologic Analysis" link on EGLE's NPS Program Web site. Figure 20 illustrates some results for sites in the northern Lower Peninsula and showcases the three conditions of increasing, stable, and decreasing flashiness.

Figure 20. Examples of R-B Index Graphs for Rivers in Michigan.

Note: The trendline in each graph shows the conditions of: (a) increasing, (b) stable, and (c) decreasing flashiness.

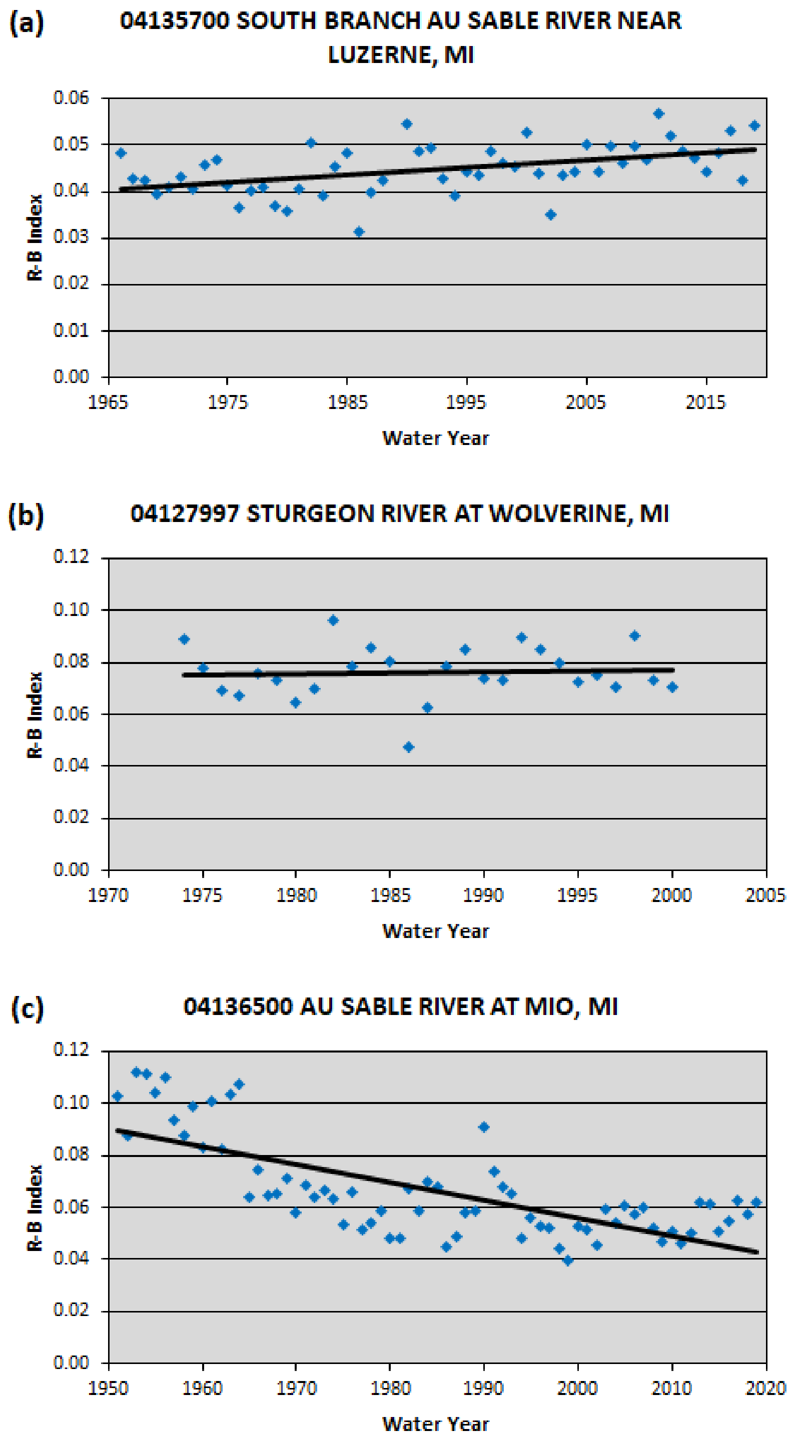


Figure 21 illustrates how stream flashiness data could influence BMP selection and siting in a watershed with multiple USGS gages. Stream flashiness is increasing at the two gages in Grayling and in the headwaters of the Au Sable River (upward red arrows), and steady or decreasing at the other four gages in the rest of the watershed (downward yellow or horizontal green arrows). Consequently, channel stability problems in the Grayling area may be due to large-scale hydrologic alteration and would