5. Fluvial Processes and Channel Characteristics Important in Stream Simulation Design

Dan Cenderelli
USDA Forest Service
Stream Systems Technology Center

1

Acknowledgements

Traci Sylte, P.E.
Hydrologist,
Lolo NF, Montana

Bob Gubernick, P.E.
Engineering Geologist,
Tongass NF, Alaska

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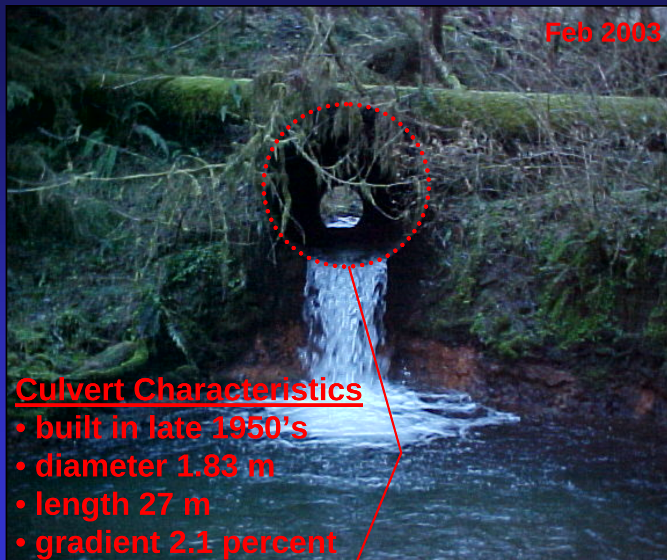
Presentation Outline

- **Watershed Context**
- **Discharge and Channel Characteristics**
- **Channel Characteristics and Fluvial Processes**
  - Channel slope
  - Channel shape, confinement, entrenchment
  - Channel planform
  - Channel slope, shape, and planform
  - Channel-bed material
  - Channel bedforms
- **Channel Classifications**
- **Understanding and Predicting Channel Adjustments/Responses**

3

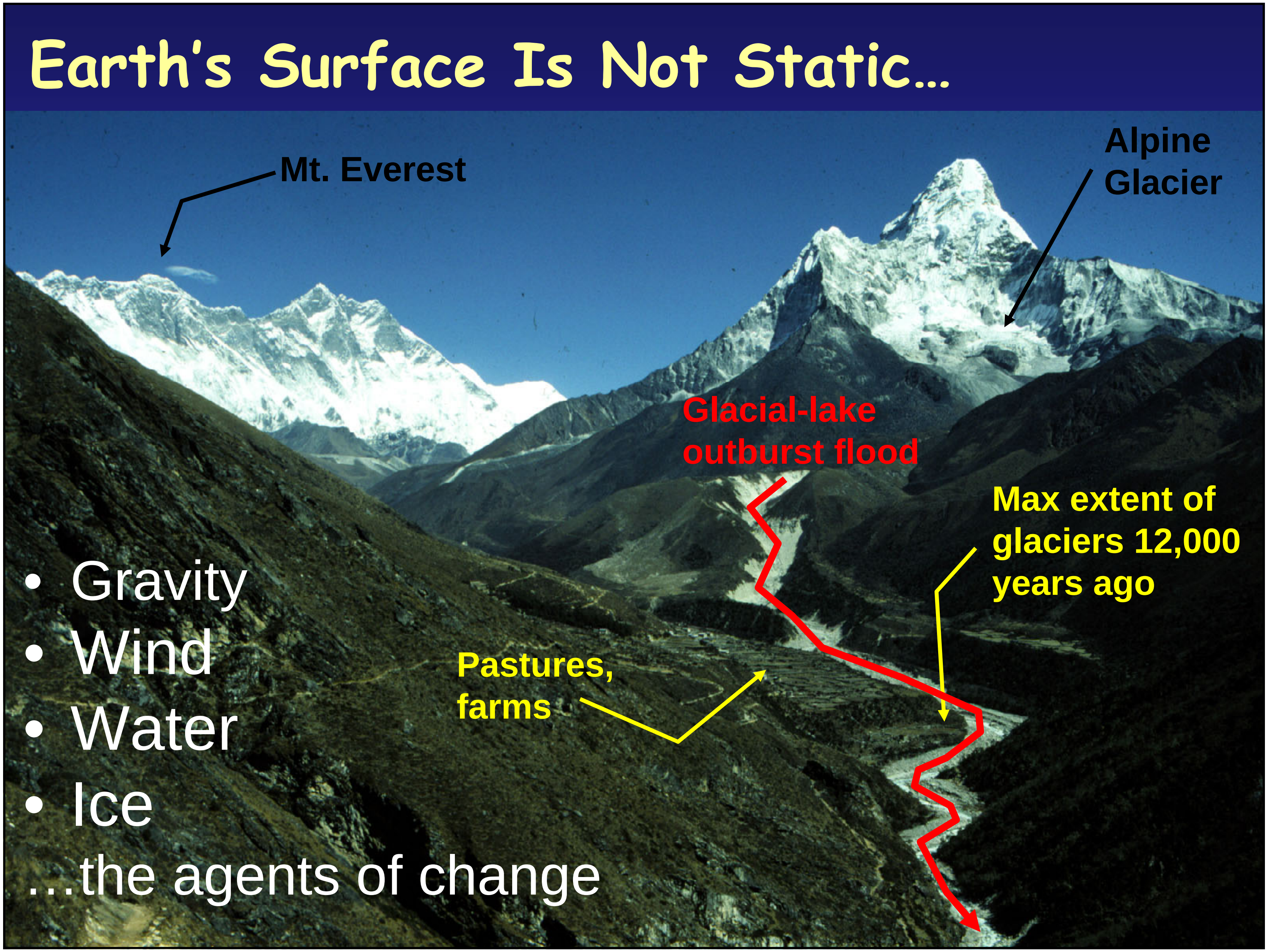


Presentation Objectives

- **A better understanding and appreciation of channel features, fluvial processes, and channel dynamics at a road-stream crossing.**

- **Understand the importance of integrating fluvial geomorphology with engineering principles to design a road-stream crossing that contains a natural and dynamic channel through the structure.**

4


Earth's Surface Is Not Static…
Mt. Everest
Alpine Glacier
Glacial-lake outburst flood
Max extent of glaciers 12,000 years ago
Pastures, farms
• Gravity
• Wind
• Water
• Ice
…the agents of change

