APPENDIX D

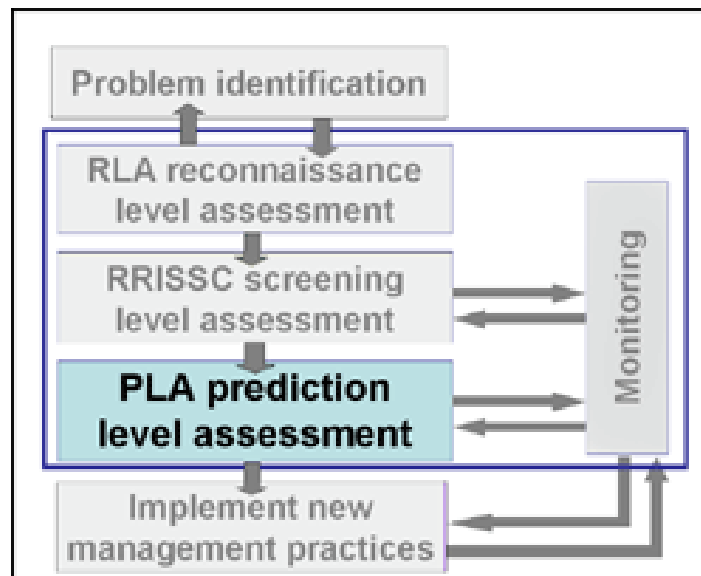## Bank Erosion Hazard Index/Near Bank Stress Methodology

**Estimating Sediment Loads using the
Bank Assessment of Non-point source Consequences of Sediment (BANCS)**
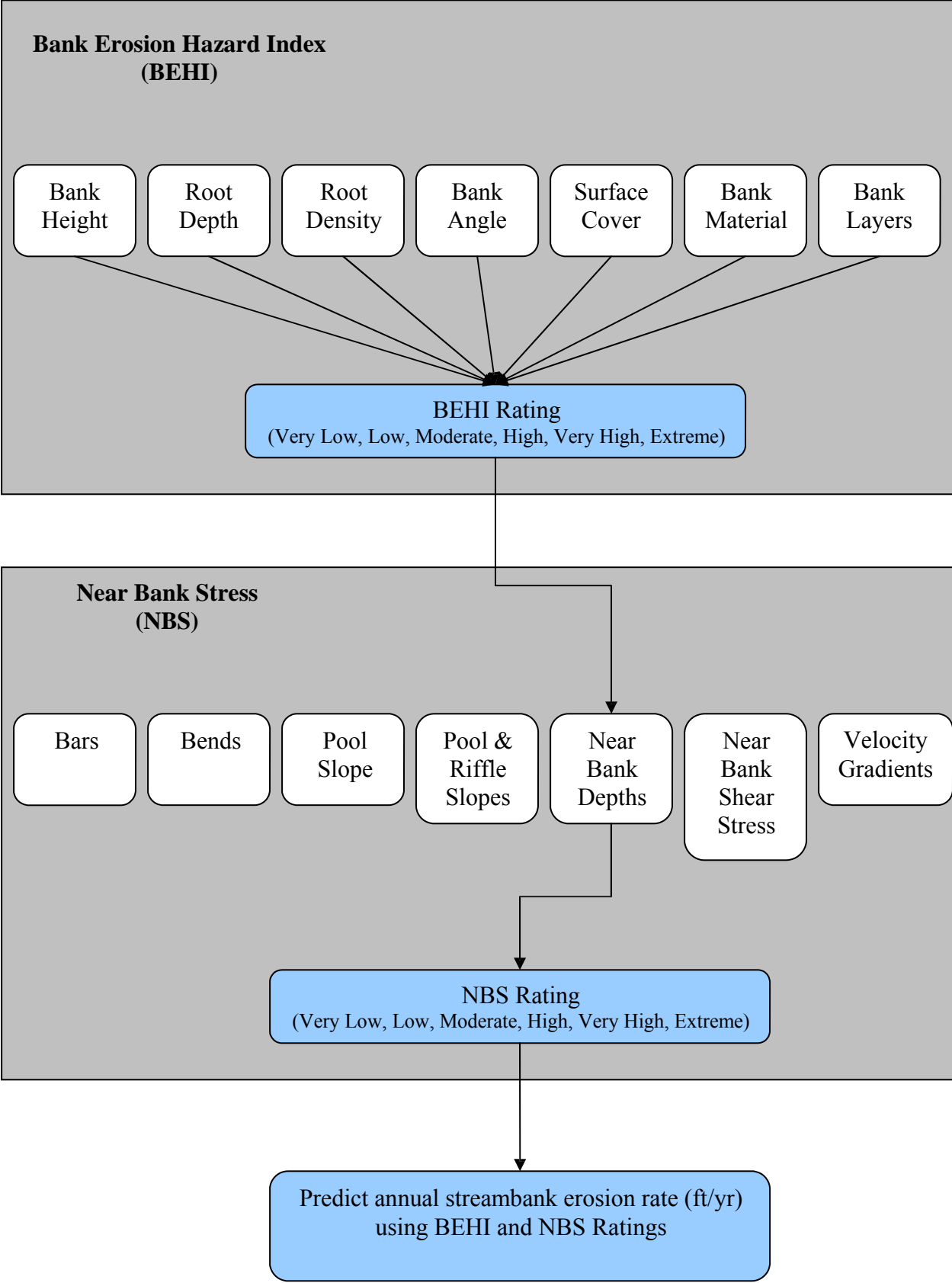
Watershed Assessment of River Stability and Sediment Supply (WARSSS): a technical
procedure developed by David L. Rosgen for water quality scientists to use in evaluating streams
and river impaired by excess sediment

