Rosgen Classification of Natural Rivers

- Based on physical characteristics (empirical)
- Requires field measurements
- Requires bankfull dimensions

ELSEVIER

CATENA

Catena 22 (1994) 169-199

A classification of natural rivers

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Abstract

A classification system for natural rivers is presented in which a morphological arrangement of stream characteristics is organized into relatively homogeneous stream types. This paper describes morphologically similar stream reaches that are divided into 7 major stream type categories that differ in entrenchment, gradient, width/depth ratio, and sinuosity in various landforms. Within each major category are six additional types delineated by dominate channel materials from bedrock to silt/clay along a continuum of gradient ranges. Recent stream type data used to further define classification interrelationships were derived from 450 rivers throughout the U.S, Canada, and New Zealand. Data used in the development of this classification involved a great diversity of hydro-physiographic/geomorphic provinces from small to large rivers and in catchments from headwater streams in the mountains to the coastal plains. A stream hierarchical inventory system is presented which utilizes the stream classification system. Examples for use of this stream classification system for engineering, fish habitat enhancement, restoration and water resource management applications are presented. Specific examples of these applications include hydraulic geometry relations, sediment supply/availability, fish habitat structure evaluation, flow resistance, critical shear stress estimates, shear stress/velocity relations, streambank erodibility potential, management interpretations, sequences of morphological evolution, and river restoration principles.

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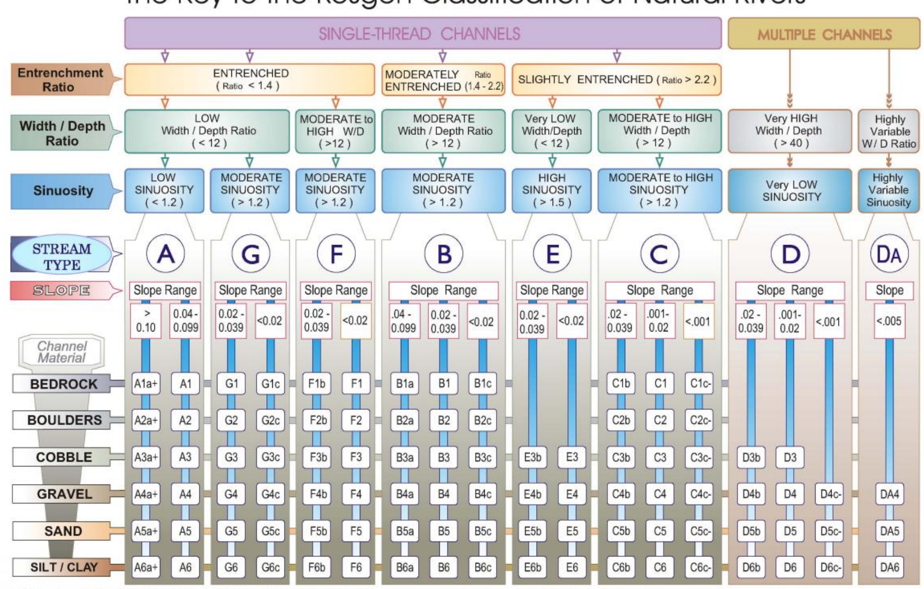
The Key to the Rosgen Classification of Natural Rivers

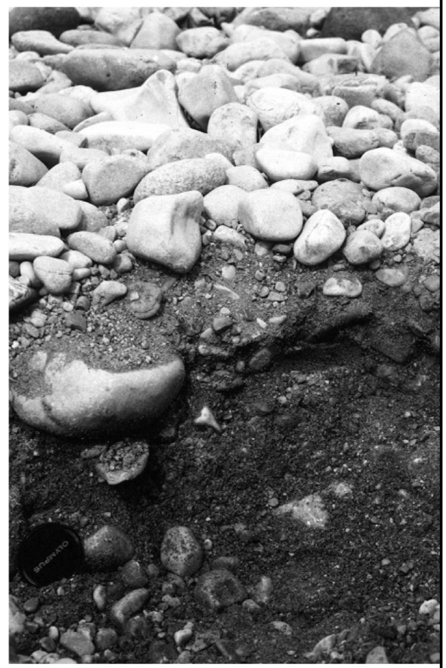


KEY to the ROSGEN CLASSIFICATION of NATURAL RIVERS. As a function of the "*continuum of physical variables*" within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

 1481 Stevens Lake Road Pagosa Springs, CO 81147 (970) 731-6100 e-mail: wildlandhydrology@pagosa.net

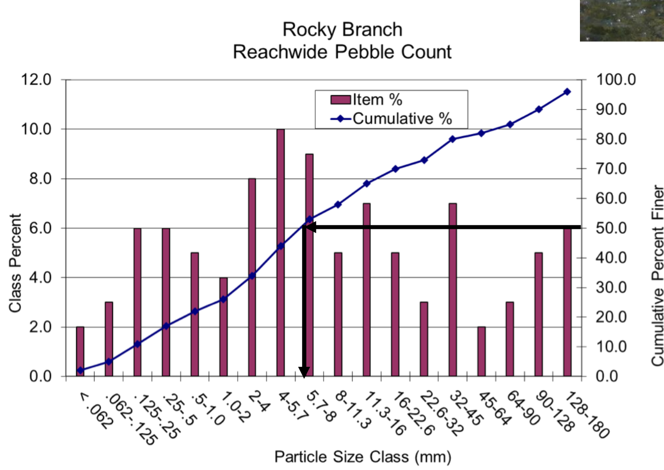
Bed Material (Substrate)

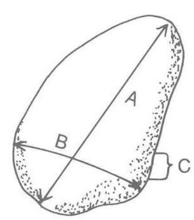
1. Bedrock
2. Boulder: 256 – 2048 mm
3. Cobble: 64 – 256 mm
4. Gravel: 2 – 64 mm
5. Sand: 0.062 – 2 mm
6. Silt/Clay: < 0.062 mm



Substrate Characterization

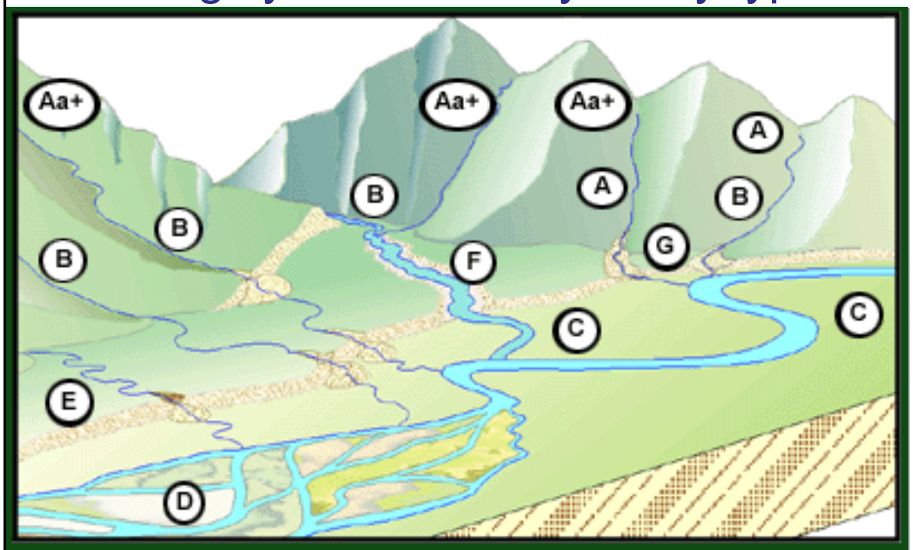
Wolman Pebble Count





D50=6 mm;
Fine Gravel

Stream types in various landscape positions largely influenced by valley type



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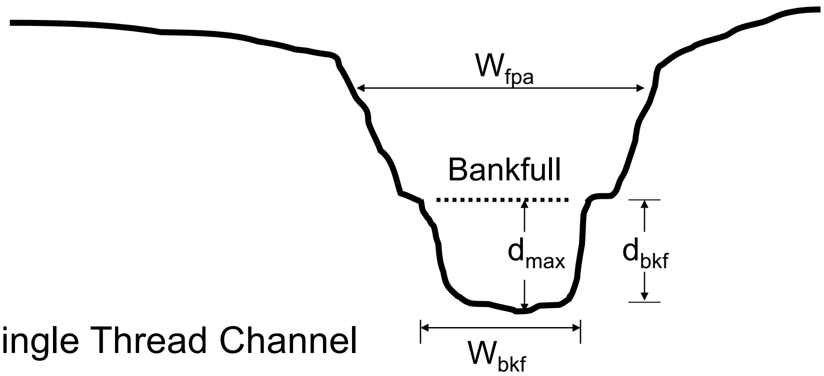
A Streams

