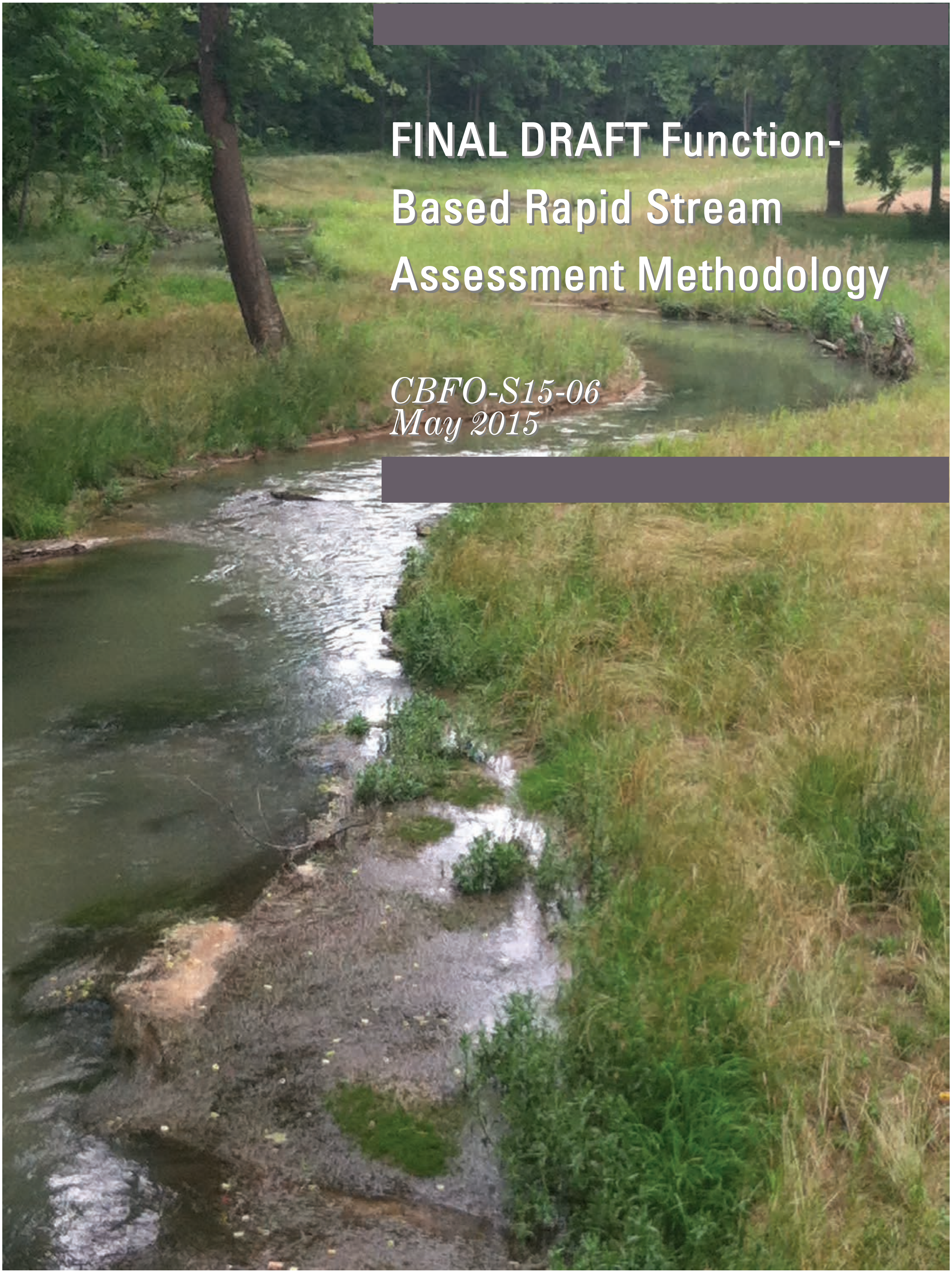


FINAL DRAFT Function-Based Rapid Stream Assessment Methodology

CBFO-S15-06
May 2015

FINAL DRAFT

FUNCTION-BASED RAPID STREAM ASSESSMENT METHODOLOGY

By: Richard Starr, Will Harman and Sandra Davis

Habitat Restoration Division
Chesapeake Bay Field Office
U.S. Fish and Wildlife Service

CAFE – S15 - 06

Annapolis, MD
May 2015

TABLE OF CONTENTS

I. INTRODUCTION....1

II. PURPOSE OF FUNCTION-BASED RAPID STREAM ASSESSMENT METHODOLOGY....1

III. ASSESSMENT METHODOLOGY OVERVIEW....1

A. Overview....1
B. Mwthodology Sequence....2

IV. OFFICE PRE SITE VISIT TASKS....3

V. WATERSHED ASSESSMENT....4

A. Watershed Impoundments....4
B. Concentrated Flow....5
C. Existing and Change in Land Use....6
D. Distance to Roads....6
E. Flashiness....7
F. Riparian Vegetation....8
G. Sediment Supply....8
H. Water Quality....10
I. Landscape Connectivity....11
J. Overall Watershed Condition Rating....11

VI. EXISTING AND PROPOSED FUNCTION-BASED RAPID REACH LEVEL STREAM ASSESSMENT....12

A. Field Equipment....14
B. Bankfull Determination and Rosgen Classification....15
1. Bankfull Determination....15
2. Rosgen Classification....17
C. Function-based Rapid Reach Level Stream Assessment....18
1. Level 1 – Hydrology....18
a) Runoff....18
b) Level 1 - Hydrology Overall Function-based Rating....19
2. Level 2 - Hydraulics....19
a) Floodplain Connectivity....19
b) Level 2 - Hydraulic Overall Function-based Rating....26
3. Level 3 - Geomorphology....26
a) Riparian Vegetation....26
b) Lateral Stability....29
c) Bedform Diversity....38
d) Geomorphology Overall Function-based Rating....50
4. Level 4 - Physicochemical....50
a) Water Appearance and Nutrient Enrichment....51
b) Detritus....52

c) Physicochemical Overall Function-based Rating 53
5. Level 5 - Biology 54
a) Macroinvertebrate 55
b) Fish 58
c) Biology Overall Function-based Rating 60
D. Rapid Assessment Summary 62
1. Rapid Watershed Assessment 62
2. Overall Existing Reach Level Stream Condition 62
3. Channel Evolution Trend 63
a) Channel Evolution 65
4. Reach Area Restoration Potential 69
5. Overall Proposed Assessment Reach Function-based Condition 69
E. Overall project evaluation 70
1. Proposed Project Goals and Objectives 70
2. Watershed Condition Influence 70
3. Restoration Potential 70
4. Proposed Project Description 71
5. Potential Function-based Uplift and/or Loss 71
6. Project Effectiveness 71
7. Design Completeness 71
8. Project Potential Success 72
9. Alternatives Analysis 72
10. Are all other regulatory considerations satisfied 72

Title: FINAL DRAFT Function-Based Rapid Field Stream Assessment Methodology

Date: May 2015

Prepared by:

- Richard Starr, U.S. Fish and Wildlife Service, Annapolis MD
- Will Harman, Stream Mechanics, Raleigh, NC
- Sandy Davis, U.S. Fish and Wildlife Service, Annapolis MD

Appropriate Citation:

Starr, R., W. Harman, S. Davis. 2015. *FINAL DRAFT Function-Based Rapid Field Stream Assessment Methodology*. U. S. Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. CAFE S15-06.

LIST OF FIGURES

Figure 1. Differing Performance Standards based on Rosgen Stream Type
Figure 2. Rating Hierarchy.
Figure 3. Potential Bankfull Indicators.
Figure 4. Rosgen Stream Types based on Landscape Position (Rosgen 2006)
Figure 5. Bank Height Ratio, after Rosgen, 1996.
Figure 6. Measurement of Bank Height Ratio from a Longitudinal Profile (Source Michael Baker International).
Figure 7. Measurement of Entrenchment Ratio.
Figure 8. Vegetation Layers
Figure 9. BEHI Variables (Rosgen 2006).
Figure 10. Example Bank Erosion Rate Curve (USFWS 2005)
Figure 11. NBS Condition (Rosgen 2006).
Figure 12. Depositional Patterns (Rosgen 2006).
Figure 13. Typical Pool-to-Pool Spacing Measurements.
Figure 14. Pool depth variability.
Figure 15. Selection of intolerant stream macroinvertebrates (MD DNR, 2004).
Figure 16. Lane's Diagram.
Figure 17. Simon Channel Evolution Model.
Figure 18. Rosgen Evolution Model by Stream Type (Rosgen 2006).

LIST OF TABLES

Table 1. Rosgen (1994).
Table 2. BEHI Variables (Rosgen, 2006).

LIST OF PHOTOS

Photo 1. Example of Aggradation
Photo 2. Example of Aggradation
Photo 3. Example of Degradation
Photo 4. Example of a Headcut
Photo 5. Example of Riffle Macroinvertebrate Habitat
Photo 6. Example of Woody Debris Macroinvertebrate Habitat
Photo 7. Detritus.
Photo 8. Macroinvertebrates.
Photo 9. Brook Trout.

APPENDICES

Appendix A. Draft Function-based Rapid Stream Assessment Forms
Appendix B. Regional Curves
Appendix C. Rosgen Stream Classification System and Valley Types
Appendix D. BEHI and NBS Conditions
Appendix E. Stream Macroinvertebrates
Appendix F. Examples of Channel Evolution Photos

I. INTRODUCTION

The Maryland Department of Environment (MDE), Maryland State Highway Administration (SHA) and the U.S. Fish and Wildlife Service (Service) - Chesapeake Bay Field Office (CBFO) have entered into a partnership to assist MDE in meeting its goals for restoring and enhancing the quality of Maryland's water and floodplain resources. As part of this partnership, the Service has developed a rapid function-based stream assessment methodology. While this methodology is based on several existing proven rapid assessment methods, it does include some new measurement methods and performance standards. Therefore, this methodology is being released as a final draft. The Service requests feedback from users for one year. The Service will then revisit and potentially revise the methodology based on feedback. This document contains guidelines and standard forms on the use of this methodology.

II. PURPOSE OF FUNCTION-BASED RAPID STREAM ASSESSMENT METHODOLOGY

The primary purpose of this methodology is to provide MDE regulators with a function-based rapid stream assessment methodology to verify existing and proposed stream function-based conditions submitted by stream restoration permit applicants. However, it can be used for a variety of other purposes. For example, it can be a very useful tool to rapidly determine existing function-based stream conditions and if a particular site would be a good restoration site based on potential function-based uplift. It could be used as part of a pre-permit application meeting to demonstrate the need for restoration. It can also be used to prioritize potential restoration sites as part of a watershed-level assessment.

III. ASSESSMENT METHODOLOGY OVERVIEW

A. <u>OVERVIEW</u>

The methodology was developed based on the Stream Functions Pyramid Framework (SFPF) (Harman et al, 2012). The SFPF focuses on the hierarchical relationship of stream functions to determine the overall functional condition of a stream reach. It consists of three components: 1) watershed assessment, 2) existing and proposed function-based rapid stream assessment, and 3) overall project evaluation (Appendix A). The watershed assessment focuses on identifying potential constraints and stressors that influence the condition of the project area. The existing and proposed function-based rapid stream assessments have the same assessment parameters; therefore, they are combined into one assessment form. However, each assessment parameter has a space to evaluate existing function-based conditions and to predict the potential function-based uplift and/or loss of the proposed project. The overall project evaluation focuses on questions that will assist in determining the final permit decision.

Since this is a rapid methodology, it is not intended to address all stream functions but rather those critical to understanding stream processes. However, the formatting of the methodology does allow for the addition or removal of assessment parameters and measurement methods based on user goals and objectives. The assessment parameters are function-based. The term function-based is used instead of functional because the measurement methods include a combination of functions and structural measures. A functional measurement measures a function as a rate over time, whereas a structural measurement measures a function at one point in time. However, this combination is considered function-based because the parameters and measurement methods are used to quantify or qualitatively describe the overall functional condition for a given assessment parameter.

The results of the assessment only represent the function-based condition at the time of the assessment, although it does predict the direction of stability trend. Furthermore, the results of the assessment are a qualitative function-based rating rather than a quantitative function-based rating (i.e., no numerical scoring). However, the methodology can have scoring added, if so desired.

As stated above, under Purposes of Function-based Rapid Stream Assessment Methodology, the primary use of this methodology is for regulators to review stream restoration permit applications. Therefore, the guidelines provided in this document describe how to complete the assessment forms using information from the permit application package as well as data from a site visit. However, there are some guidelines provided that describe how an assessment parameter can be assessed if relevant data was not provided in the permit application or if the forms are being completed prior to the submittal of a permit application, possibly as part of a pre-permit application meeting.

The use of the rapid assessment methodology, as with most rapid methods, requires well-experienced practitioners. While reducing subjectivity was a goal during the development of the assessment methodology, many of the assessment parameters require skilled practitioners to assess correctly. Assessors must be knowledgeable in fluvial geomorphic and watershed processes and be well trained and experienced in assessing stream processes.

B. METHODOLOGY SEQUENCE

The methodology report is written based on the sequence of how the assessment should be conducted, as much as possible. However, some sections in the report are out of sequence based on where information is recorded on the data sheets. Therefore, this section lists the order of how the assessment methodology should be conducted. Detailed descriptions of how each step should be conducted are provided within the report.

Assessment Sequence:

1. Office Pre Site Visit Tasks
2. Rapid Watershed Assessment Form
3. Rapid Assessment Summary Form – Bankfull Determination
4. Rapid Assessment Summary Form – Rosgen Classification
5. Existing and Proposed Function-based Rapid Reach Level Stream Assessment Form – Only the existing conditions

6. Rapid Assessment Summary Form - Overall Existing Function-based Rapid Stream Assessment
7. Rapid Assessment Summary Form – Channel Evolution Trend
8. Rapid Assessment Summary Form - Restoration Potential
9. Existing and Proposed Function-based Rapid Reach Level Stream Assessment Form - proposed conditions
10. Rapid Assessment Summary Form – Overall Proposed Function-based Rapid Stream Assessment
11. Overall Project Evaluation

IV. OFFICE PRE SITE VISIT TASKS

Office tasks should be completed prior to a site visit in order to gather background information needed to complete the assessment forms and to have a thorough understanding of the proposed project, existing conditions, and potential conditions, as documented by the permit applicant. The assessor will record the results of the office assessment on the Watershed Assessment, Reach Level Assessment and Overall Project Review forms. Additionally, the reviewer should identify critical information in the permit application needed to conduct the site assessment. Such information could include reference reach data, design criteria, constraints (e.g., bridges, utilities, property lines, etc.), proposed restoration activities, critical areas (e.g., wetlands, rare and threatened species, etc.) and bankfull determination. The results of the assessment forms and application review are used for two primary purposes during the site assessment. First, to verify existing and proposed stream function-based conditions submitted by a stream restoration permit applicant and second, to provide the assessors with the necessary information to conduct the site assessment. The following is a list of tasks to perform:

1. Review applicant assessment and design report and design plan set.
2. Complete the Function-based Stream Assessment Checklist (Starr et al, 2015).
3. Complete appropriate design review checklist (Starr et al, 2015), if the design is 60% complete or greater.
4. Complete Rapid Watershed Assessment form. Refer to Section V - Watershed Assessment for directions.
5. Complete, as much as possible, the Rapid Watershed and Reach Level (existing and proposed conditions) Assessment forms based on the design report. This rapid assessment will be verified as part of the site visit and any parameters not addressed in the report will be addressed in the field. Note that more than one Rapid Reach Level Assessment form may need to be completed for the project area. Refer to Section VI – Existing and Proposed Function-based Rapid Reach Level Assessment for specific guidance on how to determine if more than one rapid assessment form needs to be completed.
6. Complete questions 1, 4, 6 and 7 of the Overall Project Review form. These questions relate mostly to the watershed assessment, proposed project description and proposed project design plan set. The remaining questions on the Overall Project Review form will be completed during the site visit.

V. WATERSHED ASSESSMENT

The watershed assessment focuses on identifying potential constraints and stressors that influence the condition and restoration potential of the proposed project site. The focus of the assessment is on how the watershed specifically influences flow regimes, water quality, sediment supply, connectivity and land uses. Most of watershed assessment occurs in the office, but some parameters require field verification. Each assessment parameter will be rated as Good (G), Fair (F) or Poor (P) depending upon existing conditions. Guidance is provided below on how to rate each parameter.

A. WATERSHED IMPOUNDMENTS

WATERSHED ASSESSMENT					
	Category / Parameter / Measurement Method	Description of Watershed Condition			Rating (G, F, P)
		Good	Fair	Poor	
1	Hydrology / Runoff / Watershed impoundments	No impoundment upstream of project area	No impoundment within 1 mile upstream of project area OR impoundment does not adversely affect hydrology or fish passage	Impoundment(s) located within 1 mile upstream of project area and/or has an adverse effect on hydrology and/or fish passage	

An impoundment is any man-made structure located in-line on a stream system that impedes the natural flow of running water and movement of aquatic species. Impoundments upstream of a project area can significantly influence the flow regimes and sediment supply. If an impoundment is large enough, it could alter the magnitude, frequency, and duration of flows. Specifically, it could reduce the flows needed to transport sediment and/or flows needed to inundate floodplains. If sediment transport capacity is reduced, then streambed aggradation can occur, resulting in smothering of critical aquatic habitats. However, immediately downstream of an impoundment, channel bed degradation can to occur. This happens because water released from impoundments lack sediment and is high energy. Impeded flows can also reduce floodplain inundation that can cause adverse impacts to adjacent wetland habitats. Lastly, impoundments upstream or downstream could adversely influence anadromous and resident fish movement.

To identify impoundments, such resources as aerial photography, USGS quadrangle maps, road maps, Maryland dam inventory data, and the Chesapeake Fish Passage Prioritization (Martin and Apse, 2013) can be used. If any impoundments are identified within one mile upstream of the project area, determine if it is large enough to influence the flow regime and sediment supply and transport by determining what storm flow events are controlled by the impoundment. To determine the storm flows controlled by an impoundment, visit the site or speak with the persons responsible for managing the impoundment. If the event is less than the 2-year storm event, it is unlikely to have an adverse impact to the project area. As the impoundment capability to control larger storm flow events increases, the more likely the impoundment could have adverse impacts to the project area.

If there is an impoundment upstream or downstream of the project area, determine if it impedes fish passage. Note whether resident fish movement and/or anadromous fish movement is affected. Also, verify whether the impoundment has a fish passage structure.

If no impoundment exists, the assessment parameter receives a Good rating. If an impoundment is greater than one mile from the project area, does not influence storm flows greater than a 2-year storm, but could impede fish movement, then the assessment parameter receives Fair rating.

If an impoundment exists within one mile, influences storm flows greater than a 2-year storm and impedes fish movement, then the assessment parameter receives a Poor rating.

B. CONCENTRATED FLOW

WATERSHED ASSESSMENT					
	Category / Parameter / Measurement Method	Description of Watershed Condition			Rating (G, F, P)
		Good	Fair	Poor	
2	Hydrology / Runoff / Concentrated Flows	No potential for concentrated flow/impairments from adjacent land use	Some potential for concentrated flow/impairments to reach restoration site, however, measures are in place to protect resources	Potential for concentrated flow/impairments to reach restoration site and no treatments are in place	

Concentrated flows are any surface stormwater flows that enter the project area as a point source. Concentrated flows have the potential to adversely affect channel stability and aquatic resources by causing channel erosion and transporting pollutants directly to the stream. The affect is dependent upon adjacent land uses and whether there are existing stormwater treatments in place. During the site visit, walk the floodplain on both sides of the project area. If any concentrated flows exist, determine whether the source has a BMP treatment structure. If it does, this assessment parameter receives a Fair rating and if not, a Poor NF.

C. EXISTING AND CHANGE IN LAND USE

WATERSHED ASSESSMENT					
Category / Parameter / Measurement Method		Description of Watershed Condition			Rating (G, F, P)
		Good	Fair	Poor	
3	Hydrology / Runoff / Existing and Change in Land Use	Rural communities/slow growth or primarily forested (>70%)	Single family homes/suburban development occurring or active agricultural practices occurring, or commercial and/or industrial development starting, forested area 20 - 70%	Rapidly urbanizing/urban or primarily active agricultural practices (> 70%), forested area <20%	

Existing land uses and changes in land use describes how humans have modified the landscape upstream of the project area. The influences of existing land use and land use change (e.g., forested to rural, then to urban) on stream functions have been well documented. Dense development upstream of a project area can create concentrated flows, which in turn increase stream energy thus resulting in the potential for stream erosion. Conversely, a well-vegetated riparian corridor provides stability through the rooting systems of the vegetation. Knowledge of adjacent land use is required to develop an understanding of the overall function-based condition of the project area, as well as the restoration potential.

The determination of land use percentages and changes in land use is an office exercise. Ideally, the permit application package should contain the percentages for the project area. However, if it did not, a variety of sources to obtain this information are available, including County Planning offices, Maryland Department of Natural Recourses, StreamStats (USGS, 2012) and Maryland Office of Planning. Changes in land uses can also be obtained from Maryland of Planning and county level government. The overall assessment parameter rating is directly based on the delineative criteria stated in the existing and changes in land use section of the assessment form.

D. DISTANCE TO ROADS

WATERSHED ASSESSMENT					
Category / Parameter / Measurement Method		Description of Watershed Condition			Rating (G, F, P)
		Good	Fair	Poor	
4	Hydrology / Runoff / Distance to Roads	No roads in or adjacent to site. No proposed major roads in or adjacent to site in 10 year DOT plans	No roads in or adjacent to site. No more than one major road proposed in 10 year DOT plans	Roads located in or adjacent to site boundary and/or major roads proposed in 10 year DOT plans	

The location and density of roads can affect stream functions in a variety of ways. They can influence water quality, increase stream flows, reduce floodplain area, accelerate stream velocities through constrictions (e.g., undersized culverts), promote streambed degradation, and effect connectivity.

The determination of road distances is an office exercise. The easiest way to determine existing road distances is through the use of a road map. To determine future roads, refer to county planning documents or the State Highway Administration planning documents. The assessment parameter rating is directly based on the existence and location of roads and future road locations. Roads are defined as driveways and side roads. Major roads are defined as parkways, highways, interstates that could drain significant amounts of water to project area.

E. FLASHINESS

WATERSHED ASSESSMENT					
Category / Parameter / Measurement Method		**Description of Watershed Condition**			**Rating (G, F, P)**
		Good	**Fair**	**Poor**	
5	Hydrology / Runoff / Flashiness	Non-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover less than 6%	Semi-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover 7%-15%	Flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover greater than 15%	

Flashiness is typically defined as the deviation in storm flows as compared to baseflows. It reflects the frequency and rapidity of short-term changes in stream flow. Flow regime can be used to describe flashiness. Flow regime consists of stormwater magnitude, duration, and frequency. Flow regime can vary greatly depending upon the landscape character of the watershed. The primary watershed characteristics that influence flow regime include soils, geology, impervious surfaces, basin slope, time of concentration, land use and land cover. The rate and volume of flow that reaches a stream system has a direct relationship to stream functions and conditions. A watershed that is highly developed will have a different flow regime than a predominantly forested watershed. The stormwater runoff from a highly developed watershed will reach the stream rapidly, in large volumes, and have very little retention and groundwater recharge. This type of flow regime increases stream energy and sediment transport capability. Consequently, streams in urban watershed are typically unstable and characterized as deeply incised (i.e., disconnected from the floodplain) with a high width to depth ratio. In a predominantly forest watershed, runoff will reach the stream more slowly and in less volume, resulting in a lower stream energy and greater retention and groundwater recharge.

The determination of flashiness is an office and field exercise. The office exercise involves understanding watershed characteristics, rainfall patterns and stormwater infrastructure (i.e., point source discharges). If the primary watershed characteristics that influence flow regime were not provided in the permit application package it can be obtained from aerial photography, USGS quadrangle maps, county and state land use maps, county infrastructure maps, soil and geology maps, lidar, county topographic maps, and StreamStats. The overall assessment parameter rating is directly based on the delineative criteria stated in the flashiness section of the assessment form.

F. RIPARIAN VEGETATION

	Category / Parameter / Measurement Method	Description of Watershed Condition			Rating (G, F, P)
		Good	Fair	Poor	
6	Geomorphology / Riparian Vegetation	>80% of contributing stream length has >25 ft corridor width	50 - 80% of contributing stream length has >25 ft corridor width	<50% of contributing stream length has >25 ft corridor width	

Riparian vegetation is the vegetated region adjacent to streams and wetlands that provide multiple critical benefits. Some benefits include shade cover, organic matter contributions, energy dissipation of energy, nutrient uptake, stream bank stabilization landscape connectivity, and wildlife habitat.

The assessment of riparian vegetation is an office and field exercise. The office exercise involves reviewing the most recent aerial photos to determine that location and amount of riparian buffer upstream of the project area. If this information was not provided in the permit application package, aerial photography can be obtained from multiple sources such as USGS, NRCS, state and county agencies, and websites (i.e., google earth, google maps, bing maps, etc.). The field exercise involves viewing the stream at various access points upstream of the project area to verify the existence of riparian vegetation made as part of the office assessment. The overall assessment parameter rating is directly based on the delineative criteria stated in the riparian section of the assessment form.

G. SEDIMENT SUPPLY

WATERSHED ASSESSMENT					
	Category / Parameter / Measurement Method	Description of Watershed Condition			Rating (G, F, P)
		Good	Fair	Poor	
7	Geomorphology / Sediment Supply	Low sediment supply. Upstream bank erosion and bed load supply is minimal. There are few bars present in the channel.	Moderate sediment supply from upstream bank erosion and bed load supply. There are some point bars and small lateral bars.	High sediment supply from upstream bank erosion and/or bed load supply. There are numerous alternating point bars, transverse bars, and/or mid-channel bars.	

Sediment supply is the amount of bedload and suspended sediment being delivered to the project area. The amount of sediment supply is influenced by watershed characteristics and stream functions and conditions. Watershed characteristics such as highly erodible soils, impervious surfaces greater than 15 percent, steep basin slopes, rapid time of concentration, limited forested areas and highly developed land uses (e.g., residential, urban, industrial and agricultural) could result in large sediment supplies. Additionally, eroding streams are a significant source of sediment. The amount of sediment supply will significantly influence restoration potential and design restoration approach. If the project area has a significant sediment supply, then a design restoration approach should be used that transports the sediment supply or some other solution should be provided that addresses the sediment supply without impacting other stream functions.

The determination of sediment supply is an office and field exercise. Use the assessment results of the watershed parameters 5 and 6 (flashiness and riparian vegetation, respectively) as a starting point. If there is a flashy flow regime, highly erodible soils and limited riparian vegetation, then there is a higher potential for sediment supply, from eroding streambanks, to reach the project area. The site visit involves viewing the stream at various access points upstream of the project area to verify the stream stability predictions made as part of the office assessment. The field verification of stability will focus on floodplain connectivity, lateral stability, riparian vegetation, and bedform diversity. Refer to Sections VI.C.2. Hydraulics and VI.C.3. Geomorphology below that describes how to assess these parameters. The overall assessment parameter rating is directly based on the delineative criteria stated in the sediment supply section assessment form.

H. WATER QUALITY

WATERSHED ASSESSMENT					
	Category / Parameter / Measurement Method	**Description of Watershed Condition**			**Rating (G, F, P)**
		Good	**Fair**	**Poor**	
8	Physicochemical / Water Quality / 303(d) List	Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks. Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present. Not on 303d list	Considerable cloudiness most of the time; objects visible to depth 0.5 to 1.5 ft; slow sections may appear pea-green; bottom rocks or submerged objects covered with green or olive-green film; or moderate odor of ammonia or rotten eggs. Greenish water along entire reach; overabundance of lush green macrophytes; abundant algal growth, especially during warmer months. On or downstream of 303d list and TMDL/WS Mgmt plan addressing deficiencies	Very turbid or muddy appearance most of the time; objects visible at depth< 0.5 ft; slow moving water maybe bright green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface; or strong odor of chemicals, oil, sewage, or other pollutants. Pea-green, gray, or brown water along entire reach; dense stands of macrophytes clogging stream; severe algal blooms creating thick algal mats in stream. On or downstream of 303d list and no TMDL/WS mgmt plan to address deficiencies	

The water quality assessment parameter evaluates water turbidity, potential pollutants and nutrients. Turbidity is evaluated after the stream has had time to settle following a storm event. Streams that contain pollutants will have any one of the following indicators; surface scum, oily sheen, strong odors from sewage and chemicals, substrate covered with orange material from acid inputs, and greenish color from excessive nutrient inputs. Note that orange material in the stream can be naturally occurring because of iron decomposition.

The amount of algae and macrophytes in a stream is influenced by the level of nutrient loads in a stream. The greater the amount of algae and macrophytes within a stream generally indicates excessive nutrients. Additionally as nutrient levels rise, the greenish color of the water becomes more intense. Alga production and aquatic vegetation growth decreases during the cooler times of the year. High order streams open to the sun often have murkier water when sunlight allows greater algae growth.

The determination of water quality is an office and field exercise. The office exercise involves reviewing MDE's 303(d) list to determine if there are any listed water quality pollutants upstream and within the project area. The field exercise involves observing the water appearance and odor upstream and within the project area. The overall assessment parameter rating is directly based on the delineative criteria stated in the water quality section of the assessment form.

I. LANDSCAPE CONNECTIVITY

WATERSHED ASSESSMENT					
Category / Parameter / Measurement Method		Description of Watershed Condition			Rating (G, F, P)
		Good	Fair	Poor	
9	Biology / Landscape Connectivity	Channel upstream and downstream of project area has native bed and bank materials and is not impaired	Channel upstream and downstream of project area has native bed and bank materials but is impaired	Channel upstream and downstream of project area is concrete piped, or hardened	

Landscape connectivity is related to the stream corridor function and condition upstream and downstream of the project area. The function and condition of the stream corridor significantly influences restoration potential. If the upstream functions and conditions are Fair or Poor, the potential to restore a fully functioning stream within the project area is unlikely.

The determination of landscape connectivity is an office and field exercise. The office exercise involves the review of aerial photography to determine if a stream exists upstream and downstream of the project area, as well as if any adjacent land uses may have adverse impacts to existing stream corridor functions and conditions. Land use activities such as agriculture, residential and commercial development, deforestation, and active recreational parks are likely to affect stream corridors adversely, whereas well vegetative land covers are likely to support functioning stream corridors. Based on the aerials, identify areas likely to be Good, Fair and Poor. In the field, verify the assessments made in the office. The field verification will focus on floodplain connectivity, lateral stability, riparian vegetation, and bedform diversity. Refer to Sections VI.C.2. Hydraulics and VI.C.3. Geomorphology below that describes how to assess these parameters. The overall assessment parameter rating is directly based on the presence of a stream and its function-based condition.

J. OVERALL WATERSHED CONDITION RATING

The overall watershed condition rating is based on the individual watershed assessment parameter ratings and the influence of assessment parameters on the project area. Select the criteria below that best describes the results of the watershed assessment:

- If all the assessment parameter ratings are Good, then the overall watershed condition rating is Good.
- If all the assessment parameter ratings are Fair, then the overall watershed condition rating is Fair.

- If all the assessment parameter ratings are Poor, then the overall watershed condition rating is Poor.
- If over half of the assessment parameter ratings are Good, including water quality, and no more than two of the remainder are Poor, then the overall watershed condition rating is Fair.
- If water quality is Fair or Poor, then the overall watershed condition rating is Fair.
- If over half of the assessment parameters are Fair and the remainder are Good, including water quality, then the overall watershed condition rating is Fair.
- If over half of the assessment parameters are Poor and the remainder are either Good or Fair, then the overall watershed condition rating is Poor.

VI. EXISTING AND PROPOSED FUNCTION-BASED RAPID REACH LEVEL STREAM ASSESSMENT

The Rapid Reach Level Stream Function-based Assessment methodology evaluates aspects of hydrologic, hydraulic, geomorphic, physicochemical, and biologic functions. It focuses on only those assessment parameters that are critical to understanding stream processes. It is not intended to be an all-encompassing assessment methodology. Each assessment parameter was selected because they were considered key components in conducting an assessment on the overall health and functional condition of a stream riparian corridor. However, which assessment parameters are evaluated during a reach level assessment will vary depending on stream type, specifically, whether it is perennial, intermittent, or ephemeral. ***All assessment parameters are evaluated for perennial and intermittent streams with an understanding that biological conditions will most likely vary between perennial and intermittent streams. Only hydrology, hydraulic, and geomorphic assessment parameters are evaluated for ephemeral streams.*** In addition, some measurement methods have different performance standards based on either drainage area or Rosgen stream type (Figure 1).

Assessment Parameter	Measurement Method	Category		
		Functioning	Functioning-at-Risk	Not Functioning
Floodplain Connectivity (Vertical Stability)	Stream Function Pyramid Level 1 Hydrology			
	4a. Entrenchment (Meandering streams in alluvial valleys or Rosgen C, E, DA Streams)	>2.2	2.1 - 1.4	<1.4
	Existing Condition			
	Proposed Condition			
	4b. Entrenchment (Non meandering streams in colluvial valleys or Rosgen B Streams)	>1.4	1.3 - 1.1	<1.1
	Existing Condition			
	Proposed Condition			

Figure 1. Differing Performance Standards based on Rosgen Stream Type

The assessment method consists of four sections: 1) Function-based Rapid Reach Level Stream Assessment, 2) Bankfull Determination and Rosgen Classification, 3) Field Measurements and 4) Rapid Assessment Summary (Appendix A - Function-based Rapid Stream Assessment). The Function-based Rapid Reach Level Stream Assessment evaluates both existing function-based conditions and predicts the proposed function-based conditions of the assessment reach.

However, the proposed condition prediction can only be completed after the existing function-based condition (Assessment Form, pages 1 – 4), ***restoration potential*** (Assessment Form, page 5) ***and the appropriate design review checklist are completed*** (Starr et al, 2015). The restoration potential must be determined first to avoid predicting any potential project uplift that may not be achievable at the ***assessment site***. The results of the design review checklist are needed to determine the potential uplift that could be achieved by the ***proposed design***. The ***restoration potential*** uplift and ***potential design*** uplift may not always be the same. While the ***restoration potential*** may be up to Level 5 – Biology, the ***potential design*** uplift may only be up to Level 3 – Geomorphology, if the project goal is only for stability and not for biological lift. However, the ***potential design*** uplift can never be higher than the ***restoration potential*** uplift. Specific guidance on how to do this is provided in Section VI. C - Function-based Rapid Reach Level Stream Assessment and Section VI.D.4 - Project Area Restoration Potential.

The Bankfull Determination and Rosgen Classification (Assessment Form, page 4) are used in the Function-based Rapid Reach Level Stream Assessment to characterize some of the hydraulic and geomorphic stream functions. Specific guidance on how to determine bankfull and classify streams is provided in Section VI. B. 1. and 2. - Function-based Rapid Reach Level Stream Assessment. Additionally, some of the assessment parameters require rapid field measurements, so a measurement table is provided (Assessment Form, page 4) to record those measurements, if needed. Lastly, the Rapid Assessment Summary form summarizes the results of the Function-based Rapid Reach Level Stream Assessment.

The assessment methodology uses a rating system of Functioning (F), Functioning-At-Risk (FAR) or Not Functioning (NF). There are four levels at which ratings are used: 1) measurement methods, 2) assessment parameters, 3) pyramid level, and 4) overall reach level. Measurement method ratings describe the function-based condition of the assessment parameter. Assessment parameter ratings describe the function-based condition of the pyramid levels. The pyramid level ratings describe the function-based condition of the overall reach. Figure 2 illustrates this hierarchy. Guidance on how to determine the ratings for each level are described below in Section VI. B. 3. - Function-based Rapid Reach Level Stream Assessment.