be best addressed by BMPs like regional storm water retention or infiltration. In the rest of the watershed, channel stability problems are more likely to have a local cause and, if so, could be addressed with a small-scale BMP like stream bank stabilization.

There are pros and cons to the hydrologic flashiness index. Pros include:

- All calculations are already performed by EGLE and are available on the Nonpoint Source Hydrologic Analysis Web site.

While cons include:

- There are a limited number of gages.
- Interpretation is complicated by dams, water withdrawals, land uses, etc.

In practice, hydrologic flashiness information will be interpreted per Figure 22.

Figure 21. Example of Stream Flashiness Results:
Au Sable River, Michigan.
(Upward arrows = increasing flashiness; downward arrows = decreasing flashiness; level arrows = no trend)

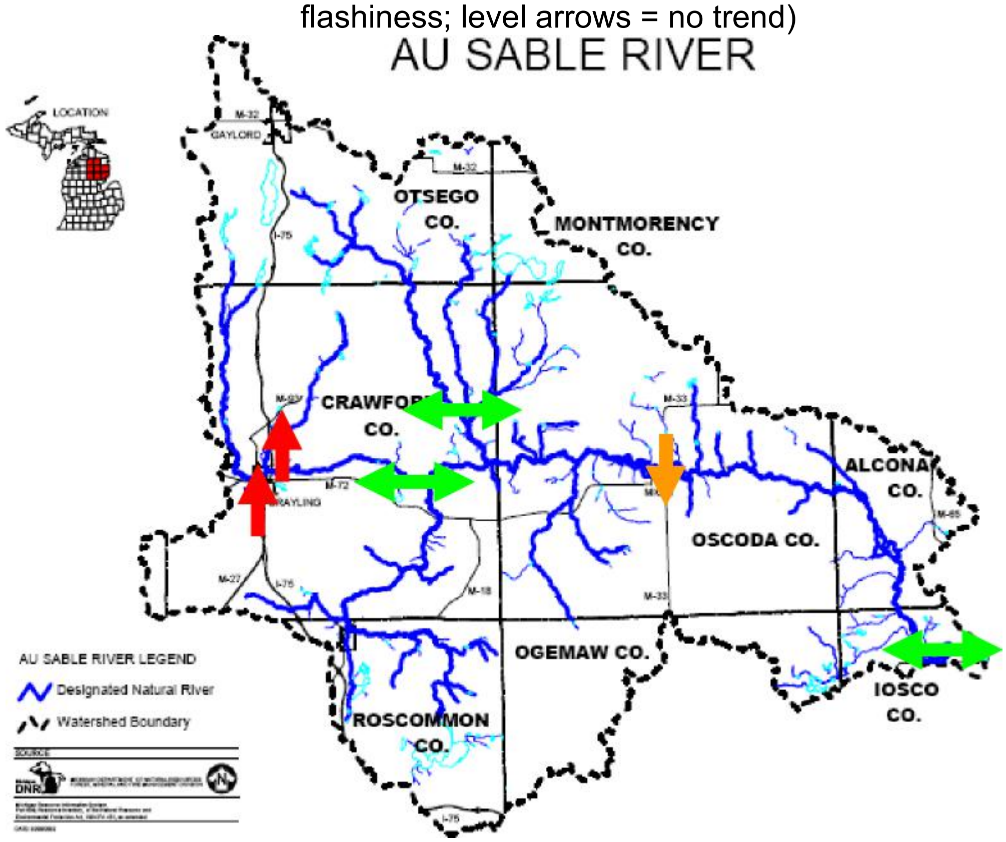
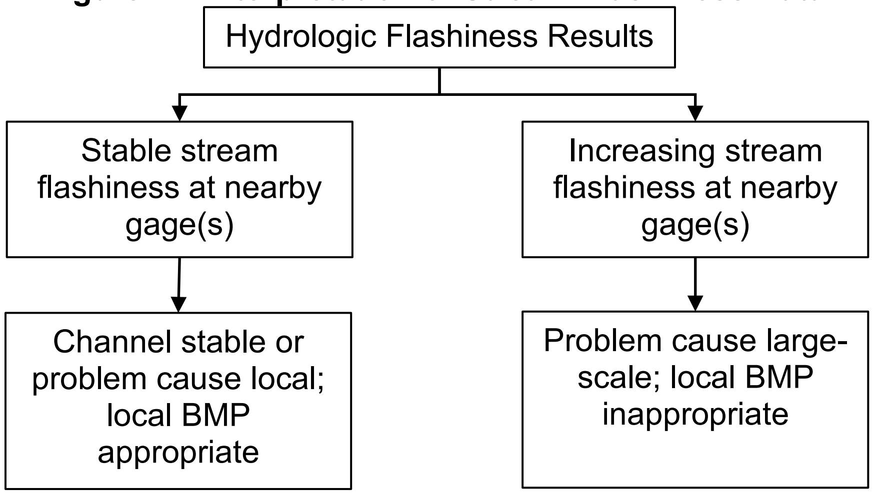