Incised, Narrow & Deep, Steep Slope Colluvial Valley

- Steep
- Straight
- Deeply Entrenched
- Cascading
- Step/Pool Sequence
- High Energy/Debris Transport
- Stability Dependent on Bed and Bank Material

A Stream Channel

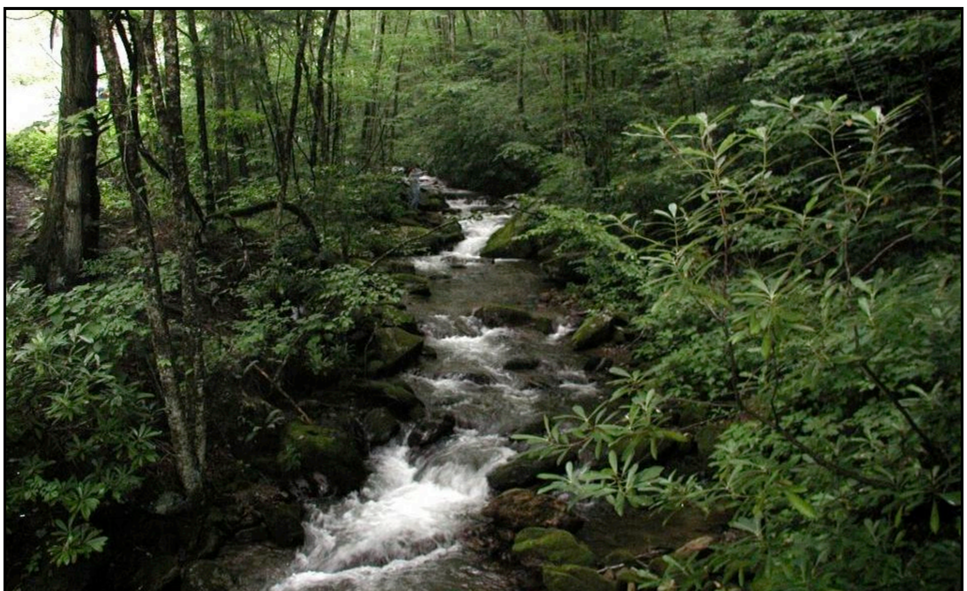


Single Thread Channel

$ER = W_{fpa}/W_{bkf} < 1.4$

$W/d = W_{bkf}/d_{bkf} < 12$

$S > 0.04$ ft/ft



ER=1.4; W/d=10; S=0.050; D50=70 mm
A3 Western NC

Aa+ Streams

Very Steep (>0.1 ft/ft)

- Very Steep
- Very Straight
- Deeply Entrenched
- Excessively High Energy & Debris Transport
- Cascading
- Torrent Streams
- Waterfalls and Chutes Prevalent

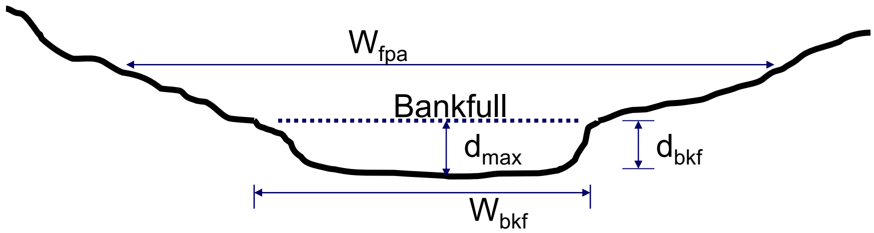
A1a+ Western NC

B Streams

Moderately Incised, Wide & Shallow, Moderate Slope, Colluvial Valley

- Moderate Gradient
- Moderate Entrenchment
- Riffles
- Infrequent Pools
- Generally Stable Bed and Banks