(images and forms available from EPA WARSSS technical tools website:
http://water.epa.gov/scitech/datait/tools/warsss/pla_box08.cfm)

May 10, 2011
Hagerstown, Maryland

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Canaan Valley Institute

Bank Erosion Hazard Index (BEHI)

| Bank Height | Root Depth | Root Density | Bank Angle | Surface Cover | Bank Material | Bank Layers |

BEHI Rating
(Very Low, Low, Moderate, High, Very High, Extreme)

Near Bank Stress (NBS)

| Bars | Bends | Pool Slope | Pool & Riffle Slopes | Near Bank Depths | Near Bank Shear Stress | Velocity Gradients |

NBS Rating
(Very Low, Low, Moderate, High, Very High, Extreme)

Predict annual streambank erosion rate (ft/yr) using BEHI and NBS Ratings

Modified from River Stability Field Guide (Rosgen, 2008)

North Carolina Stream Bank Erodibility
(Erosion from Bankfull Events)

Bank Erosion Rate (ft/yr) vs. Near Bank Stress Index
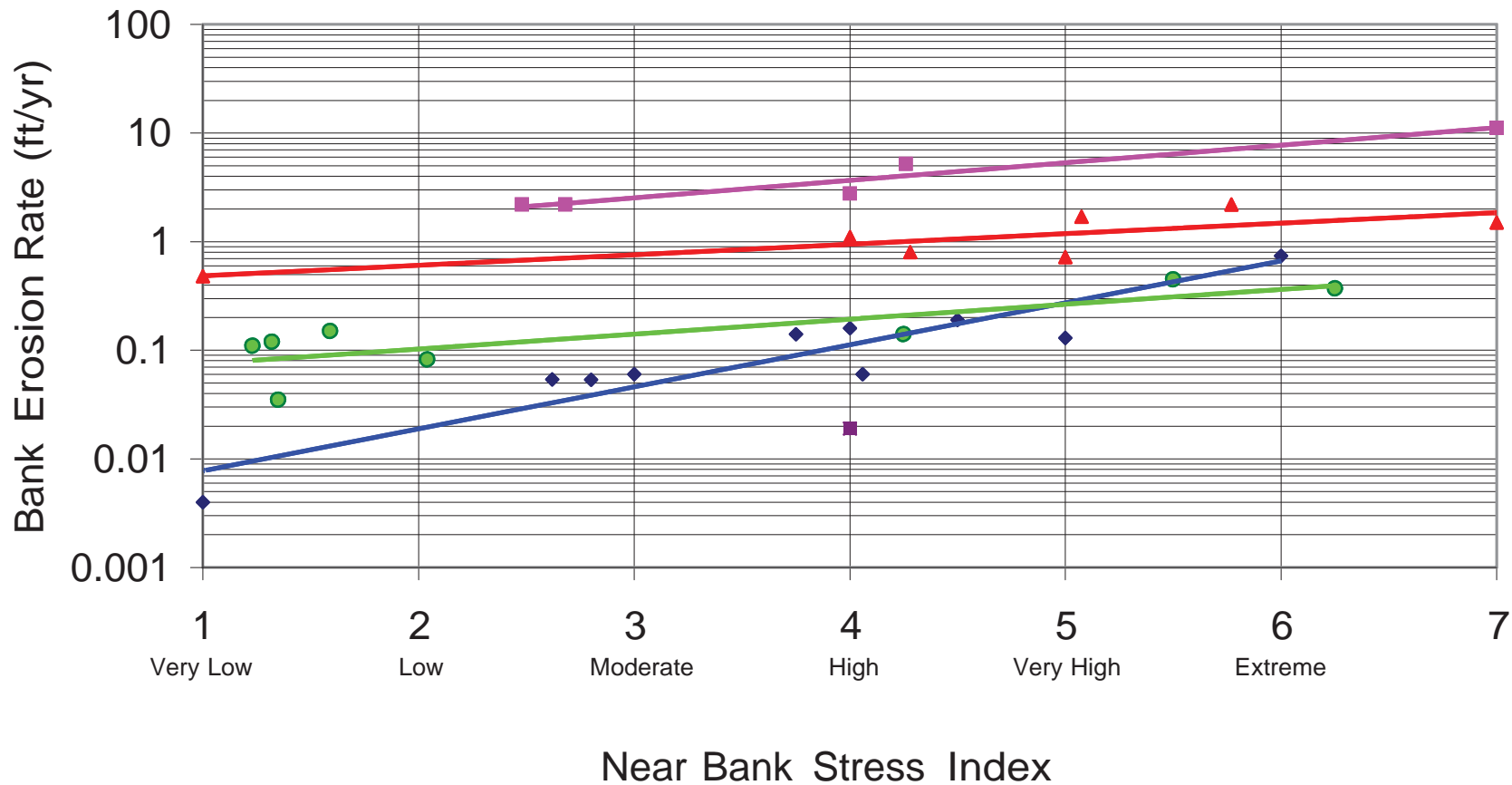
Legend:
- ◆ Moderate BEHI
- ● High BEHI
- ▲ Very High BEHI
- ■ Extreme BEHI
- ■ Very Low BEHI
- Expon. (Extreme BEHI)
- Expon. (Very High BEHI)
- Expon. (Moderate BEHI)
- Expon. (High BEHI)

X-axis labels: 1 Very Low, 2 Low, 3 Moderate, 4 High, 5 Very High, 6 Extreme, 7

Worksheet 20. BEHI variable worksheet

Stream:	Cross Section:	Date:	Observers:

Bank Height/Max Depth Bankfull (C)

Study Bank Height (ft) A	Bankfull Height (ft) B	A/B = C

Root Depth/Bank Height (E)

Root Depth (ft) D	Study Bank Height (ft) A	D/A = E

Weighted Root Density (G)

Root Density (%) F	F*E = G

Bank Angle (H)

Bank Angle (Degrees) H

Surface Protection (I)

Surface Protection % I

Bank Sketch

Vertical Distance (ft)