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6

Influence Of Geology, Climate, and Land Use On Fluvial Systems

Watershed Scale

- -runoff volume
- -sediment supply
- -basin size
- -basin shape
- -drainage density
- -basin gradient
- -vegetation type
- -vegetation density

Channel Scale

- -discharge magnitude, duration, and frequency
- -channel-bed composition and structure
- -channel form (width and depth)
- -channel gradient
- -sediment transport and deposition

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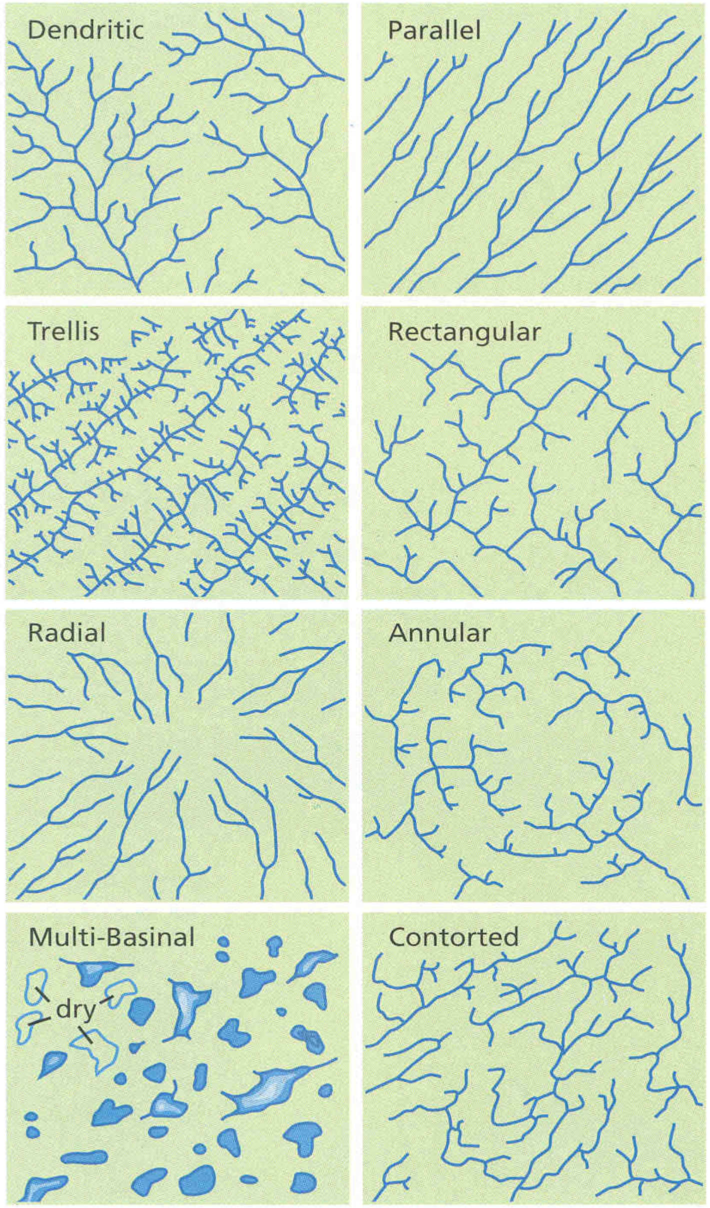
Hydrologic Differences Between Arid and Humid Climates

	ARID ZONE	HUMID ZONE
INPUT	Low and unreliable	Relatively high and dependable (often seasonally so)
	Limited duration but often high intensity storms	Long duration (often frontal) precipitation of variable intensity
	Extremely variable at the event and annual scales	Temporal variability is much less
	Spatially concentrated events	Large areas generally affected
THROUGHPUT	Horton overland flow dominant	Infiltration, throughflow and groundwater flow more significant
	Rapid onset of surface runoff	Longer lag between precipitation and runoff
	Relatively high runoff coefficient	Lower runoff coefficient
	Decreasing discharge downstream due to transmission losses	Increasing discharge downstream due to tributary inflows
OUTPUT	Mostly intermittent	Largely perennial
	Extremely flashy regime	Relatively steady regime
	Sharply peaked runoff hydrograph	Runoff hydrographs have lower amplitude
	Considerable interannual variability	Dependable interannual flows

From Knighton (1998)



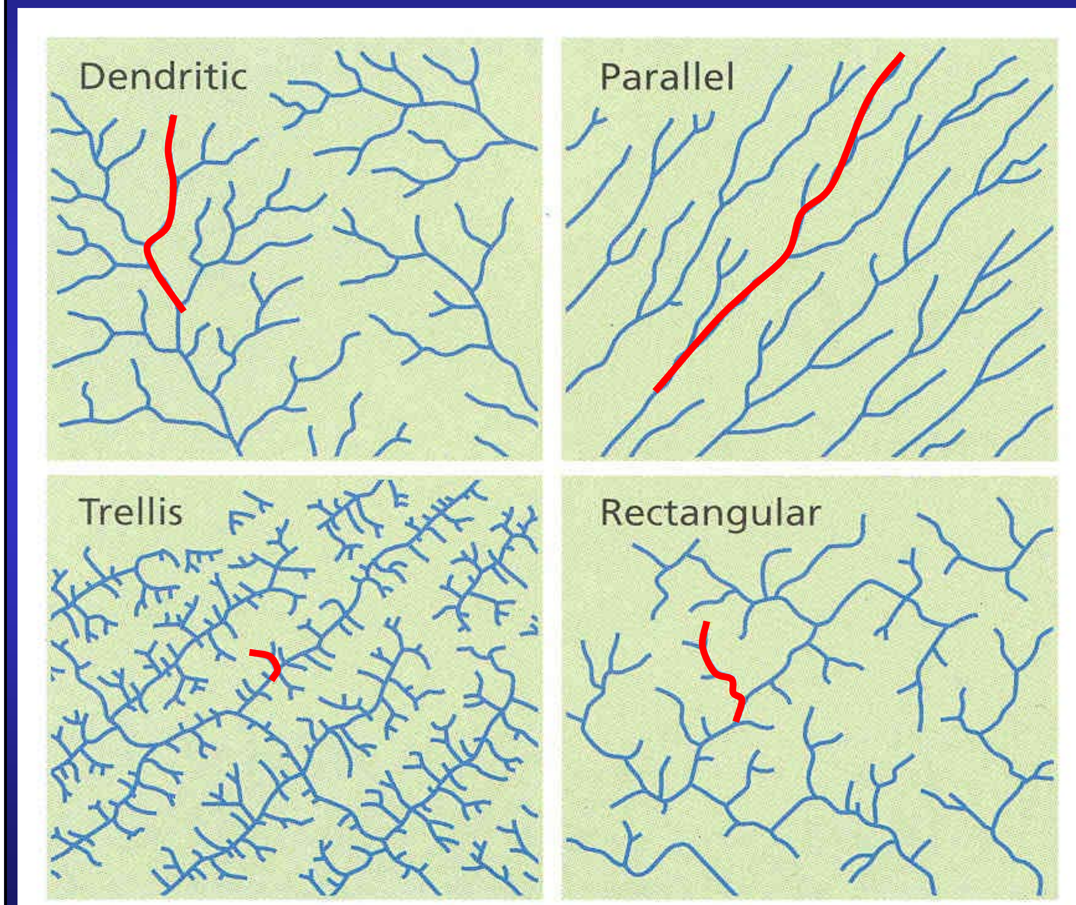
Relevance of Drainage Pattern to Road-Stream Crossing Designs