B Stream Channel

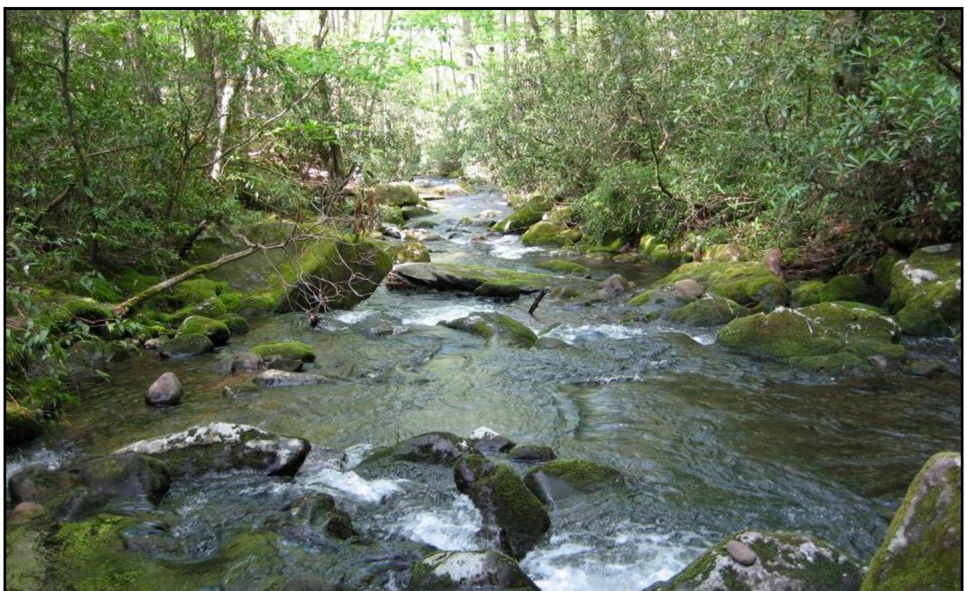


Single Thread Channel

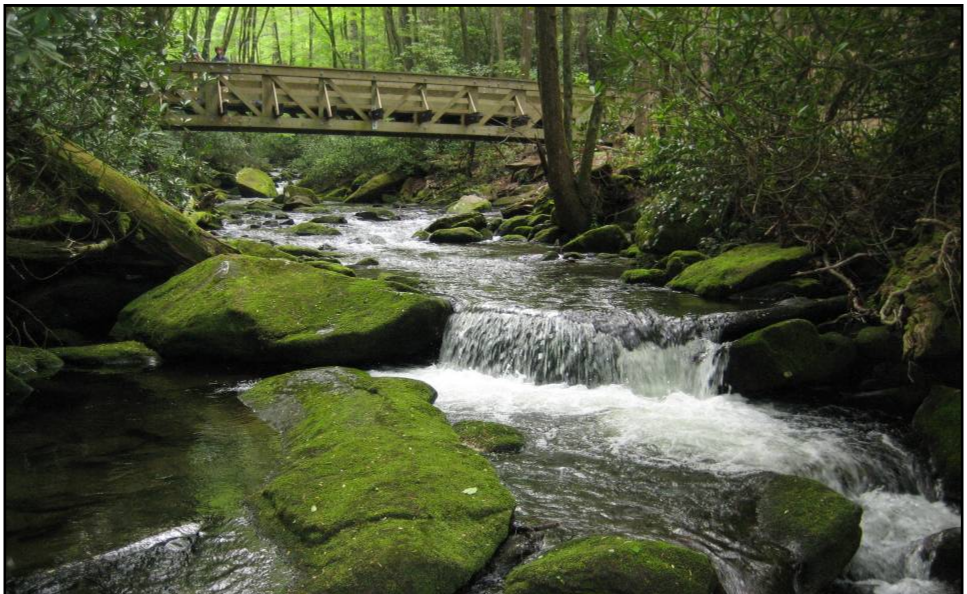
$ER = W_{fpa}/W_{bkf} = 1.4 – 2.2$

$W/d = W_{bkf}/d_{bkf} > 12$

$S = 0.02 – 0.04$ ft/ft



ER=2.2; W/d=14; S=0.035; D50=110 mm
B3 Western NC



ER=1.9; W/d=15; S=0.065; D50=120 mm
B3a Western NC

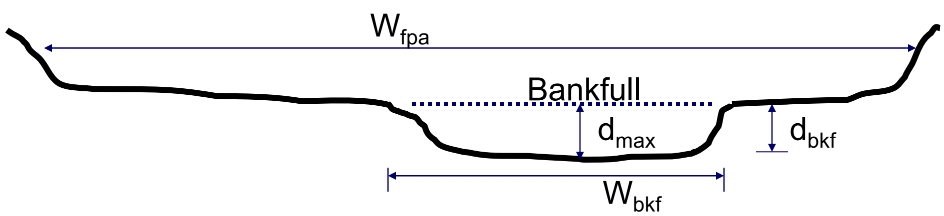
B4c Western NC

C Streams

<u>Not Incised</u>, Wide & Shallow, Low Slope
Alluvial Valley

- Low Gradient
- Meanders
- Point Bars
- Riffle/Pool Sequence
- Alluvial Channels
- Broad Floodplain

C Stream Channel



Single Thread Channel

$ER = W_{fpa}/W_{bkf} > 2.2$

$W/d = W_{bkf}/d_{bkf} > 12$

$S < 0.02$ ft/ft


C4 Washington


C4 New Zealand

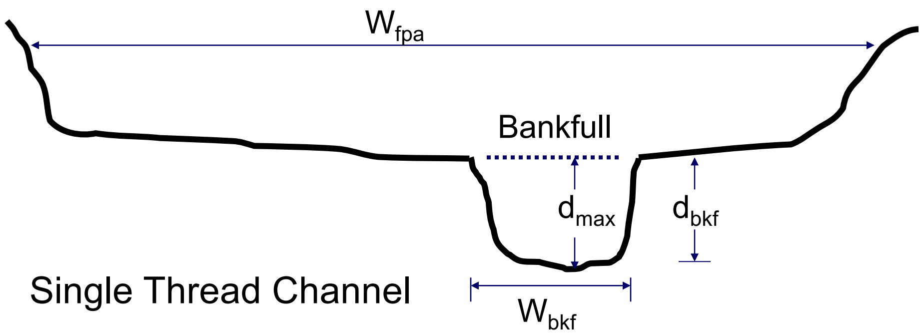
ER=4.5; W/d=14; S=0.033; D50=75 mm
C3b Western NC

E Streams

Not Incised, Narrow & Deep, Low Slope
Alluvial Valley

- Low Gradient
- Low Width/Depth Ratio
- High Meander/Width Ratio
- Riffle/Pool Sequences
- Little Deposition
- Very Stable and Efficient

E Stream Channel



Single Thread Channel

$ER = W_{fpa}/W_{bkf} > 2.2$

$W/d = W_{bkf}/d_{bkf} < 12$

$S < 0.02$ ft/ft

E4 Western NC

ER=5.5; W/d=8.2; S=0.031; D50=12 mm
E4b Western NC

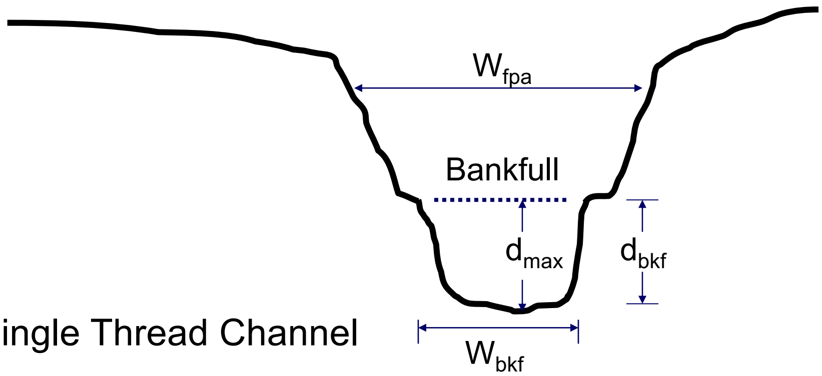
G Streams

Incised
Narrow & Deep
Moderate Slope

- Moderate Gradient
- Deeply Entrenched
- GULLIES
- Step/Pool
- Low Width/Depth Ratio

G=GULLY

G Stream Channel



Single Thread Channel

$ER = W_{fpa}/W_{bkf} < 1.4$

$W/d = W_{bkf}/d_{bkf} < 12$

S = 0.02 – 0.04 ft/ft

G4c

ER=1.2; W/d=9.5; S=0.005; D50=0.5 mm
G5c

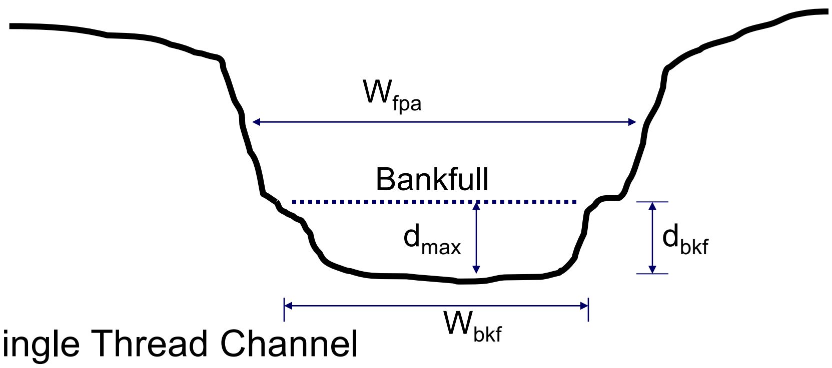
F Streams

Incised, Wide & Shallow, Low Slope

- Low Gradient
- High Width/Depth Ratio
- Entrenched Meanders
- Riffle Pool Sequence

G Stream usually widen through erosion and transform into F Streams

F Stream Channel



Single Thread Channel

$ER = W_{fpa}/W_{bkf} < 1.4$

$W/d = W_{bkf}/d_{bkf} > 12$

$S < 0.02$ ft/ft


F4


F4

D Streams
Multiple Channels, Wide & Shallow, Low Slope

- Low Gradient
- Braided Channels
- Longitudinal & Traverse Bars
- Wide Channel
- Eroding Banks

Channels are unstable and tend to move around on the valley. These streams generally transport large loads of coarse sediment and bedload

D4 Virginia

DA Streams
Multiple Channels, Wide & Shallow, Low Slope

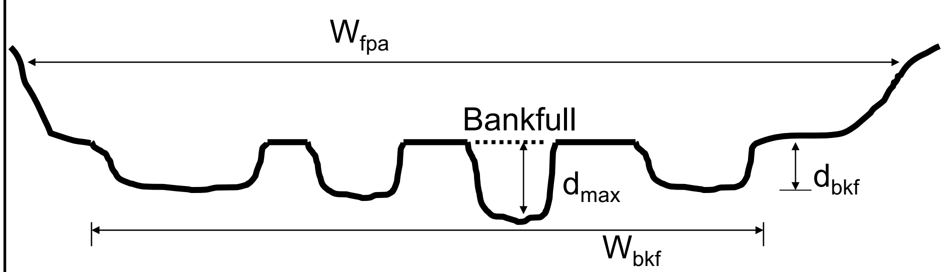
- Low Gradient
- Braided Channels
- Wide Channel

Channels are stable and generally vegetated. Slopes are generally flatter than for the DA Channels

DA Columbia River, B.C.

photo: H.J.A. Berendsen http://www.geo.uu.nl/fg/palaeogeography/results/fluvialstyle