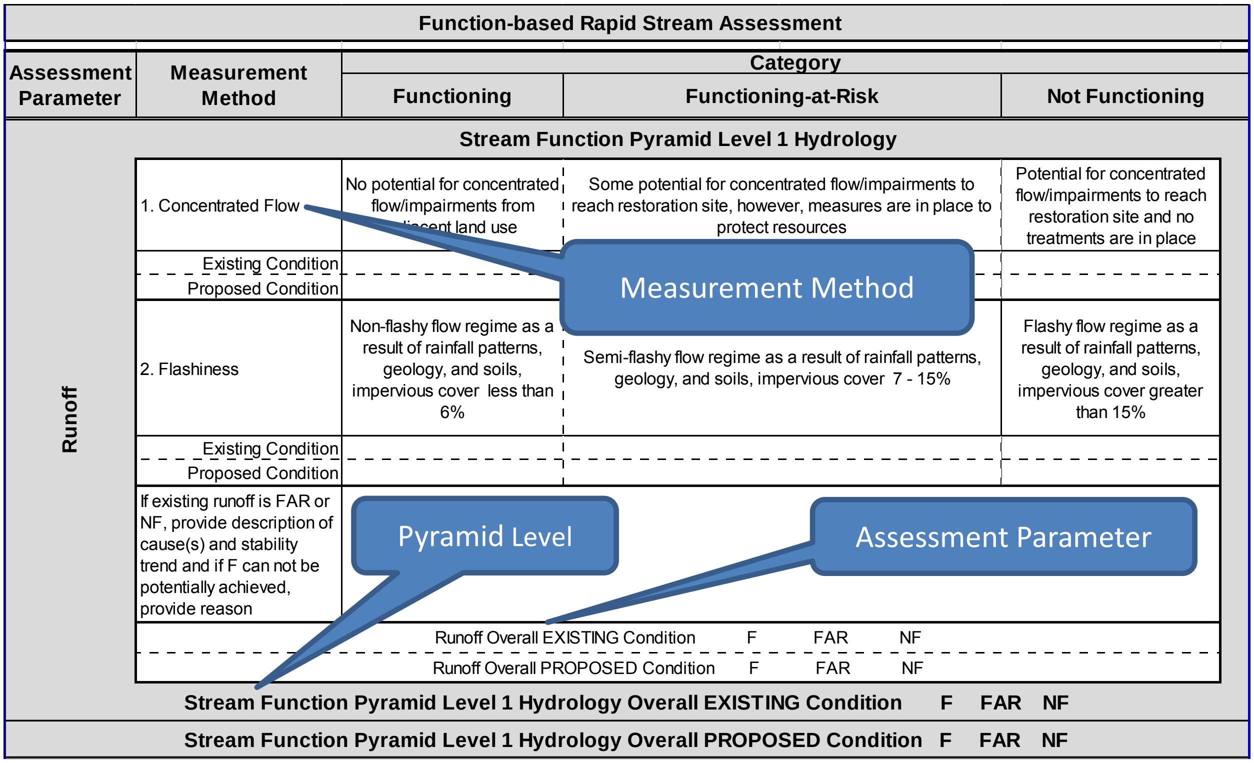


Figure 2. Rating Hierarchy.

The rapid assessment occurs in the field. However, preliminary completion of the existing/proposed assessment form can be completed in the office based on applicable information provided as part of the permit application package. The field assessment is used to verify the permit application findings.

If existing conditions vary within the project area, then a rapid assessment form needs to be completed for each differing stream reach. To determine whether existing conditions vary, consider reach wide changes and not just localized changes. Focus on changes in floodplain connectivity, lateral stability, riparian vegetation, and bedform diversity. If there are noticeable changes in any of these assessment parameters, then a new assessment form must be completed for each different reach within the project area. ***This is also required if the proposed project design approach differs within the project area, even if the existing conditions are the same throughout the entire project area***.

A. FIELD EQUIPMENT

The assessment methodology is designed to be a rapid assessment, with assessment parameters that are based on both visual observation and actual field measurements. Therefore, the amount of field equipment required is up to the discretion and experience level of the evaluator. At the minimum, the evaluator should have the Watershed Assessment and Function-based Rapid assessment field forms, a survey rod, measuring tape, line level and camera. Additional field equipment may make the survey more efficient or may be necessary for some field measurements. Refer to the Measurements Table (Assessment Form page 4) for a list of measurable assessment parameters to assist in determining appropriate field equipment. Additional information such as topographic maps, assessment report, and design plans, etc. may also be helpful.

B. BANKFULL DETERMINATION AND ROSGEN CLASSIFICATION

1. Bankfull Determination

Rosgen Stream Type (Observation)		
Regional Curve (circle one): Piedmont Coastal Plain Allegheny Plateau/Ridge and Valley Urban Karst		
DA (sqmi)	Rosgen Valley Type	
BF Width (ft)	BF Area (sqft)	
BF Depth (ft)	Percent Impervious (%)	

Bankfull discharge is used in this methodology to characterize some hydraulic and geomorphic stream functions. Therefore, proper bankfull determination is critical to ensure those functions are assessed correctly. Bankfull discharge characterizes the range of discharges that is effective in shaping and maintaining a stream. Over time, geomorphic processes adjust the stream capacity and shape to accommodate the bankfull discharge within the stream. Bankfull discharge is strongly correlated to many important stream morphological features (e.g., bankfull width, drainage area, etc.).

The first step in determining bankfull starts in the office and involves the selection of a regional curve that is appropriate for the project area. There are currently five region curves available for Maryland, which are located in Appendix B. The selection of an appropriate regional curve is based on which physiographic region the project area is located. However, if the impervious surfaces of the proposed project watershed are greater than 15 percent and within the piedmont physiographic region, then use the urban regional curve (Powell et al, 1999). Furthermore, if the underlying bedrock is carbonate and greater than 30 percent of the proposed project watershed area, then use the carbonate/karst regional curve (Chaplin, 2005). After the appropriate curve is selected, use it to determine the bankfull stream dimensions and discharge based on the drainage area of the proposed project and record the information on the assessment form (page 4 of the function-based rapid assessment).

Next, compare the regional curve data to the bankfull channel dimensions and discharge reported in the permit application, if reported. Note that regional curve data may differ from the bankfull channel dimensions and discharge reported by the applicant. If this occurs, consider the drainage area characteristics (i.e., percent imperviousness, basin size, shape, and slope, land use, etc.) and its influence on the flow regime. A steep, narrow-shaped drainage area with high imperviousness may result in a larger volume of storm runoff entering a stream, whereas a shallow, broad-shaped drainage area that is mostly forested may result in less storm runoff entering a stream. Moreover, it may be possible that the permit applicant may not have used an appropriate regional curve or they did not accurately determine bankfull. Field determination will assist in answering this question. If there is not an appropriate regional curve available for the project area, then the applicant should have provided a watershed specific curve. A watershed specific curve is developed from stream reaches within the project watershed or adjacent watersheds with similar characteristics as the project area watershed.

Field determination of bankfull involves rapid channel dimension measurements (i.e., mean depth, width, and cross section area) at geomorphic features that may be associated with bankfull discharge. The stream typically develops geomorphic features, such as a significant slope break or floodplain feature, along the stream banks at the bankfull stage (Figure 3. Potential Bankfull Indicators). However, within most stream systems there can be several geomorphic features at different elevations. Some features may have been formed by bankfull discharges, but from a past time when the channel bed was at a higher elevation. Sometimes these features are referred to as relic bankfull features. Other geomorphic features may be associated with flows that are lower than bankfull discharge. These features are common and sometimes referred to as the inner-berm. However, it is not certain how they are formed. This is why it important to compare field measurements with a regional curve to correctly identify which geomorphic feature is currently being formed and maintain by bankfull discharge.

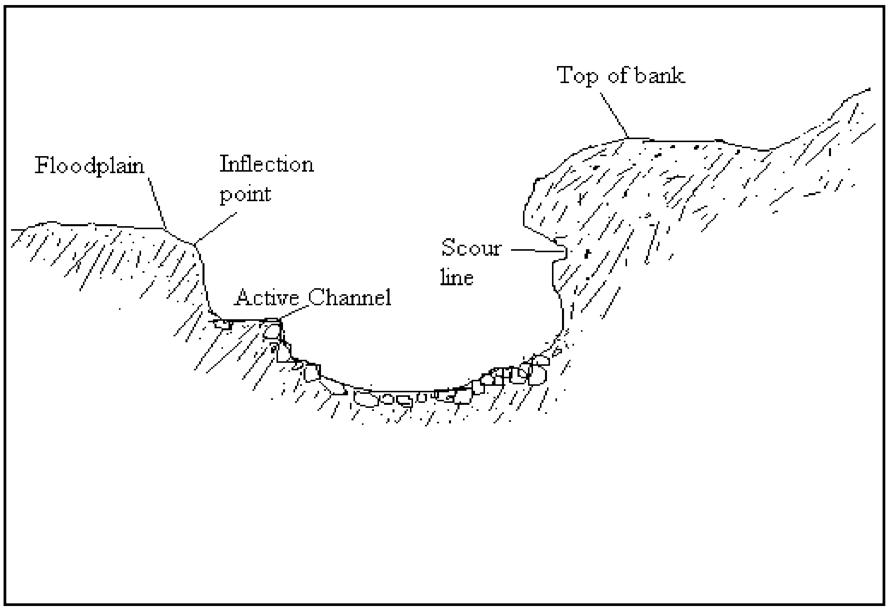


Figure 3. Potential Bankfull Indicators.

Field measurements start with identifying consistent and dominate geomorphic features throughout the entire assessment reach. Then the vertical distance between the features and water surface is measured. A consistent set of features with the same or nearly the same distance above water surface should be apparent. Moreover, as stated above, in some locations a lower and upper set of indicators may appear. Record these measurements in the Field Measurements table on the assessment form (page 4).

Next, select a riffle that is representative of the assessment reach and has clearly distinguishable geomorphic features on at least one stream bank. If geomorphic features do not exist within the assessment reach, use the cross section mean depth calculated from a regional curve as a substitute for bankfull height. At this location, take rapid channel measurements to calculate channel width, mean depth, and cross section area. To obtain the riffle bankfull mean depth, first stretch a measuring tape across the channel at bankfull elevation and make certain the tape is level. Record the bankfull channel width on the Field Measurement table on page 4 of the assessment form. Next, take a minimum of ten existing bankfull depth measurements along a riffle cross section (i.e., measure from the channel bottom to the tape). Add those numbers together and divided by the number of measurements to obtain riffle mean depth. Another quick method to determine mean riffle depth is to take one measurement at the edge of channel/toe of bank to bankfull. This measurement is generally a close approximation of riffle mean depth. To obtain cross sectional area, multiple riffle mean depth times bankfull width. Record these measurements in the Field Measurements table on the assessment form (page 4).

Compare the riffle cross section field measurements with the stream channel dimensions derived from the regional curve to select the appropriate geomorphic feature. For a detailed discussion on bankfull geomorphic indicators and how to determine bankfull, refer to the report Maryland Stream Survey: Bankfull Discharge and Channel Characteristics in the Piedmont Hydrologic Region (McCandless and Everett, 2002).

2. Rosgen Classification

Rosgen classification stream types (Rosgen 1996) are used in this methodology to characterize some geomorphic stream functions. Therefore, guidance is provided on how to apply the classification system.

While the permit application may have already classified the assessment reach using the Rosgen Classification system, it should still be validated. Start by obtaining a topographic map of the project area and determine the landscape position and valley type of the project area location. Valley types significantly influence the stream characteristics used for classifying streams as shown in Figure 4. Rosgen has described several different valley types and which stream types are typically associated with them. These descriptions, along with the Rosgen classification key are located in Appendix C. Using the information in Appendix C, select the valley type and Rosgen stream type that best represents the assessment reach and record it on the assessment form (page 4). As part of the project area site visit, validate, based on observation and/or rapid measurements, the office selected Rosgen stream type. Use the Rosgen Classification key as a guide in classifying the stream.

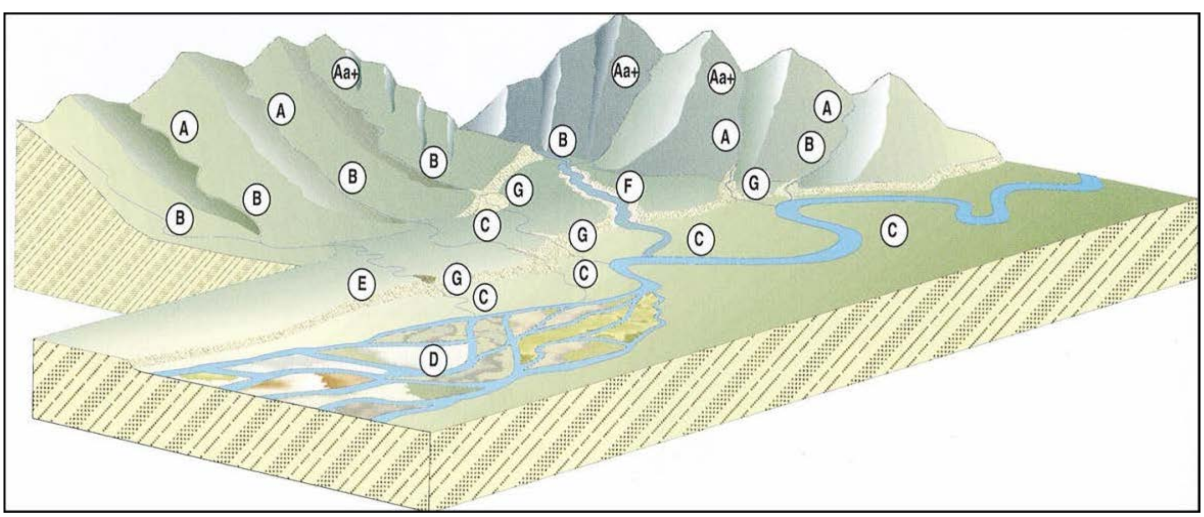


Figure 4. Rosgen Stream Types based on Landscape Position (Rosgen 2006)

C. FUNCTION-BASED RAPID REACH LEVEL STREAM ASSESSMENT

1. Level 1 – Hydrology

Hydrology functions transport water from the watershed to the channel. Physical and life scientists tend to merge hydraulics into hydrology (Harman et al, 2012 and Fischenich, 2006). However, from a stream assessment and restoration perspective there are advantages to keeping them separate. First, when conducting assessments or implementing a stream restoration project, it is important to distinguish between watershed scale functions of water transport (Hydrology) and reach scale relationships that describe how water interacts with the channel (Hydraulics). Second, the opportunity for functional lift is very different between the two.

This assessment methodology focuses on runoff and uses two measurement methods: 1) concentrated flows and 2) flashiness.

a) Runoff

i. Concentrated Flow and Flashiness

Since both concentrated flow and flashiness were measurement methods assessed as part of the Rapid Watershed Assessment, use those evaluation results for ***existing*** conditions. To predict the ***proposed*** reach condition, refer to the restoration potential (Assessment Form page 5) and the proposed project design. When making this prediction, recognize that for most stream restoration projects hydrology parameters are independent variables, meaning that the restoration practitioner cannot change them as part of the design process. However, if the proposed project is large enough or is a headwaters stream, hydrology can be changed.

ii. Overall Existing and Proposed Runoff Function-based Rating

The overall ***existing*** runoff function-based rating is based on the individual measurement ratings. The overall ***proposed*** runoff function-based rating is based on the potential of the proposed design to alter and/or restore existing FAR and NF ratings. Select the criteria below that best describes the overall runoff ***existing*** and ***proposed*** function-based ratings:

- If both the measurement ratings are either F, FAR, or NF, then the overall runoff condition rating is either F, FAR, or NF, respectively.
- If both of the measurement ratings are different, use the lowest rating as the overall runoff function-based rating.

If the overall ***existing*** and/or ***proposed*** runoff function-based ratings are FAR or NF, provide a brief explanation that describes the causes. Additionally, briefly describe the tread in stability (e.g., stable, degrading, and recovering). Use all the individual existing function-based ratings made up to this point on the assessment form, watershed assessment results and any other constraints identified to support reasons for the causes.

b) Level 1 - Hydrology Overall Function-based Rating

Since runoff is the only assessment parameter for Hydrology, the overall ***existing*** and ***proposed*** runoff function-based ratings will be applied to the Level 1 - Hydrology function-based rating.

2. Level 2 - Hydraulics

Hydraulic functions transport water in the channel, on the floodplain and through sediments (Harman et al, 2012 and Fischenich, 2006). This assessment methodology focuses on floodplain connectivity and uses three measurement methods: 1) Bank height ratio, 2) Entrenchment ratio and 3) Floodplain drainage.

a) Floodplain Connectivity

Floodplain connectivity describes how often stream flows access the adjacent floodplain and how much floodplain area is available for stream flows. In high functioning alluvial valleys, all flows greater than the bankfull discharge spread across a wide floodplain. In humid environments, streams that are well connected to the floodplain also have relatively high water tables, encouraging the development of riparian wetlands. In these systems, the channel is just deep enough to maintain sediment transport equilibrium and to create diverse bed forms and habitats. Channelization is the primary reason streams disconnect from their adjacent floodplain. Additionally, indirect impacts, like urbanization and increases to impervious cover, also contribute to channel enlargement and incision through increased runoff. The extra runoff often causes an increase in stream power, which leads to headcuts and incision. The combination of increased runoff and channelization can lead to rapid destabilization and adjustment of stream channels.

i. Bank Height Ratio

Assessment Parameter	**Measurement Method**	**Category**		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Floodplain Connectivity	3. Bank Height Ratio (BHR)	<1.10	1.11-1.50	>1.50
	Existing Condition			
	Proposed Condition			

The bank height ratio (BHR) measurement method provides assessors with an indication of flood level events that are contained within the stream channel and the erosion potential associated with those flows. Additionally, it informs the assessor of what level storm flows must reach to access the floodplain. The BHR is a direct measure of the bankfull height to the top of the lowest bank height and is calculated as follows (Figure 5):

- BHR = Dtob /Dbf, where

- Dtob = the depth from the top of the lowest bank to the toe of bank
- Dbf = the depth from the bankfull elevation to the toe of bank.
-

Bank Height Ratio:

$$\text{Ratio} = \frac{\text{Top of Bank Height}}{\text{Bankfull Height}} = \frac{8\text{ ft.}}{4\text{ ft.}} = 2$$

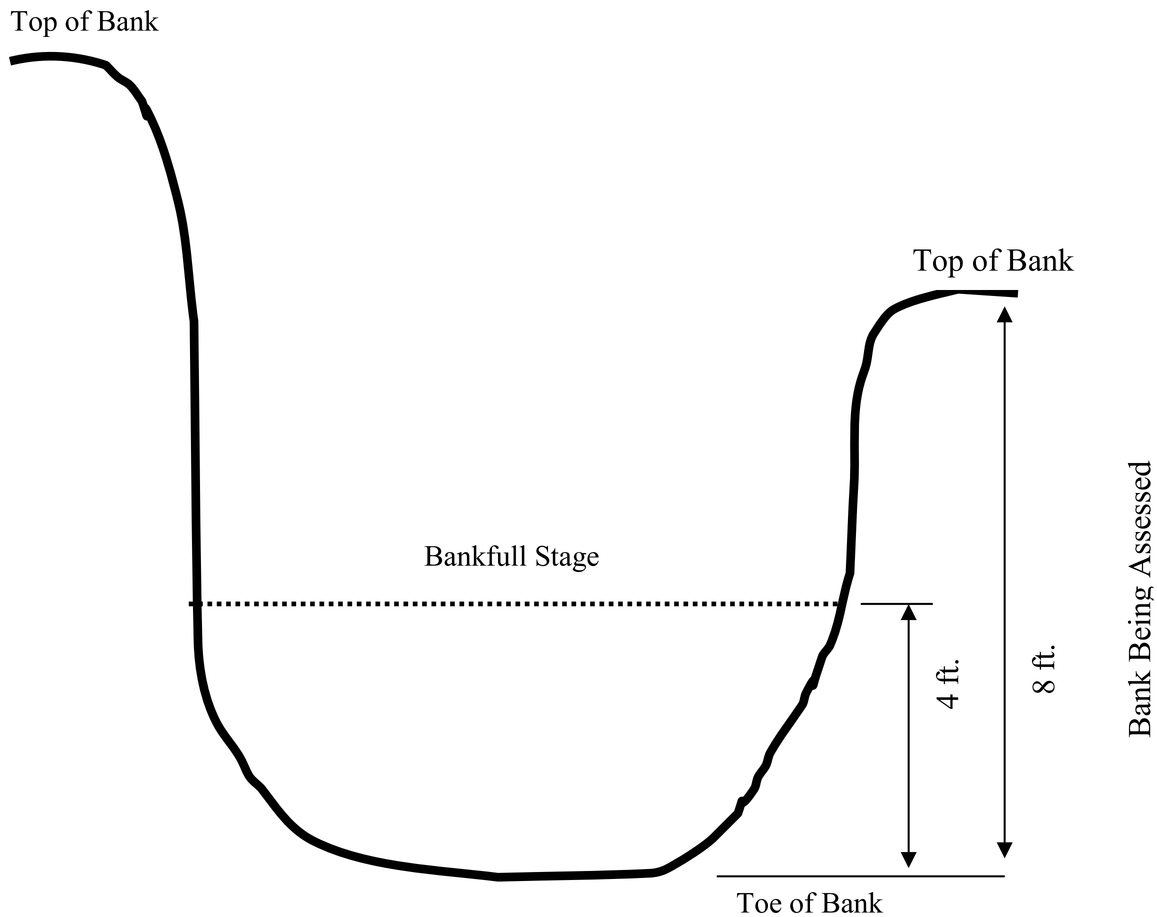


Figure 5. Bank Height Ratio, after Rosgen, 1996.

Initial measures of ***existing*** BHR condition can be taken in the office by using information from the longitudinal profile, if it is provided as part of the permit application package. An example of measuring the BHR from a longitudinal profile is shown in Figure 6. When using the longitudinal profile, take measurements from the thalweg of the riffle. Measure multiple BHRs throughout the entire assessment reach, ensuring there is one at the farthest upstream and downstream ends of the reach, to determine if there are any notable incision differences. This can assist in determining whether more than one assessment form needs to be completed.

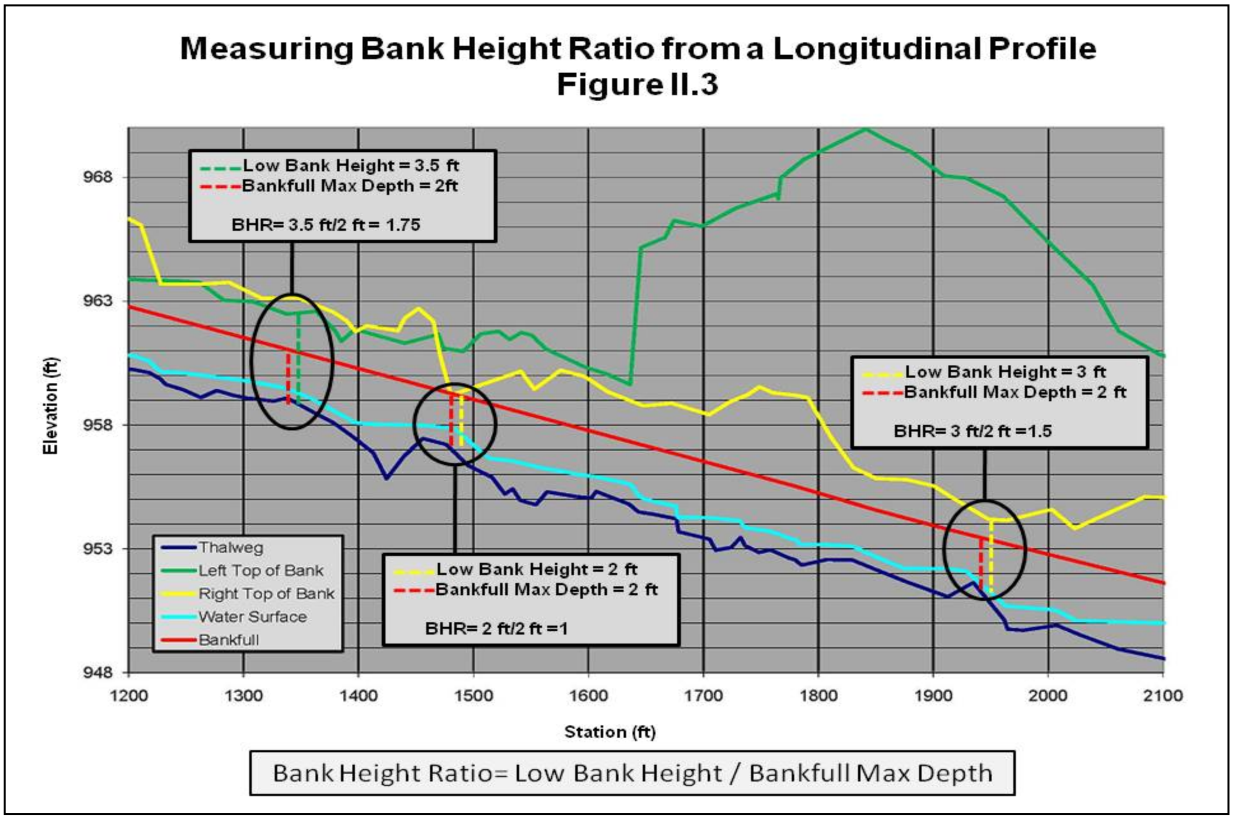


Figure 6. Measurement of Bank Height Ratio from a Longitudinal Profile (Source Michael Bake International).

Even if a longitudinal profile was provided as part of the permit application package, field measurements of BHR should be used for validation purposes. The field data collection first involves identifying bankfull features within the assessment reach following the guidance provided above in Section VI.B.2. Bankfull Determination and Rosgen Classification. Just as in measuring BHR from a longitudinal profile, measure multiple BHRs at riffles throughout the entire assessment reach, again ensuring there is one at the farthest upstream and downstream ends of the reach. If no bankfull indicators exist at riffles, use locations where there are bankfull indicators. If no bankfull indicators exist anywhere within the assessment reach, use the cross section mean depth calculated from a regional curve as a substitute for bankfull height. The overall measurement rating is directly based on the delineative criteria stated in the assessment form.

The ***proposed*** BHR function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use the proposed design longitudinal profile and follow the same office procedure described above to determine the ***proposed*** BHR function-based rating condition. Based on this and the results from the design review checklist and restoration potential (Assessment Form page 5), select the appropriate ***proposed*** BHR function-based rating.

ii. Entrenchment Ratio

Assessment Parameter	Measurement Method	Category		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Floodplain Connectivity	4a. Entrenchment (Meandering streams in alluvial valleys or Rosgen C, D, DA Streams)	>2.2	2.1-1.4	<1.4
	Existing Condition			
	Proposed Condition			
	4b. Entrenchment (Non meandering streams in colluvial valleys or Rosgen B Streams)	>1.4	1.3-1.1	<1.1
	Existing Condition			
	Proposed Condition			

The entrenchment ratio (ER) is a measure of the floodplain or floodprone area width in relation to the bankfull width (Rosgen, 1996). ER provides an assessor with an indication of how much floodplain area is available for flood flows once they reach the stream channel top of bank. The floodprone area width is measured at a stage of 2 times the bankfull max depth (e.g., generally associated with the 50 year storm event). The ER is calculated in a riffle cross section as follows (Figure 7):

- ER = W_{fpa} / W_{rbkf}, where
- W_{fpa} = floodprone width, measured at a stage of 2 times the bankfull max depth
- W_{rbkf} = bankfull riffle width.

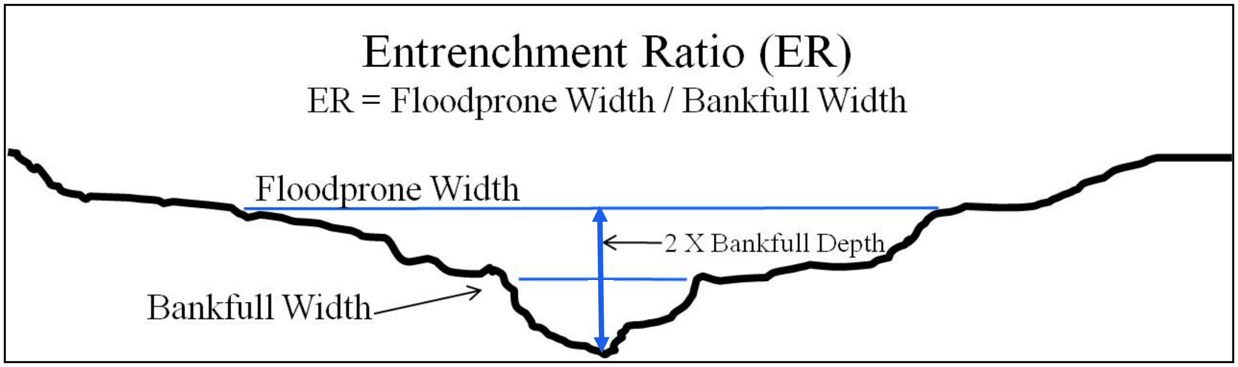


Figure 7. Measurement of Entrenchment Ratio.

The BHR and ER work well together to quantify floodplain connectivity. For all stream types, a BHR of 1.0 indicates that the stream is not incised and has access to a floodplain or floodprone area. However, the ER will naturally vary by stream type. Streams in v-shaped valleys (A stream types) and colluvial valleys (B stream types) will have lower entrenchment ratios than streams in alluvial valleys (C, E and DA stream types). Therefore, a C or E stream type with a bank height ratio of 1.0 (not incised) and an entrenchment ratio of 10 (not entrenched) is well connected to the floodplain and has a wide floodplain that will minimize flood depths, thereby encouraging flood storage, floodplain accretion and other floodplain processes. C or E stream types that have a BHR of 1.0 and an ER of 2.5 are also not incised, but are more entrenched than the previous example, meaning that flood flows do not have as large a floodplain to dissipate energy and provide wetlands. Additionally, it is possible to have a stream that is incised (e.g. BHR of 1.8) but not entrenched (ER =/> 2.2 for E or C stream types) if the floodplain has the appropriate width.

Just as the BHR measurements, initial measures of ***existing*** ER condition can be taken in the office by using channel cross sections, if they are provided as part of the permit application package. An example of measuring the ER from a cross section is shown in Figure 7 (Measurement of Entrenchment Ratio). Measure multiple ERs throughout the entire assessment reach to determine if there are any notable differences. This can assist in determining whether more than one assessment form needs to be completed.

Even if cross sections were provided as part of the permit application package, field measurements of ***existing*** ER condition should be used for validation purposes. The field data collection first involves identifying bankfull features within the assessment reach following the guidance provided in Section VI.B.2. Bankfull Determination and Rosgen Classification. Measure multiple ERs at riffles throughout the entire assessment reach. If no bankfull indicators exist anywhere within the assessment reach, use the cross section mean depth calculated from a regional curve as a substitute for bankfull height. The overall ***existing*** ER function-based rating is directly based on the delineative criteria stated in the assessment form.

The ***proposed*** ER function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use the proposed design actual cross sections (not typical cross sections), the results from the design review checklist and follow the same office procedure described above to select the ***proposed*** ER function-based rating. Additionally, refer to the restoration potential (Assessment Form page 5) and use the results from the design review checklist.

iii. Floodplain Drainage

Assessment Parameter	Measurement Method	Category		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Floodplain Connectivity	5. Floodplain Drainage	No concentrated flow; runoff is primarily sheet flow; hillslopes < 10%; hillslopes >200 ft from stream; ponding or wetland areas and litter or debris jams are well represented	Runoff is equally sheet and concentrated flow (minor gully and rill erosion occurring); hillslopes 10 - 40%; hillslopes 50 - 200 ft from stream; ponding or wetland areas and litter or debris jams are minimally represented	Concentrated flows present (extensive gully and rill erosion); hillslopes >40%; hillslopes <50 ft from stream; ponding or wetland areas and litter or debris jams are not well represented or absent
	Existing Condition			
	Proposed Condition			

Floodplain drainage is how stormwater runoff from adjacent lands and flood flows travel through the floodplain and are delivered to the stream. The amount and rate of runoff delivery to a stream is based on floodplain and hillslope characteristics. The greater amount of runoff that is slowed and stored in the floodplain, the less likely there will be adverse impacts to stream functions. Wide floodplains that are well vegetated with large woody debris and areas for ponding water are ideal for storing and slowing stormwater runoff and flood flows. To determine the ***existing*** function-based rating in the field, select the floodplain and hillslope characteristics described in the assessment form that best represent the ***existing*** assessment reach.

The ***proposed*** floodplain drainage function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use data and the proposed design provided as part of the permit application and refer to the restoration potential (Assessment Form page 5) to select the ***proposed*** floodplain drainage function-based rating.

iv. Vertical Stability Extent

Assessment Parameter	Measurement Method	Category		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Sediment Transport (Vertical Stability)	6. Vertical Stability Extent	Stable	Localized instability	Widespread instability
	Existing Condition			
	Proposed Condition			

Vertical stability extent describes the magnitude of streambed adjustments and is best described as either localized or widespread. The key in determining whether vertical adjustments are localized or widespread is whether the vertical adjustments are causing, or have the potential to cause, system-wide changes to the stream channel dimensions, bed profile, and geometry pattern. If the erosion causes system-wide changes then the vertical instability is widespread. Additional indicators of widespread vertical adjustments include multiple headcuts and/or an incision ratio greater than 1.5 throughout the assessment reach. Localized vertical instability conditions are typically associated with a specific cause. For example, outfalls and culverts which, in most situations, cause localized bed erosion. Select the vertical stability extent function-based ratings that best represent the ***existing*** and ***proposed*** function-based ratings.

v. Overall Existing and Proposed Floodplain Connectivity Function-based Rating

Assessment Parameter	Measurement Method	Category		
		Functioning	Functioning-at-Risk	Not Functioning
Floodplain Connectivity	If existing floodplain connectivity is FAR or NF, provide description of cause(s) and stability trend and if F cannot be potentially achieved, provide reason			
	Floodplain Connectivity Overall EXISTING Condition	F	FAR	NF
	Floodplain Connectivity Overall PROPOSED Condition	F	FAR	NF

The overall ***existing*** floodplain connectivity function-based rating is based on the individual measurement ratings. The overall ***proposed*** floodplain connectivity function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. In most cases, potential improvement of floodplain connectivity is possible. However, the potential for floodplain connectivity is greatly reduced where the assessment reach floodplain has been encroached upon by development. Use the criteria below to determine the overall floodplain connectivity ***existing*** and ***proposed*** function-based ratings:

- If all the measurement ratings are F, then the overall floodplain connectivity function-based rating is F.
- If all the measurement ratings are FAR, then the overall floodplain connectivity function-based rating is FAR.
- If all the measurement ratings are NF, then the overall floodplain connectivity function-based rating is NF.
- If any one measure is FAR and the remainder are F, then the overall floodplain connectivity function-based rating is FAR.
- If BHR and/or ER is NF, then the overall floodplain connectivity function-based rating is NF.

If the overall ***existing*** and/or ***proposed*** floodplain connectivity function-based ratings are FAR or NF, provide a brief explanation that describes the causes. Additionally, briefly describe the tread in stability (e.g., stable, degrading, and recovering). Use all the individual function-based ratings made up to this point on the assessment form and the watershed assessment results and any other constraints identified to support reasons for causes.

b) Level 2 - Hydraulic Overall Function-based Rating

Since there is only one assessment parameter for Hydraulics, the overall ***existing*** and ***proposed*** floodplain connectivity rating will be applied to the Hydraulic overall function-based rating.

3. Level 3 - Geomorphology

Geomorphology is the transport and storage of wood and sediment to create diverse bed forms and dynamic equilibrium (Harman et al, 2012 and Fischenich, 2006). These functions include the interaction of flowing water with the streambed, streambanks and upstream sediment supply. The interaction between flowing water, sediment supply, and channel boundary conditions creates bed forms like riffles, runs, pools and glides, which provide the critical habitats for macroinvertebrates, fish and other organisms. The result is a stream in dynamic equilibrium, which means that the streambed is not significantly aggrading nor degrading over time, and that lateral adjustments do not change the cross-sectional area, even if the stream's position on the landscape changes. This methodology will assess riparian vegetation, lateral stability, sediment transport/vertical stability, bedform diversity, and channel evolution.

a) Riparian Vegetation

Riparian vegetation or zones are the vegetated region adjacent to streams and wetlands that provide multiple critical benefits. A functioning riparian vegetation buffer contains diverse and dense plant communities and a variety of habitat conditions for terrestrial and aquatic species. Some overall benefits provided by riparian buffers include:

- Shade cover, which reduces both air and water temperature fluctuations due to sun exposure within the riparian zone (Barton et al., 1985)
- Organic matter contributions, including leaf litter that supports macrobenthos food webs and woody debris that creates more diverse bed form and additional organic matter (Dolloff and Warren 2003, Quinn et al., 2007, Opperman et al., 2004)
- Dissipation of energy and capturing of sediment from upslope overland flow and floodwater (Magette et al., 1989)
- Nutrient uptake by roots of the riparian vegetation from groundwater moving downslope, acting as a sink to limit what reaches the stream (Lowrance et al., 1984)
- Stabilization of the streambank by roots that extend throughout the bank (Wynn et al., 2004)
- Landscape connectivity for animals traveling along the stream corridor, connecting patches of riparian habitats across the landscape (Fisher et al., 1998)

- Wildlife habitat, which includes, cover, food, and nesting opportunities for birds, mammals, reptiles and amphibians.