The downstream delivery of sediment and wood by debris flows

9

from FISRWG (1998)

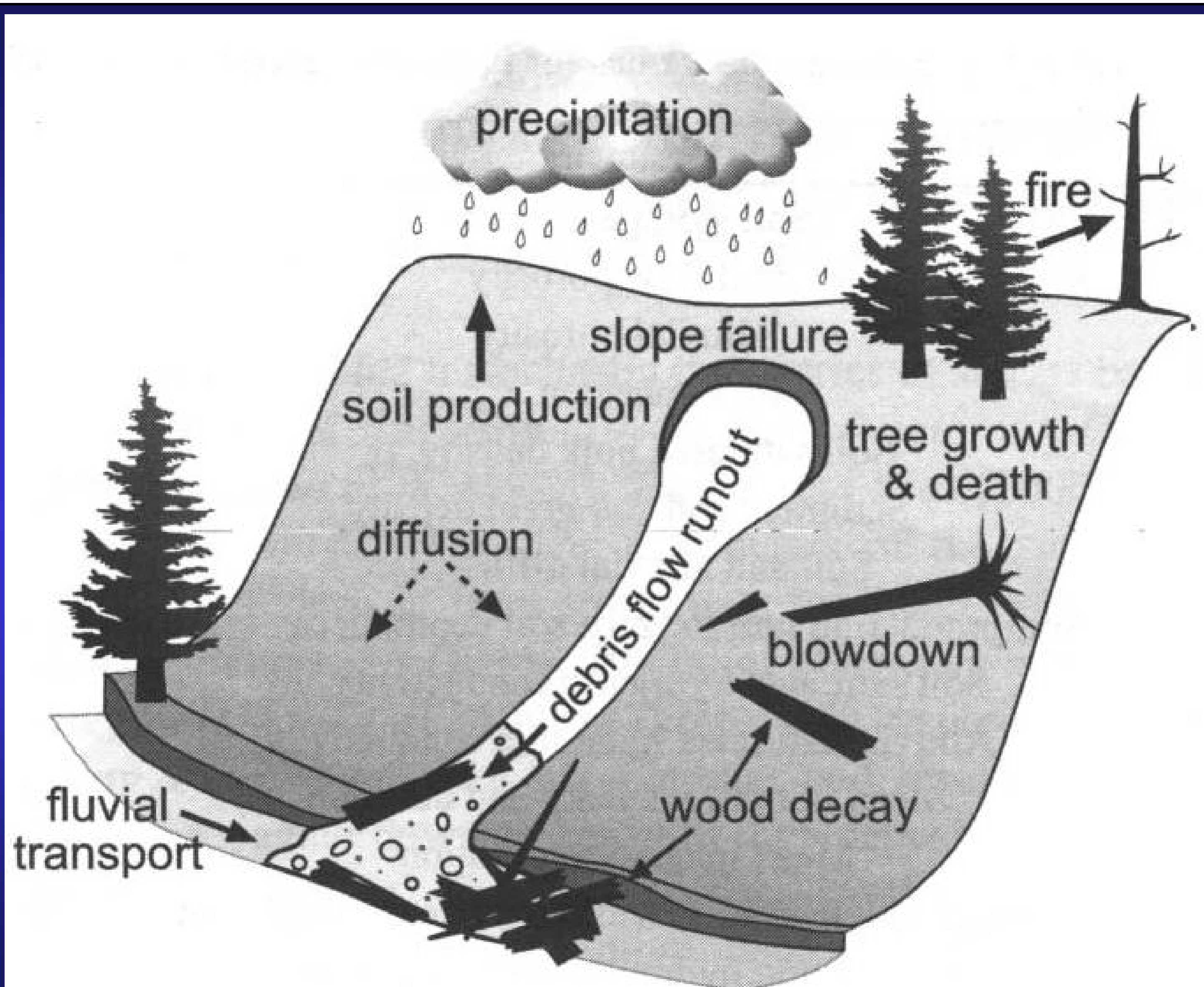
Relevance of Drainage Pattern to Road-Stream Crossing Designs



The downstream delivery of sediment and wood by debris flows (think about runout length)