D Stream Channel

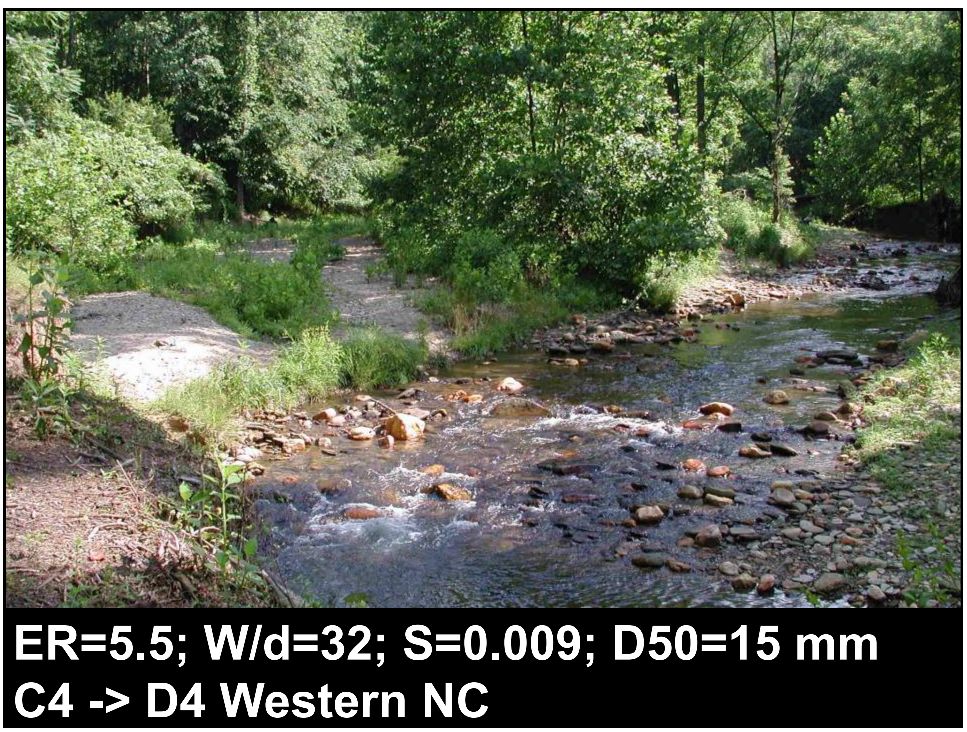


Multiple Thread Channel

$ER = W_{fpa}/W_{bkf} > 2.2$

$W/d = W_{bkf}/d_{bkf} > 40$

D4 Pennsylvania



ER=5.5; W/d=32; S=0.009; D50=15 mm
C4 -> D4 Western NC

What Makes a Stream Healthy?

- Bed stability & diversity
- Sediment transport balance
- In-stream habitat & flow diversity
- Bank stability (native plant roots)
- Riparian buffer (streamside forest)
- Active floodplain

Causes of Instability

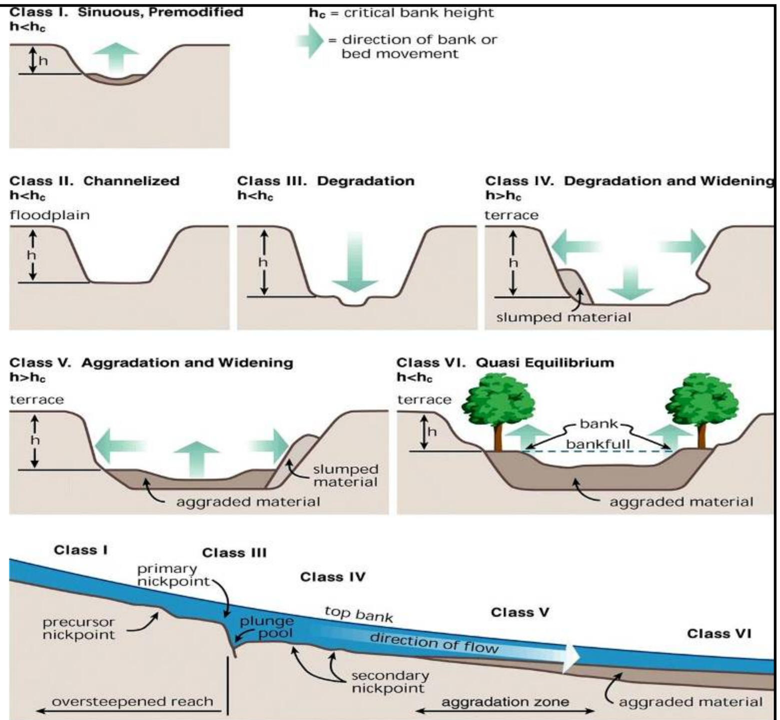
- Increase runoff
- Increase slope
- Changes in sediment load
- Loss of riparian buffer
- Floodplain filling
- Instream modification

Hydrologic Responses to Urbanization

1. Increased discharge
2. Increased peak discharge
3. Increased velocities
4. Shorter time to peak flow
5. More frequent bankfull events
6. Increased flooding
7. Lower baseflow
8. Less ground water recharge

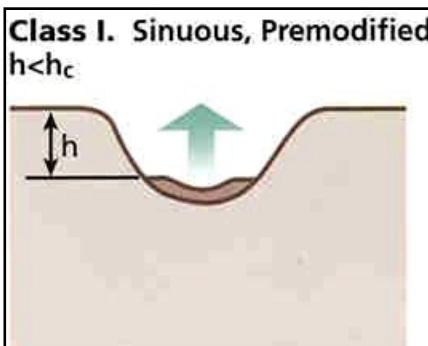
Channel incision and bank erosion increase due to channelization and increased stormwater runoff