Horizontal Distance (ft)

Root Depth

Bank Angle

Surface Protection

Start of Bank

Bankfull

Bankful l Height

Study Bank Height

| | BANK HEIGHT vs BANKFULL DEPTH | BANK ANGLE | DENSITY of ROOTS BANK SURFACE PROTECTION % of TOTAL BANK HEIGHT WITH ROOTS | SOIL STRATIFICATION | PARTICLE SIZE |

BANK EROSION POTENTIAL — LOW / MODERATE / HIGH
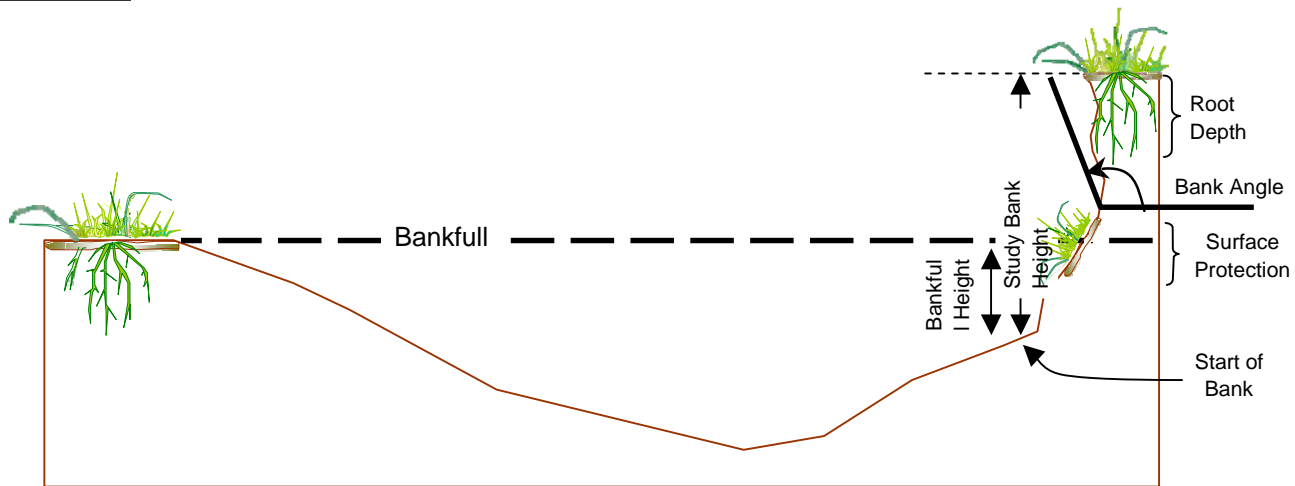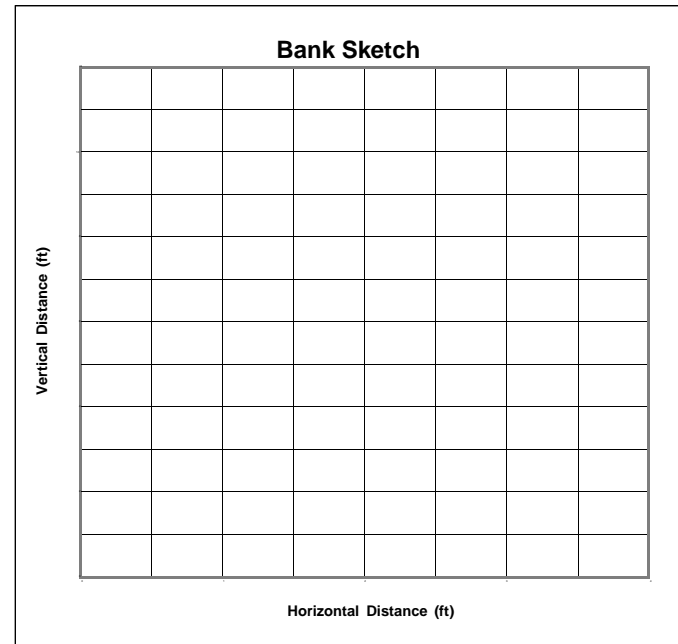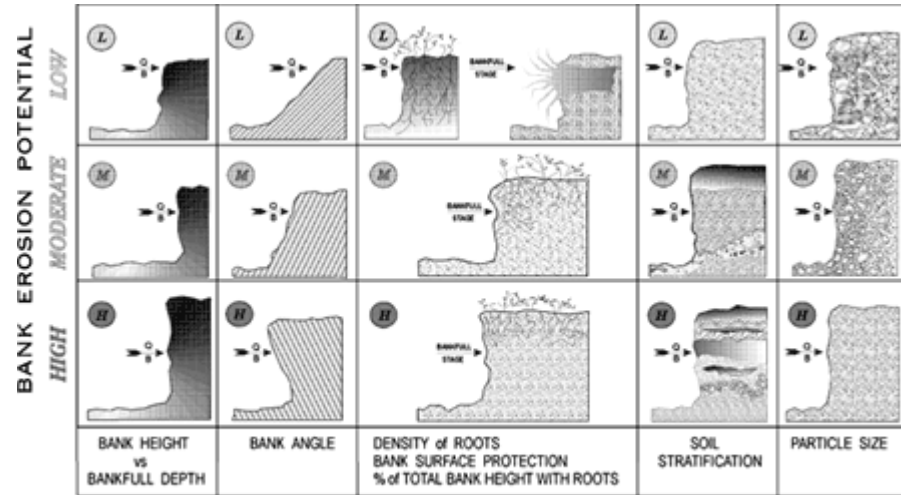
Five Common Bank Angle Scenarios