For stream assessments and restoration projects, it is also important to identify the potential impacts from land use and other stressors that may exist within and surrounding the riparian buffer area. Watershed disturbances, including livestock grazing, agriculture and urbanization may have affected the soils and hydrology of the buffer and may continue to be a challenge after restoration. Soil compaction, loss of soil fertility, and lowered water table elevations can hinder riparian vegetation establishment and growth. Land disturbance activities also increase the potential for invasive species populations to affect the native vegetation and limit the riparian buffer function. Herbivory and beaver activities can also add pressure on riparian vegetation during establishment and growth in certain watersheds. Although impacts and stressors may be difficult to control outside the buffer area, stream restoration design should always consider them when selecting vegetative species, specifying methods to improve soil conditions and attempting to reconnect the groundwater table to the riparian buffer root zone. Desirable vegetation maintenance plans address these impacts and stressors for the estimated duration of buffer function development.

This methodology focuses on the assessment of the overall riparian buffer health and evaluates such parameters as vegetation diversity, density and composition and buffer width.

i. Riparian Vegetation Zone

Assessment Parameter	Measurement Method	Category			
		Functioning	**Functioning-at-Risk**		**Not Functioning**
Riparian Vegetation	7. Riparian Vegetation Zone (EPA, 1999, modified)	Riparian zone extends to a width of >100 feet; good vegetation community diversity and density; human activities do not impact zone; invasive species not present or sparse	Riparian zone extends to a width of 25-100 feet; species composition is dominated by 2 or 3 species; human activities greatly impact zone; invasive species well represented and alter the community		Riparian zone extends to a width of <25 feet; little or no riparian vegetation due to human activities; majority of vegetation is invasive
	Left Bank Existing Condition				
	Left Bank Proposed Condition				
	Right Bank Existing Condition				
	Right Bank Proposed Condition				

The riparian vegetation zone measurement method evaluates the overall health of the riparian zone. The assessment occurs in the field and left and right banks are assessed separately. The length of the assessment is based on the length of the assessment reach. Vegetation width and diversity are the two key criteria for this assessment. A riparian zone can only receive an F rating if it is greater than 100 feet wide, has native, diverse vegetation and no human impacts. Refer to *Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed* (Slattery et al, 2003) as a native plant identification reference. A good rapid measure of vegetation diversity can be based on the presence of vegetation layers. Riparian vegetation can be categorized into three layers: 1) ground cover, 2) shrub/scrub or understory, and 3) canopy cover (Figure 8). To receive a functioning rating all three layer must be present; there should be limited bare ground; shrub/scrub or understory should be well represented; and canopy cover should be approximately 60 percent (MDNR, 1999). A riparian zone cannot receive an F rating even if it is greater than 100 feet wide, but does not contain all three layers of vegetation. Likewise, a riparian zone less than 100 feet wide cannot receive an F rating even if all three layers of vegetation exist. Based on the field assessment, select the delineative criteria described in the assessment form that best represents the assessment reach to determine the ***existing*** function-based rating.

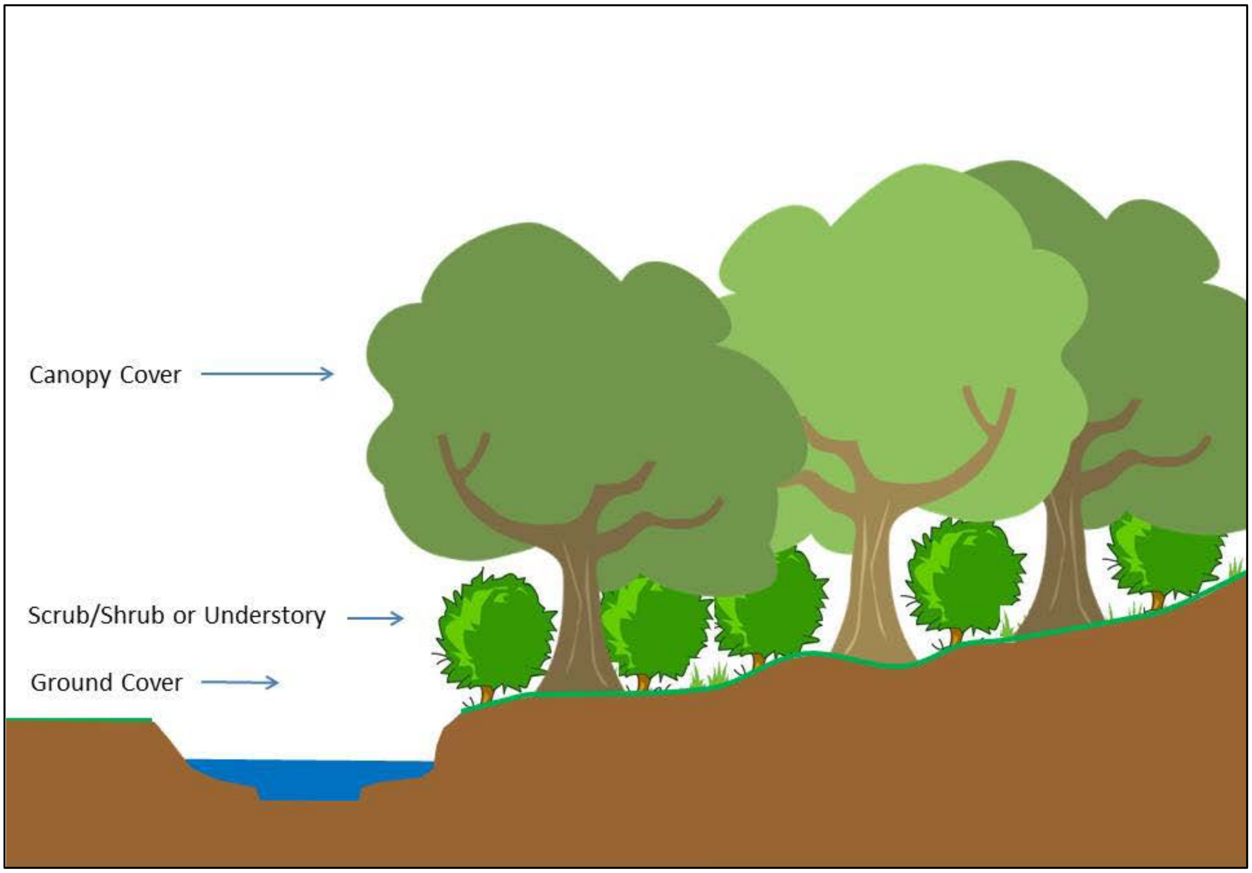


Figure 8. Vegetation Layers

The ***proposed*** riparian zone function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. In most cases, the potential to improve riparian vegetation is possible. However, the potential for improvement to riparian vegetation is greatly reduced where the assessment reach floodplain has been encroached upon by development. Use any relevant data provided as part of the permit application and proposed design to select the ***proposed*** riparian vegetation function-based rating. Additionally, use the results of the design review checklist, specifically those questions related to riparian vegetation.

ii. Riparian Vegetation Existing and Potential Function-based Rating

Assessment Parameter	Measurement Method	Category			
		Functioning	Functioning-at-Risk		Not Functioning
			Trending Towards Functioning	Trending Towards Not Functioning	
Riparian Vegetation	If existing riparian vegetation is FAR or NF, provide description of cause(s) and stability trend and if F cannot be potentially achieved, provide reason				
Riparian Vegetation Overall EXISTING Condition F FAR NF					
Riparian Vegetation Overall PROPOSED Condition F FAR NF					

Since riparian vegetation zone is the only measurement method for riparian vegetation, the overall ***existing*** and ***proposed*** riparian vegetation function-based rating will be the same as the riparian vegetation zone function-based rating.

If the overall ***existing*** and/or ***proposed*** riparian vegetation function-based ratings are FAR or NF, provide a brief explanation that describes the causes. Additionally, briefly describe the tread in stability (e.g., stable, degrading, and recovering). Use all the individual function-based ratings made up to this point on the assessment form and the watershed assessment results and any other constraints identified to support reasons for causes.

b) Lateral Stability

Lateral stream migration commonly occurs on rivers that flow through alluvial valleys. A channel migrates within the floodplain through lateral erosion on the outside of meander bends and deposition on the interior bend, or point bar. Streams and rivers are open systems, which have a continual source of potential energy supplied by topographic elevation and precipitation. The potential energy supplied by the rain and elevation is transformed to kinetic energy as water flows downhill. Kinetic energy carries sediment downstream (sediment transport) and causes some erosion from turbulence and friction along the channel boundary. In an alluvial valley where the boundary conditions (bank materials) are erodible, meanders will form and continue to erode until the stream achieves a plan form, where energy is expended uniformly and the least amount of work possible is accomplished (Leopold, 1994). Once this equilibrium is achieved, a stream may continue to migrate but will deposit materials in point bars to maintain the bankfull cross-sectional area.

Bank migration and lateral stability are as much a function of the bank materials and bank cover as they are the in-stream hydraulic forces acting upon them. This is because bank materials and vegetative cover resist hydraulic forces such as shear stress. A barren bank composed primarily of sand, for example, is more susceptible to erosion than a densely vegetated clay bank. In addition, some stream types are naturally more susceptible to bank erosion than other stream types due to their valley type. Rosgen (1994) provides a table (Table 1) showing the sensitivity to lateral adjustment and recovery potential. In this example, recovery potential means the ability of the stream to return to a laterally stable condition without human intervention.

Other factors that influence streambank erosion include (Knighton, 1998):

- Climate – amount, intensity and duration of rainfall and frequency and duration of freezing
- Subsurface conditions – seepage forces, piping, soil moisture, and porewater pressure
- Channel geometry – channel width, depth and slope, height of bank, and meander curvature
- Biology – vegetation type, density, and root system, burrowing, and trampling
- Human-induced factors – urbanization, land drainage, agriculture, residential

This methodology assesses dominant bank erosion rate potential and lateral stability extent to determine lateral stability. The bank erosion rate potential addresses bank characteristics and stream energy and lateral stability extent addresses the magnitude (e.g., localized versus widespread) of lateral erosion.

i. Dominate Bank Erosion Rate Potential

Assessment Parameter	Measurement Method	Category		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Lateral Stability	8. Dominant Bank Erosion Rate Potential	Dominate bank erosion rate potential is low or BEHI/NBS Rating: L/VL, L/L, L/M, L/H, L/VH, M/VL	Dominate bank erosion rate potential is moderate or BEHI/NBS Rating: M/L, M/M, M/H, L/Ex, H/L, M/VH, M/Ex, H/L, H/M, VH/VL, Ex/VL	Dominate bank erosion rate potential is high or BEHI/NBS Rating: H/H, H/Ex, VH/H, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex
	Existing Condition (Right bank)			
	Proposed Condition (Right Bank)			
	Existing Condition (Left bank)			
	Proposed Condition (Left Bank)			

Stream Type	Sensitivity to disturbance[a]	Recovery potential[b]	Sediment supply[c]	Streambank erosion potential	Vegetation controlling influence[d]
A1	Very low	Excellent	Very low	Very low	Negligible
A2	Very low	Excellent	Very low	Very low	Negligible
A3	Very high	Very poor	Very high	Very high	Negligible
A4	Extreme	Very poor	Very high	Very high	Negligible
A5	Extreme	Very poor	Very high	Very high	Negligible
A6	High	Poor	High	High	Negligible
B1	Very low	Excellent	Very low	Very low	Negligible
B2	Very low	Excellent	Very low	Very low	Negligible
B3	Low	Excellent	Low	Low	Moderate
B4	Moderate	Excellent	Moderate	Low	Moderate
B5	Moderate	Excellent	Moderate	Moderate	Moderate
B6	Moderate	Excellent	Moderate	Low	Moderate
C1	Low	Very good	Very low	Low	Moderate
C2	Low	Very good	Low	Low	Moderate
C3	Moderate	Good	Moderate	Moderate	Very high
C4	Very high	Good	High	Very high	Very high
C5	Very high	Fair	Very high	Very high	Very high
C6	Very high	Good	High	High	Very high
D3	Very high	Poor	Very high	Very high	Moderate
D4	Very high	Poor	Very high	Very high	Moderate
D5	Very high	Poor	Very high	Very high	Moderate
D6	High	Poor	High	High	Moderate
Da4	Moderate	Good	Very low	Low	Very high
DA5	Moderate	Good	Low	Low	Very high
DA6	Moderate	Good	Very low	Very low	Very high
E3	High	Good	Low	Moderate	Very high
E4	Very high	Good	Moderate	High	Very high
E5	Very high	Good	Moderate	High	Very high
E6	Very high	Good	Low	Moderate	Very high
F1	Low	Fair	Low	Moderate	Low
F2	Low	Fair	Moderate	Moderate	Low
F3	Moderate	Poor	Very high	Very high	Moderate
F4	Extreme	Poor	Very high	Very high	Moderate
F5	Very high	Poor	Very high	Very high	Moderate
F6	Very high	Fair	High	Very high	Moderate
G1	Low	Good	Low	Low	Low
G2	Moderate	Fair	Moderate	Moderate	Low
G3	Very high	Poor	Very high	Very high	High
G4	Extreme	Very poor	Very high	Very high	High
G5	Extreme	Very poor	Very high	Very high	High
G6	Very high	Poor	High	High	High

a Includes increases in streamflow magnitude and timing and/or sediment increases.
b Assumes natural recovery once cause of instability is corrected.
c Includes suspended and bedload from channel derived sources and/or from stream adjacent slopes.
d Vegetation that influences width/depth ratio-stability.

Table 1. Rosgen (1994). Illustrates the sensitivity to disturbance, recovery potential, typical sediment supply conditions, streambank erosion potential and the influence of bank vegetation on stability for a wide range of stream types.

There are a variety of methods to predict bank erosion rate potential; ranging from methods that are detailed and quantitative to ones that are highly qualitative. One method that can be applied both ways is the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model developed by Dave Rosgen (2006). BANCS is used to estimate the annual amount of stream lateral erosion/migration based on bank characteristics and flow distribution within stream reaches. It uses two bank erosion estimation tools to bank erosion: 1) Bank Erosion Hazard Index (BEHI) and 2) Near Bank Stress (NBS).

The BEHI method is used to estimate the potential for a bank to erode and involves collecting relatively simple measurements and visual observations of streambanks, including bank height, root depth, root density, bank angle, surface protection, bank material and bank stratification (Figure 9). The NBS method is used to estimate the energy distribution against streambanks and involves simple to complex measurements and observations of channel flow characteristics, including water surface slope, water depths, radius of curvature, stream velocities, and direction of velocity vectors.

Both methods result in a quantitative value that is then rated by an index from very low to extreme (Table 2). The combination of these ratings can be used with an appropriate streambank erodibility rating curve (USFWS 2005) (Figure 10) to derive a predicted annual linear footage of bank erosion per year. A detailed description of this method is in Rosgen (2006). Additionally, the Service has developed additional information to assist in the assessment of BEHI and NBS conditions and it is located in Appendix D along with some photos of example bank stability conditions and NBS conditions.

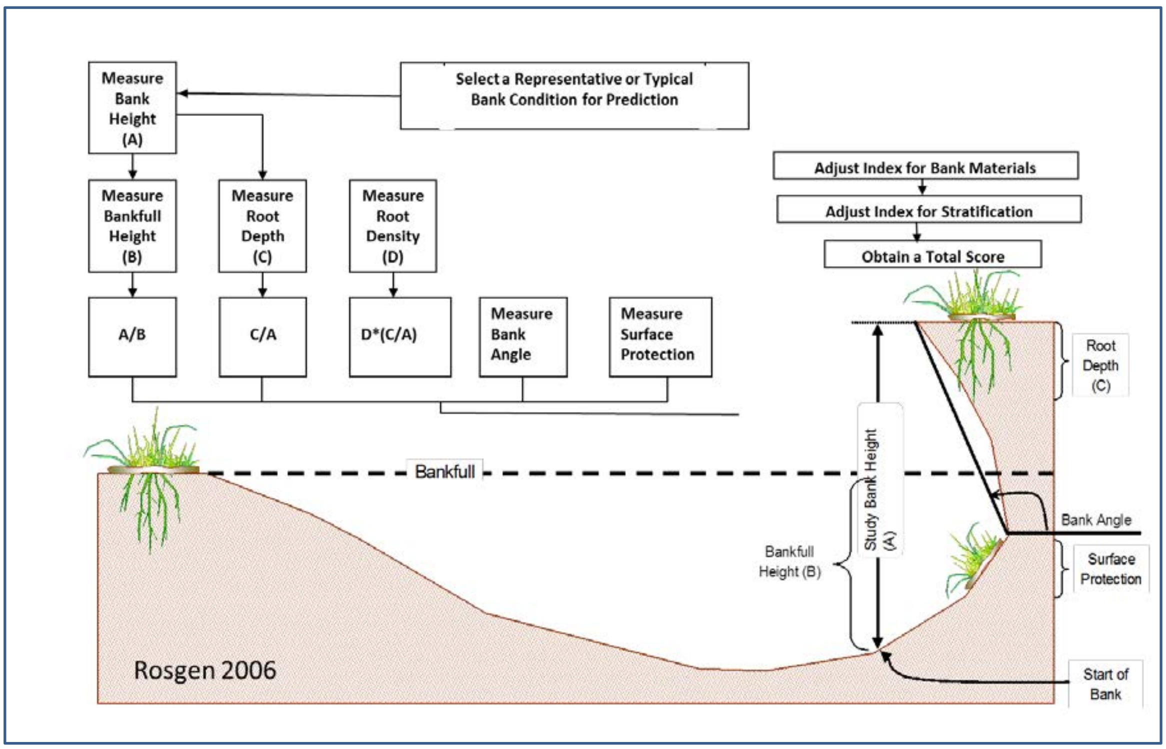


Figure 9. BEHI Variables (Rosgen 2006).

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

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

Table 2. BEHI Variables (Rosgen, 2006).

The BANCS model can be completed with a moderate level of effort if the practitioner does not quantitatively measuring every bank, but rather makes qualitative predictions with periodic measurements for calibration. Therefore, the BANCS model will be the primary assessment method to predict potential streambank erosion. However, guidance will also be provided on how to qualitatively estimate bank erosion rate potential based solely on observations.

All existing bank stability conditions (both eroding and non-eroding banks), within the assessment reach must be assessed. The only banks that will not be assessed are those that are aggrading or have depositional feature adjacent to them. For ease of assessment, right and left banks will be assessed separately to determine the dominate bank erosion rate potential.

The first step is to determine whether there are more non-eroding banks than eroding banks (i.e., greater than 50 percent). If this is the case, then the dominate bank erosion rate potential is low and therefore considered functioning. This does not totally discount if there are eroding banks. If there are some eroding banks, they will be addressed under the measurement method - extent of lateral erosion.

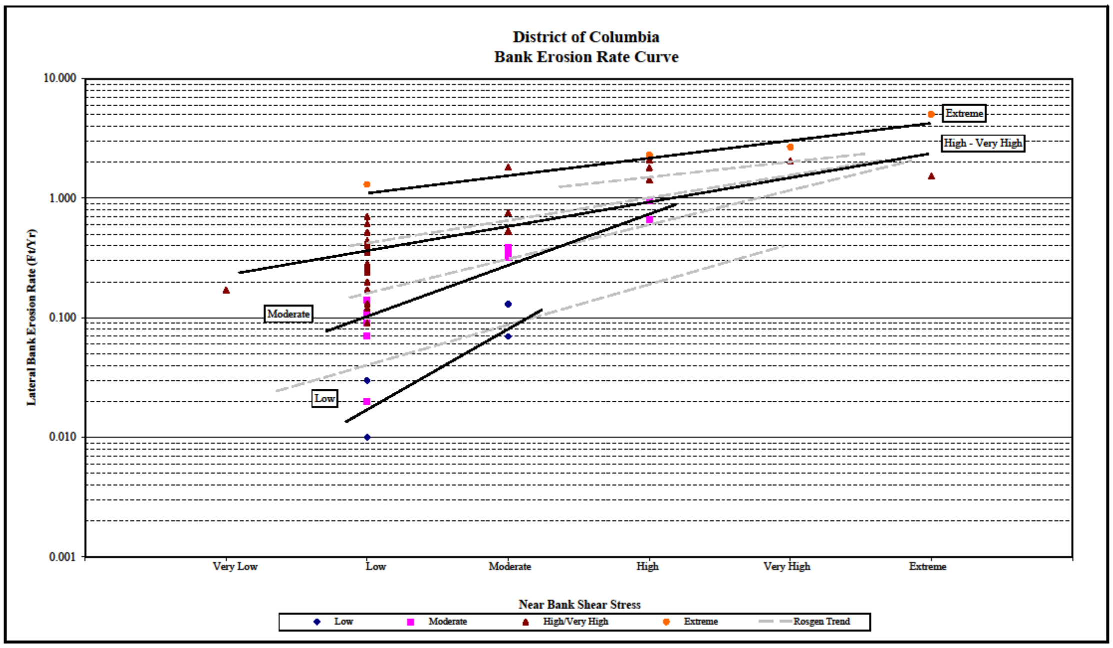


Figure 10. Example Bank Erosion Rate Curve (USFWS 2005)

If there are more eroding banks than non-eroding banks, divide the banks into similar bank characteristics using the BEHI criteria (Figure 9). Look at bank heights, root characteristics, bank angles, bank protection and bank materials. Then select the BEHI rating associated with each of the banks assessed using Table 2 BEHI Variables.

To estimate NBS, use Figure 11 to select the NBS condition and rating that best represents each bank assessed as part of the BEHI assessment. As a guide in estimating NBS, consider the direction of flows in relation to the bank and the water depth adjacent to the bank in relation to the overall depth of the channel cross section associated with the bank. Flows that are perpendicular to the bank will have higher NBS ratings than flows that are parallel to the bank. If depths adjacent to the assessment bank are deeper than elsewhere within the channel cross section, then NBS stress ratings will be higher than if the depths were less than elsewhere within the channel cross section.

Record the BEHI/NBS rating and length of each bank assessed in the Measurement Table on page 4 of the assessment form. Next, determine the ***existing*** dominant BEHI/NBS condition. The ***existing*** dominant BEHI/NBS condition is derived by the bank stability condition that represents the largest portion of all the existing bank stability conditions that includes stream banks on both sides of the assessment reach. If there are two bank stability conditions represented equally, select the BEHI/NBS ratings with the higher bank erosion potential. Use this rating to determine the overall ***existing*** BEHI/NBS function-based rating based on the delineative criteria stated in the assessment form.

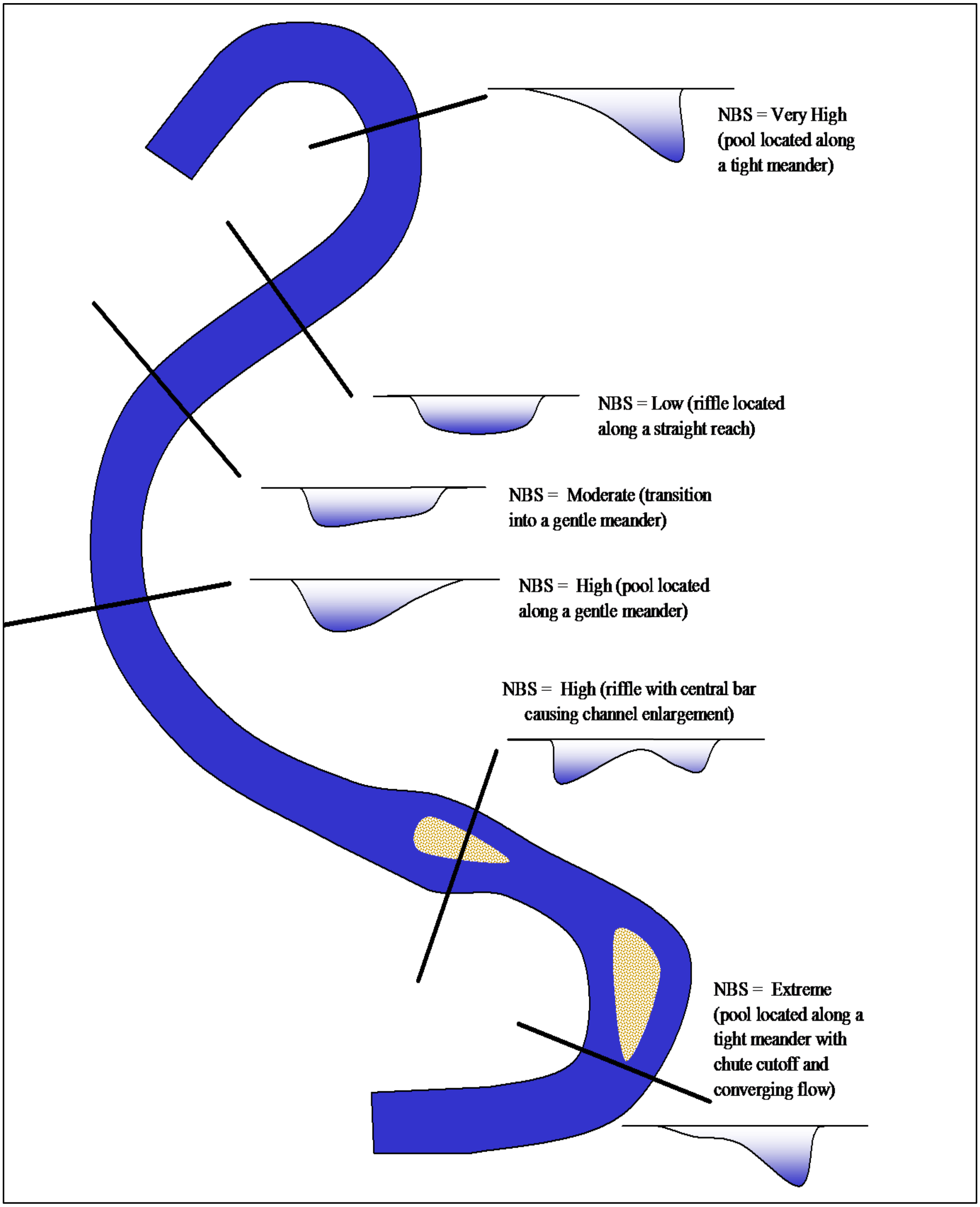


Figure 11. NBS Condition (Rosgen 2006).

The ***existing*** dominate bank erosion rate potential can also be determined by observing indicators of lateral erosion. Conduct the same procedures described above to separate right and left banks and divide banks by similar bank characteristics. Then use the following bank erosion indicators to estimate bank erosion rate potential:

- Bank height ratio (BHR): BHR equal to or less than 1.0 – ***low***; 1.1 to 1.5 – ***moderate***; greater than 1.5 – ***high***
- Bank Protection: 100 to 51% - ***low***; 50 to 25% - ***moderate***; less than 25% - ***high***
- Bank Angle: Less than 45% - ***low***; 46 to 80% – ***moderate***; greater than 80% - ***high***
- Bank Material: clay, boulders, bedrock – ***low***; at least 50% clay – ***moderate***; sand and silt – ***high***
- Fallen Bank Trees: trees upright and securely rooted to the bank – ***low***; trees leaning streamward and bank scour occurring under the roots – ***moderate***; trees lying in the stream and no longer rooted to the streambank – ***high***
- Width/depth (W/D) ratio: either high W/D ratio (greater than 24) or low (less than 5) and a BHR greater than 1.5 is consider ***high*** bank erosion rate potential
- Plan form: highly meandering and tight radius of curvatures with poor or no vegetation is consider ***high*** bank erosion rate potential
- Human-induced: removal of vegetation, straightening and deepening of the channel, and over grazing is considered ***high*** bank erosion rate potential

The ***proposed*** dominant bank erosion rate function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use any relevant data and the proposed design provided as part of the permit application and follow the same dominant bank erosion rate potential procedure described above to select the most appropriate ***proposed*** dominant bank erosion rate function-based rating. Additionally, use the results of the restoration potential (Assessment form page 5) and the results of the design review checklist, specifically questions related to plan form and in-stream structures.

ii. Lateral stability extent

Assessment Parameter	Measurement Method	Category		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Lateral Stability	9. Lateral Stability Extent	Stable	Localized instability	Widespread instability
	Existing Condition			
	Proposed Condition			

Lateral stability extent describes the magnitude of bank erosion and is described as either localized or widespread. The key in determining whether lateral erosion is localized or widespread is whether the lateral erosion is, or has the potential to, cause changes to the stream channel dimensions, bed profile, and geometry pattern throughout the entire assessment reach (e.g., system-wide). If the erosion causes system-wide changes then it is widespread lateral instability. Indicators of widespread lateral instability would include:

- Greater than 50% of banks are actively eroding
- Recently abandoned channel meanders/chute cut-offs
- Significant losses of riparian vegetation

Localized lateral instability conditions are typically associated with a specific cause. For example, outfalls, culverts, ford crossings, and localized removal of vegetation cause, in most situations, localized bank erosion.

Select the lateral stability extent function-based rating that best represent the ***existing*** and ***proposed*** conditions based on the delineative criteria stated in the assessment form.

iii. Lateral Stability Existing and Potential Function-based Rating

Assessment Parameter	Measurement Method	Category		
		Functioning	Functioning-at-Risk	Not Functioning
Lateral Stability	If existing lateral stability is FAR or NF, provide description of cause(s) and stability trend and if F cannot be potentially achieved, provide reason			
Lateral Stability Overall EXISTING Condition F FAR NF				
Lateral Stability Overall PROPOSED Condition F FAR NF				

The overall ***existing*** lateral stability function-based rating is based on the individual measurement ratings of the lateral stability assessment parameters. The overall ***proposed*** lateral stability function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. In most cases, the potential to improve lateral stability is possible. However, the potential for lateral stability is greatly reduced where the assessment reach floodplain has been encroached upon by development. Use the criteria below to determine the overall lateral stability ***existing*** and ***proposed*** function-based ratings:

- If all the measurement ratings are F, then the overall lateral stability function-based rating is F.
- If all the measurement ratings are FAR, then the overall lateral stability function-based rating is FAR.
- If all the measurement ratings are NF, then the overall lateral stability function-based rating is NF.
- If any one measurement rating is FAR, then the overall lateral stability function-based rating is FAR.

- If any measurement rating is NF, then the overall lateral stability function-based rating is NF.

If the overall ***existing*** and/or ***proposed*** lateral stability function-based ratings are FAR or NF, provide a brief explanation that describes the causes. Additionally, briefly describe the tread in stability (e.g., stable, degrading, and recovering). Use all the individual function-based ratings made up to this point on the assessment form, the watershed assessment results and any other constraints identified to support reasons for the causes.

c) Bedform Diversity

Natural streams rarely have flat uniform beds (Knighton, 1998). Instead, hydraulic and sediment transport processes shape the stream bed into myriad forms, depending on channel slope, type of bed material (sand, gravel, cobble, boulder, bedrock) and other factors. These bed forms are symptomatic of local variations in the sediment transport rate and represent vertical fluctuations in the stream bed (Knighton, 1998), dissipating energy and creating habitat diversity. These vertical fluctuations are essentially a form of meandering, but in the vertical direction rather than horizontal (like sinuosity).

Numerous classifications of bed form exist, many of which are described in Knighton (1998). At a broad level, bed form diversity can be grouped into three categories: sand bed forms (ripple, dunes and antidunes), gravel/cobble bed forms (riffle, run, pool and glide) and step-pool channels. These different bed forms are important because they provide the environmental conditions that a variety of aquatic organisms need for survival. For example, macroinvertebrates often colonize in riffle habitats and fish tend to stay in pools. Without the diversity of riffles and pools, there is also a loss of diversity in macroinvertebrates and fish.

Assessment of bedform diversity for aquatic species habitat is the focus of this methodology. ***Therefore, assessment of bedform diversity is completed only for those streams likely to support macroinvertebrates and fish (i.e., perennial and intermittent streams and not ephemeral streams).*** The specific measurement methods to be evaluated include shelter for fish and macroinvertebrates, pool-to-pool spacing and pool max depth. The shelter for fish and macroinvertebrates measurement method addresses in-stream habitat. Pool-to-pool spacing and pool max depth measurement methods address habitat as well but they also address energy dissipation. The shelter for fish and macroinvertebrates measurement method comes from the EPA rapid bioassessment method (EPA, 1999), therefore, the descriptions of these assessment parameters will be brief. For a detailed explanation of parameters, refer to the EPA and NRCS method descriptions.

Lastly, the stability of bedform diversity significantly influences functioning habitat. Highly mobile bed features that adjust frequently after storm events adversely affect aquatic species by disrupting their cover, forage, and nesting areas. The mobility of bed features is directly related to stream energy and sediment transport, as described above. Stream energy is indirectly assessed as part of floodplain connectivity and lateral stability assessment parameters in this methodology. However, sediment transport is not a measurement method used in this methodology, but it is important to understand when assessing bedform diversity. Therefore, a brief description will be presented describing sediment transport conditions and understand how it affects the overall functionality of bedform diversity.

i. Sediment Transport

Sediment transport is the movement and storage of sediments via stream energy. The total sediment load transported through a stream can be divided by the type of movement into bedload and suspended load fractions. Bedload is generally composed of larger particles, such as coarse sand, gravels and even cobbles or boulders, which are transported by rolling, sliding or hopping (saltating) along the bed. Suspended load is normally composed of fine sand, silt and clay particles transported in the water column. The ability of the stream to transport its sediment load can be determined by using sediment transport competency and capacity analyses. Sediment transport competency is the stream's ability to move particles of a given size and is a measurement of force. Sediment transport capacity is the ability of a stream to move a quantity of sediment through a riffle cross section.

There are various quantitative methods for calculating sediment transport as well as qualitative methods. One effective qualitative sediment transport method is based on sediment deposition patterns. For example, if the stream has excessive sediment, it will most likely aggrade and have increased bar development, e.g. mid-channel and lateral bars (Photos 1 and 2). Figure 12 (Rosgen 2006) shows different examples of depositional patterns. Depositional pattern B1 is considered a stable channel bed. Depositional patterns B2, B3, B4 and B5 are considered moderately unstable channel beds. Lastly, depositional patterns B6, B7 and B8 are considered highly unstable channel beds. Additional indicators of an aggrading stream may include high wide/depth ratio, braided channels, bars steeply sloped on the downstream end, soft channel bottoms, poorly defined bed features (e.g., pools, riffles, and glides), channel bottom adjustments with every storm event, a channel bottom close to the top of the bank, and excessive sand deposits on the flood plain.

Photo 1. Example of Aggradation

Photo 2. Example of Aggradation

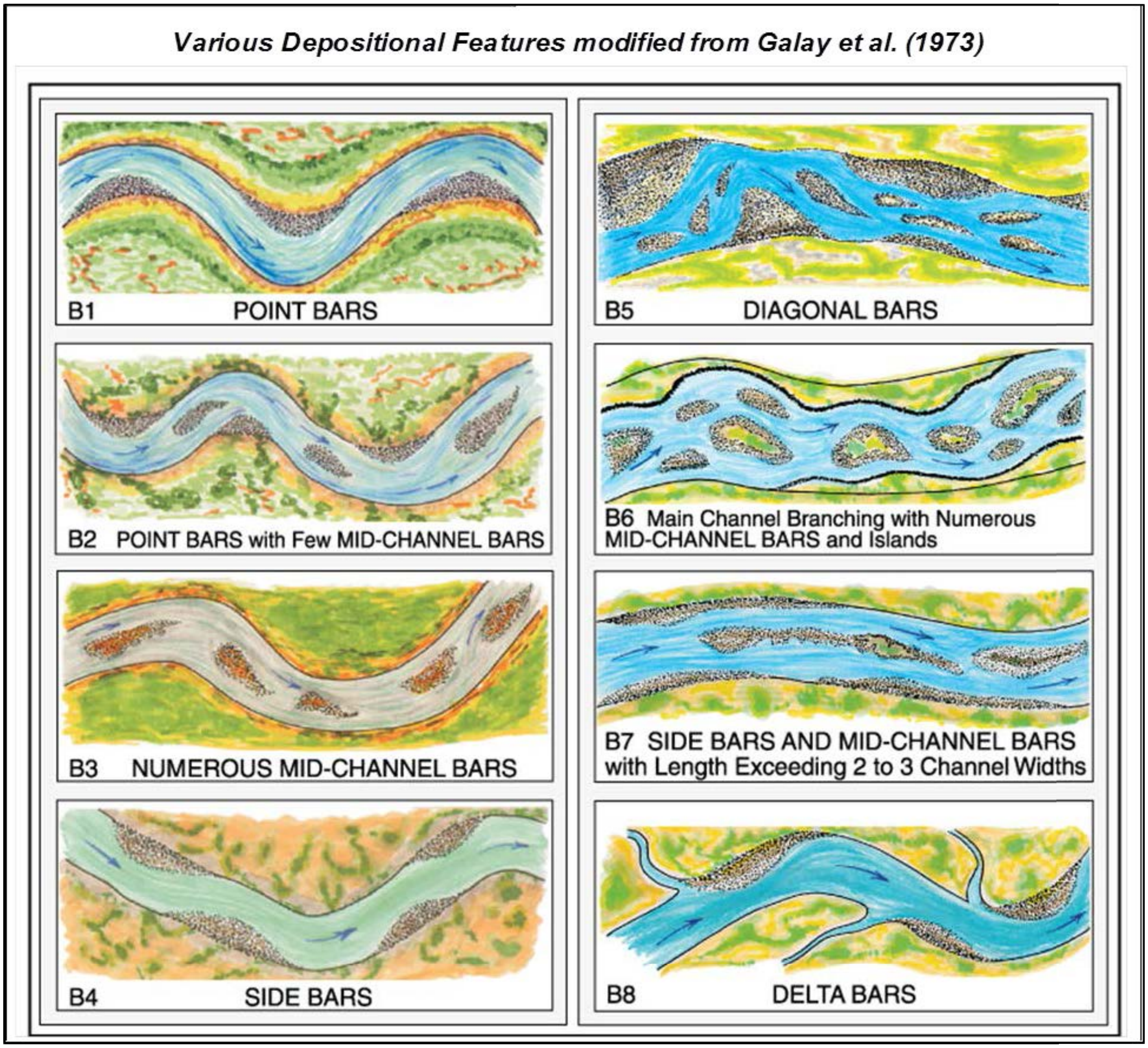


Figure 12. Depositional Patterns (Rosgen 2006).