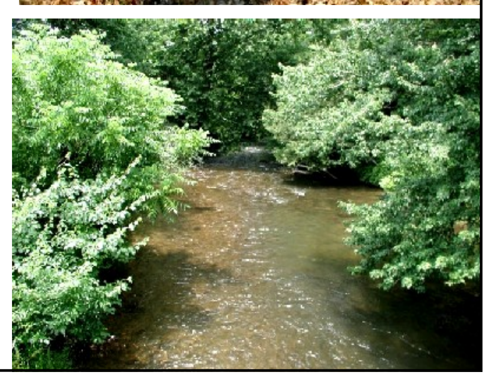
Simon Channel Evolution Model

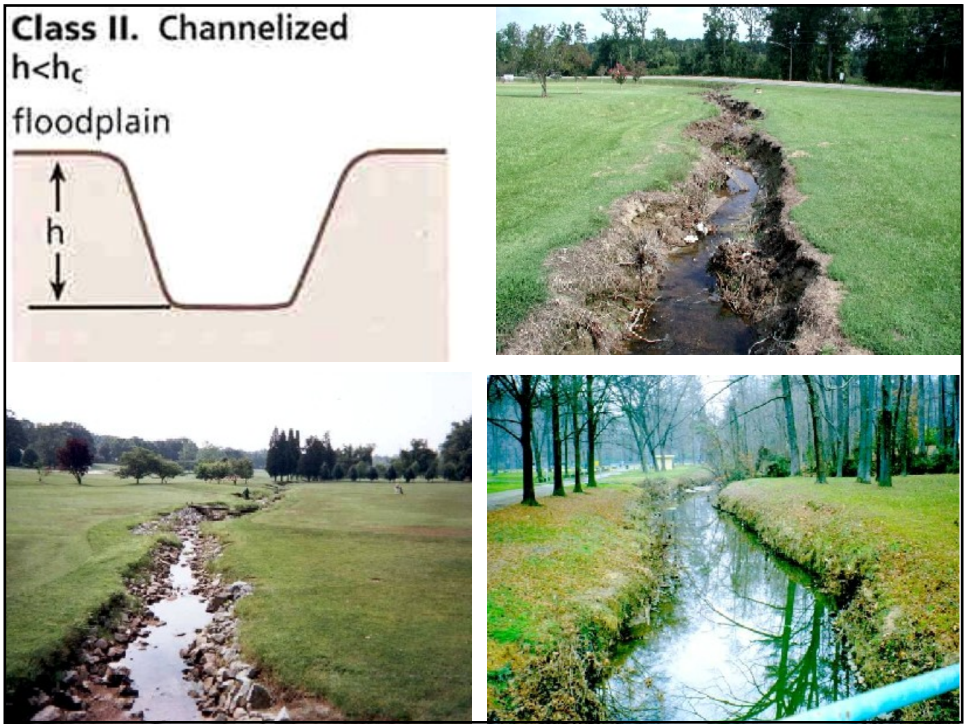


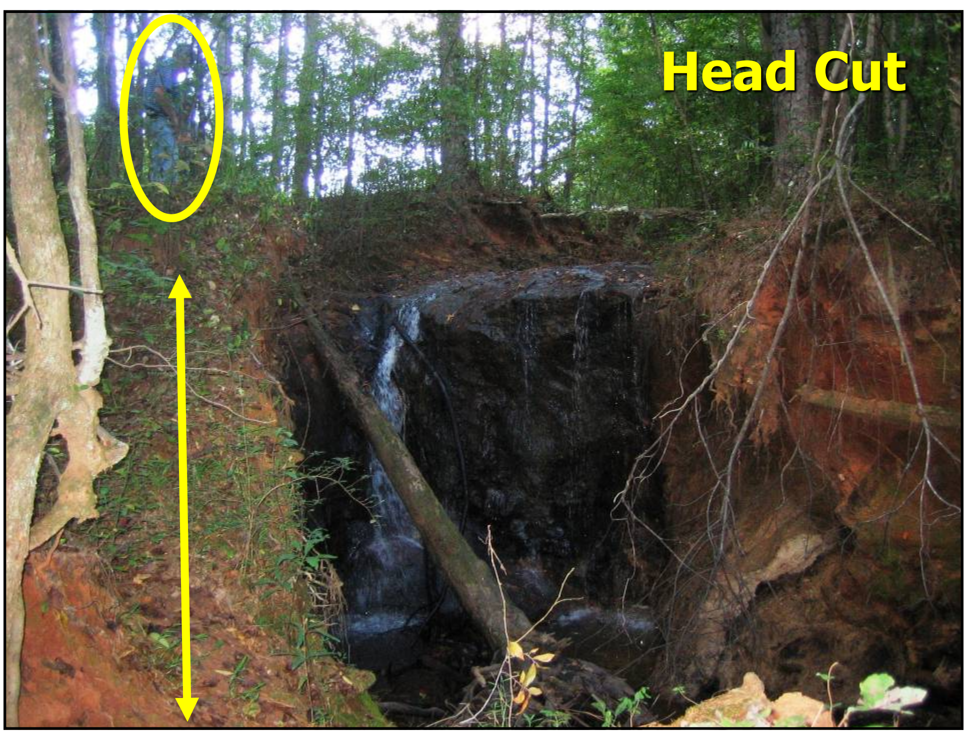
Source:

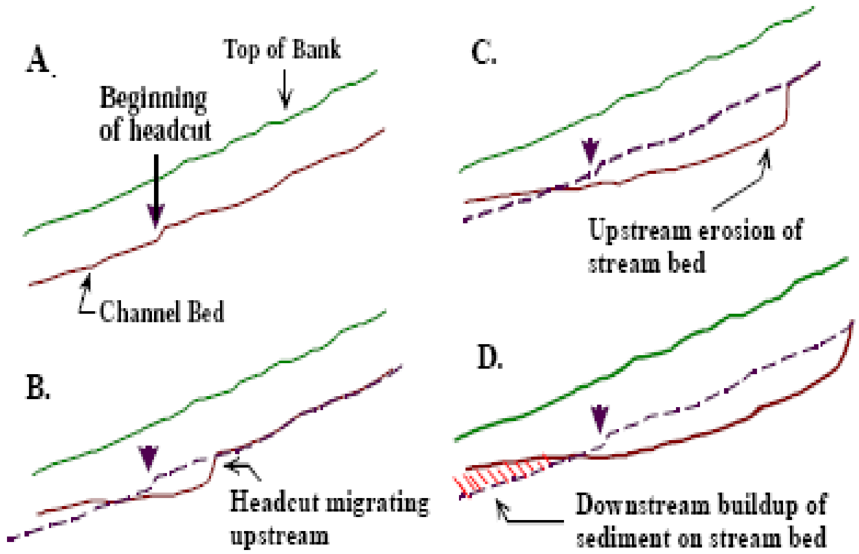
Simon, 1989, USACE 1990



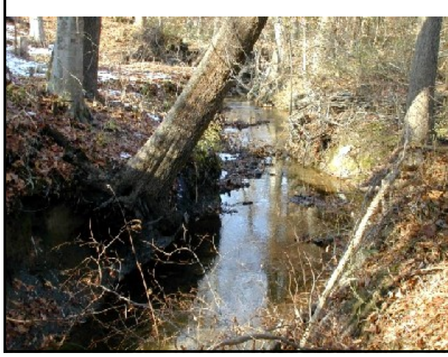


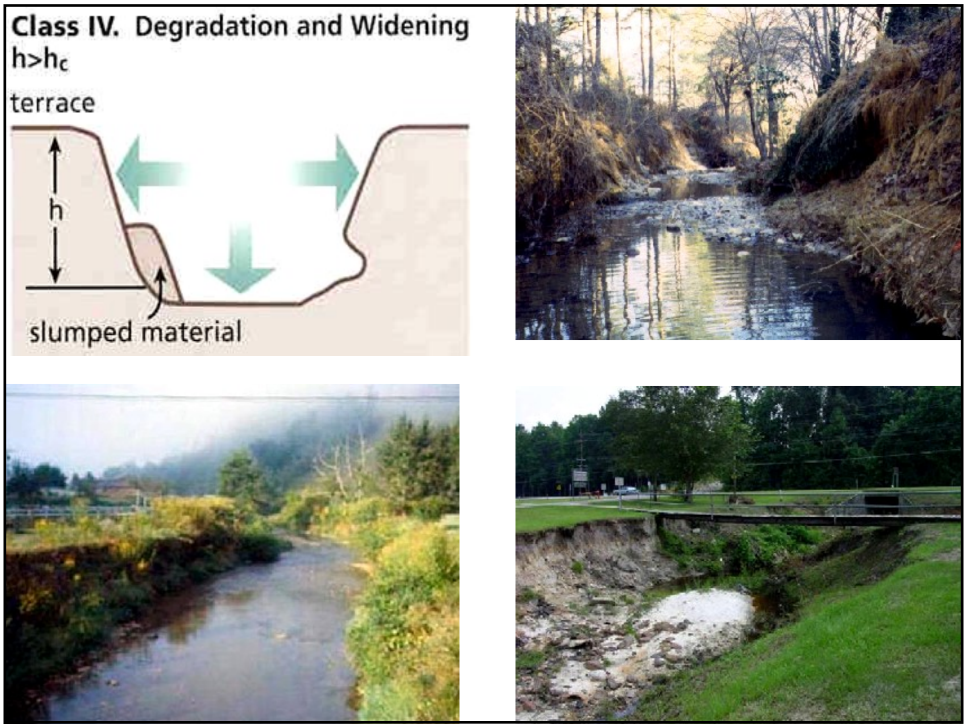

Class II. Channelized
h<hc
floodplain
h

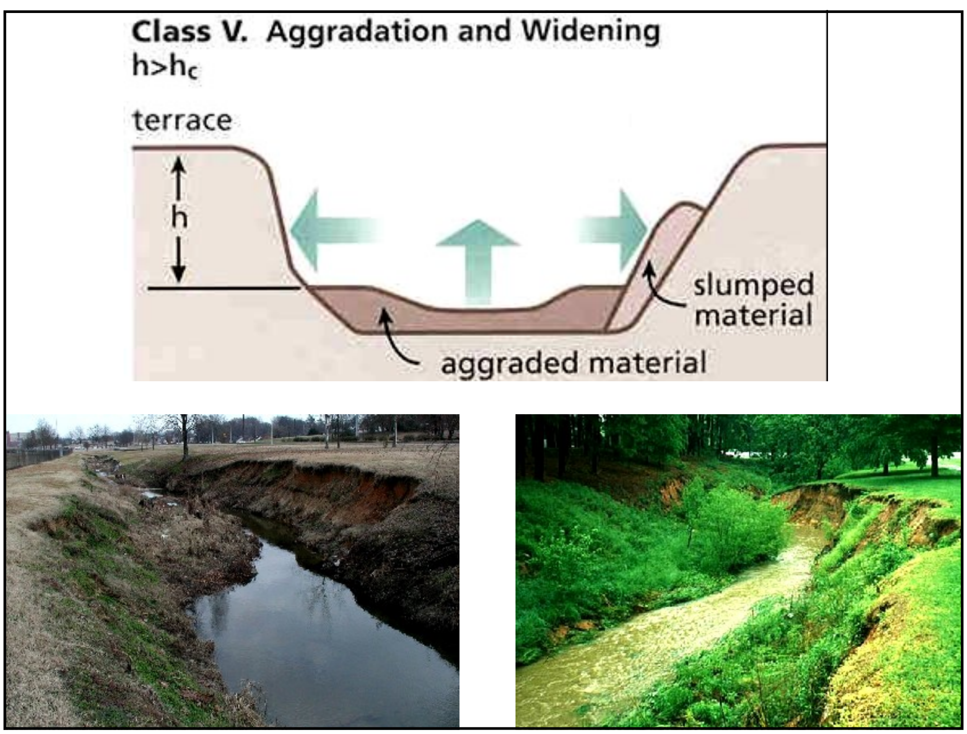

Head Cut

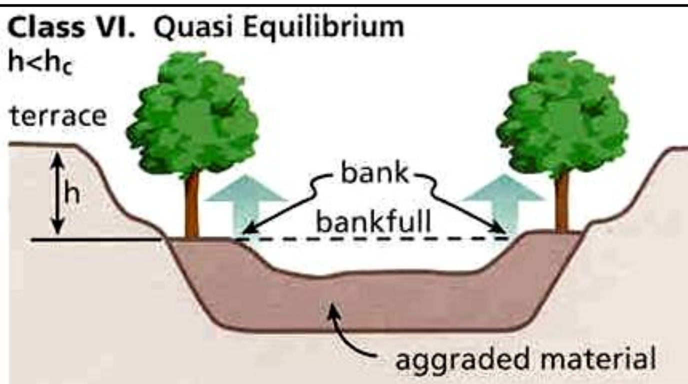


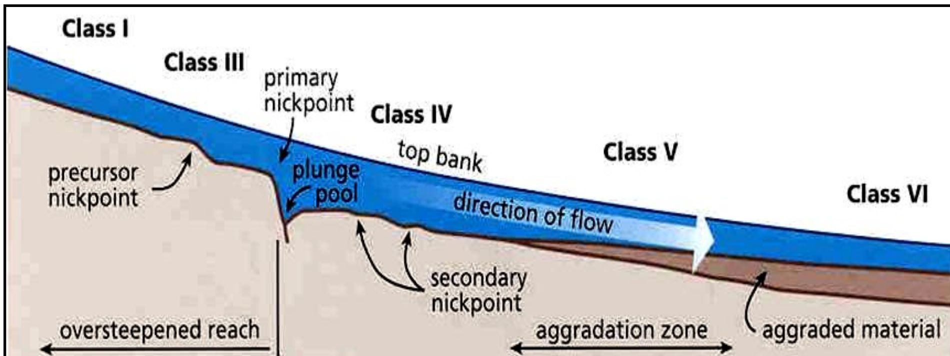
Class III. Degradation
$h<h_c$

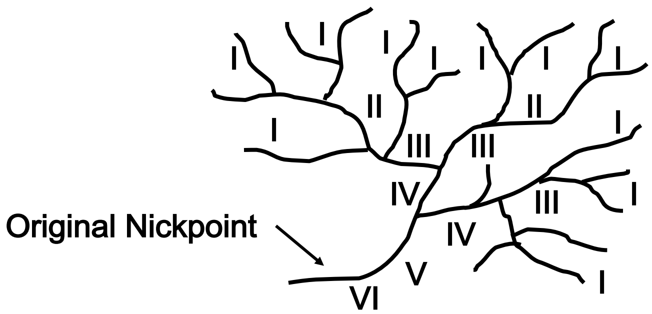



Class IV. Degradation and Widening
h>hc
terrace
h
slumped material

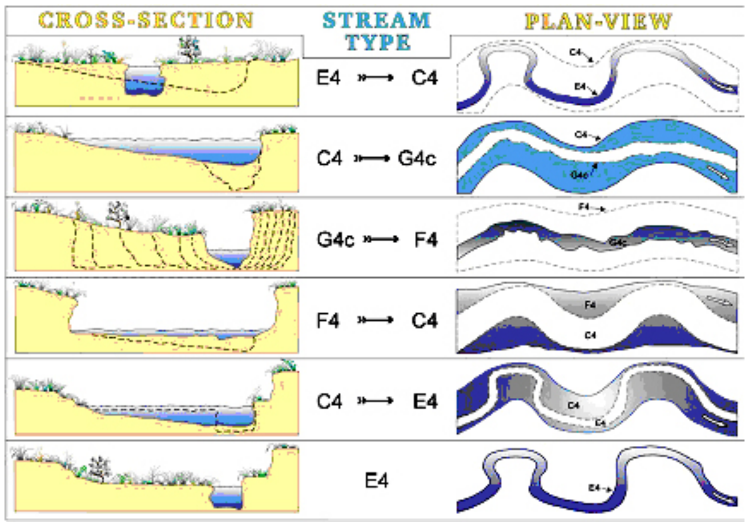

Class V. Aggradation and Widening
h>hc
terrace
h
slumped
material
aggraded material

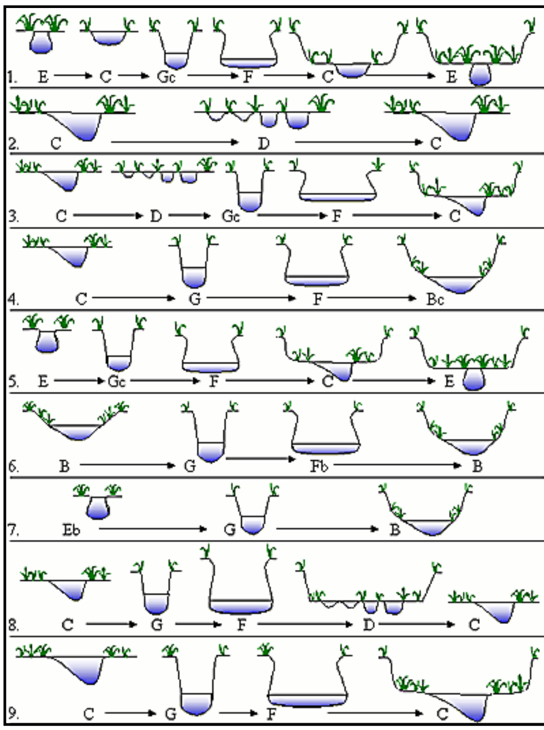

Class VI. Quasi Equilibrium
h<hc
terrace
h
bank
bankfull
aggraded material


Class I
Class III
primary nickpoint
Class IV
top bank
Class V
Class VI
precursor nickpoint
plunge pool
direction of flow
secondary nickpoint
oversteepened reach
aggradation zone
aggraded material


Original Nickpoint
I
II
III
IV
V
VI

Stream Channel Succession (WARSSS)

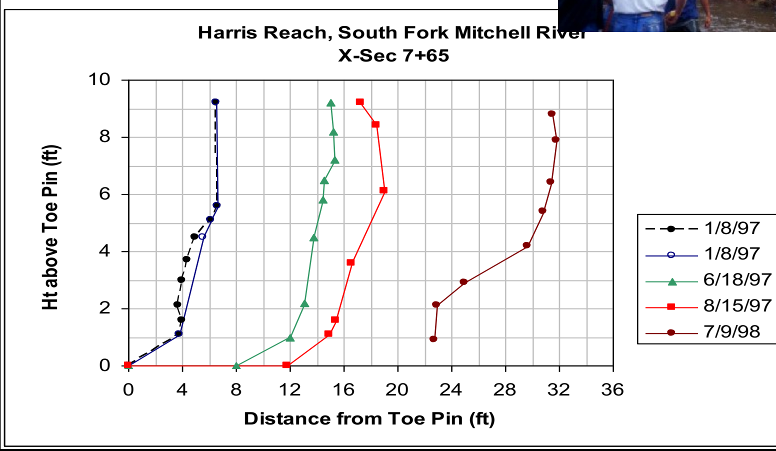




Stream Channel Succession (WARSSS)

http://www.epa.gov/WARSSS/sedsource/successn.htm

Bank Erosion Monitoring



Bank Erosion Hazard Index (BEHI)