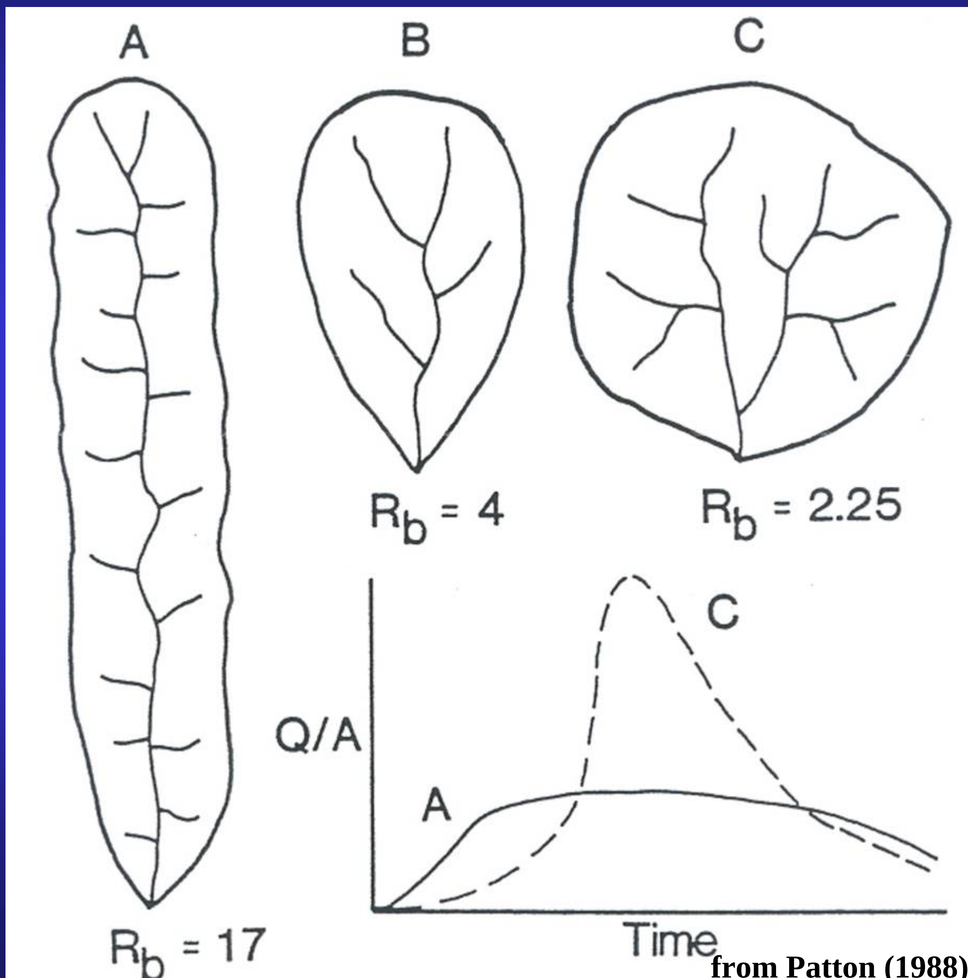
10

from FISRWG (1998)



from Lancaster et al. (2001)

Relevance of Drainage Shape to Road-Stream Crossing Designs



from Patton (1988)

The timing, magnitude, and duration of peak discharge is influenced by drainage shape

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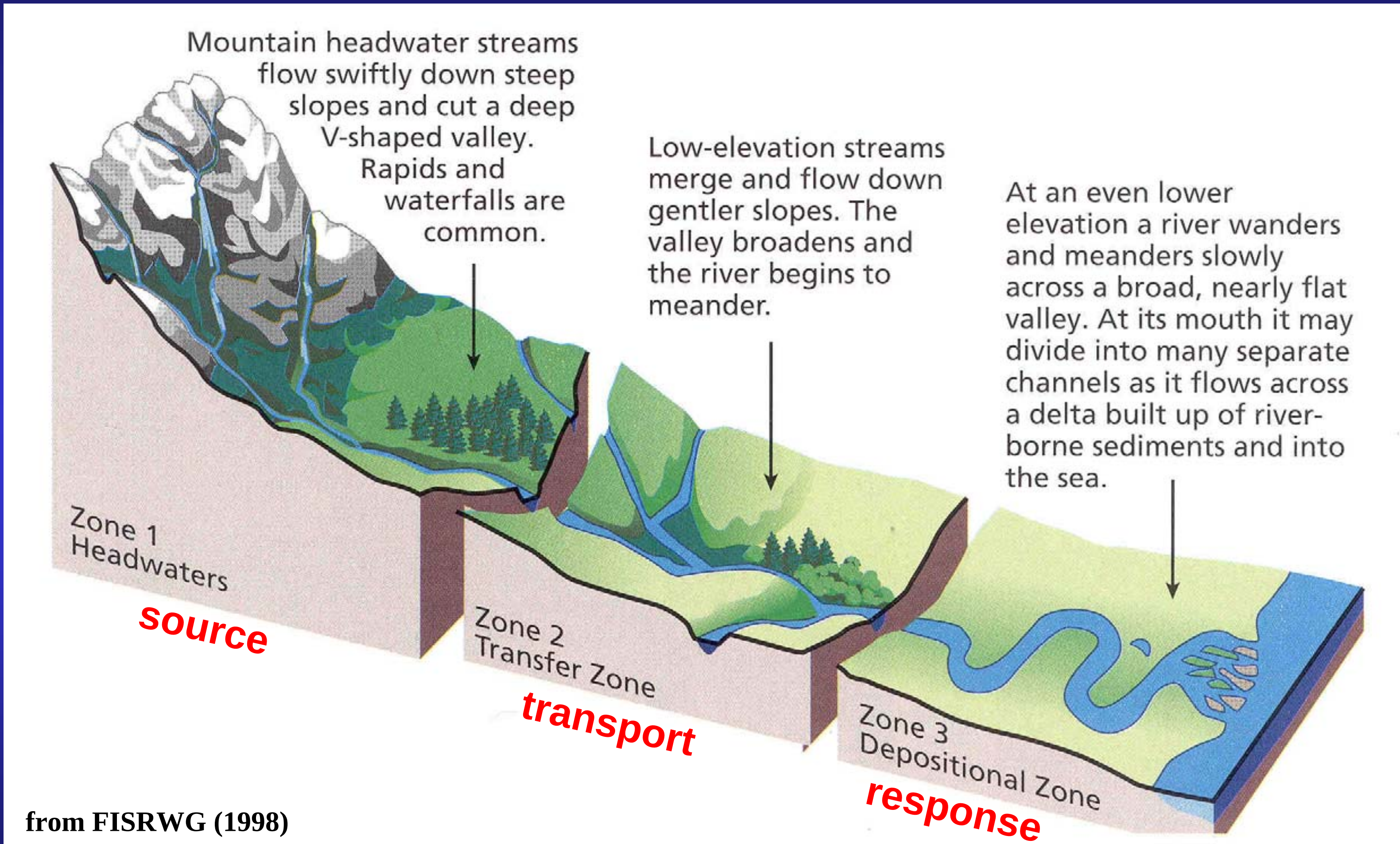
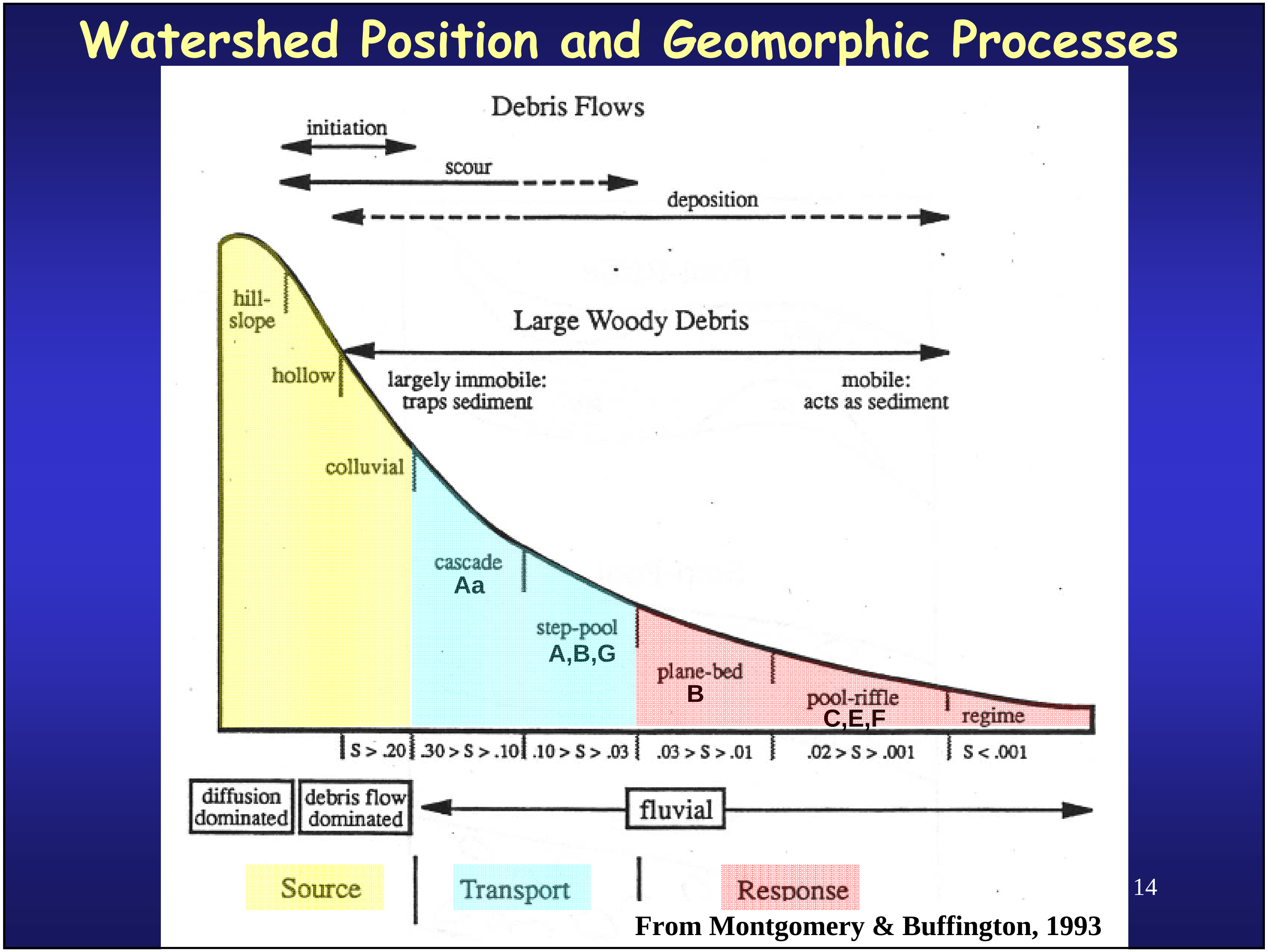
Channel Position in Watershed