Perspective: Cross section view - left bank looking downstream

Legend	
▬	Bank Profile
↱ angle	
◯◯◯	Stream Bed

1 — 108
2 — 45
3 — 130
4 — 90
5 — 90
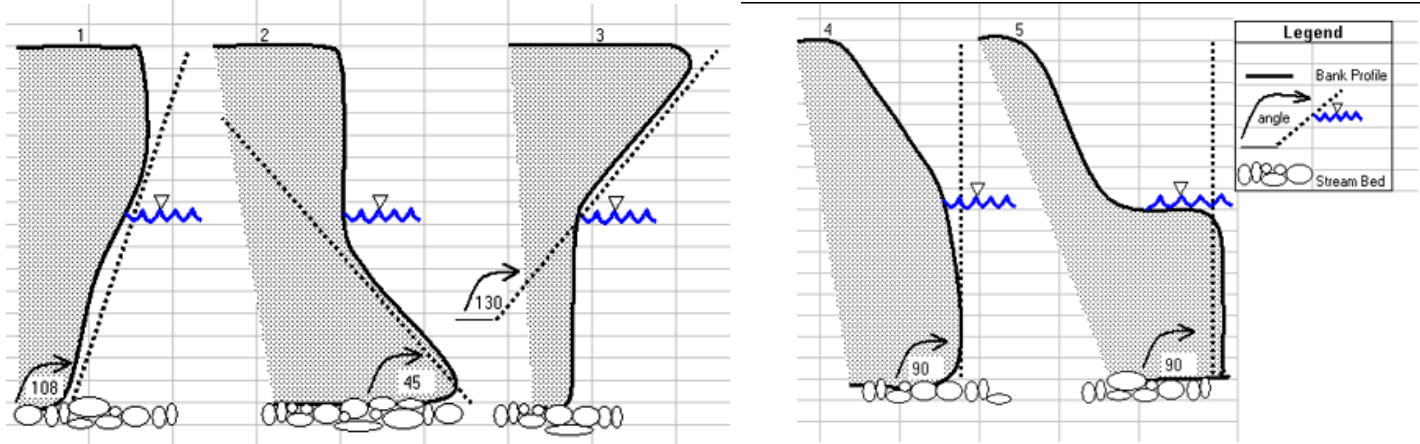
Worksheet 21. Summary of bank erosion hazard index (BEHI)