If the streambed is degrading, headcuts and/or the lack of pool features will be obvious (Photos 3 and 4). Additional indicators of degrading streambeds include high bank height ratios (>2.0), low entrenchment ratios (<1.4), low to moderate width/depth ratios (<12), channel straightening, and gully-shaped channels. However, just as with an aggrading stream, a degrading stream may be recovering and degradation indicators could be from past adjustments. The initial development of depositional features is an indicator that a stream has stopped degrading and begun to recover.

Photo 3. Example of Degradation

Photo 4. Example of a Headcut

ii. Shelter for Fish and Macroinvertebrates

Assessment Parameter	Measurement Method	Category		
		Functioning	Functioning-at-Risk	Not Functioning
Bedform Diversity (Do not complete if stream is ephemeral)	10. Shelter for Fish and Macroinvertebrates (EPA 1999)	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, rubble, gravel, cobble and large rocks, or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient)	20-70% mix of stable habitat; suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new fall, but not yet prepared for colonization (may rate at high end of scale)	Less than 20% mix of stable habitat; lack of habitat availability less than desirables obvious; substrate unstable or lacking
	Existing Condition			
	Proposed Condition			

The shelter for fish and macroinvertebrates measurement method evaluates the amount and availability of physical habitat for both fish and aquatic macroinvertebrates. Diverse and abundant submerged structures within the stream provide aquatic species with a variety of niches, thus improving habitat diversity (Photos 5 and 6). As the amount of structures decrease, so does the quality of habitat. Shelter for fish and macroinvertebrates is considered a structural measure and is formed because of sediment transport and input of large woody debris. Therefore, the presence of well-formed bed features, specifically riffles and/or runs and submerged stream structures, are critical in providing functioning habitat.

The ***existing*** shelter for fish and macroinvertebrates measurement method is an overall rating for the entire assessment reach. Therefore, walk the entire assessment reach and select the delineative criteria from the assessment form that best represents the overall ***existing*** condition.

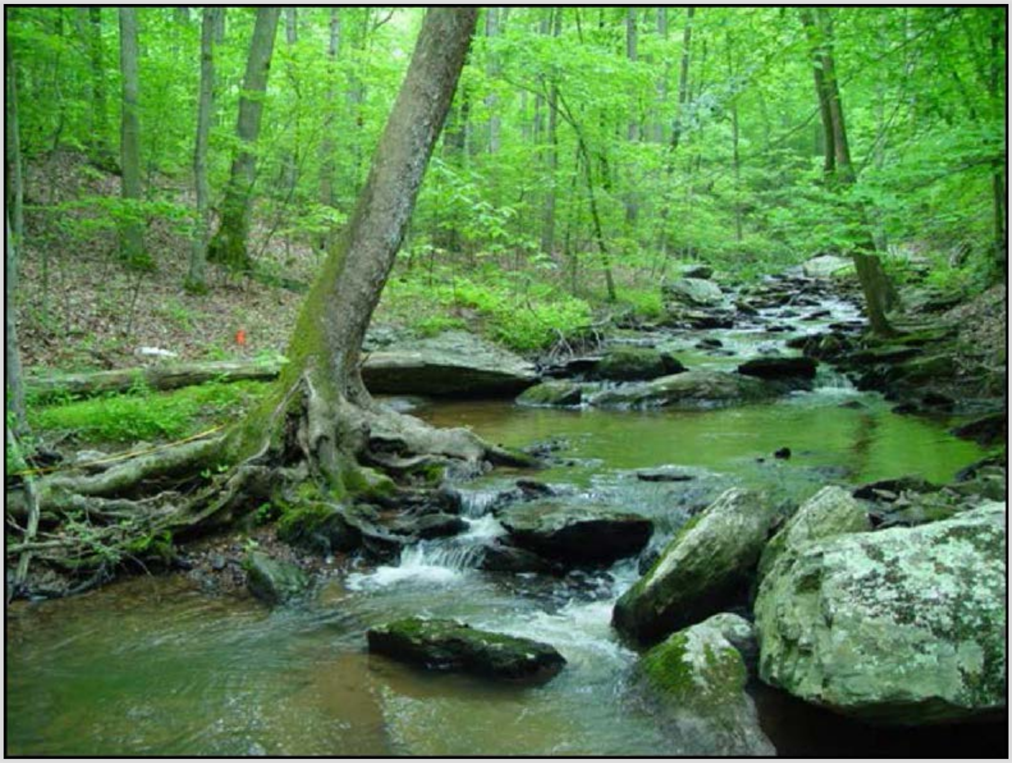


Photo 5. Example of Riffle Macroinvertebrate Habitat

Photo 6. Example of Woody Debris Macroinvertebrate Habitat

The ***proposed*** shelter for fish and macroinvertebrates function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use any relevant data and the proposed design provided as part of the permit application to select the appropriate ***proposed*** reach function-based rating. Additionally, use the results of the restoration potential (Assessment form page 5) and the results of the design review checklist, specifically questions related to sediment transport, stream profile and in-stream structures.

iii. Pool-to-Pool Spacing

Assessment Parameter	**Measurement Method**	**Category**		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Bedform Diversity	**Perennial Streams in Alluvial Valleys (C,E Stream Types)**			
	11a. Pool-to-Pool Spacing Ratio (Watersheds < 10 mi^2)	4.0 - 5.0	3.0 - 4.0 or 5.0 - 7.0	< 3.0 or >7.0
	Existing Condition			
	Proposed Condition			
	11b. Pool-to-Pool Spacing Ratio (Watersheds > 10 mi^2)	5.0 - 7.0	3.5 - 5.0 or 7.0 - 8.0	<3.5 or >8.0
	Existing Condition			
	Proposed Condition			
	Moderate Gradient Perennial Streams in Colluvial Valleys			
	11. Pool-to-Pool Spacing Ratio (3-5% Slope)	2.0 - 4.0	4.0 - 6.0	>6.0
	Existing Condition			
	Proposed Condition			

Pool-to-pool spacing measures the frequency of pools in the stream reach and is the distance measured along the stream centerline or thalweg, between the deepest points of two pools (Figure 13, Typical Pool-to-Pool Spacing Measurements). As stated above, diverse bed form, specifically pools, perform a significant function in dissipating energy and creating habitat diversity. Spacing requirements vary based on stream gradient and watershed size (Rosgen 2006). Typically, low gradient streams are associated with alluvial valleys and are Rosgen C and E stream types and high gradient streams are in located in colluvial valleys and are Rosgen A and B stream types. If pool spacing is too close or too far apart, then bed stability issues could occur. If pool-to-pool spacing becomes too low, then severe bank erosion can occur. In these cases, erosion can be observed from the outside meander bend to the downstream point bar. For streams in colluvial valleys (A and B stream type), it is the opposite. Generally, closer pool-to-pool spacing leads to more stable and diverse bed forms. Pool-to-pool spacing ratios that are too high often have minor to major headcut problems, especially in areas where the channel was reconstructed (Harman et al, 2012).

Pool-to-pool spacing is measured as a ratio by dividing pool-to-pool spacing length by riffle bankfull width. It can be measured in the office as well as in the field. If a longitudinal profile of the ***existing*** stream was provided as part of the permit application package, measure all pool-to-pool spacing within the assessment reach to obtain the range of conditions (Figure 13). Even if a longitudinal profile was provided, measurements should be taken in the field for verification purposes. This can be done simply by using a tape to measure the distance between the deepest points of pools. Note that this performance standard relates to pools in meander bends (Rosgen C/E stream types) or with steps (Rosgen B stream type). It does not include pools in a riffle. Once the measurements are completed, convert them to ratios by dividing them by the riffle bankfull width. Record the pool-to-pool ratios on the Measurement Table (page 4 of the assessment form). Select the appropriate stream type, by stream gradient and watershed size, and then select the delineative criteria stated in the assessment form that best represents the ***existing*** conditions of the assessment reach.

The ***proposed*** pool-to-pool spacing function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use any relevant data and the proposed design provided as part of the permit application and follow the same office procedure described above to select the ***proposed*** pool-to-pool spacing function-based rating. Additionally, use the results of the restoration potential (Assessment form page 5) and the results of the design review checklist, specifically questions related to sediment transport, stream profile and in-stream structures.

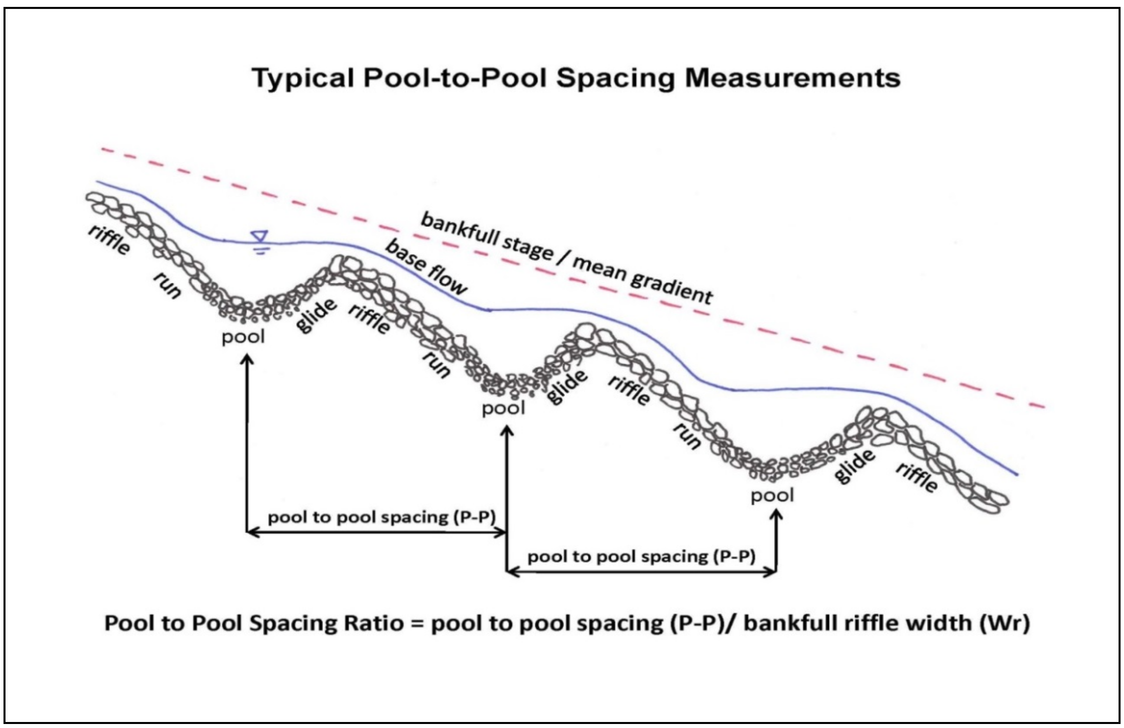


Figure 13. Typical Pool-to-Pool Spacing Measurements.

iv. Pool Max Depth Ratio

Assessment Parameter	Measurement Method	Category		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
	Perennial Streams in Alluvial Valleys (C,E Stream Types)			
	12a. Pool Max Depth Ratio/Depth Variability (Gravel Bed Streams)	>1.5	1.2 - 1.5	<1.2
	Existing Condition			
	Proposed Condition			
Bedform Diversity	12b. Pool Max Depth Ratio/Depth Variability (Sand Bed Streams)	>1.2	1.1 - 1.2	<1.1
	Existing Condition			
	Proposed Condition			
	Moderate Gradient Perennial Streams in Colluvial Valleys			
	12. Pool Max Depth Ratio/Depth Variability	>1.5	1.2 - 1.5	<1.2
	Existing Condition			
	Proposed Condition			

Pool depth variability measures max pool depths, based on bankfull stage, within the stream reach (Figure 14). Like pool-to-pool spacing, pool depths significantly influence energy dissipation and habitat diversity. Depths are also influenced by bed material composition. Gravel/cobble dominated streambeds typically have deeper pools. When looking at a stream reach, the variability between pool max depth ratios provides information on how the stream is processing sediment. If all the ratios are near the same value as the riffle depth, it indicates that the pools are likely filling with sediment. It is most desirable to have a range of pool max depth ratios, as it indicates a wide variety of pool depths and high pool habitat diversity, but they must be deeper than riffles. Also, note that pools can fill in after large storm events (i.e., 50-year return interval or greater) because these type of storms transport and deposit large amounts of sediment. After events like this, the stream must process the newly deposited sediment over time with smaller storm events. So if during the assessment of the site the max pool depths are low, first determine whether a large storm event may be the cause.

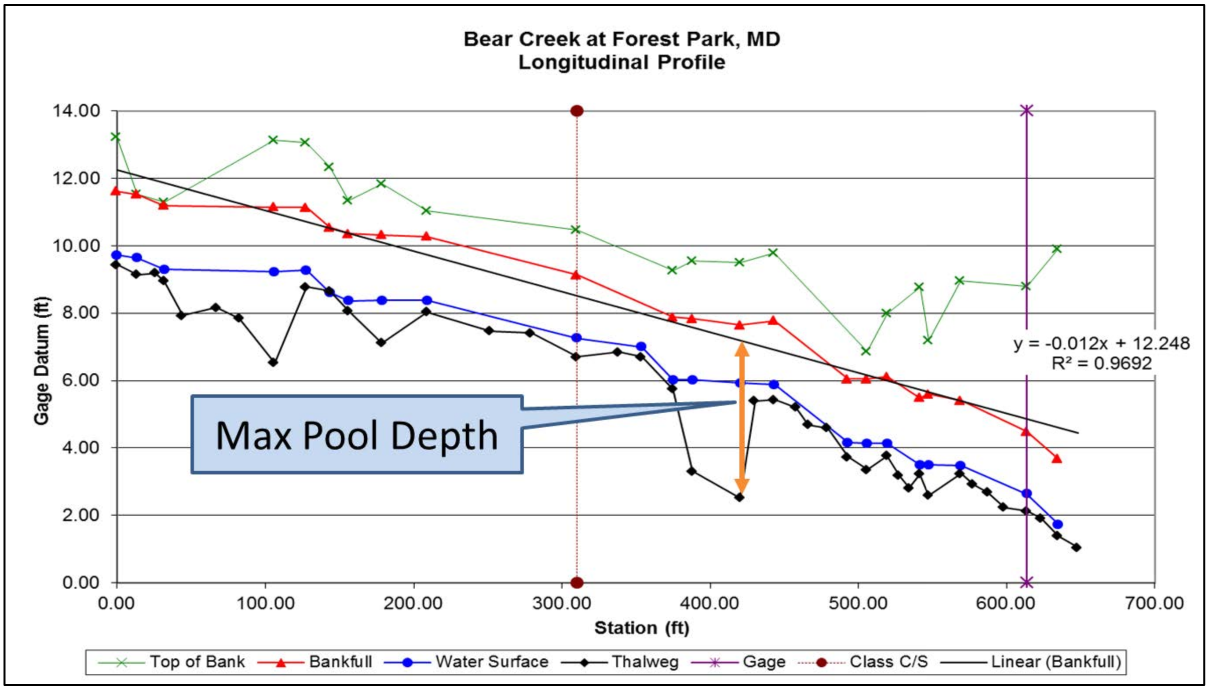


Figure 14. Pool depth variability.

Depth variability can be assessed by measuring the bankfull pool depth at each pool within the assessment reach, and then dividing these depths by a representative mean riffle bankfull depth. This can be accomplished in the office or in the field. If the permit application package provided a longitudinal profile and riffle cross section of the ***existing*** stream, measure all max pool depths within the assessment reach to obtain the range of conditions. Then, using the riffle cross section, divide the riffle bankfull cross section area by the riffle bankfull width to calculate the riffle bankfull mean depth. Divide all max pool depth measurements by the riffle mean depth to calculate max pool depth ratios.

Even if a longitudinal profile and cross section were provided, measurements should be taken in the field for verification purposes. To determine max pool depths in the field, first determine the distance between the existing water surface and the bankfull elevation identified at the beginning of the field assessment (refer to Section V.B.2. Bankfull Determination for instructions). This measurement is often referred to as water surface to bankfull elevation difference. Measure the existing max water depth for each pool within the reach. Then add each max water depth measurement to the water surface to bankfull elevation distance. This will provide the bankfull max pool depths.

To obtain the max pool depth ratios, divide all of the max pool depths by the riffle mean depth. Use the mean riffle depth obtained as part of the bankfull determine described in Section VI. A. 1. Record the max depth ratios on the Measurement Table (page 4 of the assessment form). With this information, select the appropriate stream type and then select the delineative criteria stated in the assessment form that best represents the ***existing*** max pool depth function-based condition of the assessment reach.

The ***proposed*** pool max depth function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use any relevant data and the proposed design provided as part of the permit application and follow the same office procedure described above to select the ***proposed*** pool max depth function-based rating. Additionally, use the results of the restoration potential (Assessment form page 5) and the results of the design review checklist, specifically questions related to sediment transport, stream profile and in-stream structures.

v. Bedform Diversity Existing and Potential Function-based Rating

<table>
<tr><th rowspan="3">Assessment Parameter</th><th rowspan="3">Measurement Method</th><th colspan="4">Category</th></tr>
<tr><th rowspan="2">Functioning</th><th colspan="2">Functioning-at-Risk</th><th rowspan="2">Not Functioning</th></tr>
<tr><th>Trending Towards Functioning</th><th>Trending Towards Not Functioning</th></tr>
<tr><td>Bedform Diversity</td><td>If existing bedform diversity is FAR or NF, provide description of cause(s) and stability trend and if F cannot be potentially achieved, provide reason</td><td colspan="4"></td></tr>
<tr><td colspan="6">Bedform Diversity Overall EXISTING Condition F FAR NF</td></tr>
<tr><td colspan="6">Bedform Diversity Overall PROPOSED Condition F FAR NF</td></tr>
</table>

The overall ***existing*** bedform diversity function-based rating is based on the individual measurement ratings. The overall ***proposed*** bedform diversity function-based rating is based on the potential to alter and/or restore existing FAR and NF ratings. In most cases, the potential to improve bedform diversity is possible. Use the criteria below to select the best description of the overall bedform diversity existing and proposed function-based ratings:

- If all the measurement ratings are F, then the overall bedform diversity function-based rating is F
- If all the measurement ratings are FAR, then the overall bedform diversity function-based rating is FAR
- If all the measurement ratings are NF, then the overall bedform diversity function-based rating is NF
- If any one measure is FAR, then the overall bedform diversity function-based rating is FAR
- If either pool-to-pool spacing or max pool depth measurement rating is NF, then the overall bedform diversity function-based rating is NF

If the overall ***existing*** and/or ***proposed*** bedform diversity function-based ratings are FAR or NF, provide a brief explanation that describes the causes. Additionally, briefly describe the tread in stability (e.g., stable, degrading, and recovering). Use all the individual function-based ratings made up to this point on the assessment form, the sediment transport condition, the watershed assessment results and any constraints identified to support reasons for causes.

d) Geomorphology Overall Function-based Rating

The overall ***existing*** geomorphology function-based rating is based on the individual assessment parameter ratings. The overall ***proposed*** geomorphology function-based rating is based on the potential to alter and/or restore existing FAR and NF ratings. In most cases, the potential to improve geomorphology function is possible. However, the potential to improve geomorphic functions are greatly reduced in areas where floodplain encroachment has occurred because of human activities. Therefore, focus on the ***existing*** and ***proposed*** entrenchment ratio function-based ratings to determine if there is available space for restoration. Restoration of a laterally meandering stream in an alluvial valley will not be possible if there is not enough space to meet the entrenchment ratio of =/> 2.2. However, if the entrenchment ratio is at least 1.4, then restoration can still occur, but the restored stream type will be different from what the watershed would naturally produce (i.e., B4c stream type versus a C or E stream type). While restoration is possible in this situation, the long-term stability of this stream has a potential moderate to high risk of failure. If the ***proposed*** bank height ratio or entrenchment ratio function-based rating is NF, then restoration of a natural, self-sustaining stream is unlikely. Use the criteria below to select the rating that best describes the overall existing and proposed geomorphology function-based ratings:

- If all the assessment parameters ratings are F, then the overall geomorphology function-based rating is F
- If all the assessment parameter ratings are FAR, then the overall geomorphology function-based rating is FAR
- If all the assessment parameter ratings are NF, then the overall geomorphology function-based rating is NF
- If one assessment parameter rating is FAR and the remainder are F, then the overall geomorphology function-based rating is FAR
- If floodplain connectivity rating is NF, then the geomorphology function-based rating is NF
- If any assessment parameter rating is NF (except for floodplain connectivity) and the remainder are F, then the geomorphology function-based rating is FAR

If the overall ***existing*** and/or ***proposed*** geomorphology function-based ratings are FAR or NF, provide a brief explanation that describes the causes. Additionally, briefly describe the tread in stability (e.g., stable, degrading, and recovering). Use all the individual function-based ratings made up to this point on the assessment form, the watershed assessment results and any constraints identified to support reasons for causes.

4. Level 4 - Physicochemical

Physicochemical functions include the interaction of physical and chemical processes to create the basic water quality of the stream (including temperature, dissolved oxygen, conductivity, pH and turbidity), as well as to facilitate nutrient and organic carbon processes (Harman et al, 2012 and Fischenich, 2006). These parameters provide both direct and indirect indications of stream condition and its ability to support biological communities. Additionally, measurement of physicochemical functions requires an understanding of what influential variables are present at the reach scale but are not caused by reach scale variables. These variables include external discharges from upstream, point source and non-point source contributions, and the effects of land use changes in the watershed. These variables highlight the need for preliminary considerations of site selection and reach length if the goal is to improve stream physicochemical function. Climate factors will also have a significant effect on physicochemical functions, but these environmental variables cannot be controlled at any scale.

The conditions of stream physicochemical functions are a determining factor of aquatic ecosystem health. Even small changes in water chemistry affect many lotic organisms. This methodology will assess water appearance, nutrient enrichment, and detritus.

This methodology will assess water appearance, nutrient enrichment and detritus.

a) Water Appearance and Nutrient Enrichment

Assessment Parameter	**Measurement Method**	**Category**		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Water Quality and Nutrients	13. Water Appearance and Nutrient Enrichment (USDA 1999)	Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks. Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present	Frequent cloudiness especially after storm events; objects visible to depth 0.5 to 3.0 ft; may have slight green color; no oil sheen on water surface. Fairly clear or slightly greenish water along entire reach; moderate algal growth on stream substrate	Very turbid or muddy appearance most of the time; objects visible at depth< 0.5 ft; slow moving water maybe bright green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface; or strong odor of chemicals, oil, sewage, or other pollutants. Pea-green, gray, or brown water along entire reach; dense stands of macrophytes clogging stream; severe algal blooms creating thick algal mats in stream
	Existing Condition			
	Proposed Condition			

The water appearance and nutrient enrichment measurement method evaluates water turbidity and potential nutrient pollutants. Turbidity is evaluated after the stream has had time to settle following a storm event. Streams that contain pollutants will have any one of the following indicators; surface scum, oily sheen, strong odors from sewage and chemicals, substrate covered with orange material that comes can from acid inputs, and greenish color from excessive nutrient inputs. Note that orange material in the stream can be naturally occurring because of iron decomposition.

The type and amount of aquatic vegetation in a stream typically represents the level of nutrient loads in a stream. The greater the amount of algae and macrophytes within a stream generally indicates excessive nutrients. Additionally as nutrient levels rise, the greenish color of the water becomes more intense. Alga production and aquatic vegetation growth decreases during the cooler times of the year. High order streams open to the sun often have murkier water when sunlight allows greater algae growth.

Walk the entire assessment reach and select the function-based rating from the delineative criteria described on the assessment form that best represents the ***existing*** water appearance and nutrient enrichment condition of the assessment reach.

The ***proposed*** water appearance and nutrient enrichment function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use any relevant data and the proposed design provided as part of the permit application to select the ***proposed*** water appearance and nutrient enrichment function-based rating condition. Additionally, use the results of the restoration potential (Assessment form page 5).

b) Detritus

Assessment Parameter	**Measurement Method**	**Category**		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Water Quality and Nutrients	14. Detritus (Petersen, 1992)	Mainly consisting of leaves and wood without sediment covering it	Leaves and wood scarce; fine organic debris without sediment	Fine organic sediment - black in color and foul odor (anaerobic) or detritus absent
	Existing Condition			
	Proposed Condition			

Detritus is non-living particulate organic matter. In aquatic systems, it consists of leaf litter, animal waste and other organic debris. Although the presence of detritus is crucial to aquatic systems because it is a food source and shelter for many organisms, the decay of organic material can cause oxygen depletion and excess nitrogen; therefore it can be a source of organic carbon and/or nutrients into the stream system. Allochthonous sources of carbon or nutrients come from outside the aquatic system (such as plant and soil material). Carbon sources from within the system, such as algae and the microbial breakdown of particulate organic carbon, are autochthonous. In streams and small lakes, allochthonous sources of carbon are dominant while in large lakes and the ocean, autochthonous sources dominate (Eby, 2004).

Walk the entire assessment reach and select the ***existing*** detritus function-based rating from the delineative criteria described on the assessment form that best represents the ***existing*** detritus condition.

Photo 7. Detritus.

The ***proposed*** detritus function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use any relevant data and proposed design provided as part of the permit application and the watershed assessment to select the ***proposed*** detritus function-based rating. Additionally, use the results of the restoration potential (Assessment form page 5).

c) Physicochemical Overall Function-based Rating

Assessment Parameter	Measurement Method	Category		
		Functioning	Functioning-at-Risk	Not Functioning
Water Quality and Nutrients	If existing water quality is FAR or NF, provide description of cause(s) and stability trend and if F cannot be potentially achieved, provide reason			
Water Quality Overall EXISTING Condition		F	FAR	NF
Water Quality Overall PROPOSED Condition		F	FAR	NF

The overall ***existing*** physicochemical function-based rating is based on the individual assessment parameter ratings. The overall ***potential*** physicochemical function-based rating is based on the potential to alter and/or restore existing FAR and NF ratings. In most cases, potential improvement of physicochemical function can be challenging. Smaller watersheds have a greater potential for water quality lift when the sources of water quality pollutants are mostly non-point source pollutants (e.g. runoff). In addition, the size of the project influences the potential water quality lift. Larger projects have the greatest potential to influence water quality. Unfortunately, quantitative measures do not exist that state how large a project must be in order to affect water quality. However, research does exist that documents water quality lift based on project location. If the sources of water quality pollutants are mostly point sources, then water quality uplift is possible. However, the point source(s) must be addressed as part of the proposed project actions. Use the criteria below to select the rating that best describes the overall ***existing*** and ***proposed*** physicochemical function-based ratings:

- If both the assessment parameters ratings are F, then the overall physicochemical function-based rating is F
- If both the assessment parameter ratings are FAR, then the overall physicochemical function-based rating is FAR
- If both the assessment parameter ratings are NF, then the overall physicochemical function-based rating is NF
- If one assessment parameter rating is FAR and the remainder are F, then the overall physicochemical function-based rating is FAR
- If water appearance and nutrient enrichment rating is FAR, then the physicochemical function-based rating is FAR
- If water appearance and nutrient enrichment rating is NF, then the physicochemical function-based rating is NF
- If detritus rating is NF and water appearance and nutrient enrichment rating is F or FAR, then the physicochemical function-based rating is FAR

If the overall ***existing*** and/or ***proposed*** physicochemical function-based ratings are FAR or NF, provide a brief explanation that describes the causes. Additionally, briefly describe the tread in stability (e.g., stable, degrading, and recovering). Use all the individual function-based ratings made up to this point on the assessment form, the watershed assessment results and any constraints identified to support reasons for causes.

5. Level 5 - Biology

Biology functions include processes that support the life histories of aquatic and riparian plants and animals (Harman et al, 2012 and Fischenich, 2006). The ability of the lotic system to support biological processes is dependent upon the hydrology, hydraulic, geomorphology, and physicochemical functions as described previously. Stream biological communities have a highly interconnected trophic structure starting from primary producers and moving up the food chain to fish. When habitat degradation occurs due to functional loss in the lower level, and when supporting functions and valuable energy resources are removed, the trophic structure is disrupted and biological assemblages lose diversity and abundance.

This methodology will assess macroinvertebrate and fish communities.

a) Macroinvertebrate

The macroinvertebrate communities of lotic systems are commonly composed of mussels (mollusk), crayfish (crustaceans), worms (annelids) and insects (arthropods). Aquatic insects that live along the substrate are referred to as benthic macroinvertebrates, and this group is the most commonly evaluated in stream systems due to their higher diversity and abundance across stream types. They inhabit many different areas of a stream (Photo 8), and location often depends on their primary feeding mechanism (i.e., predators, collectors, scrapers and shredders). Some feed from available detritus while others scrape periphyton from the stream substrate.

Macroinvertebrates are influenced by water quality, habitat availability and food resources. Benthic macroinvertebrates have a range of sensitivities to changes in organic pollutants, sediments and toxicants, as well as habitat conditions. Macroinvertebrates are good indicators of water quality and stream condition because they have relatively short lifecycles that span multiple seasons, species have differential tolerances to water quality and stream condition, and they are less mobile than fish populations (Kuehne, 1962; Bartsch and Ingram, 1966; Wilhm and Dorris, 1968; Warren, 1971; Cairns and Pratt, 1993).

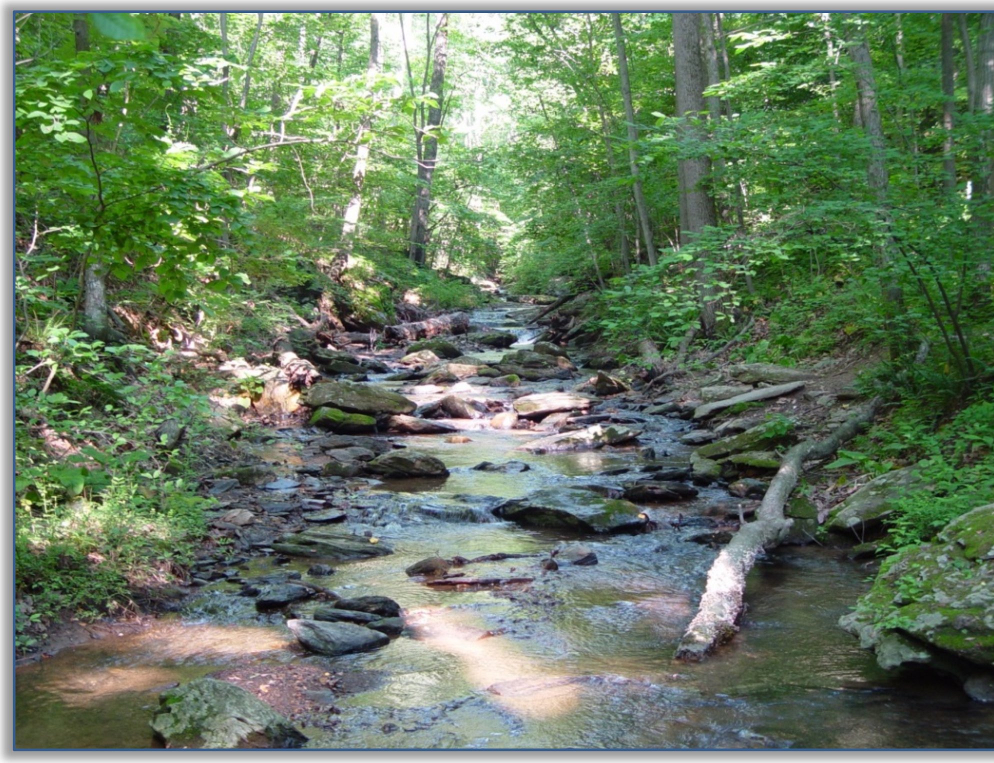


Photo 8. Macroinvertebrates. *Occur in a variety of habitats within the stream channel, including the riffles and pools created by the rocks and woody debris in this mountain stream.*

The measurement methods assessed for this methodology include macroinvertebrate presence and tolerance.

i. *Macroinvertebrate Presence*

Assessment Parameter	Measurement Method	Category		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Biology	15. Macroinvertebrate Presence	Abundant	Rare	Not present
	Existing Condition			
	Proposed Condition			

Presence/absence of aquatic macroinvertebrates can be determined in a variety of ways, with differing levels of difficulty. For the purpose of this methodology, the assessor can use visual observations to determine macroinvertebrate presence/absence. The evaluation should take place throughout the entire assessment reach, however, it is important to target habitats that best support macroinvertebrates. Although they can inhabit a variety of bedform features, the most favorable habitats are cobble or large gravel riffles. In riffles, evaluators should turn over a number of rocks to determine macroinvertebrate presence and abundance. Other habitats to evaluate are root wads, root mats and woody debris, leaf packs, and undercut banks, among others. Less favorable habitats are small gravel, clay lumps or detrital or sand areas in runs (Stranko, et al, 2014). Although it is not necessary for the purpose of this assessment, diligent evaluators may find it useful to use a D-net, particularly in non-riffle habitats. Evidence of benthic macroinvertebrates should also be taken into consideration when evaluating presence. For example, certain benthic macroinvertebrates, such as caddisflies, produce casings made of stones, leaves or sticks, which are adhered to the underside of rocks or other organic debris. Occurrence of the cases indicates caddifies are present within the assessment reach.

When determining ***existing*** macroinvertebrate presence, it is important to take the season into consideration. Many species are inactive or burrow into substrate during cold weather, making determination of presence difficult. Although some species are found all year, macroinvertebrates presence will be easiest to assess before reproduction in the spring. Walk the entire assessment reach and physically pick up numerous rocks and woody debris throughout the preferred macroinvertebrate habitats. If macroinvertebrates were observed in almost every sample, then presence is considered abundant. If macroinvertebrates were observed in less than half of the samples, then presence is considered rare. If macroinvertebrates were not observed in any samples, then presence is considered not present. Select the ***existing*** marcoinvertebrate presence function-based rating from the delineative criteria described on the assessment form that best represents the ***existing*** marcoinvertebrate presence condition.

The ***proposed*** marcoinvertebrate presence function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use any relevant data and the proposed design provided as part of the permit application and watershed assessment to select the ***proposed*** marcoinvertebrate presence function-based rating. Additionally, use the results of the restoration potential (Assessment form page 5). Restoration potential is a critical factor when determine potential macroinvertebrate uplift. If the restoration potential indicates that biological uplift will be challenging, then uplift in macroinvertebrates is unlikely.

ii. Macroinvertebrate Tolerance

Assessment Parameter	Measurement Method	Category		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Biology	16. Macroinvertebrate Tolerance	Abundant intolerant species	Limited intolerant species	Only tolerant species
	Existing Condition			
	Proposed Condition			

The macroinvertebrate tolerance rating is determined at the same time as the presence/absence rating, and is based on the amount of pollution sensitive macroinvertebrates present in the assessment site. Accurate identification of macroinvertebrates, and knowledge of their sensitivity to pollutants, is crucial for completion of this rating. Some intolerant species typically found in healthy stream systems are mayflies, stoneflys, caddisflies, water pennies, hellgrammites, and gilled snails (Maryland DNR, 2004). Descriptions and pictures of these species are found in Figure 15. As with the macroinvertebrate presence/absence rating, evaluators should take note of caddisfly cases made of stick, stones, or leaves. These cases indicate that intolerant species of caddisflies are present in the stream.