Figure 22. Interpretation of Stream Flashiness Data.



Reporting requirements: If flashiness trends are used to assess stream stability for an NPS grant application, the USGS site identification number of the gage(s) used and a short summary of their results should be included with the application.

6.0 Tool 4 – Tractive Force Calculations.

The tractive force equation is used to calculate the stress exerted by the water flowing in the stream channel on the stream bed, which is also known as the shear stress (τ). Shear stress increases with both increasing water depth and increasing channel slope, and higher shear stresses are capable of mobilizing larger stream bed particles. This relationship between shear stress and particle size allows it to be used as a rapid assessment of channel stability. The following three-step process describes how to determine channel stability via tractive force calculations: (1) calculate the shear stress produced by bankfull discharges and express it as the mobile particle size at that discharge, (2) perform a “pebble count” to measure the size of bedded sediment particles available to be moved at the bankfull discharge, and (3) calculate the ratio of the values determined in steps 1 and 2 to assess if the shear stress produced by bankfull discharges is likely to cause channel erosion and instability.

Step 1: Shear Stress Calculation

The first step in evaluating channel stability is to calculate the shear stress for a given site. This is accomplished by using the tractive force equation. For this application, the form of the tractive force equation that should be used is presented as follows:

$$\tau = D_{BF} \times S$$

where D_{BF} is the maximum bankfull depth and S is the channel slope. When D_{BF} is expressed in millimeters and S is dimensionless (feet/feet or meter/meter), τ is approximately equal to the particle size (in centimeters) that is mobile at bankfull discharges. This particle size is also known as the calculated incipient particle diameter

(IPD_c), which for simplicity will be denoted as “A” for the rest of this section. An example calculation is provided below:

Example of Calculated Incipient Particle Diameter (A)

Bankfull Depth: $D_{BF} = 1.97\ ft \approx 60\ cm \approx 600\ mm$
Channel Slope: $S = 0.002\ ft/ft$

Calculated Incipient Particle Diameter (A): $D_{BF} \times S \rightarrow 600 \times 0.002 = 1.2\ cm\ (small\ gravel)$

Key to this calculation is proper determination of bankfull depth and channel slope. Section 2 of this document provides guidance for determining bankfull depth and Harrelson et al. (1994) describes procedures for measuring channel slope. It must be noted that it can be very difficult to identify bankfull dimensions in unstable, incised streams. In these situations, and only when using tractive force calculations, channel depth from the top of the bank to the thalweg is substituted for bankfull depth (Figure 23).