Bank Erosion Hazard Rating Guide

Stream		Reach		Date		Crew	
Bank Height (ft):		**Bank Height/**	**Root Depth/**	**Root**	**Bank Angle**	**Surface**
Bankfull Height (ft):		**Bankfull Ht**	**Bank Height**	**Density %**	**(Degrees)**	**Protection%**

Bank Erosion Potential			Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
	VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
		Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
		Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
		Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
		Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
		Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	EXTREME	Value	>2.8	<0.05	<5	>119	<10
		Index	10	10	10	10	10
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
V = value, I = index						**SUB-TOTAL** (Sum one index from each column)	

Bank Material Description:

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, then do not adjust)

Gravel (Add 5-10 points depending percentage of bank material that is composed of sand)

Sand (Add 10 points)

Silt Clay (+ 0: no adjustment)
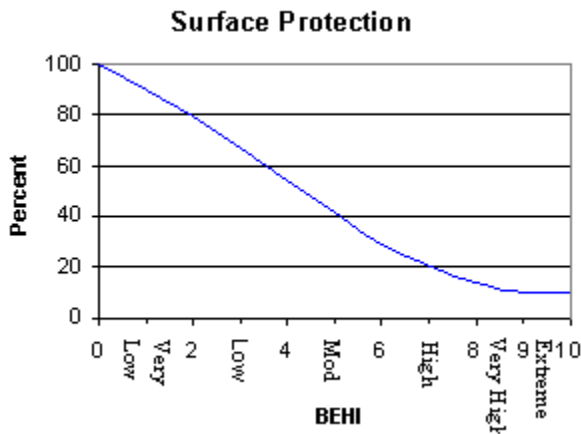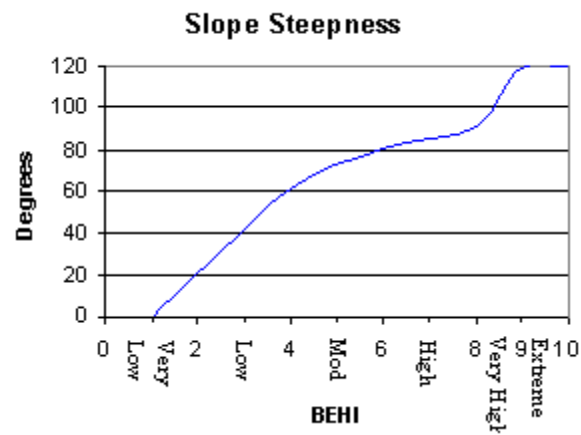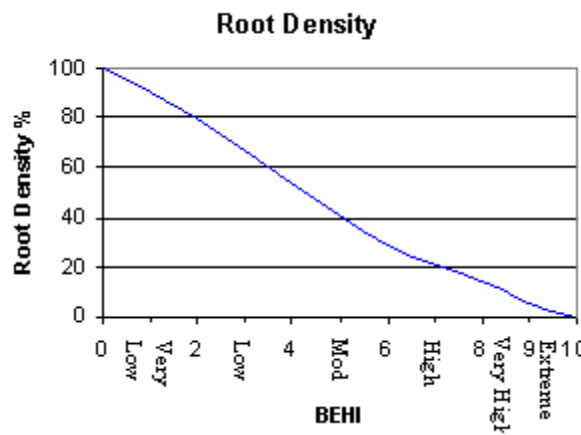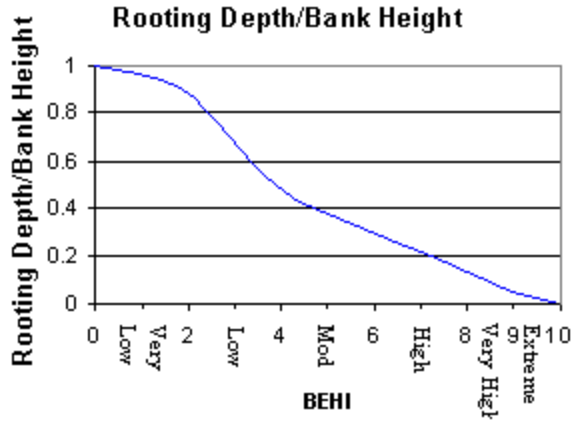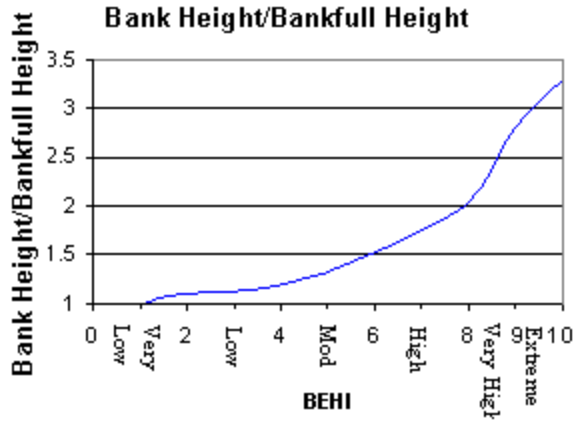
BANK MATERIAL ADJUSTMENT