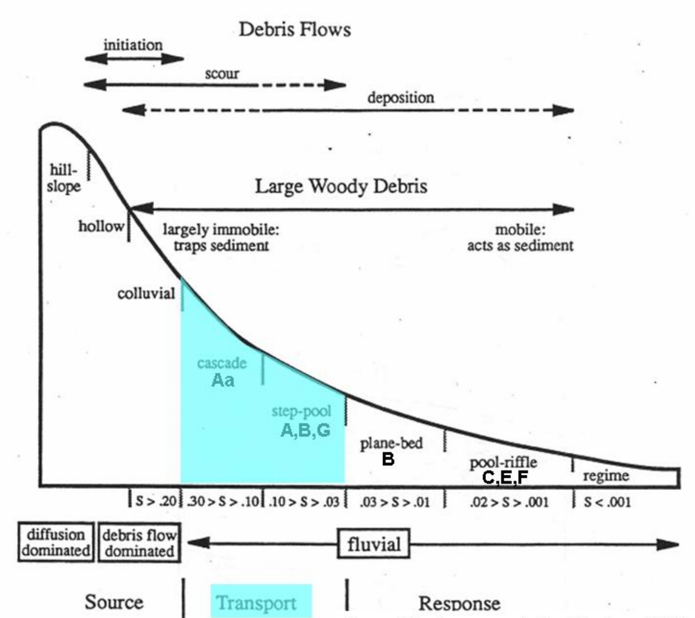


from FISRWG (1998)