Figure 23. Top of Bank (dashed lines) in an Incised Channel (Rouge River, Wayne County, Michigan)
Note: The banks are actually the same elevation, but the angle of the photo makes the bank on the right look lower.

Step 2: Pebble Count Measure

The second step in determining channel stability is to perform a “pebble count” at the given site. This is done by measuring the intermediate diameter of at least 100 "pebbles" (bedded particles that can range from silt to boulders). More information regarding the pebble count procedure can be found in Chapter 11 from Harrelson et al., 1994. After performing the pebble count, the 84th percentile diameter (D_{84}) needs to be calculated from the collected data (Figure 24). A number of empirical studies have indicated that the D_{84} is the maximum particle size mobile at bankfull discharges. This particle size is also known as the measured incipient particle diameter (IPD_m), which for simplicity will be denoted as "B" for the rest of this section.

Step 3: Ratio Calculation

The final step in determining channel stability is to calculate the ratio of A and B from steps 1 and 2, respectively. This ratio should be interpreted by comparing it to the values shown in Table 5.

There are pros and cons to tractive force measurements. Pros include:

- Requires a moderate level of effort (an experienced crew of two can survey two or three sites per day).
- Tractive force assesses the likely stability of the stream bed, unlike BANCS and the qualitive stability indicators that focus on the stream banks.

While cons include:

- Correctly determining bankfull elevation in stable streams requires training and experience.
- Substituting top of bank of bankfull elevation in incised streams can result in inappropriately high IPD_c, especially in over-wide but otherwise generally stable ditches.

The cons of this stream stability assessment tool in particular emphasize the need for a weight-of-evidence approach (Section 8.0).

Figure 24. Example of Pebble Count Data (Dashed red line = D_{84}).

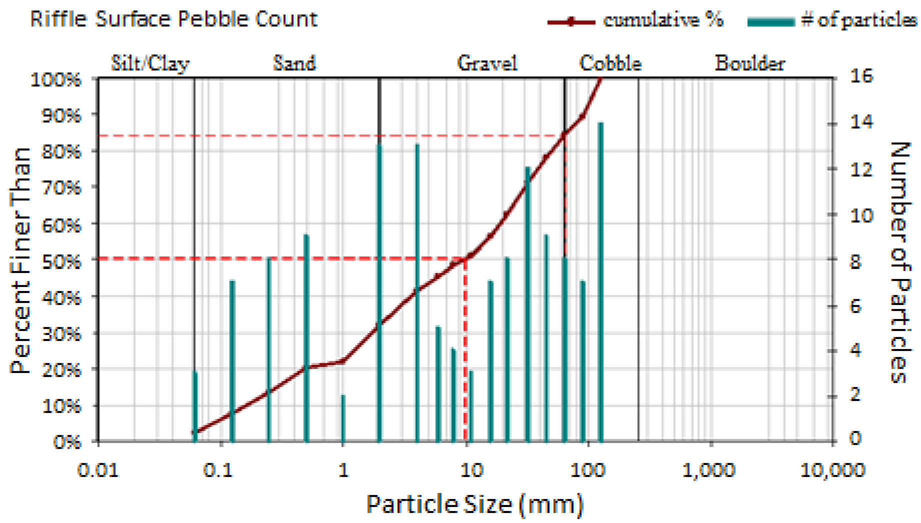
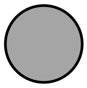
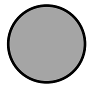
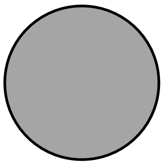
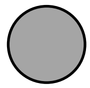