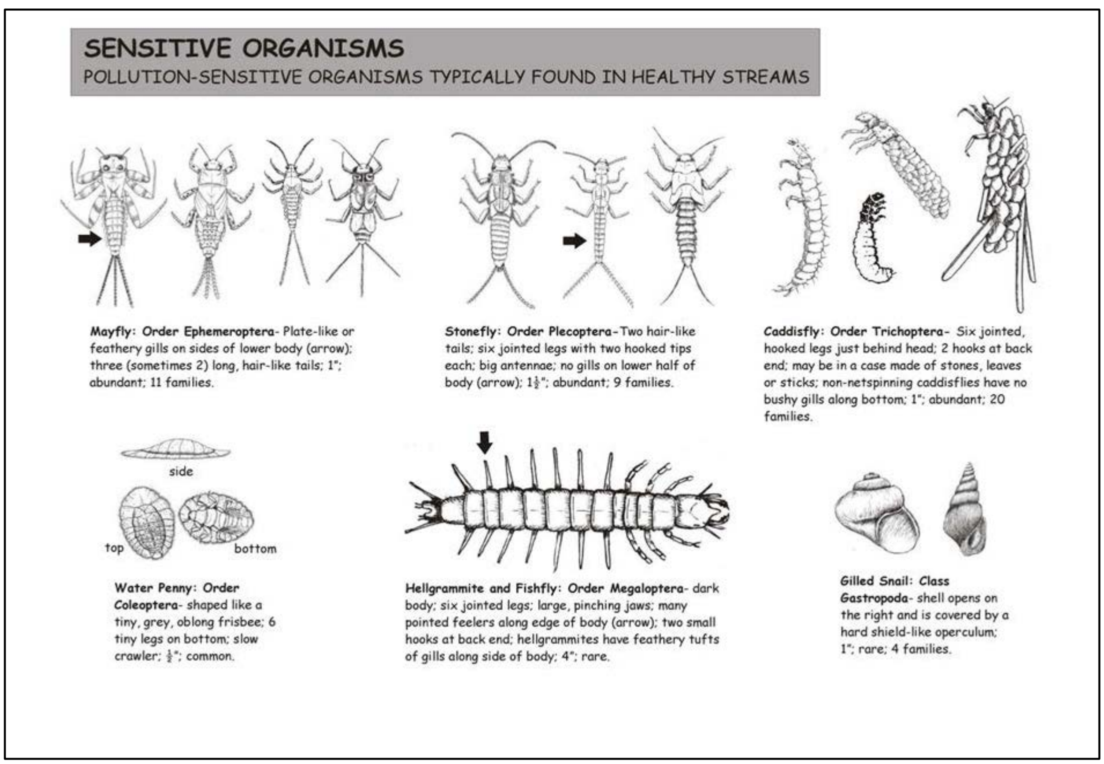


Figure 15. Selection of intolerant stream macroinvertebrates (MD DNR, 2004).

Other benthic macroinvertebrates commonly encountered include moderately sensitive organisms such as alderflies and craneflies, moderately sensitive organisms such as damselflies, dragonflies, can crayfish, and tolerant species such as black fly larvae, leeches, and aquatic worms (Maryland DNR, 2004). Descriptions and pictures of various stream macroinvertebrates are found in Appendix E.

When determining marcoinvertebrate presence, also identify the species observed and record them on the Measurement Table (Assessment form page 4). Then select the ***existing*** marcoinvertebrate tolerance function-based rating from the delineative criteria described on the assessment form that best represents the ***existing*** marcoinvertebrate tolerance condition.

The ***proposed*** marcoinvertebrate tolerance function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use any relevant data and proposed design provided as part of the permit application and watershed assessment to select the ***proposed*** marcoinvertebrate tolerance function-based rating. Additionally, use the results of the restoration potential (Assessment form page 5). Restoration potential is a critical factor when determine potential macroinvertebrate uplift. If the restoration potential indicates that biological uplift will be challenging, then uplift in macroinvertebrates is unlikely.

b) <u>Fish</u>

Assessment Parameter	Measurement Method	Category		
		Functioning	**Functioning-at-Risk**	**Not Functioning**
Biology	17. Fish Presence	Abundant	Rare	Not present
	Existing Condition			
	Proposed Condition			

Fish communities include herbivores, insectivores, detritivores and piscivores. They are the most ubiquitous vertebrate species found in rivers and streams. Fish are the top aquatic predators in most lotic systems and are food for many terrestrial species. They serve as important links in aquatic food chains because they move the energy captured from lower trophic levels up to higher-level predators such as terrestrial animals.

Stream fishes have many adaptations for living in high velocity environments. They can use low-velocity microhabitats like pools, downstream sides of cover elements, or areas under and between substrate. Fish are often specialized feeders with anatomical adaptations for feeding on the bottom, scraping periphyton, picking macroinvertebrates off of rocks or capturing other fishes. They have adapted reproductive approaches that protect their eggs and young, such as spawning on the undersides of exposed rocks, building clean pebble bounds in which to scatter their eggs, or burying the eggs in clean, well-aerated gravel beds (Balon, 1975).

Photo 9. Brook Trout.

The ability of fish populations to fulfill their life history requirements normally depends on streamflow, water quality and habitat availability. Adequate flow in rivers and streams must be maintained to allow fish movement and survival. Good habitat includes creating riffle, run, pool and glide bed forms, as well as providing diverse cover elements within the channel. Diverse habitat will support different stages of a fish's life cycle and/or different species of fish over varying spatial and temporal scales (Rohde et al., 1994). Fish are good indicators of both short-term and long-term water quality and stream condition because they are relatively long-lived, mobile and some species have a lifecycle that requires high water quality. Assessing stream fish populations provides important information for understanding the functions of the biological community, for evaluating biological integrity and for protecting surface water resource quality (Barbour et al., 1999).

The measurement method assessed for this methodology includes fish presence. For the purpose of this methodology, ***existing*** fish presence is determined through visual observation. At this time, there are no established methods for rapid visual evaluation of fish presence in a stream reach; however, this methodology outlines some suggestions for evaluators. The easiest way to determine fish presence visually is to look for indications of fish movement when walking through the assessment site. Fish can inhabit a variety of habitat types, and the most productive types should be evaluated. This will require some knowledge of the natural history of fish species typically found in the area. For example, some species, such as darters and sculpins, are easily observed hiding under or between rocks in riffle and run habitats. Larger fish can be spotted in deeper areas, such as pools or undercut banks. Therefore, the evaluator should look in a variety of habitat features throughout the entire stream reach. Although unnecessary for this methodology, some evaluators may find it useful to use methods such as seining to determine fish presence. If this method is employed, only the most favorable habitats should be assessed.

This method does not distinguish between tolerant and intolerant fish species for the rating due to the difficulty in visually identifying fish species without physically collecting them.

Walk the entire assessment reach and look for the presence of fish throughout the preferred fish habitats. If fish were observed in almost every preferred habitat, then presence is considered abundant. If fish were observed in less than half of the preferred habitats, then presence is considered rare. If fish were not observed in any preferred habitats, then presence is considered not present. Select the ***existing*** fish presence function-based rating from the delineative criteria described on the assessment form that best represents the ***existing*** fish presence condition.

The ***proposed*** fish presence function-based rating is based on the potential of the proposed project to alter and/or restore existing FAR and NF ratings. Use any relevant data and the proposed design provided as part of the permit application and watershed assessment to select the ***proposed*** reach function-based rating. Additionally, use the results of the restoration potential (Assessment form page 5). Restoration potential is a critical factor when determine potential fish uplift. If the restoration potential indicates that biological uplift will be challenging, then uplift in fish is unlikely.

c) <u>Biology Overall Function-based Rating</u>

Assessment Parameter	**Measurement Method**	**Category**			
		Functioning	**Functioning-at-Risk**		**Not Functioning**
			Trending Towards Functioning	**Trending Towards Not Functioning**	
Biology	If existing biology is FAR or NF, provide description of cause(s) and stability trend and if F cannot be potentially achieved, provide reason				
Biology Overall EXISTING Condition F FAR NF					
Biology Overall PROPOSED Condition F FAR NF					

The overall ***existing*** biology function-based rating is based on the individual assessment parameter ratings. The overall ***proposed*** biology function-based rating is based on the potential for the proposed project to alter and/or restore existing FAR and NF ratings. In most cases, it is difficult to improve the potential improvement of biological function. The most influential factor is the watershed condition and water quality upstream of the assessment reach. If the upstream watershed condition and water quality are good, biological functional lift is possible. However, if the upstream watershed condition and water quality are poor and cannot be corrected, then full biological function lift is unlikely. There can be partial biological lift, meaning there is a low presence of macroinvertebrates and fish and those present are mostly tolerant species.

As a general guide, a healthy functioning macroinvertebrate community occurs when the following conditions are present:

- Floodplain connectivity at bankfull channel stage – dissipates energy of large storm events to prevent excessive scouring of substrate; provides access to organic carbon sources available on the floodplain; prevents sediment inundation of substrate habitat
- Healthy hyporheic zones – provides habitat for macroinvertebrates and facilitates exchange of dissolved constituents for healthy periphyton communities, a valuable food resource
- Bed form diversity and complexity – creates diverse habitats for feeding and reproduction; dissipates stormflow energy; provides opportunities for organic carbon storage and retention; provides substrates such as large woody debris; provides scour holes and offers shelter
- Channel stability – prevents sediment inundation of habitat and the detrimental effects of turbidity on filter feeders
- Riparian community – provides allochthonous carbon inputs for food resources; provides shade for cooler temperatures; provides vegetative roots for available habitat

A healthy, functioning fish community occurs when the following conditions are present:

- Continuous upstream streamflow sources – removal of impoundments and excessive water consumption for human activities will provide adequate streamflow throughout the year
- Floodplain connectivity and bankfull channel – dissipates energy of large storm events to prevent excessive scouring of substrates used for reproduction; prevents sediment inundation of substrate habitat
- Healthy hyporheic zones – provides habitat for food resources
- Bed form diversity and in-stream structures – creates diverse habitats for feeding and reproduction; dissipates stormflow energy; provides opportunities for organic carbon storage and retention; provides substrate such as large woody debris; provides scour pools for reproduction, feeding and shelter
- Channel stability – prevents sediment inundation of habitat and excessive turbidity contributed from channel erosion
- Riparian community – provides allochthonous carbon inputs for food resources; provides shade for cooler temperatures; provides vegetative roots for available habitat
- Adequate dissolved oxygen – required for fish survival and health.

Use the criteria below to select the rating that best describes the overall ***existing*** and ***proposed*** function-based ratings:

- If all the assessment parameters ratings are F, then the overall biology function-based rating is F
- If all the assessment parameter ratings are FAR, then the overall biology function-based rating is FAR

- If all the assessment parameter ratings are NF, then the overall biology function-based rating is NF
- If one assessment parameter rating is FAR and the remainder are F, then the overall biology function-based rating is FAR
- If macroinvertebrate tolerance rating is FAR, then the biology function-based rating is FAR
- If macroinvertebrate presence rating is NF and fish presence rating is F or FAR then the biology function-based rating is FAR.
- If fish presence rating is NF and macroinvertebrate presence rating is F or FAR then the biology function-based rating is FAR

If the overall ***existing*** and/or ***proposed*** biology function-based ratings are FAR or NF, provide a brief explanation that describes the causes. Additionally, briefly describe the tread in stability (e.g., stable, degrading, and recovering). Use all the individual function-based ratings made up to this point on the assessment form, the watershed assessment results and any constraints identified to support reasons for causes.

D. RAPID ASSESSMENT SUMMARY

The Rapid Assessment Summary form summarizes the results of the watershed and rapid reach level assessments. It consists of the following: 1). Rapid Watershed Assessment, 2). Overall Existing Reach Level Stream Condition, 3). Channel Evolution Trend, 4). Restoration Potential and 5). Overall Potential Reach Level Stream Condition.

1. Rapid Watershed Assessment

Overall Watershed Condition	Good	Fair	Poor

Circle the appropriate watershed condition based on the Rapid Watershed Assessment form completed for the project area.

2. Overall Existing Reach Level Stream Condition

Overall EXISTING Stream Condition F FAR NF				
LEVEL 1 - F FAR NF	LEVEL 2 - F FAR NF	LEVEL 3 - F FAR NF	LEVEL 4 - F FAR NF	LEVEL 5 - F FAR NF
If existing overall condition is FAR or NF, provide description of cause(s)				

The overall ***existing*** reach level function-based rating is based on the individual pyramid level (i.e., Level 1, 2, 3, 4, and 5) ratings. Circle the appropriate function-based rating, by pyramid level (i.e., Level 1, 2, 3, 4, and 5), which was already completed on the Function-based Rapid Reach Level Stream Assessment form for the assessment reach. Use the criteria below to select the overall ***existing*** reach level function-based rating that best describes the existing assessment reach condition:

- If all the pyramid level ratings are F, then the overall assessment reach function-based rating is F
- If all the pyramid level ratings are FAR, then the overall assessment reach function-based rating is FAR
- If all the pyramid level ratings are NF, then the overall assessment reach function-based rating is NF
- If one pyramid level rating is FAR, then the overall assessment reach function-based rating is FAR
- If one or two assessment parameter ratings are NF and floodplain connectivity is F, then the assessment reach function-based rating is FAR
- If three or more of the assessment parameter ratings are NF and the remainder are F or FAR, then the overall assessment reach function-based rating is NF

If the overall ***existing*** assessment reach function-based ratings is either FAR or NF, provide a brief explanation that describes the causes. Use all the individual function-based ratings made up to this point on the assessment form, the watershed assessment results and any constraints identified to support reasons for causes.

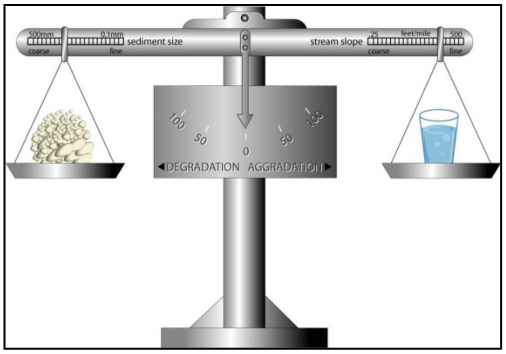
3. Channel Evolution Trend

Channel evolution occurs when a stream system begins to change its morphology from one condition or stream type to a new condition or stream type. Channel evolution can be a negative or positive trend. As described by Leopold (1994), a stream system is a “transporting machine” for water and sediment. An open system, such as a stream, will attempt to work toward two end goals: (1) to perform a minimum amount of work and (2) to expend energy uniformly. A stream system that is in equilibrium is one where these goals are balanced (Leopold, 1994).

Channel evolution can be the result of a channel changing to a more stable or efficient form. This is commonly seen in stream restoration projects or streams that are self-recovering. Restored channels are typically constructed so that they can improve (evolve) their functional capacity over time.

Channel evolution can also be the result of a disruption to the stream or watershed. If a disruption to either the amount of stream power (such as from a change in slope or discharge) or to the work to be done (such as a change in the amount of sediment supply), the stream’s equilibrium may be disturbed, and the stream channel may begin evolving to meet the new conditions. This relationship was first described by Lane (1955). Lane’s diagram states that the sediment size multiplied by the sediment load is proportional to the stream discharge multiplied by the slope (Figure 16. Lane’s Diagram).

A common sequence of physical adjustments (channel evolution) has been observed in many streams following disturbance. Disturbance can result from channelization, which is an increase in runoff due to build-out in the watershed, removal of streamside vegetation or other changes that negatively affect stream stability. These disturbances occur in both urban and rural environments. Several models have been used to describe this process of physical adjustment for a stream.



The sediment size and load is shown on the left, and discharge and slope (power) is shown on the right. When one of these parameters changes, there is often a change in streambed elevation. For example, an increase in channel slope from channelization often leads to degradation.

Figure 16. Lane's Diagram.

The channel evolutionary stage conveys important information about the pressures on stream systems and the stream channel's response. Understanding channel evolution is helpful during geomorphic assessments, restoration goal setting and project evaluation. Channel evolution can be used during the geomorphic assessment phase to determine whether the stream reach is trending towards stability or instability. This determination helps to establish better goals. If the stream is trending towards stability (late stage of evolution), then the restoration goals can be more passive. These passive approaches often include land use management changes or simply re-establishing a wide riparian buffer. If the stream is stable but is showing signs of instability (early stage of channel evolution), like the early signs of a headcut, then the goal may be to simply stabilize the headcut to prevent further upstream damage. Full-scale restoration goals are often needed for streams that have been disturbed and are evolving towards increasingly unstable conditions or reaches that will require many years of adjustment before reaching equilibrium. Channel evolution can then be used after restoration to help show that the stream is moving from a newly constructed condition to a reference condition, e.g. a C stream type evolving to an E stream type. Refer to Appendix F for photo examples of different types of channel evolution.

a) Channel Evolution

Assessment Parameter	Measurement Method	Category			
		Functioning	Functioning-at-Risk		Not Functioning
Channel Evolution Trend	Channel Evolution Trend (Rosgen, 1996 and Simon, 1989)	Little or no presence of active vertical or lateral stream adjustment; floodplain and/or flood prone area well developed, vegetated, and hydrologically connected to stream. Simon Stage 1 & 6. Rosgen Stream type E, C, B, A, & DA.	Presence of localized vertical or lateral stream adjustment; floodplain well developed, vegetated and hydrologically connected to stream (floodplain can be newly formed within a channel that shows past active vertical or lateral stream adjustments). Simon Stage 5. Rosgen Stream type F→C, D→C, F→Bc, & Gc→Bc.	Channel shows past evidence of active vertical downcutting and lateral widening but is currently rebuilding a new floodplain; presence of moderately defined riffles and pools; moderate aggradation occurring; width/depth ratio 12-40. Rosgen Stream type C→F, C→D, Bc→F, E→Gc, B→G & C→Gc.	Channel has widespread active vertical downcutting and lateral widening; floodplain not hydrologically connected (abandoned floodplain); lack of well-defined riffles and pools; incision ratio > 2.1; and for laterally meandering stream a sinuosity ratio < 1.2; entrenchment < 1.4. Simon Stage 2, 3, 4, & 5. Rosgen Stream type F, D, Gc, & G .
	Existing Condition				
	Proposed Condition				
	If existing channel evolution is FAR or NF, provide description of cause(s) and if F cannot be potentially achieved, provide reason				
Channel Evolution Overall EXISTING Condition F FAR NF					
Channel Evolution Overall PROPOSED Condition F FAR NF					

This methodology uses Simon's Channel Evolution Model, Rosgen's Stream Type Succession Scenarios, and other indicators of adjustment to assess channel evolution. The Simon (1989) Channel Evolution Model (Figure 17. Simon Channel Evolution Model) characterizes evolution in six steps, including:

1. Sinuous, pre-modified
2. Channelized

3. Degradation
4. Degradation and widening
5. Aggradation and widening
6. Quasi-equilibrium

The channel evolution process is initiated once a stable stream that is well connected to its floodplain is disturbed. Disturbance commonly results in an increase in stream power that causes degradation, often referred to as channel incision (Lane, 1955). Incision eventually leads to over-steepening of the banks, and when critical bank heights are exceeded, the banks begin to fail. Incision and widening continue as head-cutting moves upstream. Eventually the bed slope is reduced, and sedimentation from bank erosion begins to fill the channel (aggradation). A new low-flow channel begins to form in the sediment deposits. By the end of the evolutionary process, a stable stream geometry, similar to those of undisturbed channels, forms in the deposited alluvium. The new channel is at a lower elevation than its original form, with a new floodplain constructed of alluvial material (FISRWG, 1998).

The first step in determining the channel evolution using this method is to characterize the channel in its current condition. This may involve using similar morphological indicators as those described above to determine vertical and lateral stability, as well as using the results from the sediment transport analysis. A newly channelized stream corresponds to Stage 2 of the Simon model. If an active headcut is observed in this channelized stream, it indicates vertical instability, which corresponds to Stage 3 of the Simon model. If BHRs are high, indicating incision, the stream may begin to have rotational and slab bank failure from the changes in bank hydrostatic pore pressure caused by the drop in the water table. This will cause the channel to widen, which would indicate that the stream is in Stage 4 of the Simon model. Stage 4 also corresponds to an increase in width to depth ratios. As the stream continues to widen, the slope decreases from downcutting, and the channel loses the capacity to transport the sediment received. Depositional features, such as mid-channel and transverse bars, begin to develop and force velocity vectors towards streambanks and cause increased bank erosion or widening. This is Stage 5 of the Simon model.

Rosgen's Stream Type Succession Scenarios (2006) (Figure 18. Rosgen Evolution Model by Stream Type) uses changes in stream type to illustrate channel evolution. Scenario 5 most closely matches the Simon (1989) approach. The first step toward determining the channel evolution with this method is to classify the channel using the Rosgen (1994) methodology. After determining the stream type, observations should extend to the valley to determine what the naturally forming stream type is for the given valley. Rosgen (1996) provides information regarding which stream types occur naturally in certain valleys. Knowing the naturally occurring, stable stream type provides the potential evolutionary start and/or end point for the stream.

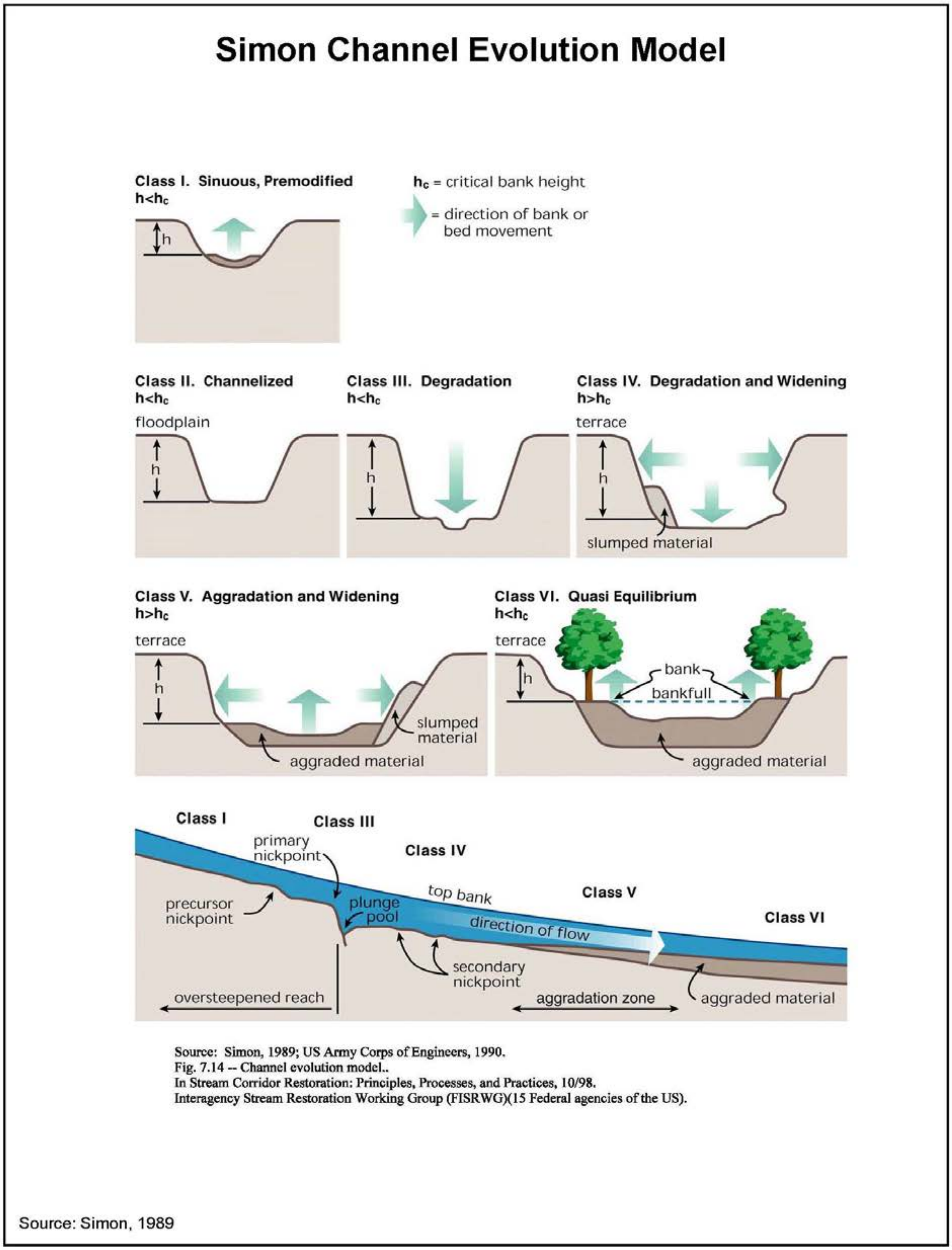


Figure 17. Simon Channel Evolution Model.

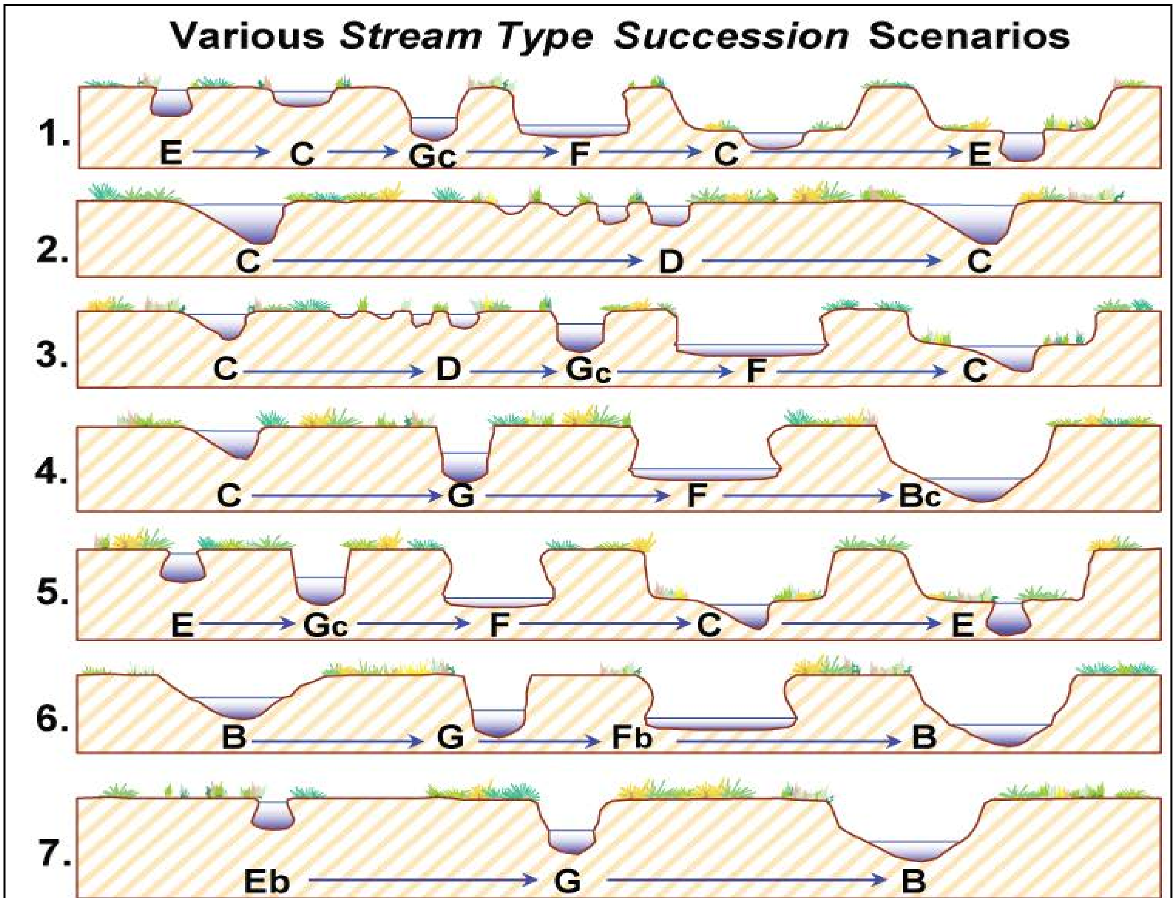


Figure 18. Rosgen Evolution Model by Stream Type (Rosgen 2006).

The next step in determining the channel evolution is to determine if the stream is already at its evolutionary end point, or if it is in one of the stages of evolution. Morphological indicators can give clues as to whether a channel is vertically unstable, laterally unstable or both. These include the presence (or absence) of features such as headcuts and depositional bars; the presence and location of bank erosion; and geomorphic channel measurements, such as bank height ratio, entrenchment ratio and width to depth ratio. These indicators provide insight into whether the channel is aggrading or degrading.

Use any relevant data provided as part of the permit application and the assessment form delineative criteria to select the Rosgen stream type evolution and/or Simon stage function-based rating that best represents the assessment reach.

4. Reach Area Restoration Potential

Restoration potential is the highest level of restoration that can be achieved, given the watershed and site-level conditions, stressors, and constraints. Also, it is at this point the actual amount of potential functional uplift will be determined. For example, the assessment results may indicate that a stream reach is severely incised, has extreme bank erosion, low bed form diversity, and no riparian vegetation. If this site is in a rural setting (low lateral constraints) with a healthy watershed, then the restoration potential is high because functional uplift can likely be achieved for water quality and biological functions. However, if this same site is in an urban area or a setting with lateral constraints like a road or even cropland that cannot be removed from production, then the restoration potential is lower because the functional uplift may only occur for fluvial geomorphologic functions and not physicochemical and biological functions.

Select the highest pyramid level (i.e., hydrology, hydraulic, geomorphology, physicochemical, and biology) that restoration can achieve based on the, watershed assessment results, existing conditions rapid function-based assessment results, identified constraints and any other pertinent information provided in the permit application. ***Note that the restoration potential is determined prior to the completion of the proposed reach level rapid function-based assessment.*** Potential functional uplift or loss cannot be determined for the proposed project until the restoration potential is known. Following this sequence will assist in avoiding over predictions in functional uplift.

5. Overall Proposed Assessment Reach Function-based Condition

The overall ***proposed*** reach level function-based rating is based on the individual pyramid level ratings. In most cases, the potential to restore a fully functioning stream is highly dependent upon the watershed condition upstream of the project area, just as it is for potential biological lift and for the same reasons. Even though the potential to restore a stream to fully functioning can be difficult, some pyramid levels can be restored to functioning more easily such as geomorphology and hydraulic pyramid levels. Use the restoration potential predictions, by pyramid level, made as part of the ***proposed*** reach level assessment and select which pyramid levels can be restored. Use the criteria below to select the rating that best describes the overall ***proposed*** reach level function-based condition:

- If all the pyramid level ratings are F, then the overall assessment reach function-based rating is F
- If all the pyramid level ratings are FAR, then the overall assessment reach function-based rating is FAR
- If all the pyramid level ratings are NF, then the overall assessment reach function-based rating is NF
- If one pyramid level rating is FAR, then the overall assessment reach function-based rating is FAR
- If one or two assessment parameter ratings are NF and floodplain connectivity is F, then the assessment reach function-based rating is FAR
- If three or more of the assessment parameter ratings are NF and the remainder are F or FAR, then the overall assessment reach function-based rating is NF

If the overall ***proposed*** assessment reach function-based ratings is FAR or NF, provide a brief explanation that describes the causes. Use all the individual function-based ratings made up to this point on the assessment form, the watershed assessment results and any constraints identified to support reasons for causes.

E. OVERALL PROJECT EVALUATION

The overall project evaluation focuses on questions that will assist in determining the final permit decision. It is based on the results of the rapid assessment, detailed function-based stream assessment checklist, design review checklist and any supporting information supplied as part of the permit application.

1. Proposed Project Goals and Objectives

Project goals and objectives document why the project is being proposed and how it will be completed. Goals are statements about why the project or effort is needed. They are general intentions and often cannot be validated. Objectives are more specific. They help explain how the project will be completed. They are tangible and can be validated, typically by performance standards. Well-articulated goals and objectives establish a foundation for project success and will be used throughout the entire project process.

From the information provided as part of the permit application, list the project goals and objectives and determine whether the objectives are clear, concise, quantifiable and measurable.

2. Watershed Condition Influence

As described above in the watershed assessment section, the watershed health has a significant influence on the restoration potential of the project area. List the constraints of the project area based on the results of the watershed assessment.

3. Restoration Potential

Restoration potential is the highest level of restoration that can be achieved, given the watershed and site-level conditions, stressors, and constraints. Use the project area restoration potential determined as part of the rapid assessment and list the highest pyramid level and can be achieved.

4. Proposed Project Description

Provide a brief description of the proposed project from the information provided as part of the permit application. Focus on the design approach and the individual restoration activities proposed under the design approach.

5. Potential Function-based Uplift and/or Loss

The potential function-based uplift or loss communicates the amount of function-based improvement or loss by comparing the existing condition to the proposed condition. The potential function-based uplift or loss will be determined from the results of the rapid assessment and information provided as part of the permit application, specifically at the parameter assessment level. For example, floodplain connectivity may have an existing function-based rating of Not Functioning, but because of the stream restoration project, the floodplain connectivity would be Functioning. This would be a function-based uplift. On the other hand, riparian vegetation may have an existing function-based rating of Functioning, but because mature vegetation would be removed as part of the stream restoration project, the riparian vegetation would be Functioning-at-Risk. This would be a function-based loss, at least until the new vegetation matured. List which functions will have uplift and those that will be lost or degraded of the project was implemented.

6. Project Effectiveness

Project effectiveness addresses whether the proposed project design achieves the project goals and objectives. The proposed project design can achieve higher functions than the project goals and objectives but must, at least, meet the project goals and objectives. The information to answer this question can come from the results of the rapid assessment and/or the results of the design review checklist. If using the rapid assessment results, refer to the proposed function-based ratings and determine if uplift occurs in the functions that support the project objectives. Again, this is done at the parameter assessment level. Therefore, if there is a project design objective to reduce lateral erosion; determine if the rapid assessment of lateral erosion predicts that the proposed project would reduce lateral erosion. This same question is asked on the design review checklist; therefore, the answer on the checklist can be transferred to this form. List each project design objective and state whether they were met.

7. Design Completeness

Design completeness addresses if there are any design components missing that could adversely affect the success of the project. This also includes impacts from access and construction activities. The answer to this question also comes from the design review checklist.

8. Project Potential Success

Project potential success addresses the potential success of the proposed project based on risk. Projects that have low complexity and minimal constraints have low risk/high potential for success. However, projects that are highly complex and have many constraints have high risk/low potential for success. This does not mean that the project will be unsuccessful; it just means that success is more uncertain. The answer for this question also comes from the design review checklist.

9. Alternatives Analysis

The alternatives analysis addresses whether any other design approach could achieve equal functional uplift with less loss or achieve greater uplift. The information to answer this question should come from the information provided as part of the permit application. If it was not provided, the evaluator must use best professional judgment to determine if there is a more effective design solution. This process starts by identifying other design approaches or techniques that could meet project goals and design objectives. For example, a project may have a design objective of inundating the floodplain with flood flows more frequent than bankfull flows. There are two ways this could be accomplished. One is to excavate the entire flood plain at half bankfull stage. Another is to cut side channels from the main channel at half bankfull stage. Both meet the design objective, but if the entire floodplain is forested, then the first alternative would result in greater functional loss through the removal of the mature forest.

10. Are all other regulatory considerations satisfied

Project permit issuance addresses whether the proposed project should be permitted. This decision will be made by MDE, according to standards and requirements in statute and regulation for waterway permits and potentially nontidal wetlands.
Applicants should be aware that while a stream restoration project may be shown to provide functional uplift, MDE is required to consider other factors in addition to restoration when making a permit decision. Failure to comply with requirements associated with other considerations may result in a requirement to modify the design before a final permit decision is made. While most projects are authorized or modified and approved, under rare circumstances construction of a particular design at a specific location may be denied.

Considerations include:

Flooding increases to other property owners, blockage of free passage of fish, diversion of stream flow during construction, Maryland Historical Trust concerns and Maryland DNR Environmental Review concerns.

State water quality standards. A certification is required to ensure that activities would not result in a violation of State water quality standards. Standards to be considered include potential increases of temperature in Use III/Use IV waters; discharge of sediment (turbidity) or other contaminants; and decreases in oxygen levels from algal blooms.

Adverse impacts to nontidal wetlands. Nontidal wetlands are most often affected in stream restoration projects by temporary construction access, permanent structures or fill, and alteration of water levels. Wetlands may be permanently lost or converted to a different vegetation type if:

- Temporary impacts are not properly protected and restored, or

- Water levels or duration of inundation are increased so that existing vegetation cannot tolerate the wetter condition, and are replaced by a different plant community.

Applicants should be prepared to justify to MDE why existing vegetation would not be altered, or that if altered, that the change would be beneficial to wetland condition and function. If the wetland alterations are not beneficial, the applicant should justify why the overall benefits of stream restoration outweigh the adverse impacts to wetlands.