Stratification Comments:

Stratification

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

STRATIFICATION ADJUSTMENT

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach   Outside of Bend

GRAND TOTAL

BEHI RATING

Bank Height/Bankfull Height

Rooting Depth/Bank Height

Root Density

Slope Steepness

Surface Protection

Worksheet 22A. Various field methods of estimating Near-Bank Stress risk ratings for the calculation of erosion rate.

Estimating Near-Bank Stress (NBS)						
Stream:		**Location:**		**Date:**		**Cre w:**

Methods for Estimating Near-Bank Stress

(1) Trans vers e 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 stres s to bankfull shear stres s (τ_{nb}/τ_{bkf}): **Level III - Detailed Prediction.**

(7) Velocity profiles/Is ovels /Velocity gradient: **Level IV - Validation.**

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 R_c (feet)	Bankfull Width W_{bkf} (feet)	Ratio R_c/W	Near-Bank Stress

(3)

Pool Slope S_p	Average Slope S	Ratio S_p/S	Near-Bank Stress

Dominant 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

Converting Values to a Ne ar-Bank Stress Rating

Near-Bank Stress Ra ting	Method Number						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Ve ry 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	See (1) Above	1.81 - 2.0	0.61 - 0.80	0.81 - 1.0	1.81 - 2.5	1.15 - 1.19	1.61 - 2.0
Ve ry 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
Extre me		< 1.5	> 1.0	> 1.2	> 3.0	> 1.6	> 2.3

Overall Near-Bank Stress Rating

Worksheet 23. Total Bank Erosion Calculation

	Station (ft)	BEHI (adjective)*	Near Bank Stress (adjective)	Erosion Rate (ft/yr)*	Length of Bank (ft)	Bank Height (ft)	Erosion Sub-Total (ft^3/yr)
Stream:				Total Bank Length:		Stream Type:	
Observers:				Date:		Graph Used:	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
I. Sum erosion sub-totals for each BEHI/NBS combination						Total Erosion (ft^3/yr)	
II. Divide total erosion (feet^3) by 27 feet^3/yard^3						Total Erosion (yd^3/yr)	
III. Multiply Total Erosion (yard^3) by 1.3 (conversion of yd^3 to tons for average material type)						Total Erosion (tons/year)	
IV. Calculate erosion per unit length: divide total erosion (ton/year) by total length of stream (ft) surveyed						Total Erosion (tons/yr/ft)	

*Use numerical category spread to predict rates. (i.e. 21 = Moderate but at start of category, where as 28 is on upper end of relation - use prediction values appropriate to numerical rating).