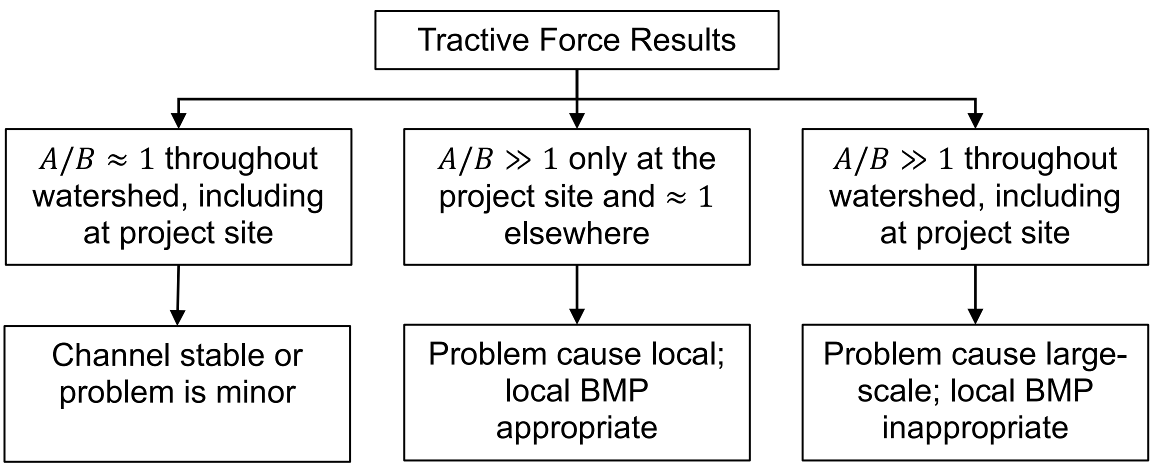
Table 5. Interpretation of the Tractive Force Calculation Results.

Calculated IPD (A)	Measured D84 (B)	Ratio of A / B	Conclusion
		$A / B \approx 1$	Stable Stream
		$A / B \gg 1$	Unstable Stream

*Note: If the ratio of A/B is less than 1, it is indicative of aggradation at the site.

In practice, tractive force measurements should be made at the project site and at several locations in the vicinity of the project site, and their data interpreted as per Figure 25.

Figure 25. Interpretation of Tractive Force Data.



Field work needed for collecting data for the tractive force calculations (channel depth, slope, and pebble counts) requires more training than the qualitive indicators. An experienced field crew of two could complete the field measurements in a couple of hours to one-half day per location, depending on stream size.

<u>Reporting requirements</u>: If tractive force data are used to access stream stability for an NPS grant application, ratio values from the project site and from several locations in the vicinity of the project site should be included with the application.

7.0 Tool 5 – Regional Geomorphic Reference Curves.

A regional reference curve (RRC) is a plot of drainage area *vs.* one of several channel dimensions or hydrologic attributes; most commonly, bankfull width, depth, cross-sectional area and discharge (Figure 26). Data for RRCs must be collected from stable stream reaches, but the curves can then be used to assess whether the dimensions of other streams are comparable and, therefore, whether the other streams are stable. A local reference curve could be more applicable to your site than a regional reference curve. RRCs for the state are currently being finalized and once complete will be posted to the NPS Program Web site.

Using RRCs to assess stream stability involves collecting channel dimension data (width, depth, and cross-sectional area) at the proposed project site and at several locations upstream, and then comparing the measured dimensions to the appropriate curves. Field techniques for collecting channel morphology data are described in Harrelson et al. (1994) and the Michigan Stream Team's field protocol (Michigan Stream Team, 2010). An important aspect of collecting field data from other streams for comparison to RRCs is recognizing bankfull elevations (Section 2). In most stable Michigan streams, a floodplain break or inflection point are the most reliable bankfull field indicators (Figure 2).

In practice, RRCs are used as follows:

1. Select the RRC appropriate to the project location (the coming report will identify which parts of the state are covered by RRCs).
2. Collect the field data described above and identify the drainage area upstream of the proposed project location.
3. Identify the expected bankfull dimensions by plotting the project location's drainage area on the appropriate RRCs.
4. Compare the expected bankfull dimensions to the bankfull dimensions measured at the project location. The RRCs will be plotted with confidence intervals around the drainage area: dimension regression line (as opposed to Figure 26, which does not show confidence intervals, just the regression intervals). If the measured dimensions fall inside the confidence intervals, that location is considered stable; otherwise, the channel may be unstable.