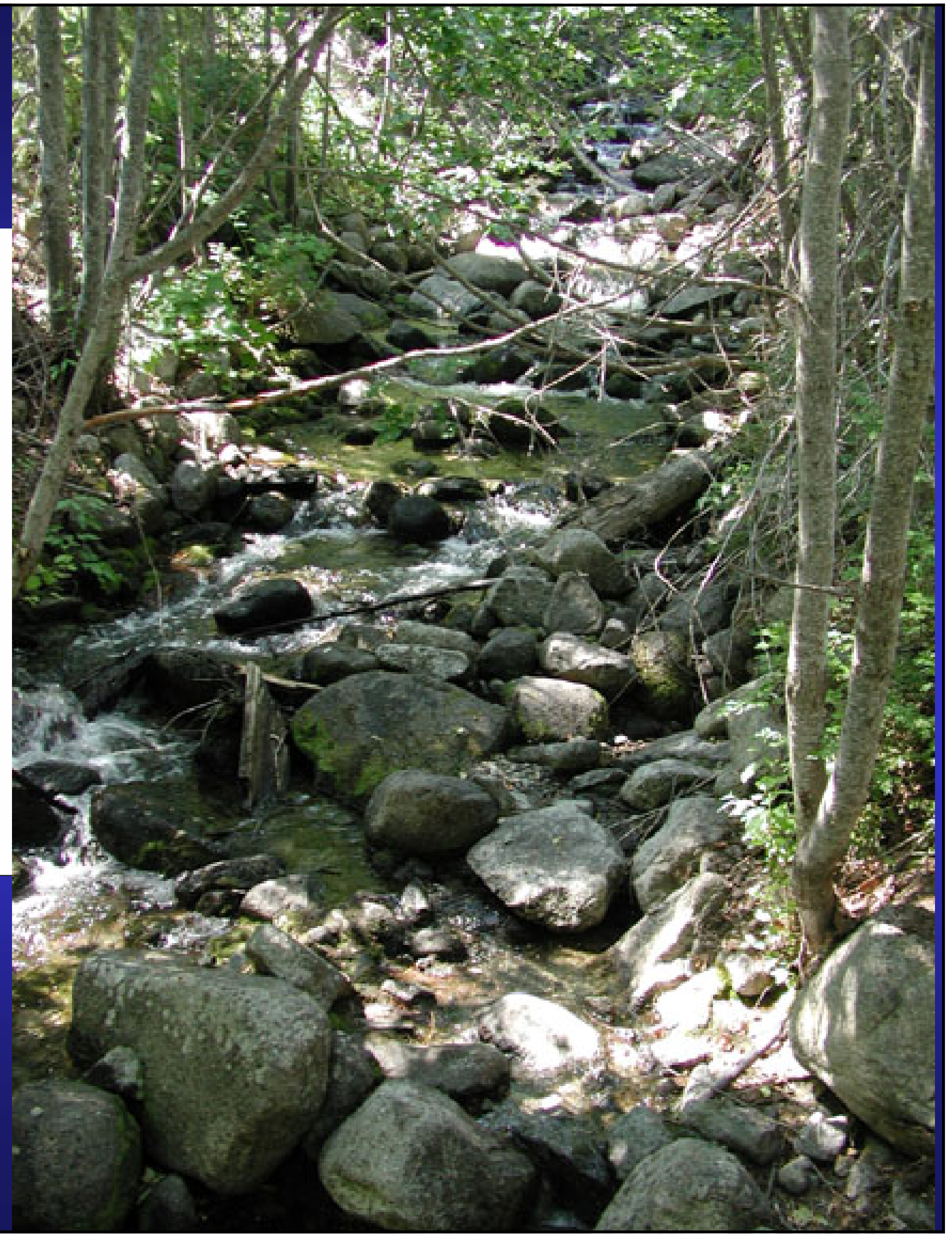
13

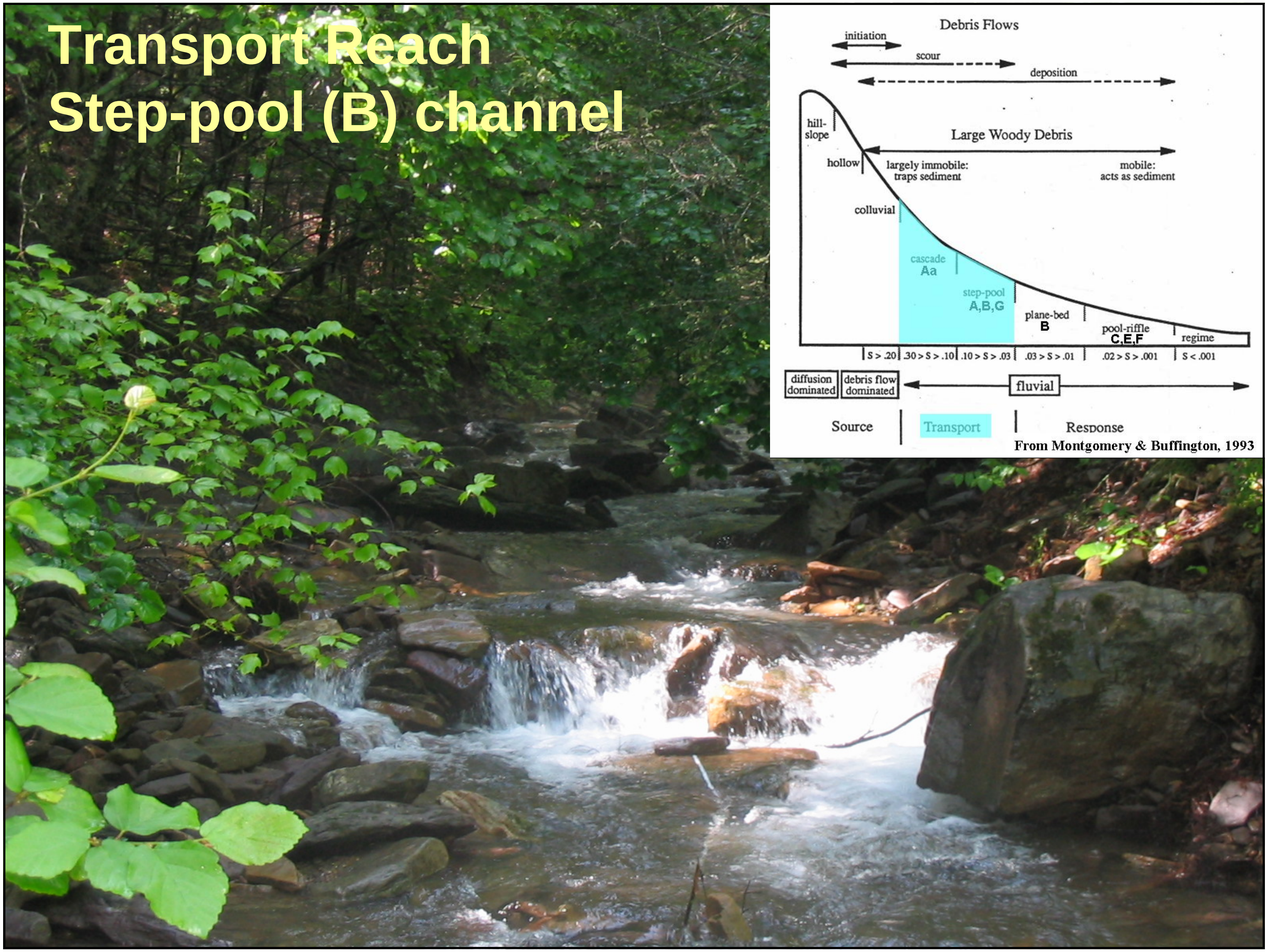

Watershed Position and Geomorphic Processes
Debris Flows
initiation
scour
deposition
hill-slope
hollow
Large Woody Debris
largely immobile: traps sediment
mobile: acts as sediment
colluvial
cascade
Aa
step-pool
A,B,G
plane-bed
B
pool-riffle
C,E,F
regime
S > .20
.30 > S > .10
.10 > S > .03
.03 > S > .01
.02 > S > .001
S < .001
diffusion dominated
debris flow dominated
fluvial
Source
Transport
Response
From Montgomery & Buffington, 1993
14