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)

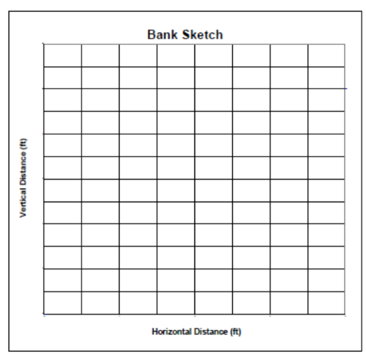
Root Density (%) F	F*E = G

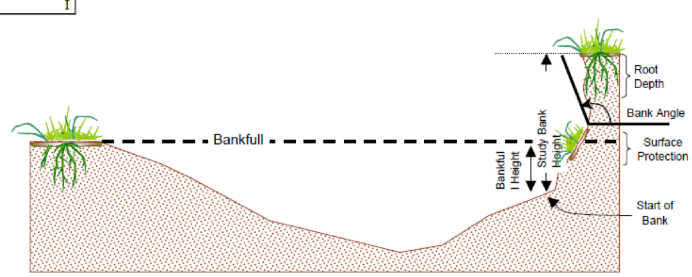
Bank Angle (H)

Bank Angle (Degrees) H

Surface Protection (I)

Surface Protection % I



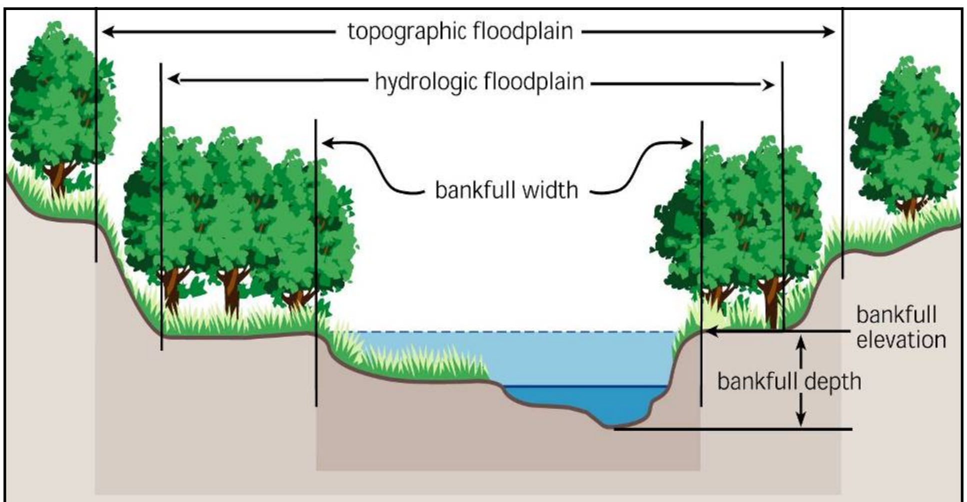


Bank Erosion Hazard Index (BEHI)

TABLE 6-8. Streambank characteristics used to develop Bank Erosion Hazard Index (BEHI)

Adjective Hazard or risk rating categories		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Bank Height	Bank Angle (Degrees)	Surface Protection %	Totals
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	5-9.5
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	10-19.5
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	20-29.5
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	30-39.5
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	40-45
Extreme	Value	>2.8	<0.05	<5	<119	<10	
	Index	10	10	10	10	10	46-50

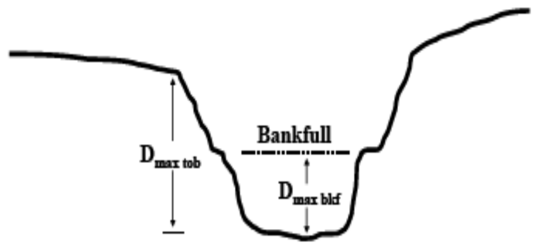
For adjustments in points for specific nature of bank materials and stratification, the following is used:
Bank Materials: Bedrock (very low), Boulders (low), cobble (subtract 10 points unless gravel/sand > 50%, then no adjustment), gravel (add 5-10 points depending on % sand), sand (add 10 points), silt/clay (no adjustment).
Stratification: Add 5-10 points depending on the number and position of layers.



Bankfull Stage: Water fills the active channel and begins to spread onto the floodplain

Stream Corridor Restoration: Principles, Processes, and Practices. 1998. Federal Interagency Stream Restoration Working Group.

<u>Bank Height Ratio</u> is the ratio of the maximum depth from the top of bank to the maximum depth from the bankfull stage (see diagram below). The potential for streambank erosion increases as bank height ratio increases. For incised channels, higher bank height ratios indicate that flood flows are carried within the channel, increasing the potential for bank erosion.



Bank Height Ratio = $D_{max\ tob}$ / $D_{max\ bkf}$

Example: $D_{max\ tob}$ = 5.4 ft; $D_{max\ bkf}$ = 3.0 ft; Bank Height Ratio = 5.4 / 3.0 = 1.8

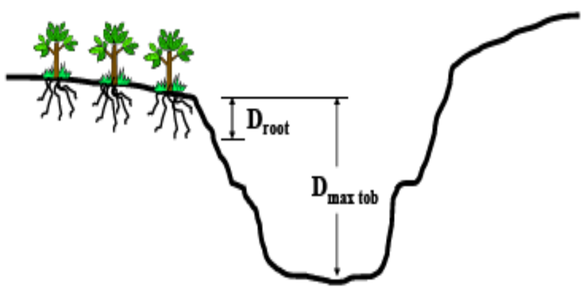
Bank Height Ratio

Low BEHI

Bank Height Ratio

High BEHI

Root Depth Ratio is the ratio of root depth from top of bank to the maximum depth from the top of bank (see diagram below). This ratio provides an indication of the bank protection provided by live plant roots. Very low values of root depth ratio indicate high bank erosion potential. Values of rooting depth ratio near 1 indicate relatively low bank erosion potential.



Root Depth Ratio = $D_{root} / D_{max\ tob}$

Example: D_{root} = 1.2 ft; $D_{max\ tob}$ = 6.0 ft; Root Depth Ratio = 1.2 / 6.0 = 0.2

Root Depth Ratio

Low BEHI

Root Depth Ratio

High BEHI

Root Density Percentage is the percentage of the streambank soil material containing roots that stabilize the streambank. The potential for streambank erosion is highest for banks with very low root densities.

Root Density

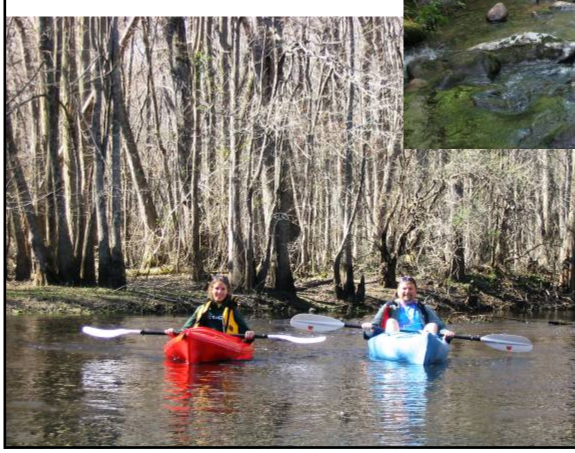
Low BEHI

Root Density

High BEHI

Bank Angle

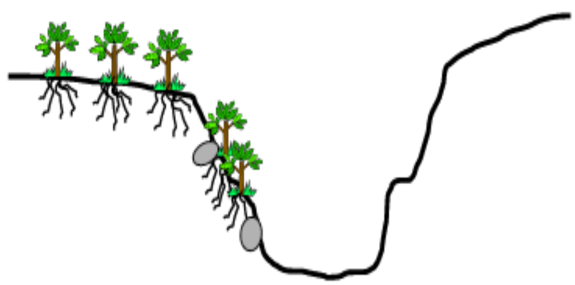
Low BEHI



Bank Angle

High BEHI

<u>Surface Protection Percentage</u> is the percentage of bank protected from erosive flows by vegetation, roots, rocks, large woody debris, or other materials (see diagram below).