It should be noted that developing RRCs for the entire state is an ongoing process and some regions will not have curves for some years (e.g., the Lake Erie shoreline in southeastern Michigan).

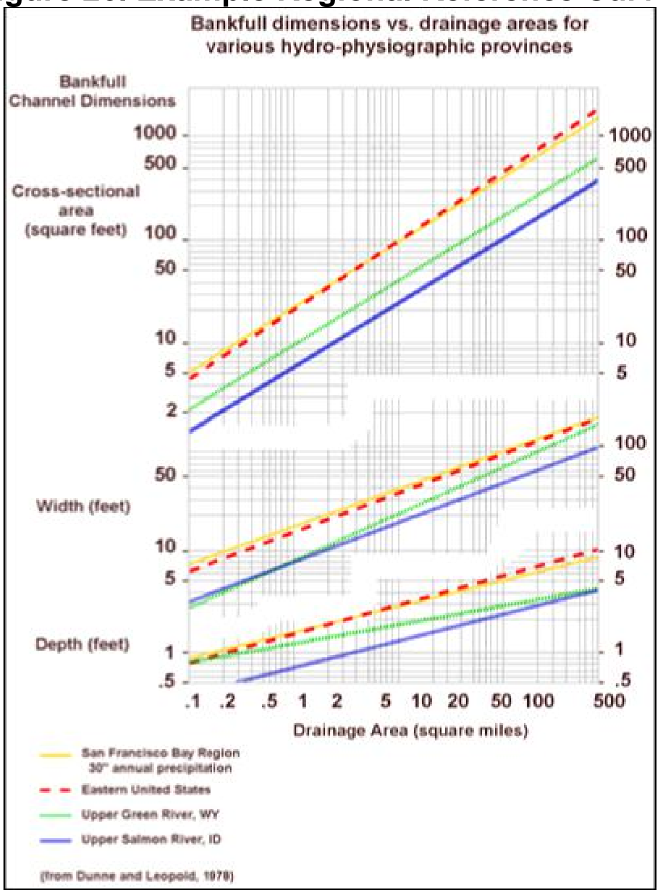
Regional reference curves have pros and cons, including a major limitation; the curves are currently under development and are not currently available, and even then, probably won't cover the entire state. Pros include:

- Requires a moderate level of effort (usually ≤1 day in the field for a crew of 2).
- If channel dimensions are abnormal, curves will identify approximate stable dimensions.

While cons include:

- Curves are currently being finalized and probably will not cover the entire State.
- Training is required for field measurements, especially for correctly identifying bankfull indicators.
- Only appropriate for alluvial channels (channels whose boundaries and dimensions are maintained by the sediment carried by the current), not for bedrock channels.

Figure 26. Example Regional Reference Curve.



Reporting requirements: If regional reference curves are used to assess stream stability for an NPS grant application, three graphs illustrating the channel dimensions (bankfull width, depth, and cross-sectional area) at the project site and several locations in the vicinity of the project site, plotted on the appropriate reference curve graphs, should be included with the application.