LITERATURE CITED

Balon, E.K., 1975. Reproductive Guilds of Fish: A Proposal and Definition. Journal of the Fisheries Research Board of Canada 32:821-864.

Barbour, M.T., J. Gerritsen, B.D. Snyder and J.B. Stribling, 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition, EPA 841-B-99-002. U.S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/owow/monitoring/rbp/ch07main.html.

Barton D.R., W.D. Trylor and R.M. Bierre, 1985. Dimensions of Riparian Buffer Strips Required to Maintain Trout Habitat in Southern Ontario Streams. North American Journal of Fishery Management 5:364-378.

Bartsch, A.F. and W.M. Ingram, 1966. Biological Analysis of Water Pollution in North America. Verhandlungen der Internationalen Vereinigung fur Theoretische und Angewandte 16:786-800.

Eby, G.N., 2004. Principles of Environmental Geochemistry: Thomson Brooks/Cole, Pacific Grove, CA.

Cairns, J. and J.R. Pratt, 1993. A History of Biological Monitoring Using Benthic Macroinvertebrates. *In*: Freshwater Biomonitoring and Benthic Macroinvertebrates, D.M. Rosenberg and V.H. Resh (Editors). Routledge, Chapman, and Hall, New York, New York.

Chaplin, J.J., 2005. Development of Regional Curves Relating Bankfull-Channel Geometry and Dishcharge to Drainage Area for Streams in Pennsylvania and Selected Areas of Maryland. U.S. Geological Survey Scientific Investigations Report 2005-5147.

Dolloff, C.A. and M.L.Warren, Jr., 2003. Fish Relationships with Large Wood in Small Streams. American Fisheries Society Symposium 37:179–193.

Fischenich, J.C., 2006. Functional Objectives for Stream Restoration, EMRRP Technical Notes Collection (ERDC TN-EMRRP-SR-52), U.S. Army Engineer Research and Development Center, Vicksburg, Mississippi. http://el.erdc.usace.army.mil/elpubs/pdf/sr52.pdf.

Fisher, S.G., N.B. Grimm, E. Martı´, R.M. Holmes and J.B. Jones, Jr., 1998. Material Spiraling in Stream Corridors: A Telescoping Ecosystem Model. Ecosystems 1:19-34.

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, D.C. EPA 843-K-12-006.

Knighton, D., 1998. Fluvial Forms and Processes: A New Perspective. Oxford University Press Inc., New York, New York.

Kuehne, R.A., 1962. A Classification of Streams, Illustrated by Fish Distribution in an Eastern Kentucky Creek. Ecology 43(4):608-614.

Lowrance, R.R., R.L. Todd, J. Fail, O. Hendrickson, R. Leonard, and L.E. Asmussen, 1984. Riparian Forests as Nutrient Filters in Agricultural Watersheds. Bioscience 34:374-377.

Leopold, L.B., 1994. A View of the River. Harvard University Press, Cambridge, Massachusetts.

Magette, W.L., R.B. Brinsfield, R.E. Palmer, and J.D. Wood, 1989. Nutrient and Sediment Removal by Vegetated Filter Strips. Transactions, American Society of Agricultural Engineers 32:663–667.

Maryland Department of Natural Resources, 2004. Stream Macroinvertebrates. Annapolis, Maryland.

Martin, E. H. and Apse, C.D., 2013. Chesapeake Fish Passage Prioritization: An Assessment of Dams in the Chesapeake Bay Watershed. The Nature Conservancy, Eastern Division Conservation Science. http://maps.tnc.org/erof_ChesapeakeFPP.

McCandless, T.L. and R.A. Everett, 2002. Maryland Stream Survey: Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region. U.S. Fish and Wildlife Service Technical Report CBFO-S02-01, U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, Maryland.

Maryland Department of Natural Resources, 1999. FIDS/Forestry Task Force Chesapeake Bay Area Timber Harvest Plan Guidelines. Maryland Department of Natural Resources, Annapolis, Maryland.

Opperman, J.J. and A.M. Merenlender, 2004. The Effectiveness of Riparian Restoration for Improving Instream Fish Habitat in Four Hardwood-dominated California Streams. North American Journal of Fisheries Management 24:822-834.

Powell, R., N. Pentz, and E. Gemmill, 1999. Hydrologic, Hydraulic and Geomorphologic Assessment of Streams in the Piedmont Region of Maryland. Baltimore County Department of Environment Projection and Resource Management, Towson, Maryland. (updated by Powell in 2002).

Quinn, J.M., N.R. Phillips, and S.M. Parkyn, 2007. Factors Influencing Retention of Coarse Particulate Organic Matter in Streams. Earth Surface Processes and Landforms 32:1186-1203.

Rohde, F.C., R.G. Arndt, D.G. Lindquist, and J.F. Parnell, 1994. Fishes of the Carolinas, Virginia, Maryland, and Delaware. University of North Carolina Press, Chapel Hill, North Carolina.

Rosgen, D.L., 1994. A Classification of Natural Rivers. Catena 22:169-199.

Rosgen, D.L., 1996. Applied River Morphology. Wildland Hydrology Books, Pagosa Springs, Colorado.

Rosgen, D.L., 2006. A Watershed Assessment for River Stability and Sediment Supply (WARSSS). Wildland Hydrology Books, Fort Collins, Colorado. http://www.epa.gov/warsss

Simon, A., 1989. A Model of Channel Response in Disturbed Alluvial Channels. Earth Surface Processes and Landforms 14:11-26.

Slattery, Britt E., Kathryn Reshetiloff, and Susan M. Zwicker. 2003. Native Plants for Wildlife Habitat and Conservation Landscaping: Chesapeake Bay Watershed. U.S. Fish & Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. 82 pp.

Starr, R. and W. Harman, 2015. Function-based Stream Restoration Project Process Guidelines. U.S. Fish and Wildlife Service – Chesapeake Bay Field Office. Annapolis, Maryland. CBFO-S15-09.

Starr, R. and W. Harman. 2015. Analytical Design Review Checklist Version 3. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. CBFO-S15-02.

Starr, R. and W. Harman. 2015. Natural Channel Design Review Checklist Version 3. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. CBFO-S15-03.

Starr, R., W. Harman. 2015. Regenerative Storm Conveyance Design Review Checklist Version 3. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. CBFO-S15-04.

Starr, R. and W. Harman. 2015. Valley Restoration Design Review Checklist Version 3. U.S. Fish and Wildlife Service, Chesapeake Bay Field Office, Annapolis, MD. CBFO-S15-05.

Stranko, S., D. Boward, J. Kilian, A.Becker, M.Ashton, M.Southerland, Franks, W.Harbold, and J.Cessna, 2014. Maryland Biological Stream Survey:Round Four Field Sampling Manual. Maryand Department of Natural Resources, Annapolis, MD.

U.S. Geological Survey, 2012, The StreamStats Program. http://streamstats.usgs.gov.

U.S. Fish and Wildlife Service, 2005. Washington D.C. Bank Erosion Rate Curve. U.S. Fish and Wildlife Service – Chesapeake Bay Field Office, Annapolis, Maryland.

Warren, C.E., 1971. Biology and Water Pollution Control. W.B. Saunders, Philadelphia, Pennsylvania.

Wilhm, J.L. and T.C. Dorris, 1968. Biological Parameters for Water Quality Criteria. Bioscience 18:477-481.

Wynn, T., S. Mostaghimi, J.A. Burger, A.A. Harpold, M.B. Henderson, and L. Henry, 2004. Variation in Root Density along Stream Banks. Journal of Environmental Quality 33:2030-2039.

APPENDIX A

METHODOLOGY SEQUENCE

A report has been completed that provides detailed guidance on how this assessment is to be conducted (Starr et al, 2015). It can be located on the USFWS Chesapeake Bay Field Office website under Stream Restoration Protocol Publications. The methodology report in written based on the sequence in how the assessment should be conducted, as much as possible. However, there are some sections in the report that are out of sequence based on where that information is recorded on the data sheets. Therefore, this section lists the order of how the assessment should be conducted. The following is the rapid function-based assessment stepwise procedure:

1. Office Pre Site Visit Tasks
2. Rapid Watershed Assessment Form
3. Rapid Assessment Summary Form – Bankfull Determination
4. Rapid Assessment Summary Form – Rosgen Classification
5. Existing and Proposed Function-based Rapid Reach Level Stream Assessment Form – Only the existing conditions
6. Rapid Assessment Summary Form - Overall Existing Function-based Rapid Stream Assessment
7. Rapid Assessment Summary Form – Channel Evolution Trend
8. Rapid Assessment Summary Form - Restoration Potential
9. Existing and Proposed Function-based Rapid Reach Level Stream Assessment Form - proposed conditions
10. Rapid Assessment Summary Form – Overall Proposed Function-based Rapid Stream Assessment
11. Overall Project Evaluation

RAPID WATERSHED ASSESSMENT DATA SHEET

Watershed: ______________________ Rater(s): ______________________

Stream: ______________________ Date: ______________________

Photo(s): ______________________

Overall Watershed Condition Good Fair Poor

WATERSHED ASSESSMENT

Category / Parameter / Measurement Method		Description of Watershed Condition			Rating (G/F/P)
		Good	Fair	Poor	
1	Hydrology / Runoff / Watershed Impoundments	No impoundment upstream of project area	No impoundment within 1 mile upstream of project area OR impoundment does not adversely affect hydrology or fish passage	Impoundment(s) located within 1 mile upstream of project area and/or has an adverse effect on hydrology and/or fish passage	
2	Hydrology / Runoff / Concentrated Flow	No potential for concentrated flow/impairments from adjacent land use	Some potential for concentrated flow/impairments to reach restoration site, however, measures are in place to protect resources	Potential for concentrated flow/impairments to reach restoration site and no treatments are in place	
3	Hydrology / Runoff / Land Use Change	Rural communities/slow growth or primarily forested (>70%)	Single family homes/suburban development occurring or active agricultural practices occurring, or commercial and/or industrial development starting, forested area 20 - 70%	Rapidly urbanizing/urban or primarily active agricultural practices (> 70%), forested area <20%	
4	Hydrology / Runoff / Distance to Roads	No roads in or adjacent to site. No proposed major roads in or adjacent to site in 10 year DOT plans	No roads in or adjacent to site. No more than one major road proposed in 10 year DOT plans	Roads located in or adjacent to site boundary and/or major roads proposed in 10 year DOT plans	
5	Hydrology / Runoff / Flashiness	Non-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover less than 6%	Semi-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover 7%- 15%	Flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover greater than 15%	
6	Geomorphology / Riparian Vegetation	>80% of contributing stream length has >25 ft corridor width	50 - 80% of contributing stream length has >25 ft corridor width	<50% of contributing stream length has >25 ft corridor width	
7	Geomorphology / Sediment Supply	Low sediment supply. Upstream bank erosion and bed load supply is minimal. There are few bars present in the channel	Moderate sediment supply from upstream bank erosion and bed load supply. There are some point bars and small lateral bars	High sediment supply from upstream bank erosion and bed load supply. There are numerous alternating point bars, transverse bars and/or mid-channel bars	
8	Physicochemical / Water Quality / 303(d) List	Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks. Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present. Not on 303d list	Considerable cloudiness most of the time; objects visible to depth 0.5 to 1.5 ft; slow sections may appear pea-green; bottom rocks or submerged objects covered with green or olive-green film; or moderate odor of ammonia or rotten eggs. Greenish water along entire reach; overabundance of lush green macrophytes; abundant algal growth, especially during warmer months. On or downstream of 303d list and TMDL/WS Mgmt plan addressing deficiencies	Very turbid or muddy appearance most of the time; objects visible at depth< 0.5 ft; slow moving water maybe bright green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface; or strong odor of chemicals, oil, sewage, or other pollutants. Pea-green, gray, or brown water along entire reach; dense stands of macrophytes clogging stream; severe algal blooms creating thick algal mats in stream. On or downstream of 303d list and no TMDL/WS mgmt plan to address deficiencies	
9	Biology / Landscape Connectivity	Channel upstream and downstream of project area has native bed and bank materials and is not impaired	Channel upstream and downstream of project area has native bed and bank materials but is impaired	Channel upstream and downstream of project area is concrete piped, or hardened	

EXISTING and PROPOSED REACH LEVEL STREAM FUNCTION-BASED RAPID ASSESSMENT FIELD DATA SHEET

Watershed: ______________________ Rater(s): ______________________

Stream: ______________________ Date: ______________________

Reach Length: ______________________ Latitude: ______________________

Photo(s): ______________________ Longitude: ______________________

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category		
		Functioning	Functioning-at-Risk	Not Functioning
Stream Function Pyramid Level 1 Hydrology				
Runoff	1. Concentrated Flow	No potential for concentrated flow/impairments from adjacent land use	Some potential for concentrated flow/impairments to reach restoration site, however, measures are in place to protect resources	Potential for concentrated flow/impairments to reach restoration site and no treatments are in place
	Existing Condition			
	Proposed Condition			
	2. Flashiness	Non-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover less than 6%	Semi-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover 7 - 15%	Flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover greater than 15%
	Existing Condition			
	Proposed Condition			
	If existing runoff is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			
	Runoff Overall EXISTING Condition F FAR NF			
	Runoff Overall PROPOSED Condition F FAR NF			
Stream Function Pyramid Level 1 Hydrology Overall EXISTING Condition F FAR NF				
Stream Function Pyramid Level 1 Hydrology Overall PROPOSED Condition F FAR NF				
Stream Function Pyramid Level 2 Hydraulics				
Floodplain Connectivity (Vertical Stability)	3. Bank Height Ratio (BHR)	<1.10	1.11 - 1.50	>1.50
	Existing Condition			
	Proposed Condition			
	4a. Entrenchment (Meandering streams in alluvial valleys or Rosgen C, E, DA Streams)	>2.2	2.1 - 1.4	<1.4
	Existing Condition			
	Proposed Condition			
	4b. Entrenchment (Non meandering streams in colluvial valleys or Rosgen B Streams)	>1.4	1.3 - 1.1	<1.1
	Existing Condition			
	Proposed Condition			
	5. Floodplain Drainage	no concentrated flow; runoff is primarily sheet flow; hillslopes < 10%; hillslopes >200 ft from stream; ponding or wetland areas and litter or debris jams are well represented	runoff is equally sheet and concentrated flow (minor gully and rill erosion occurring); hillslopes 10 - 40%; hillslopes 50 - 200 ft from stream; ponding or wetland areas and litter or debris jams are minimally represented	concentrated flows present (extensive gully and rill erosion); hillslopes >40%; hillslopes <50 ft from stream; ponding or wetland areas and litter or debris jams are not well represented or absent
	Existing Condition			
	Proposed Condition			
	6. Vertical Stability Extent	Stable	Localized Instability	Widespread Instability
	Existing Condition			
	Proposed Condition			
	If existing floodplain connectivity is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			
	Floodplain Connectivity Overall EXISTING Condition F FAR NF			
	Floodplain Connectivity Overall PROPOSED Condition F FAR NF			
Stream Function Pyramid Level 2 Hydraulics Overall EXISTING Condition F FAR NF				
Stream Function Pyramid Level 2 Hydraulics Overall PROPOSED Condition F FAR NF				

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Functioning-at-Risk	Not Functioning
Stream Function Pyramid Level 3 Geomorphology				
Riparian Vegetation	7. Riparian Vegetation Zone (EPA, 1999, modified)	Riparian zone extends to a width of >100 feet; good vegetation community diversity and density; human activities do not impact zone; invasive species not present or sparse	Riparian zone extends to a width of 25-100 feet; species composition is dominated by 2 or 3 species; human activities greatly impact zone; invasive species well represented and alter the community	Riparian zone extends to a width of <25 feet; little or no riparian vegetation due to human activities; majority of vegetation is invasive
	Left Bank Existing			
	Left Bank Proposed			
	Right Bank Existing			
	Right Bank Proposed			
	If existing riparian vegetation is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			
	Riparian Vegetation Overall EXISTING Condition F FAR NF			
	Riparian Vegetation Overall PROPOSED Condition F FAR NF			
Lateral Stability	8. Dominant Bank Erosion Rate Potential	Dominate bank erosion rate potential is low or BEHI/NBS Rating: L/VL, L/L, L/M, L/H, L/VH, M/VL	Dominate bank erosion rate potential is moderate or BEHI/NBS Rating: M/L, M/M, M/H, L/Ex, H/L, M/VH, M/Ex, H/L, H/M, VH/VL, Ex/VL	Dominate bank erosion rate potential is high or BEHI/NBS Rating: H/H, H/Ex, VH/H, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex
	Existing Condition (Right bank)			
	Proposed Condition (Right Bank)			
	Existing Condition (Left bank)			
	Proposed Condition (Left Bank)			
	9. Lateral Stability Extent	Stable	Localized Instability	Widespread Instability
	Existing Condition			
	Proposed Condition			
	If existing lateral stability is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			
	Lateral Stability Overall EXISTING Condition F FAR NF			
	Lateral Stability Overall PROPOSED Condition F FAR NF			
Bedform Diversity (Do not complete if stream is ephemeral)	10. Shelter for Fish and Macroinvertebrates (EPA 1999)	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, rubble, gravel, cobble and large rocks, or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient)	20-70% mix of stable habitat; suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new fall, but not yet prepared for colonization (may rate at high end of scale)	Less than 20% mix of stable habitat; lack of habitat availability less than desirables obvious; substrate unstable or lacking
	Existing Condition			
	Proposed Condition			
	11a. Pool-to-Pool Spacing Ratio (Watersheds < 10 mi^2)	4.0 - 5.0	3.0 - 4.0 ***or*** 5.0 - 7.0	< 3.0 ***or*** >7.0
	Existing Condition			
	Proposed Condition			
	11b. Pool-to-Pool Spacing Ratio (Watersheds > 10 mi^2)	5.0 - 7.0	3.5 - 5.0 ***or*** 7.0 - 8.0	<3.5 ***or*** >8.0
	Existing Condition			
	Proposed Condition			

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Functioning-at-Risk	Not Functioning
Bedform Diversity (Do not complete if stream is ephemeral)	12a. Pool Max Depth Ratio/Depth Variability (Gravel Bed Streams)	>1.5	1.2 - 1.5	<1.2
	Existing Condition			
	Proposed Condition			
	12b. Pool Max Depth Ratio/Depth Variability (Sand Bed Streams)	>1.2	1.1 - 1.2	<1.1
	Existing Condition			
	Proposed Condition			
	Moderate Gradient Perennial Streams in Colluvial Valleys			
	11. Pool-to-Pool Spacing Ratio (3-5% Slope)	2.0 - 4.0	4.0 - 6.0	>6.0
	Existing Condition			
	Proposed Condition			
	12. Pool Max Depth Ratio/Depth Variability	>1.5	1.2 - 1.5	<1.2
	Existing Condition			
	Proposed Condition			
	If existing bedform diversity is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			
	Bedform Diversity Overall EXISTING Condition F FAR NF			
	Bedform Diversity Overall PROPOSED Condition F FAR NF			
Stream Function Pyramid Level 3 Geomorphology Overall EXISTING Condition F FAR NF				
Stream Function Pyramid Level 3 Geomorphology Overall PROPOSED Condition F FAR NF				
Stream Function Pyramid Level 4 Physicochemical				
Water Quality and Nutrients (Do not complete if stream is ephemeral)	13. Water Appearance and Nutrient Enrichment (USDA 1999)	Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks. Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present	Frequent cloudiness especially after storm events; objects visible to depth 0.5 to 3.0 ft; may have slight green color; no oil sheen on water surface. Fairly clear or slightly greenish water along entire reach; moderate algal growth on stream substrate	Very turbid or muddy appearance most of the time; objects visible at depth< 0.5 ft; slow moving water maybe bright green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface; or strong odor of chemicals, oil, sewage, or other pollutants. Pea-green, gray, or brown water along entire reach; dense stands of macrophytes clogging stream; severe algal blooms creating thick algal mats in stream
	Existing Condition			
	Proposed Condition			
	14. Detritus (Petersen, 1992)	Mainly consisting of leaves and wood without sediment covering it	Leaves and wood scarce; fine organic debris without sediment	Fine organic sediment - black in color and foul odor (anaerobic) or detritus absent
	Existing Condition			
	Proposed Condition			
	If existing water quality is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			
Stream Function Pyramid Level 4 Physicochemical Overall EXISTING Condition F FAR NF				
Stream Function Pyramid Level 4 Physicochemical Overall PROPOSED Condition F FAR NF				

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category		
		Functioning	Functioning-at-Risk	Not Functioning
Stream Function Pyramid Level 5 Biology				
Biology (Do not complete if stream is ephemeral)	15. Macroinvertebrate	Abundant	Rare	Not present
	Existing Condition			
	Proposed Condition			
	16. Macroinvertebrate Tolerance	Abundant intolerant species	Limited intolerant species	Only tolerant species
	Existing Condition			
	Proposed Condition			
	17. Fish Presence	Abundant	Rare	Not present
	Existing Condition			
	Proposed Condition			
	If existing biology is FAR or NF, provide description of cause (s) and stability trend and if F can not be potentially achieved, provide reason			
Stream Function Pyramid Level 5 Biology Overall EXISTING Condition F FAR NF				
Stream Function Pyramid Level 5 Biology Overall PROPOSED Condition F FAR NF				

Bankfull Determination and Rosgen Stream Classification

Rosgen Stream Type (Observation)		
Regional Curve (circle one): Piedmont Coastal Plain Allegheny Plateau/Ridge and Valley Urban Karst		
DA (sqmi)	Rosgen Valley Type	
BF Width (ft)	BF Area (sqft)	
BF Depth (ft)	Percent Impervious (%)	

Field Measurements

Parameter	Measurements and Ratios			
Water surface to geomorphic feature elevation difference				
Riffle Mean Depth at Bankfull Stage (dbkf)				
Riffle Width at Bankfull Stage (Wbkf)				
Riffle XS Area at Bankfull Stage (Abkf = dbkf*Wbkf)				
Floodprone Area Width (Wfpa) (Wfpa=Width at elevation determined by 2xDmax)				
Entrenchment Ratio (ER) (ER=Wfpa/Wbkf)				
Low Bank Height (LBH)				
Riffle Maximum Depth at Bankfull Stage (Dmax)				
Bank Height Ratio (BHR) (BHR=LBH/Dmax)				
BEHI/NBS Ratings and Lengths				
Pool to Pool Spacing (P-P)				
Pool to Pool Spacing Ratio (P-P Ratio) (P-P Ratio=P-P/Wbkf)				
Pool Maximum Depth at Bankfull Stage (Dmbkfp)				
Pool Depth Ratio (Dmbkfp Ratio) (Dmbkfp Ratio=Dmbkfp/dbkf)				
Macroinvertebrate Species Observed				

Reach ID:	

Rapid Assessment Summary

Overall Watershed Condition Good Fair Poor

Overall EXISTING Reach Level Stream Condition F FAR NF				
LEVEL 1 - F FAR NF	**LEVEL 2 - F FAR NF**	**LEVEL 3 - F FAR NF**	**LEVEL 4 - F FAR NF**	**LEVEL 5 - F FAR NF**
If existing overall condition is FAR or NF, provide description of cause(s)				

	Functioning	**Functioning-at-Risk**		**Not Functioning**
		Trending Towards Functioning	**Trending Towards Not Functioning**	
Channel Evolution Trend (Rosgen, 1996)	Little or no presence of active vertical or lateral stream adjustment; floodplain and/or flood prone area well developed, vegetated, and hydrologically connected to stream. Simon Stage 1 & 6. Rosgen Stream type E, C, B, A, & DA	Presence of localized vertical or lateral stream adjustment; floodplain well developed, vegetated and hydrologically connected to stream (floodplain can be newly formed within a channel that shows past active vertical or lateral stream adjustments). Simon Stage 5. Rosgen Stream type F→C, D→C, F→Bc, & G→B	Channel shows past evidence of active vertical downcutting and lateral widening but is currently rebuilding a new floodplain; presence of moderately defined riffles and pools; moderate aggradation occurring; width/depth ratio 12-40. Rosgen Stream type C→F, C→D, Bc→F, E→Gc, B→G & C→Gc	Channel has widespread active vertical downcutting and lateral widening; floodplain not hydrologically connected (abandoned floodplain); lack of well defined riffles and pools; incision ratio > 2.1; and for laterally meandering stream a sinuosity ratio < 1.2; entrenchment < 1.4. Simon Stage 2, 3, 4, & 5. Rosgen Stream type F, D, Gc, & G
If existing channel evolution is FAR or NF, provide description of cause(s)				

Restoration POTENTIAL Level 1 2 3 4 5 Functioning	
Provide reason(s) for restoration potential prediction	

Overall PROPOSED Reach Level Stream Condition				
LEVEL 1 - F FAR NF	**LEVEL 2 - F FAR NF**	**LEVEL 3 - F FAR NF**	**LEVEL 4 - F FAR NF**	**LEVEL 5 - F FAR NF**
If any Pyramid Level proposed condition cannot potentially achieve F, provide reason(s)				

OVERALL PROJECT EVALUATION FORM

Watershed: ______________________________ Rater(s): ____________________ Existing Stream Function-based Condition: F FAR NF

Stream: ______________________________ Date: ____________________ Overall Watershed Condition: Good Fair Poor

Reach ID: ______________________________ Latitude: ____________________ Potential Stream Function-based Condition: F FAR NF

Reach Length: __________ Photo(s): __________ Longitude: ____________________ **Permit Project** **Yes** **No**

OVERALL PROJECT EVALUATION

1. What are the proposed project goals (purpose) and objectives (need) and are they clear, concise and measurable?

2. How does the watershed condition influence the proposed project area?

3. What is the restoration potential of the proposed project area? (what functional level can achieved based on the functional pyramid)

4. Provide a description of the proposed project.

5. What is the potential functional uplift and/or loss of the proposed project?

6. Does the design approach address the project goals and objectives? (note project can achieve greater than goals and objectives, but must at least meet the goals and objectives)

7. Are there any design components that are missing or could adversely affect the success of the project, including impact from access and construction?

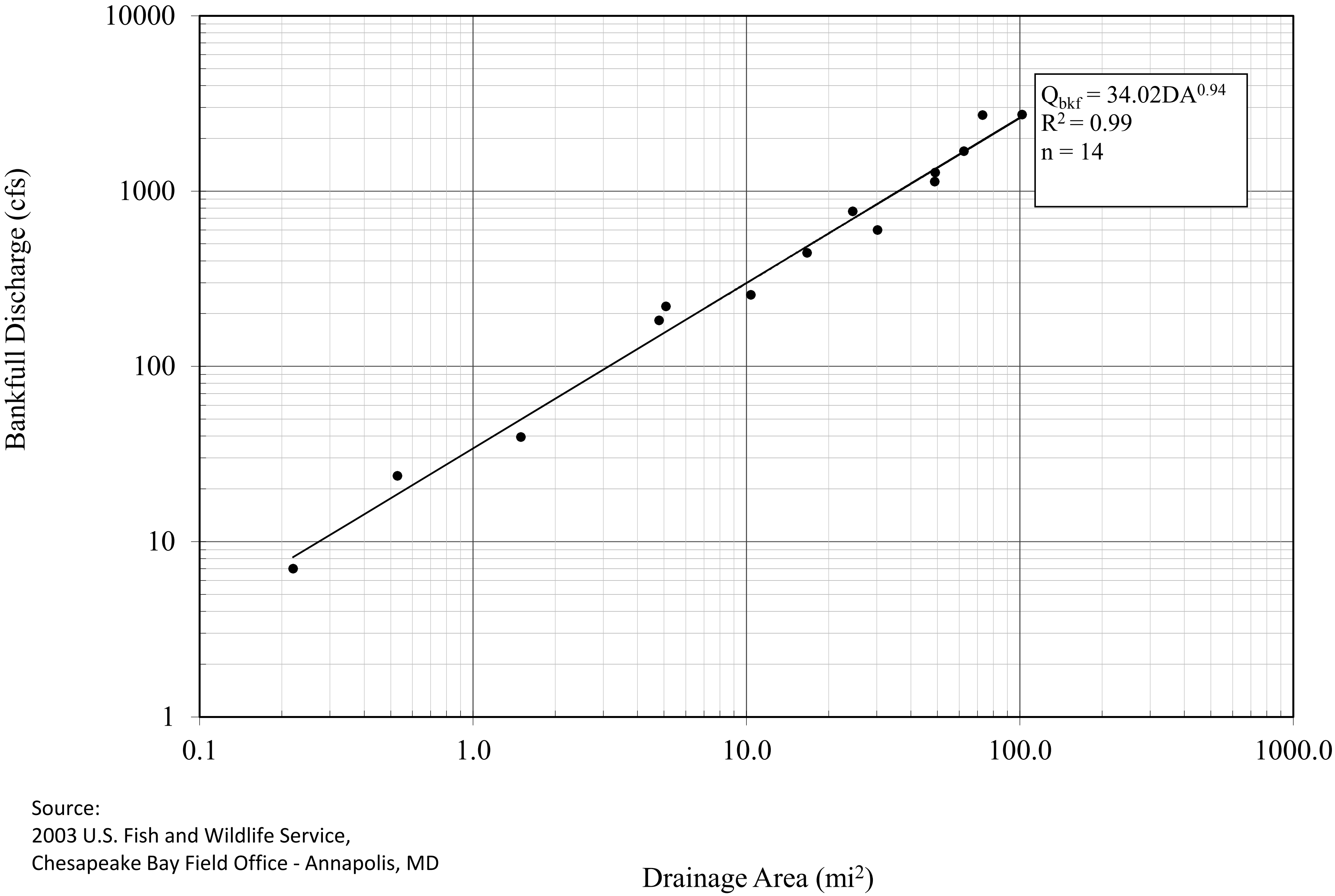
8. Does the project have a high potential for success?

9. Can any other design approach achieve equal uplift with less functional loss or achieve greater uplift?

10. Are all other regulatory considerations satisfied?

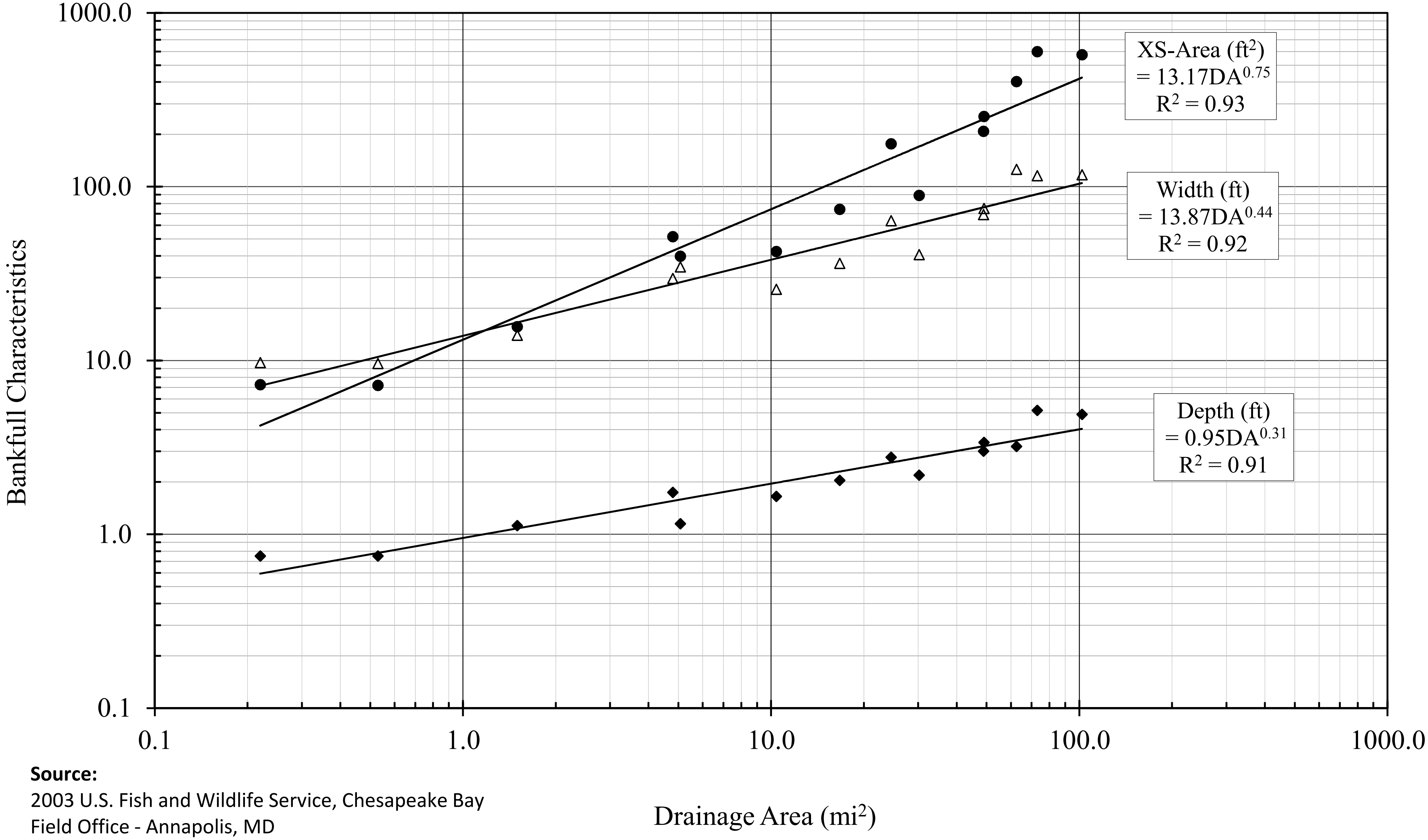
APPENDIX B

Bankfull Discharge as a Function of Drainage Area for the
Maryland Allegheny Plateau/Valley Ridge Hydro-physiographic Region



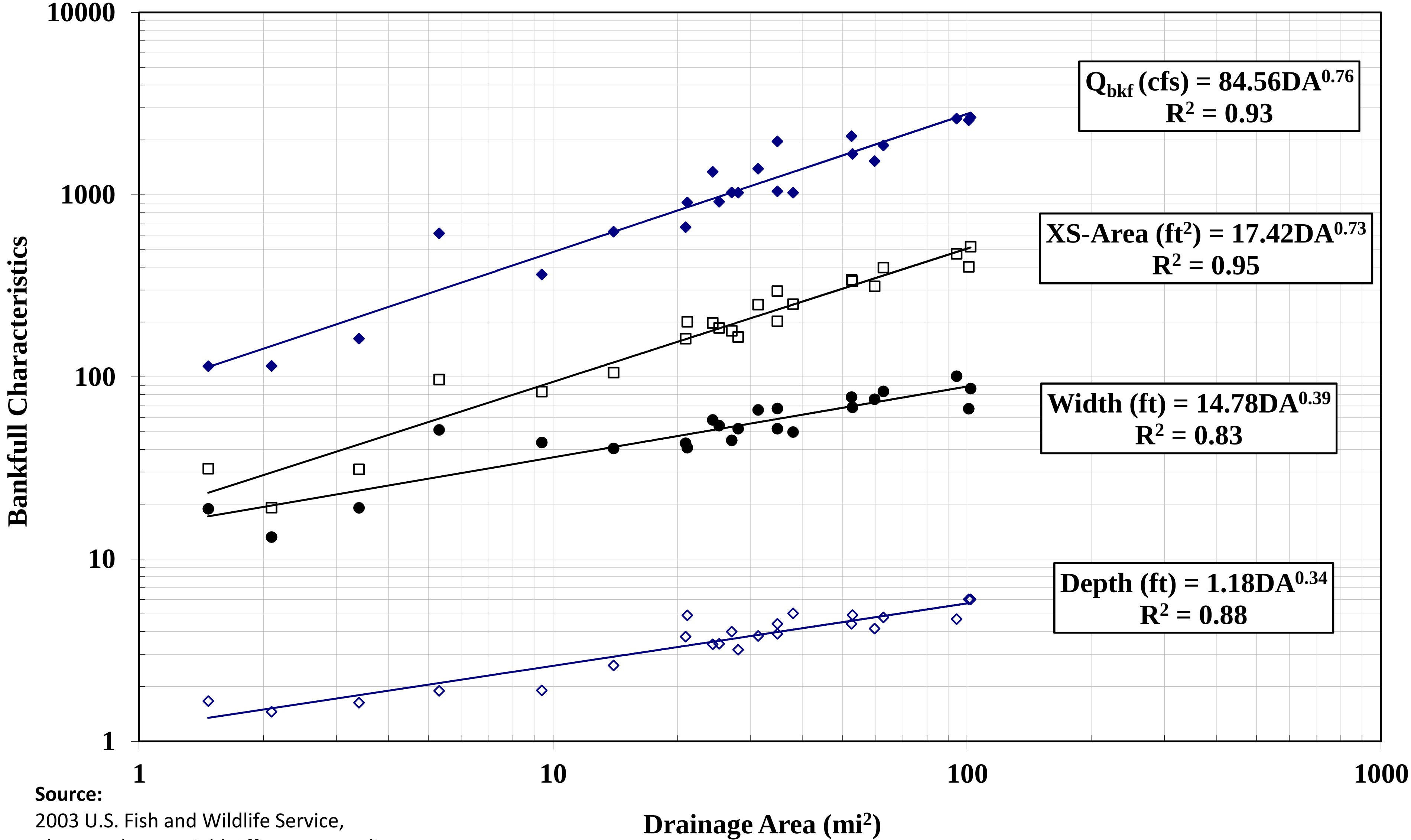
Source:
2003 U.S. Fish and Wildlife Service,
Chesapeake Bay Field Office - Annapolis, MD