Surface Protection

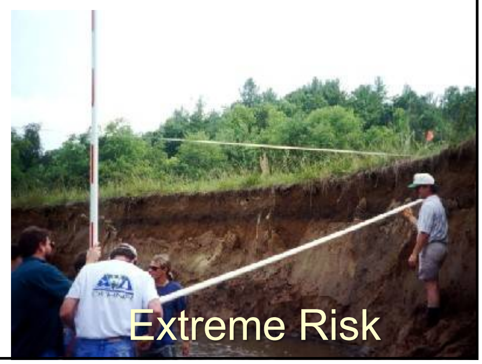
Low BEHI

Surface Protection

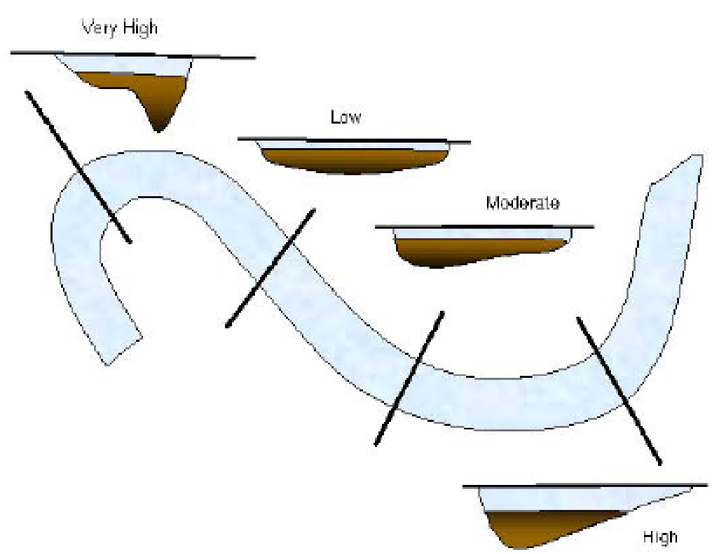
High BEHI

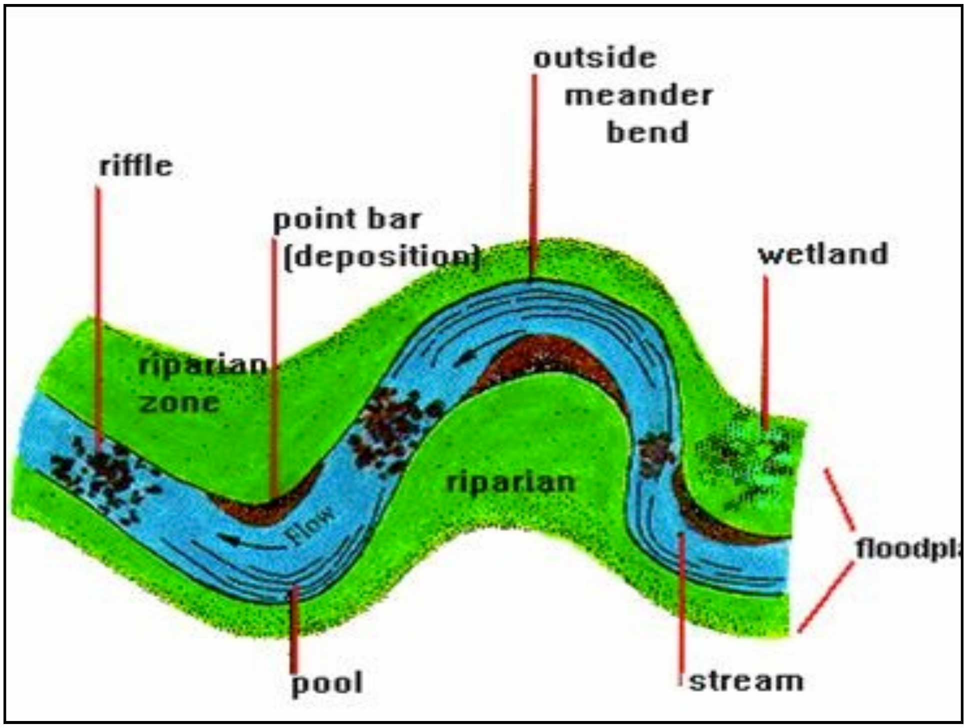
Bank Materials

Add up to 10 points for erodible soils



Near Bank Stress (NBS) is a visual assessment of the amount of stress the channel flow is exhibiting in the near bank area of the channel (see diagram below). NBS is highest at the outside of a very tight meander bend and lowest in a straight section with uniform channel dimension.





Estimating Near-Bank Stress (NBS)

Stream:			Location:		Date:		Crew:	

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.**

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	Bankfull Width	Ratio	Near-Bank Stress				
		Rc (feet)	W_{bkf} (feet)	Rc/W					
	(3)	Pool Slope	Average Slope	Ratio	Near-Bank Stress		Dominant Near-Bank Stress		
		S_p	S	S_p/S					
	(4)	Pool Slope	Riffle Slope	Ratio	Near-Bank Stress				
		S_p	S_{rif}	S_p/S_{rif}					
Level III	(5)	Near-Bank Max Depth	Mean Depth	Ratio	Near-Bank Stress				
		d_{nb} (feet)	d (feet)	d_{nb}/d					
	(6)	Near-Bank Max Depth	Near-Bank Slope	Near-Bank Shear Stress	Mean Depth	Average Slope	Shear Stress	Ratio	Near-Bank Stress
		d_{nb} (feet)	S_{nb}	τ_{nb} (lb/ft^2)	d (feet)	S	τ (lb/ft^2)	τ_{nb}/τ	
Level IV	(7)	Velocity Gradient (ft/s/ft)		Near-Bank Stress					

Converting Values to a Near-Bank Stress Rating

Near-Bank Stress Rating	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	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
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

Near Bank Stress

Low NBS

Near Bank Stress

High NBS

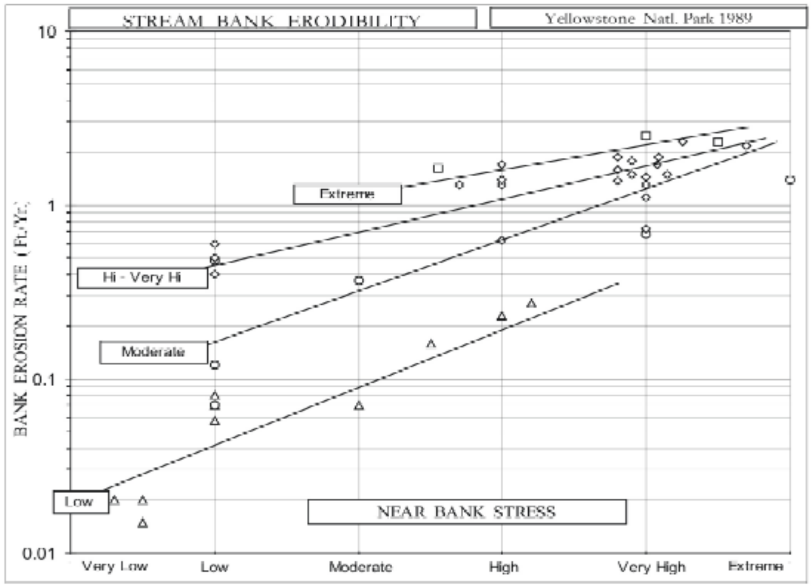


Figure 116. Relationship of BEHI and NBS to predict annual streambank erosion rates, Yellowstone National Park data, 1989 (Rosgen 1996, 2001a).