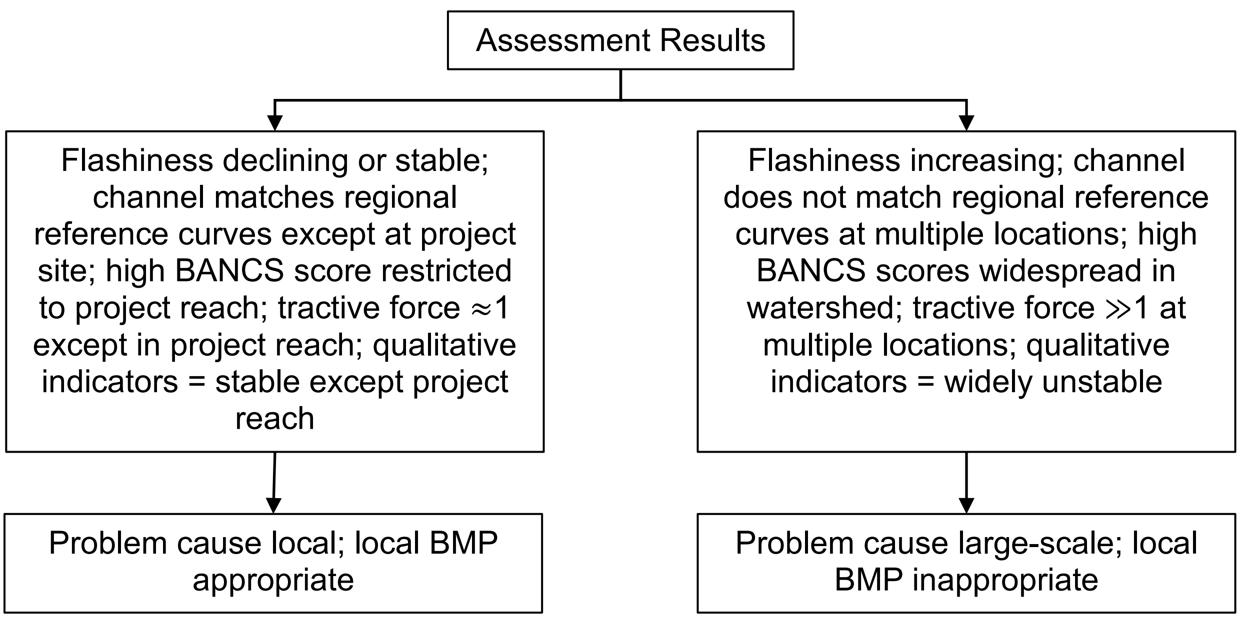
8.0 Combining the Tools – the Weight-of-Evidence Approach.

Since the stability assessment tools described in this document separately address different aspects of the stream channel condition (stream hydrology, stream banks, stream bed, and overall channel dimensions), and since channel stability problems can affect one or more of these aspects in a single stream, it is highly recommended that NPS grant applicants utilize as many of these stream stability assessment tools as possible when applying for an NPS grant. This is referred to as a weight-of-evidence approach. For example, for a proposed project in a particular watershed:

- Flashiness trends at nearby USGS gages, if available, can be assessed. This is free and quick given that the data are available from EGLE.
- Qualitative indicator observations and the BEHI observations can be made at the proposed project site and at multiple locations in the vicinity of the project site. An experienced crew of two could perform this work at many locations in a day.
- Field measurements for the tractive force calculations and comparison to the regional reference curves (when available) can be made at the proposed project site and at multiple locations in the vicinity of the project site. An experienced crew of two could perform this work at one or two locations per day.

In practice, information from multiple locations collected using a weight-of-evidence approach would be interpreted per Figure 27.

Figure 27. Weight-of-Evidence Approach to Stream Stability Assessment



9.0 Other Stream Stability Assessment Tools.

There are multiple other approaches to assessing stream channel stability, including channel evolution models (e.g., Simon, 1989), channel stability indices (e.g., Simon and Downs, 1995; Center for Watershed Protection, 2003; Center for Watershed Protection, 2005), steam bank stability indices (Pfankuch, 1975; Vermont Agency of Natural Resources, 2009), and sediment budget-based approaches to channel stability (Rosgen, 2006).

Most of these alternative approaches are more complicated than the five assessment tools described in this document, and some are more appropriate for more rocky, mountainous watersheds than are common in Michigan. Several, however, also provide more detailed and quantitative information. EGLE will consider the application of these alternative analyses on a case-by-case basis. Contact Alyssa Riley, NPS Program, at RileyA3@Michigan.gov or 517-512-9623 for more details.

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