Bankfull Characteristics for Selected USGS Gage Sites in the Maryland Allegheny Plateau/Valley Ridge Hydro-physiographic Region



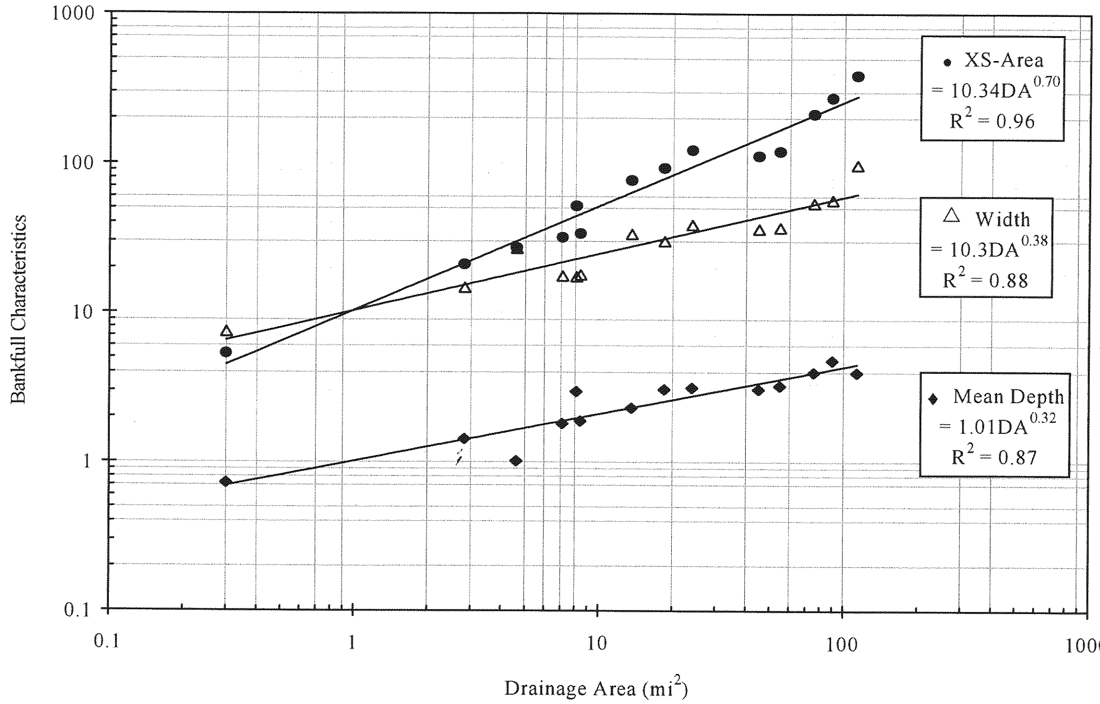
Source:
2003 U.S. Fish and Wildlife Service, Chesapeake Bay
Field Office - Annapolis, MD

Bankfull Characteristics for Selected USGS Gage Sites in the Maryland Piedmont Hydro-physiographic Region

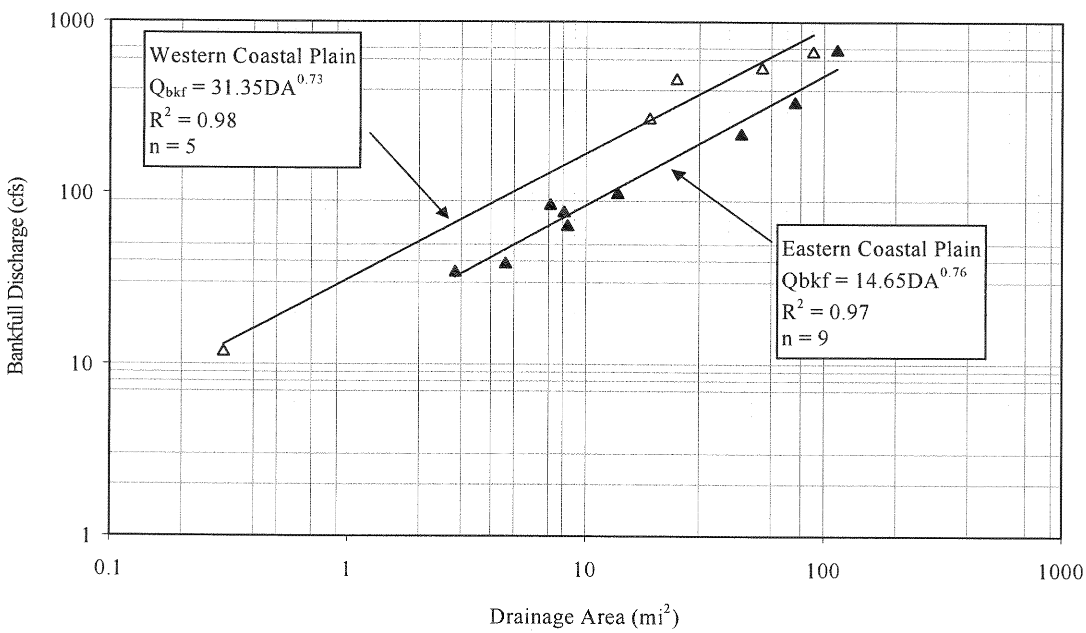


Source:
2003 U.S. Fish and Wildlife Service,
Chesapeake Bay Field Office - Annapolis, MD

Exhibit 11a. Bankfull Characteristics for Selected USGS Gage Site in the Maryland Coastal Plain Hydro-physiographic Region (from USFWS-Chesapeake Bay Field Office)

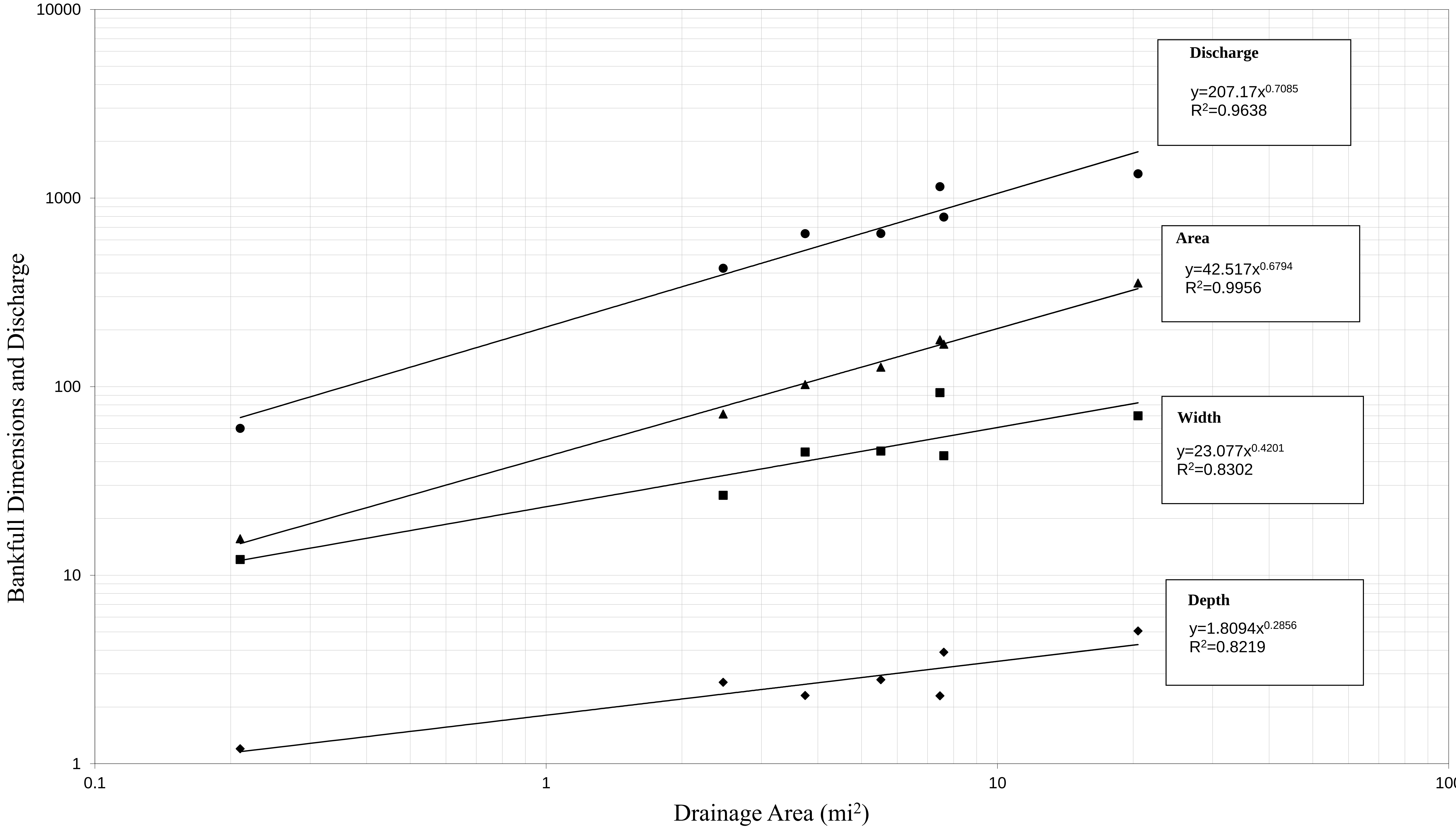


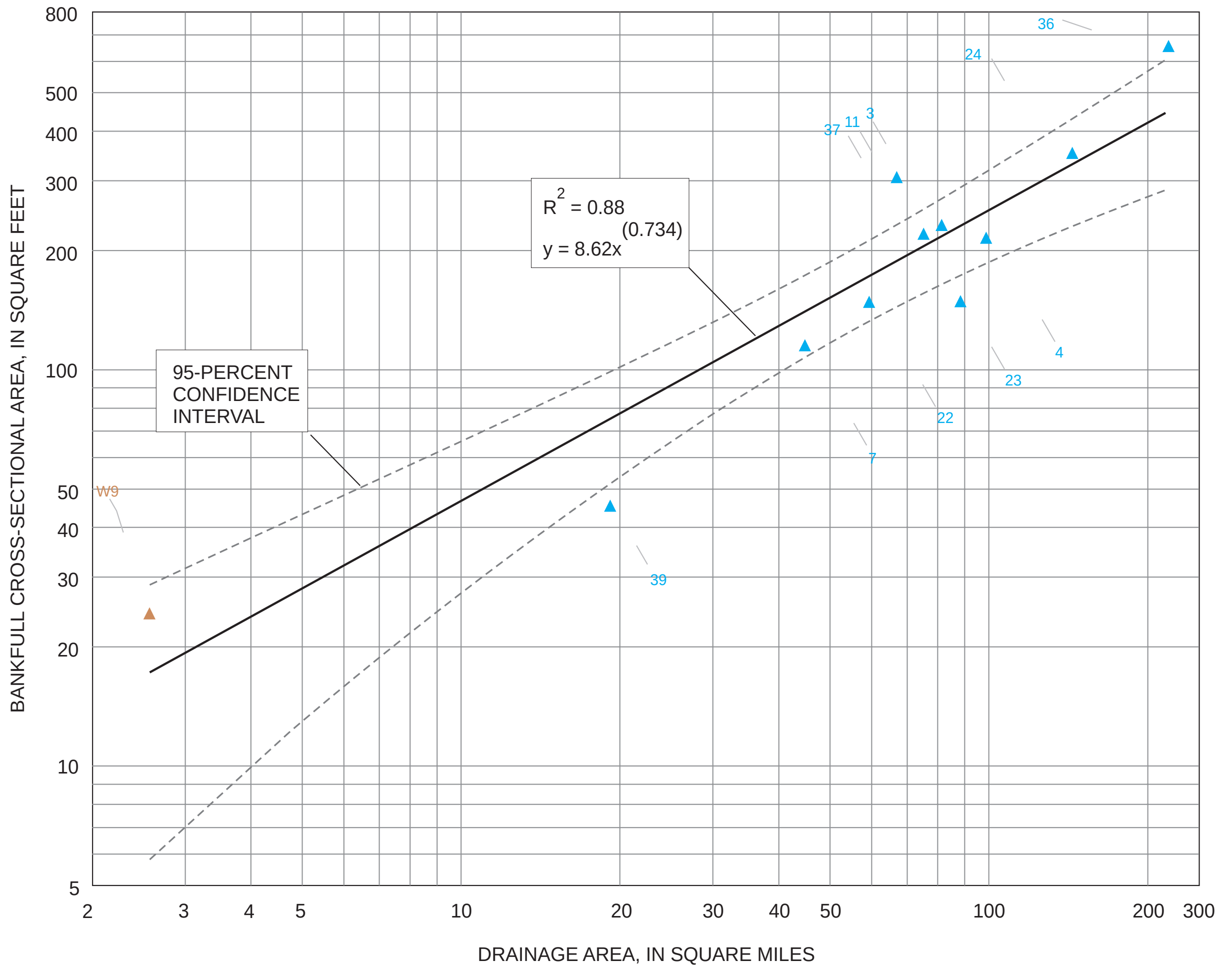
Bankfull channel dimensions as a function of drainage area for Coastal Plain survey sites (n = 14).



Bankfull discharge as a function of drainage area for Eastern and Western Coastal Plain survey sites.

Baltimore County
Urban Piedmont Hydrologic and Hydraulic Regional Curve

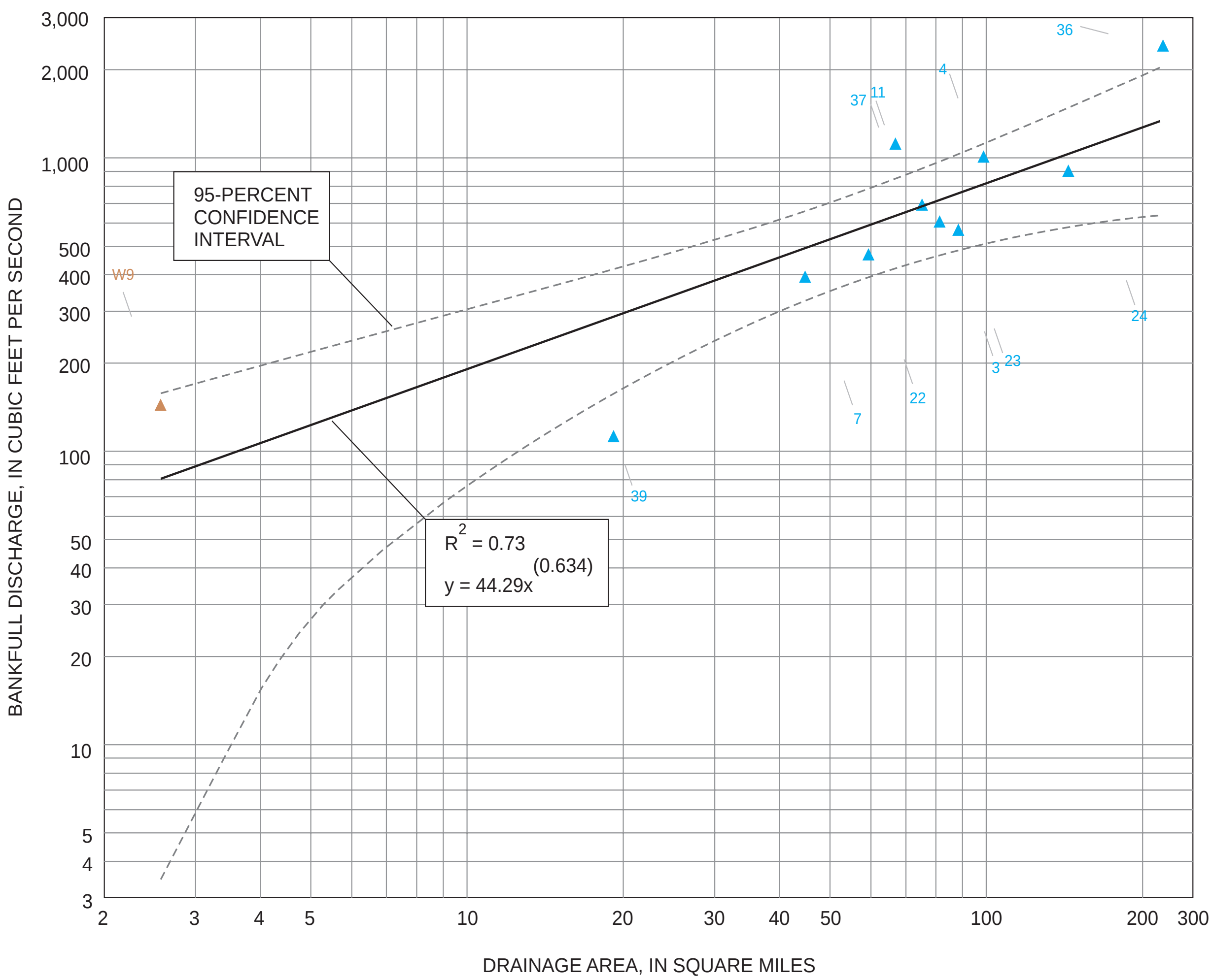




EXPLANATION

▲	STATION REPRESENTING THE PIEDMONT PHYSIOGRAPHIC PROVINCE	1 STATION
▲	STATION REPRESENTING THE RIDGE AND VALLEY PHYSIOGRAPHIC PROVINCE	10 STATIONS

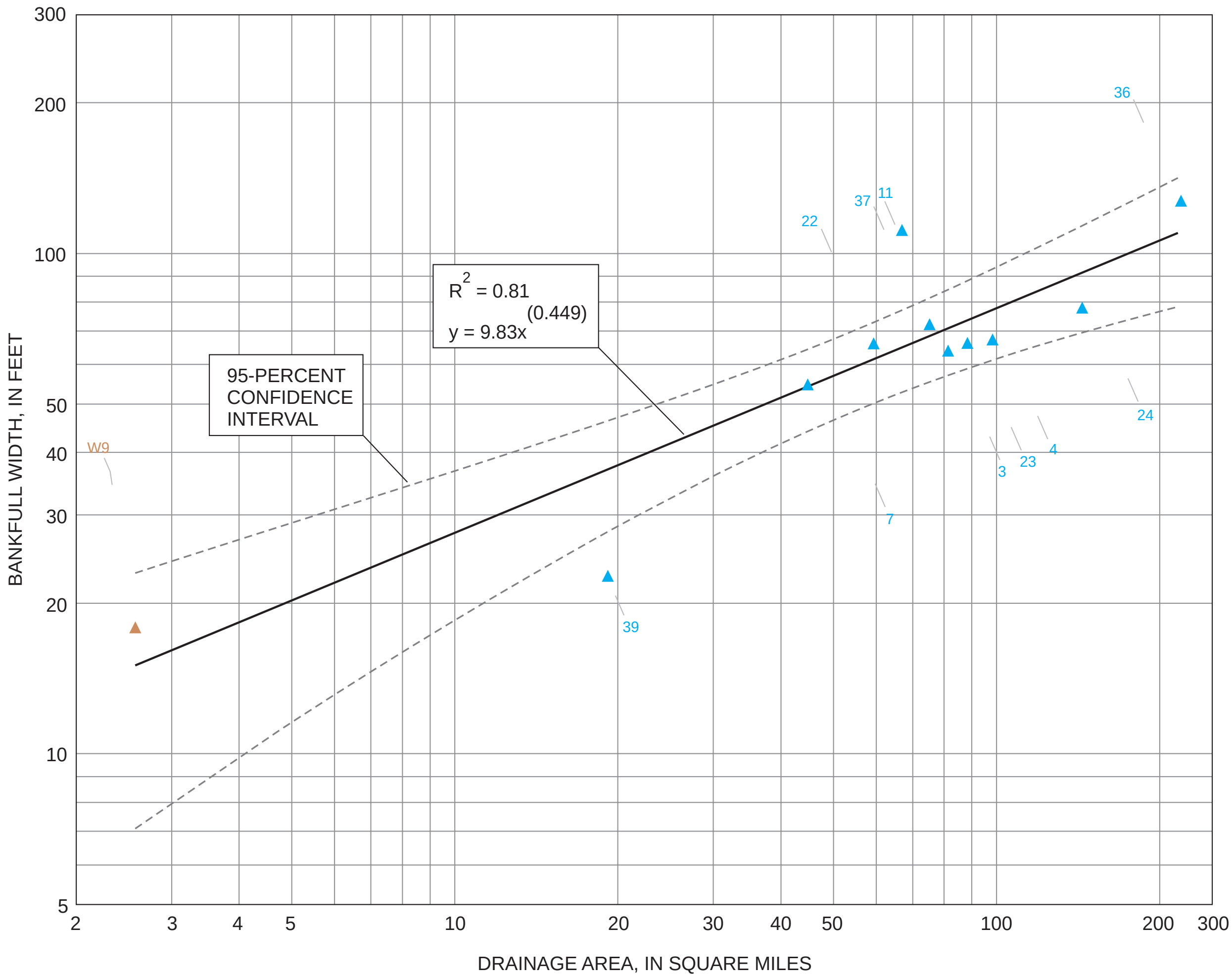
Figure 9. Regional curve representing the relation between bankfull cross-sectional area and drainage area for carbonate settings of Pennsylvania and selected areas of Maryland. See table 1 for information associated with cross-reference numbers identifying each station shown in this figure.



EXPLANATION

▲	STATION REPRESENTING THE PIEDMONT PHYSIOGRAPHIC PROVINCE	1 STATION
▲	STATION REPRESENTING THE RIDGE AND VALLEY PHYSIOGRAPHIC PROVINCE	10 STATIONS

Figure 10. Regional curve representing the relation between bankfull discharge and drainage area for carbonate settings of Pennsylvania and selected areas of Maryland. See table 1 for information associated with cross-reference numbers identifying each station shown in this figure.



EXPLANATION

▲	STATION REPRESENTING THE PIEDMONT PHYSIOGRAPHIC PROVINCE	1 STATION
▲	STATION REPRESENTING THE RIDGE AND VALLEY PHYSIOGRAPHIC PROVINCE	10 STATIONS

Figure 11. Regional curve representing the relation between bankfull width and drainage area for carbonate settings of Pennsylvania and selected areas of Maryland. See table 1 for information associated with cross-reference numbers identifying each station shown in this figure.

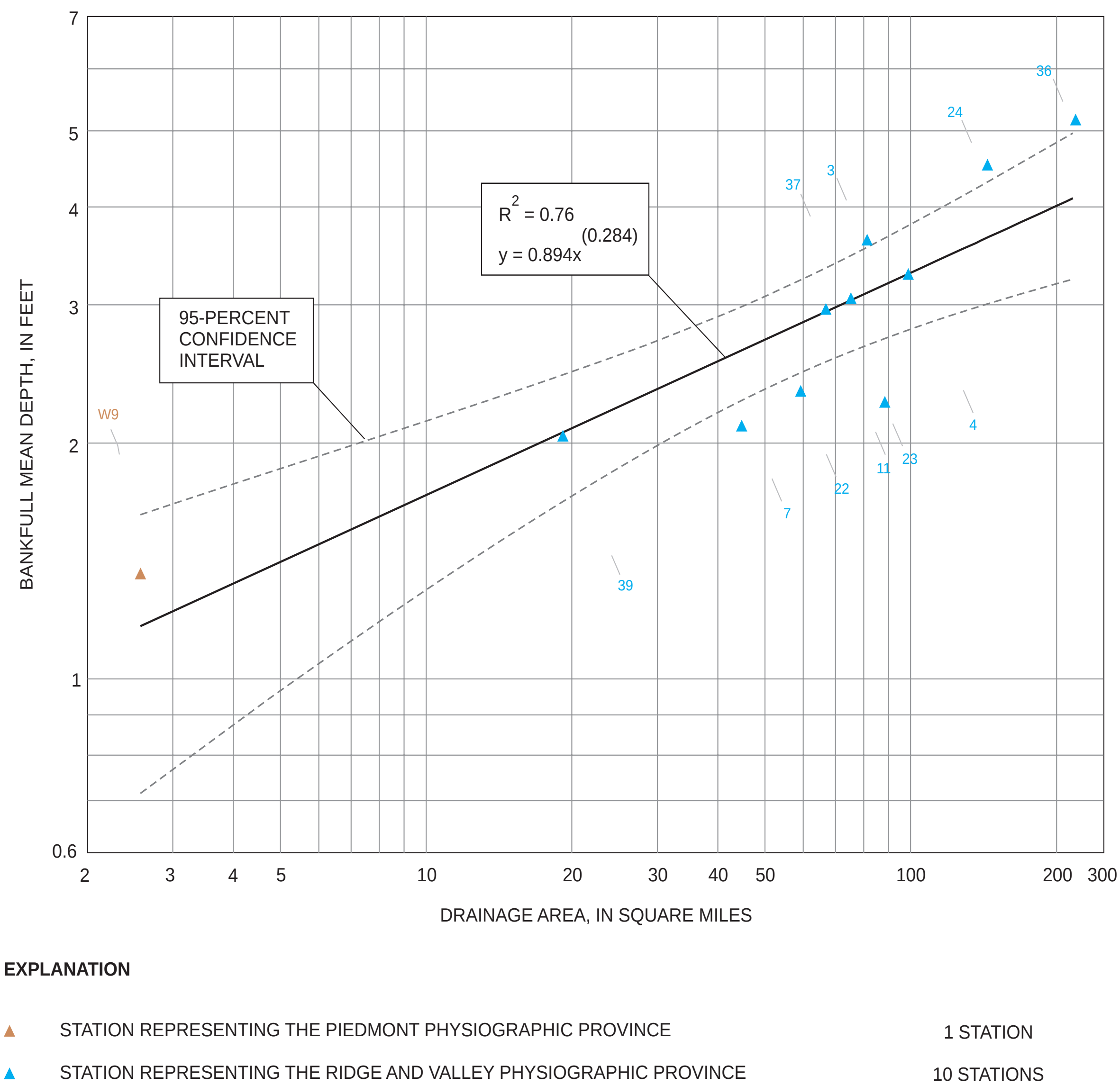


Figure 12. Regional curve representing the relation between bankfull mean depth and drainage area for carbonate settings of Pennsylvania and selected areas of Maryland. See table 1 for information associated with cross-reference numbers identifying each station shown in this figure.

APPENDIX C

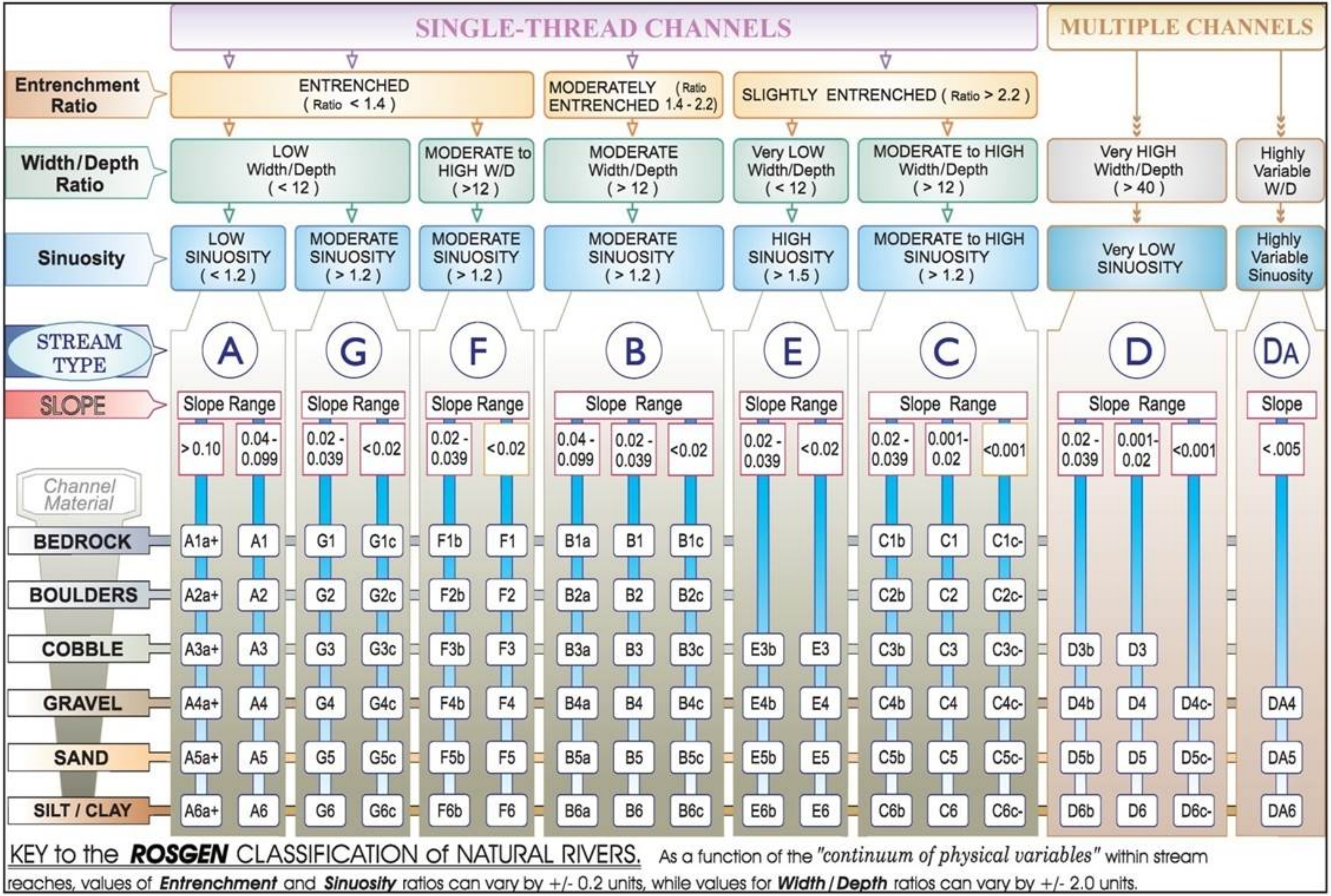


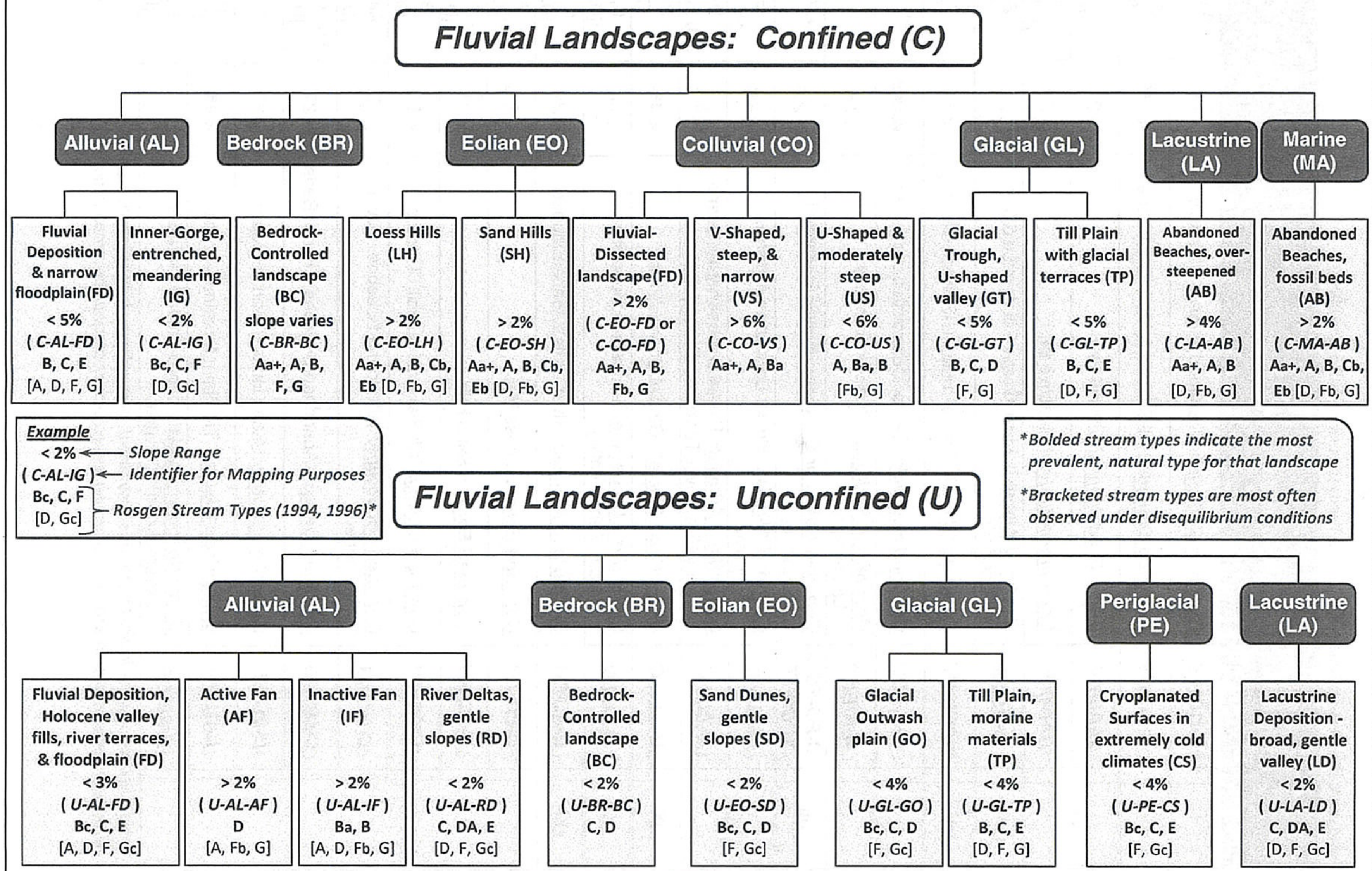
Figure A-1. Key to the Rosgen Classification of Natural Rivers.

Landscape Delineation Related to Valley Types Described in Rosgen (1996)

Valley Type in Rosgen (1996)	New Identifier for Mapping	Delineation of Fluvial Landscapes	Slope Range	Associated Stream Types*
I	*C-CO-VS*	***Confined Colluvial:*** V-Shaped, Steep, & Narrow	*> 6%*	**Aa+, A, Ba**
II	*C-CO-US*	***Confined Colluvial:*** U-Shaped & Moderately Steep	*< 6%*	**A, Ba, B** [Fb, G]
III	*U-AL-AF*	***Unconfined Alluvial:*** Active Fan	*> 2%*	**D** [A, Fb, G]
	U-AL-IF	***Unconfined Alluvial:*** Inactive Fan	*> 2%*	**Ba, B** [A, D, Fb, G]
IV	*C-AL-IG*	***Confined Alluvial:*** Inner-Gorge – Entrenched & Meandering	*< 2%*	**Bc, C, F** [D, Gc]
V	*C-GL-GT*	***Confined Glacial:*** Glacial Trough, U-Shaped Valley	*< 5%*	**B, C, D** [F, G]
VI	*C-BR-BC*	***Confined Bedrock:*** Bedrock-Controlled Landscape	*varies*	**Aa+, A, B, F, G**
	U-BR-BC	***Unconfined Bedrock:*** Bedrock-Controlled Landscape	*< 2%*	**C, D**
VII	*C-EO-FD or C-CO-FD*	***Confined Eolian or Colluvial:*** Fluvial-Dissected Landscape	*> 2%*	**Aa+, A, B, Fb, G**
VIII	*C-AL-FD*	***Confined Alluvial:*** Fluvial Deposition & Narrow Floodplain	*< 5%*	**B, C, E** [A, D, F, G]
	U-AL-FD	***Unconfined Alluvial:*** Fluvial Deposition, Holocene Valley Fills, River Terraces, & Floodplain	*< 3%*	**Bc, C, E** [A, D, F, Gc]
IX	*U-GL-GO*	***Unconfined Glacial:*** Glacial Outwash Plain	*< 4%*	**Bc, C, D** [F, Gc]
X	*U-LA-LD*	***Unconfined Lacustrine:*** Lacustrine Deposition - Broad, Gentle Valley	*< 2%*	**C, DA, E** [D, F, Gc]
XI	*U-AL-RD*	***Unconfined Alluvial:*** River Deltas, Gentle Slopes	*< 2%*	**C, DA, E** [D, F, Gc]
	C-EO-LH	***Confined Eolian:*** Loess Hills	*> 2%*	**Aa+, A, B, Cb, Eb** [D, Fb, G]
	C-EO-SH	***Confined Eolian:*** Sand Hills	*> 2%*	**Aa+, A, B, Cb, Eb** [D, Fb, G]
	C-GL-TP	***Confined Glacial:*** Till Plain with Glacial Terraces	*< 5%*	**B, C, E** [D, F, G]
	C-LA-AB	***Confined Lacustrine:*** Abandoned Beaches, Over-Steepened	*> 4%*	**Aa+, A, B** [D, Fb, G]
	C-MA-AB	***Confined Marine:*** Abandoned Beaches, Fossil Beds	*> 2%*	**Aa+, A, B, Cb, Eb** [D, Fb, G]
	U-EO-SD	***Unconfined Eolian:*** Sand Dunes, Gentle Slopes	*< 2%*	**Bc, C, D** [F, Gc]
	U-GL-TP	***Unconfined Glacial:*** Till Plain, Moraine Materials	*< 4%*	**B, C, E** [D, F, G]
	U-PE-CS	***Unconfined Periglacial:*** Cryoplanated Surfaces in Extremely Cold Climates	*< 4%*	**Bc, C, E** [F, Gc]

**Bolded stream types indicate the most prevalent, natural type for that landscape; Bracketed stream types are most often observed under disequilibrium conditions*

Hierarchical Delineation of Fluvial Landscapes & Associated Stream Types



APPENDIX D

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. Reach BEHI Assessment

    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. Cross Section BEHI Assessment

    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.

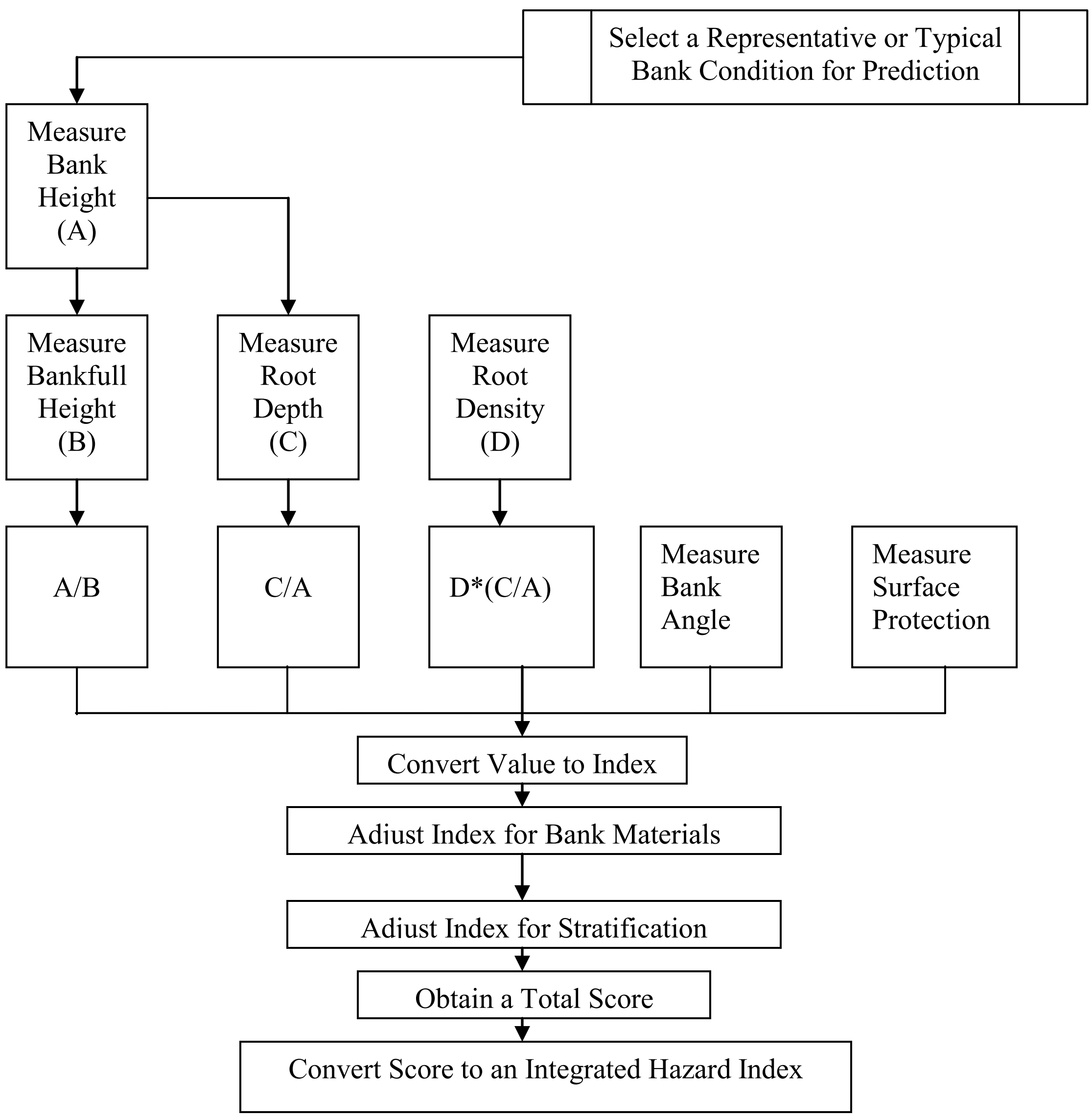
d. Avoid evaluating upstream and downstream influences, such as boulder diversions or protection, when assessing the study bank.

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.



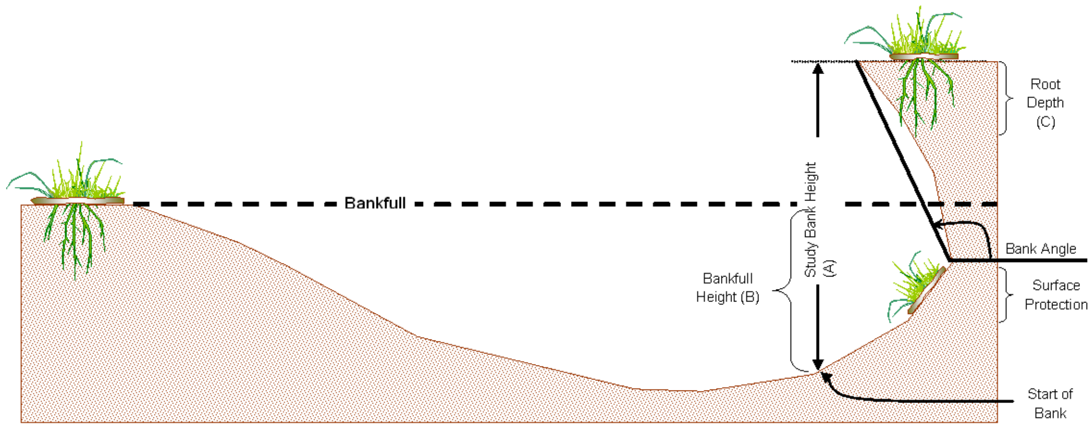


Figure 1. BEHI Variables (Rosgen 2003).

Bank Erosion Hazard Index

Erodibility Variable			Very Low	Low	Moderate	High	Very High	Extreme
			Bank Erosion Potential					
	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.

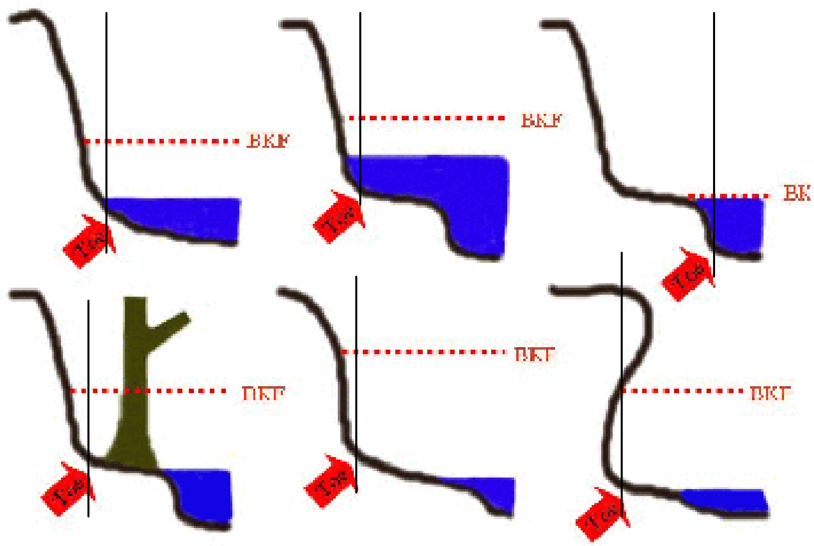
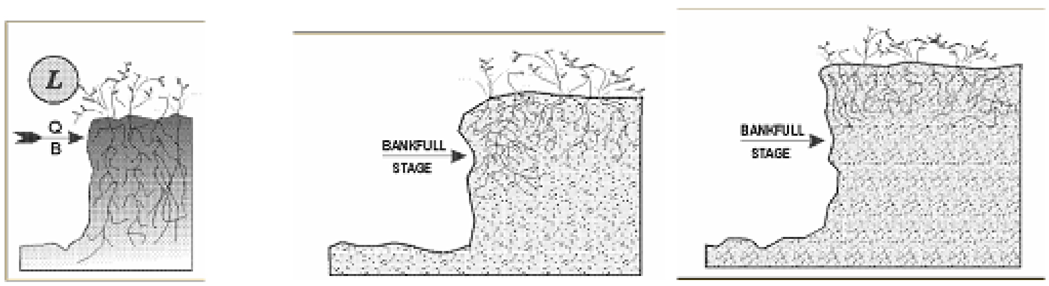


Figure 3. Bank toe location examples.

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.

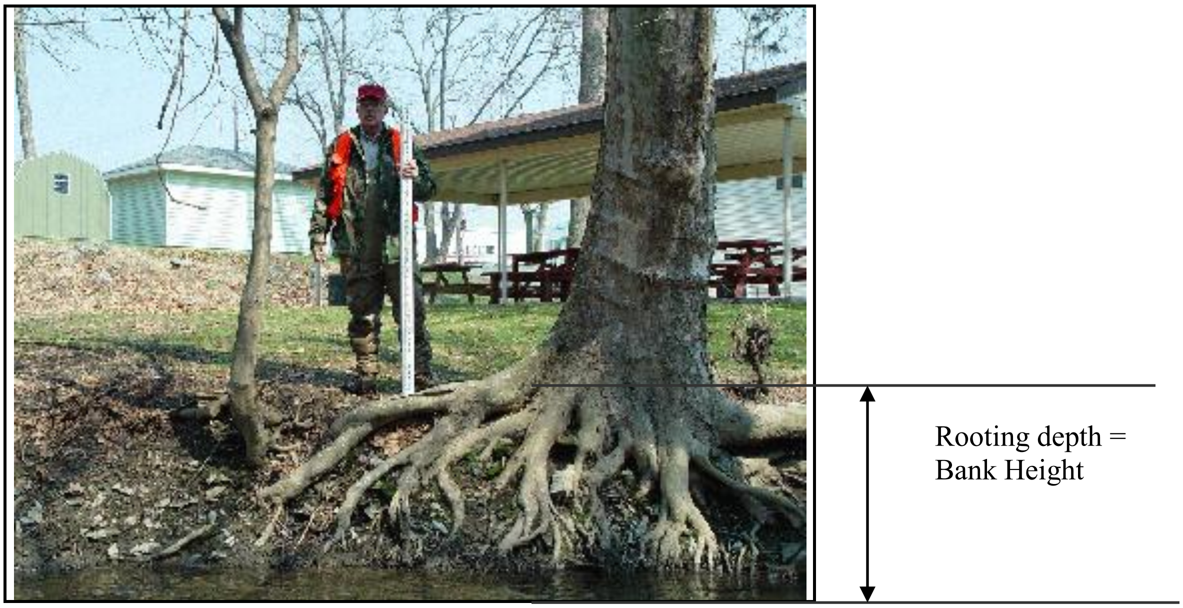


Figure 5. Tree roots extending down the stream bank.

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).

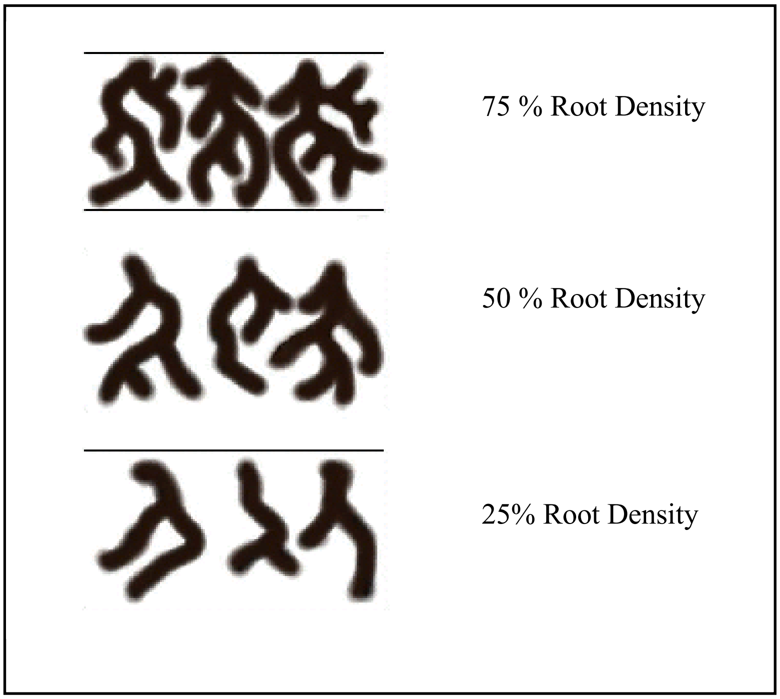


Figure 6. Root density examples.

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

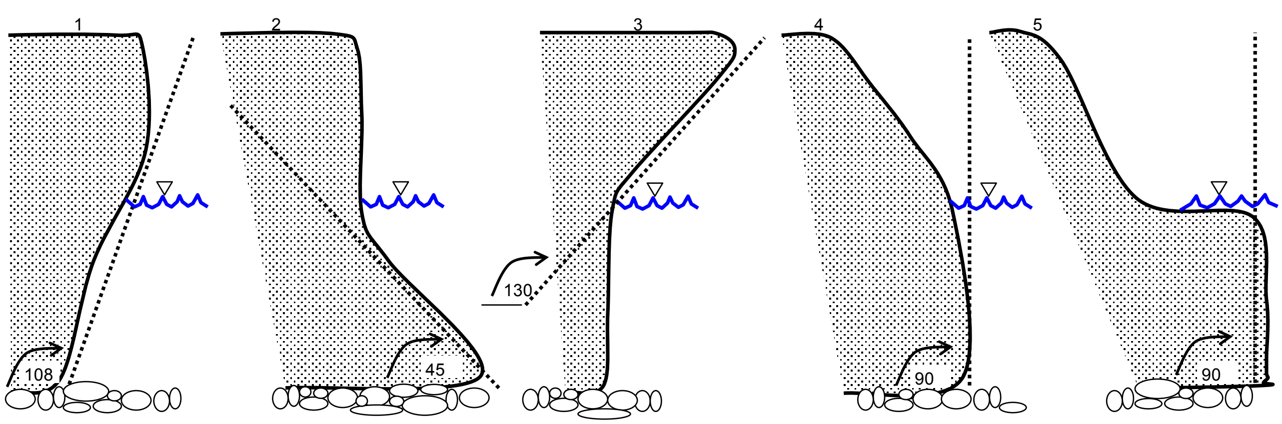


Figure 7. Bank angle scenarios (perspective: cross-section view)(Rosgen 2003).

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.

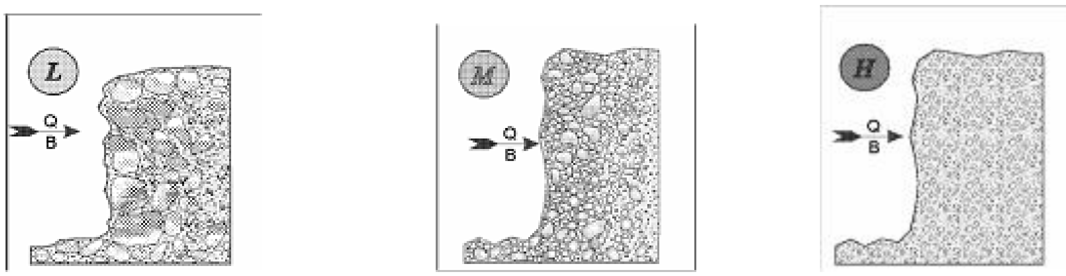
Figure 9. Woody bank vegetation.

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. Bank Material Adjustment

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.

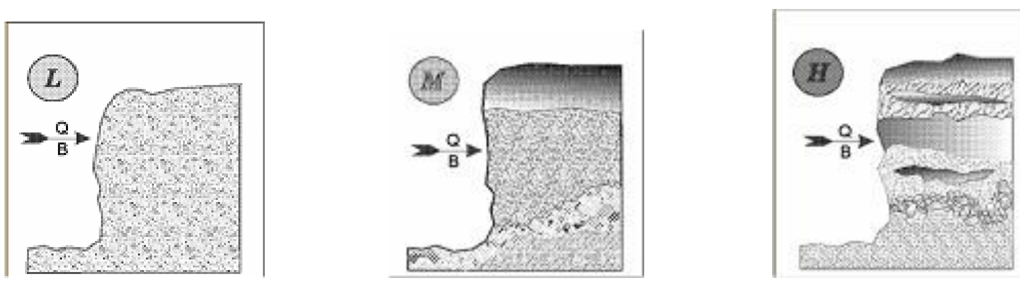
Table 2. Bank Material Adjustment

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	Method								
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				
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					

Dominant 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.**

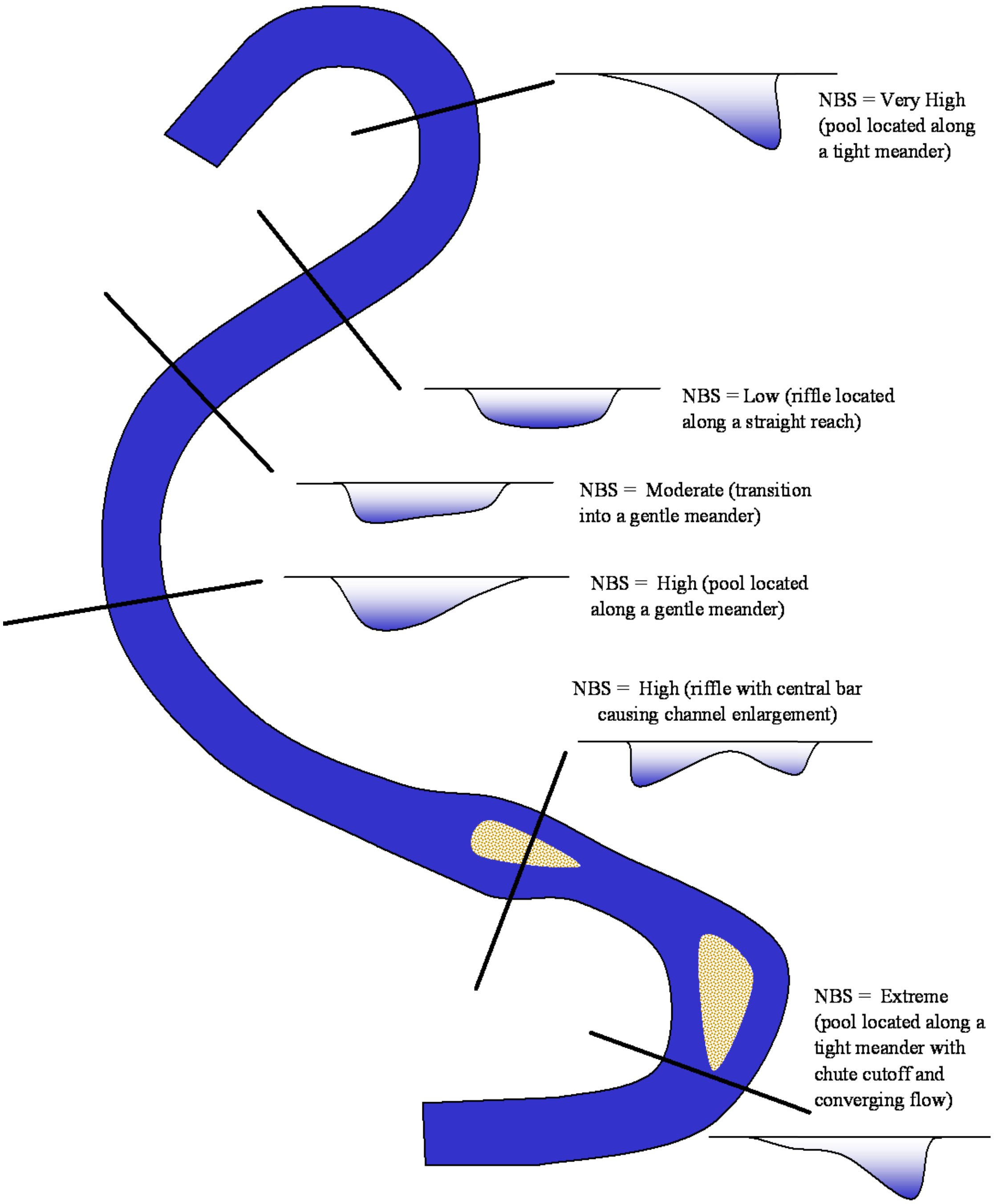


Figure 2. Near-bank stress estimation based on channel pattern, depositional features, and cross-section shape (Level I Reconnaissance) (Rosgen 2003).

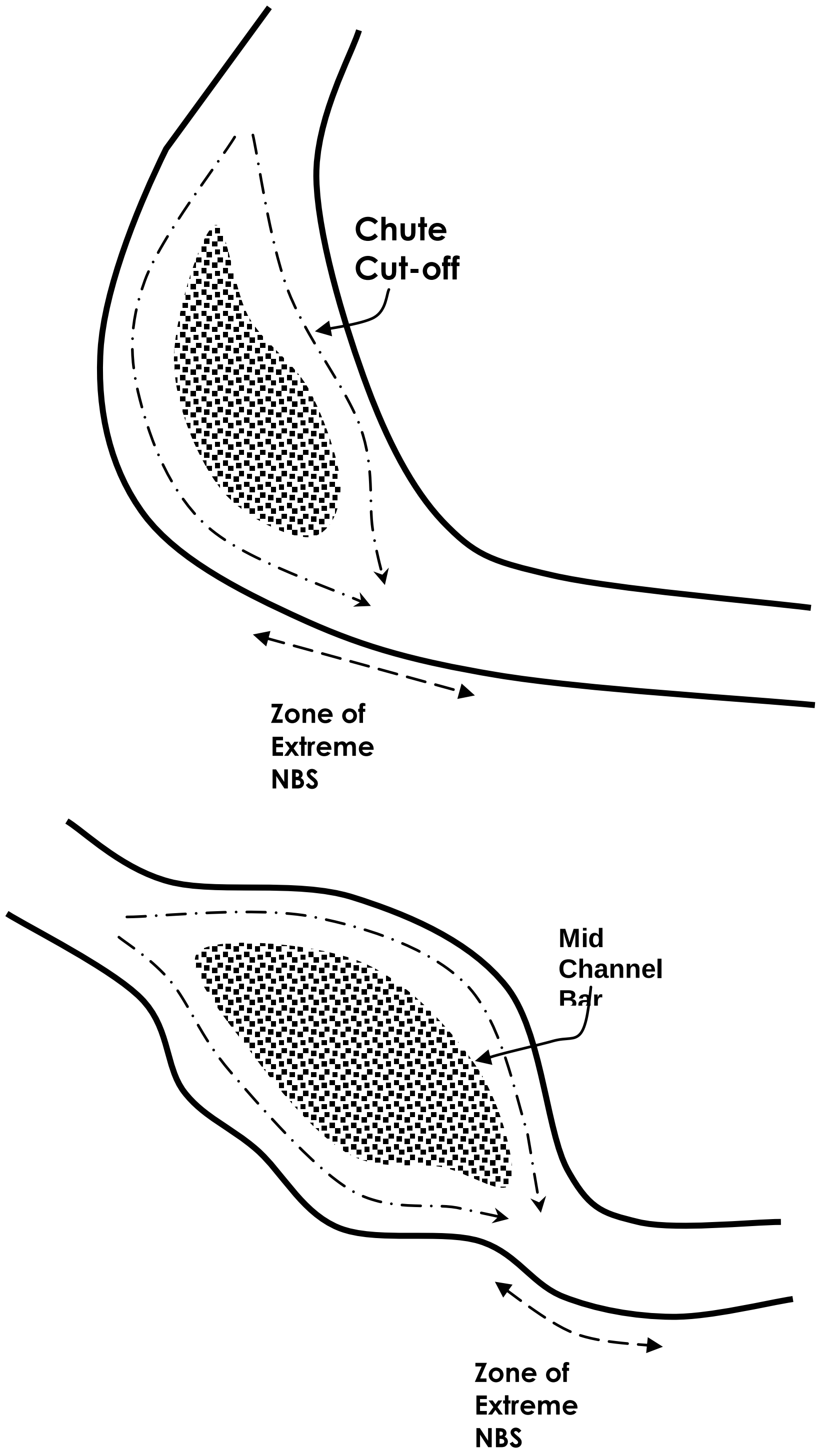


Figure 3. Examples of converging flows from chute cutoffs and central bars (Rosgen 2003).

APPENDIX E

Stream Macroinvertebrates

Maryland Department of Natural Resources

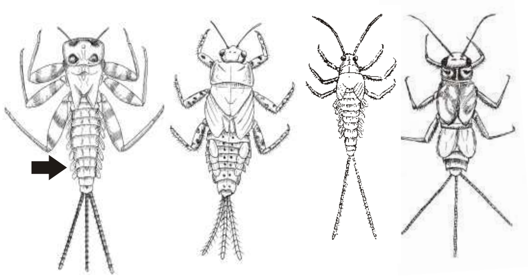
Joseph P. Gill, Secretary

Martin O'Malley, Governor

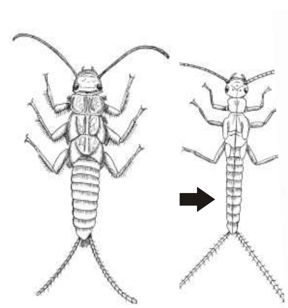
Relative abundances in Maryland are indicated by "rare", "common", or "abundant". The number of families in Maryland for higher taxonomic levels are also listed (if applicable). Sizes are for "full grown" animals. To learn more about these fascinating creatures, go to http://www.dnr.maryland.gov/bay/cblife/insects/index.html. To learn about DNR's volunteer stream monitoring program, Maryland Stream Waders, send an inquiry to streamwaders@dnr.state.md.us.

SENSITIVE ORGANISMS

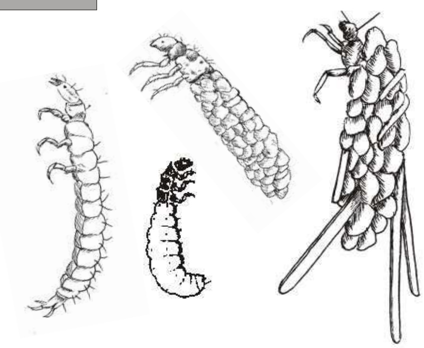
POLLUTION-SENSITIVE ORGANISMS TYPICALLY FOUND IN HEALTHY STREAMS



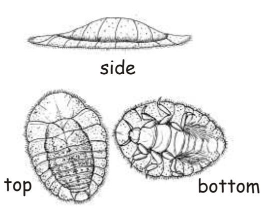
Mayfly: Order Ephemeroptera- Plate-like or feathery gills on sides of lower body (arrow); three (sometimes 2) long, hair-like tails; 1"; abundant; 11 families.



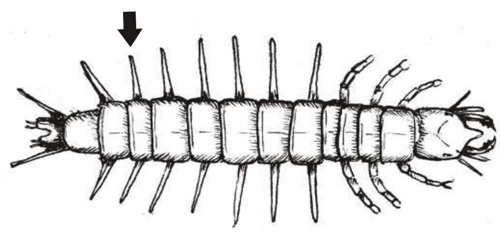
Stonefly: Order Plecoptera- Two hair-like tails; six jointed legs with two hooked tips each; big antennae; no gills on lower half of body (arrow); 1½"; abundant; 9 families.



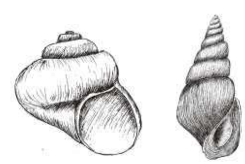
Caddisfly: Order Trichoptera- Six jointed, hooked legs just behind head; 2 hooks at back end; may be in a case made of stones, leaves or sticks; non-netspinning caddisflies have no bushy gills along bottom; 1"; abundant; 20 families.



Water Penny: Order Coleoptera- shaped like a tiny, grey, oblong frisbee; 6 tiny legs on bottom; slow crawler; ½"; common.



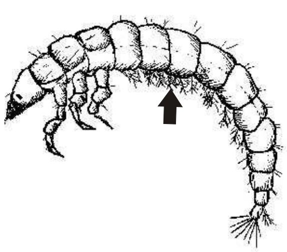
Hellgrammite and Fishfly: Order Megaloptera- dark body; six jointed legs; large, pinching jaws; many pointed feelers along edge of body (arrow); two small hooks at back end; hellgrammites have feathery tufts of gills along side of body; 4"; rare.



Gilled Snail: Class Gastropoda- shell opens on the right and is covered by a hard shield-like operculum; 1"; rare; 4 families.

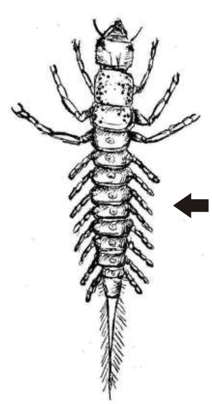
MODERATELY-SENSITIVE ORGANISMS

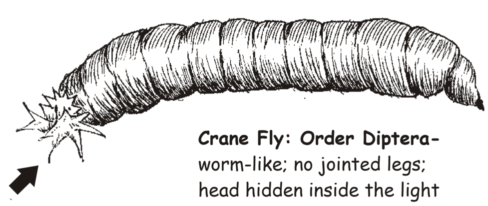
MODERATELY POLLUTION-SENSITIVE ORGANISMS FOUND IN HEALTHY OR FAIR QUALITY STREAMS



Net-spinning Caddisfly: Order Trichoptera- six jointed, hooked legs just behind head; 2 hooks at back end; bushy gills along lower half (arrow); 1"; abundant.

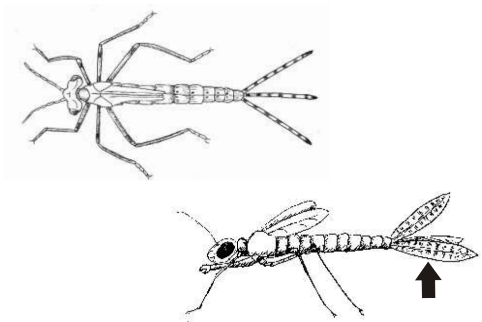
Alderfly: Order Megaloptera- six jointed legs; pinching jaws; many pointed feelers along edge of body (arrow); long tail at the end; 1"; rare.



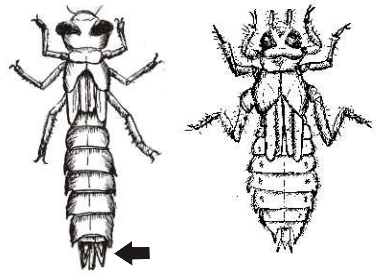


Crane Fly: Order Diptera- worm-like; no jointed legs; head hidden inside the light brown body; 4 finger-like lobes at back end (arrow); 2"; abundant.

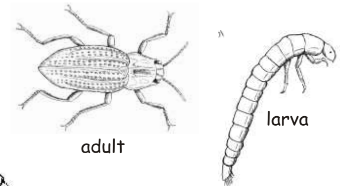
MODERATELY-SENSITIVE ORGANISMS (continuted)



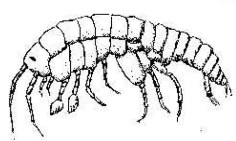
Damselfly: Order Odonata- 6 long, thin legs; 3 broad oval tails at end (arrow); may have wing pads; no gills along sides of body; 2"; common; 3 families.



Dragonfly: Order Odonata- large eyes; bullet-shaped, round or leaf-like body; 6 long legs; 3 short-spike-like tails (arrow); may have wing pads; 2"; common; 6 families.

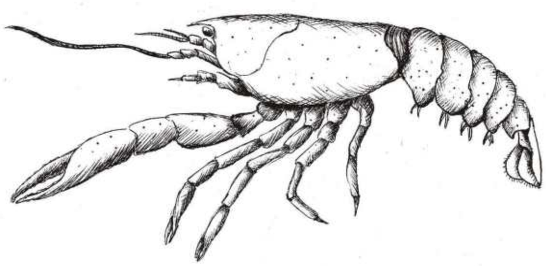


Riffle Beetle: Order Coleoptera - 6 jointed legs; brown or black; adults have hard covering over the wings, body with fairly hard covering; 3/8"; abundant.

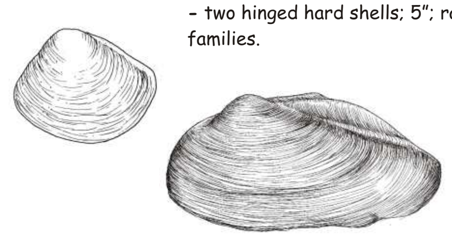


Scud: Order Amphipoda - white to gray; more than six legs; swims on its side; looks like a small shrimp; 1/4"; abundant; 3 families.

Crayfish: Order Decapoda- 8 walking legs and 2 pinching claws; 6"; abundant.

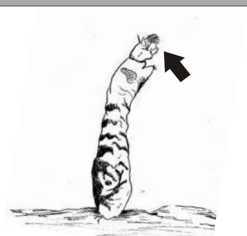


Clams and mussels: Class Bivalvia - two hinged hard shells; 5"; rare; 2 families.

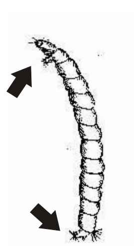


TOLERANT ORGANISMS

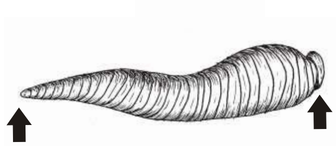
POLLUTION-TOLERANT ORGANISMS FOUND IN HEALTHY, FAIR OR POOR QUALITY STREAMS



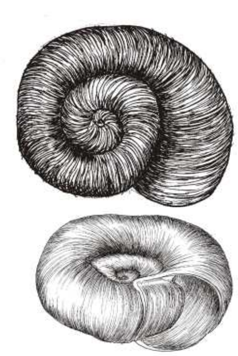
Black Fly: Order Diptera - shaped like a little bowling pin; black head with tiny bristles for filtering food (arrow); suction pad on end; no jointed legs; ½"; abundant.



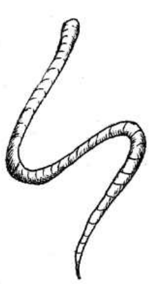
Non-biting Midge: Order Diptera - dark head; body white, gray or reddish; worm-like segmented body; 2 tiny unjointed legs on both ends (arrow); ½"; abundant.



Leech: Order Hirudinea - brown or grey, slimy, suction pads on both ends (arrow); 2"; rare; 3 families.



Ramshorn Snails: Class Gastropoda - No hard cover over opening; shell coiled in one plane; ½"; common.



Aquatic worm: Class Oligochaeta - thin and hairlike or thicker like an earthworm; 2 ½"; common; 8

Pouch Snail: Class Gastropoda - shell opens on the left; no hard covering over shell opening; 3/4"; common.

Maryland Department of Natural Resources; Resource Assessment Service; 580 Taylor Avenue; Annaoplis, Maryland 21401 Published March 2004
www.dnr.maryland.gov; toll free in MD 1-877-620-8DNR (dial 9 then extension 8623)
TTY users call via MD Relay

APPENDIX F

Channel Evolution Examples

Photo 1 _Rosgen E / Class I

Photo 2 _ Rosgen E → G / Class 2 & 3

Photo 3 __Rosgen G → F / Class 4___

Photo 4 _Rosgen F → C / Class 5

Photo 5 __ Rosgen C ➔ E / Class 5/6