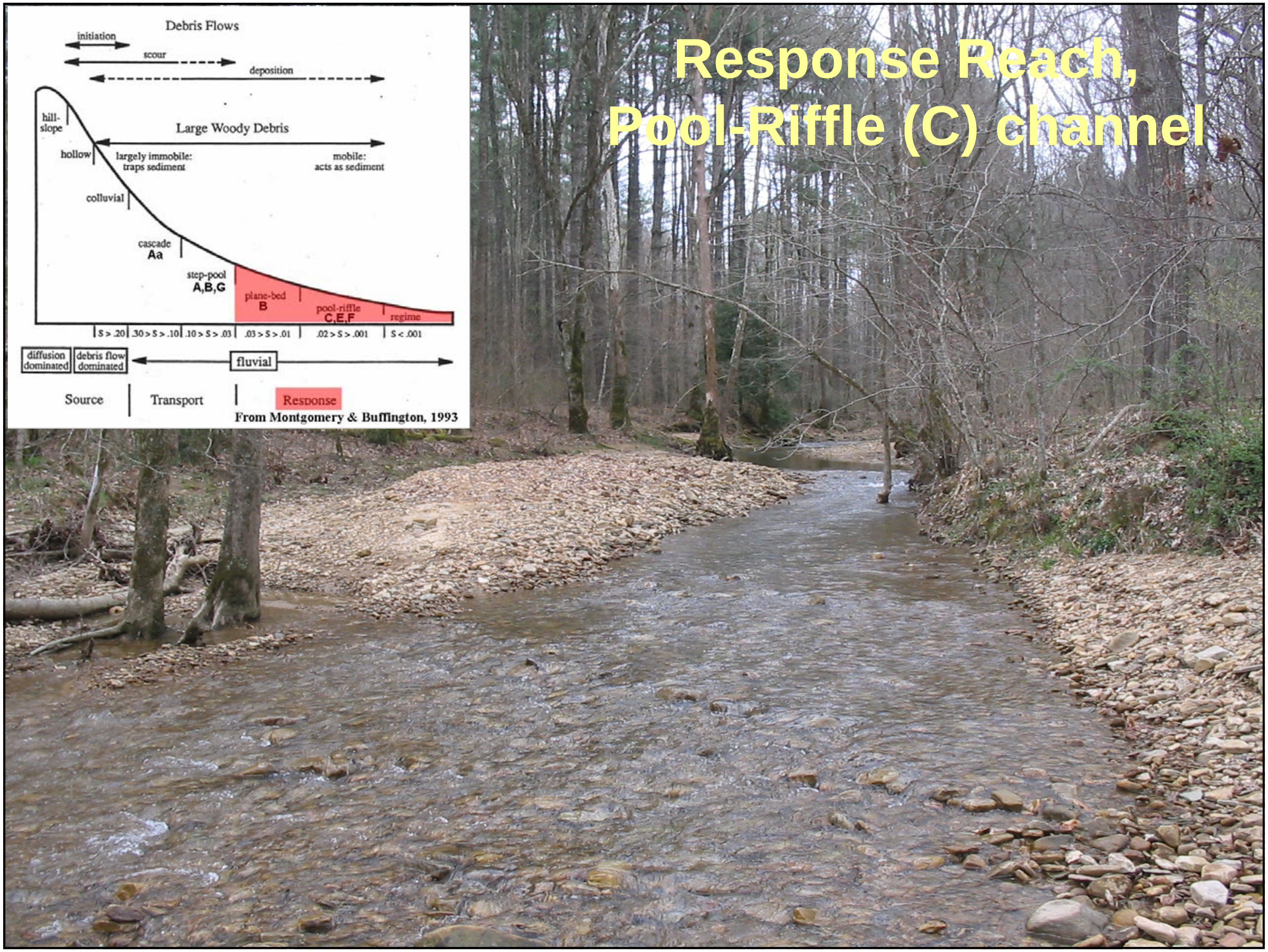
Transport Reach
Cascade (Aa) channel

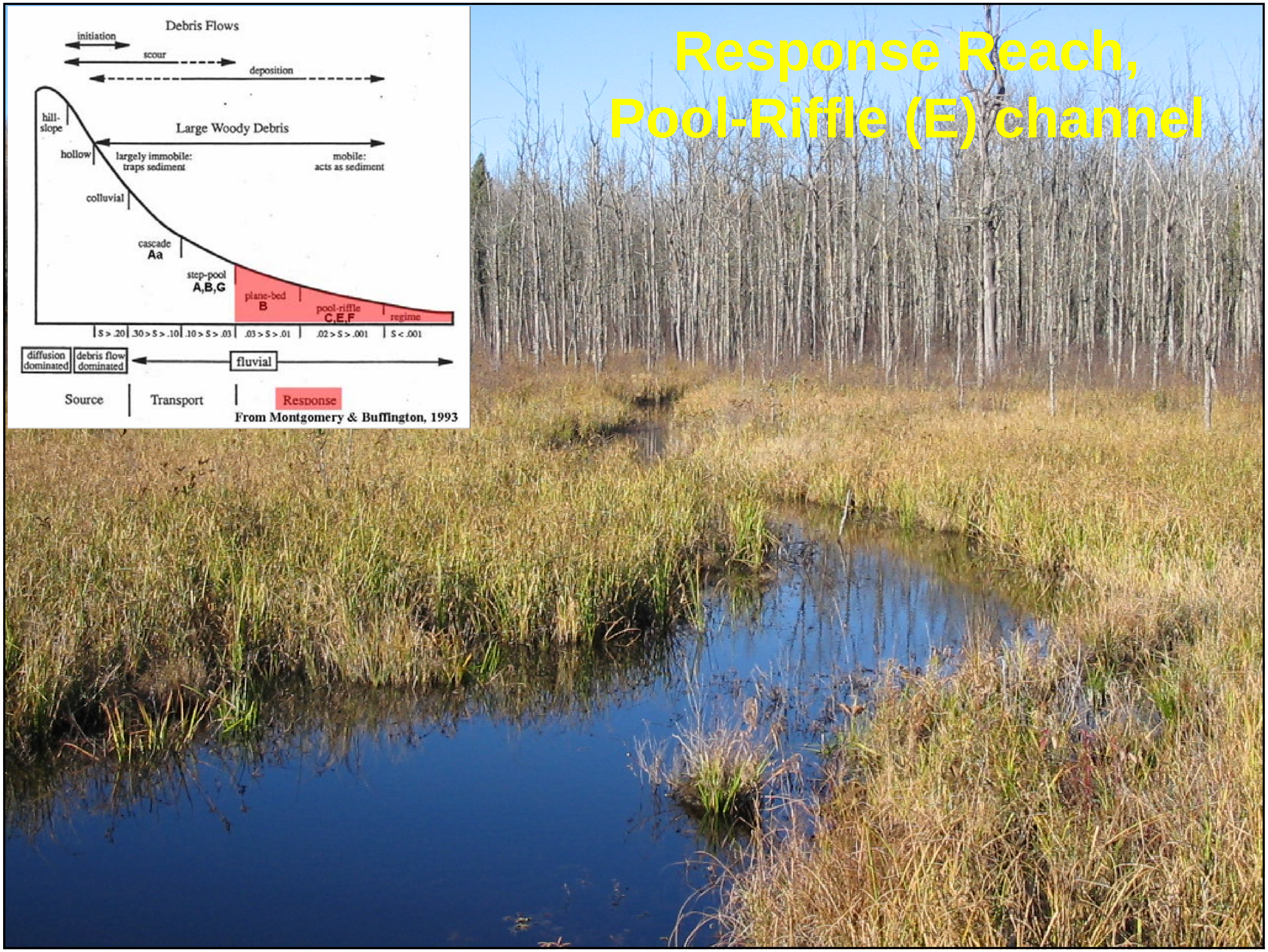


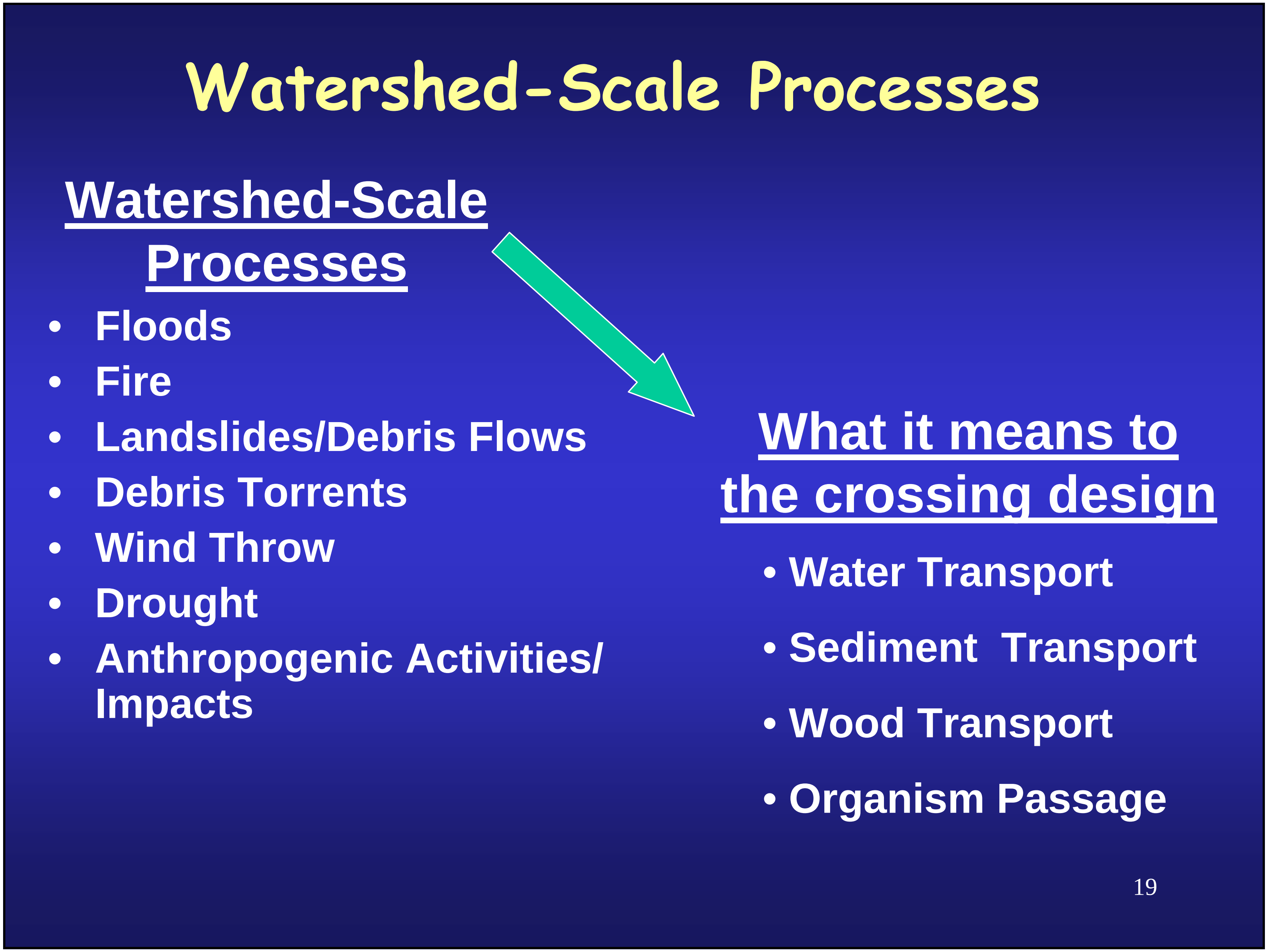
From Montgomery & Buffington, 1993




Transport Reach
Step-pool (B) channel
Debris Flows
initiation
scour
deposition
hill-slope
hollow
Large Woody Debris
largely immobile: traps sediment
mobile: acts as sediment
colluvial
cascade Aa
step-pool A,B,G
plane-bed B
pool-riffle C,E,F
regime
S > .20
.30 > S > .10
.10 > S > .03
.03 > S > .01
.02 > S > .001
S < .001
diffusion dominated
debris flow dominated
fluvial
Source
Transport
Response
From Montgomery & Buffington, 1993

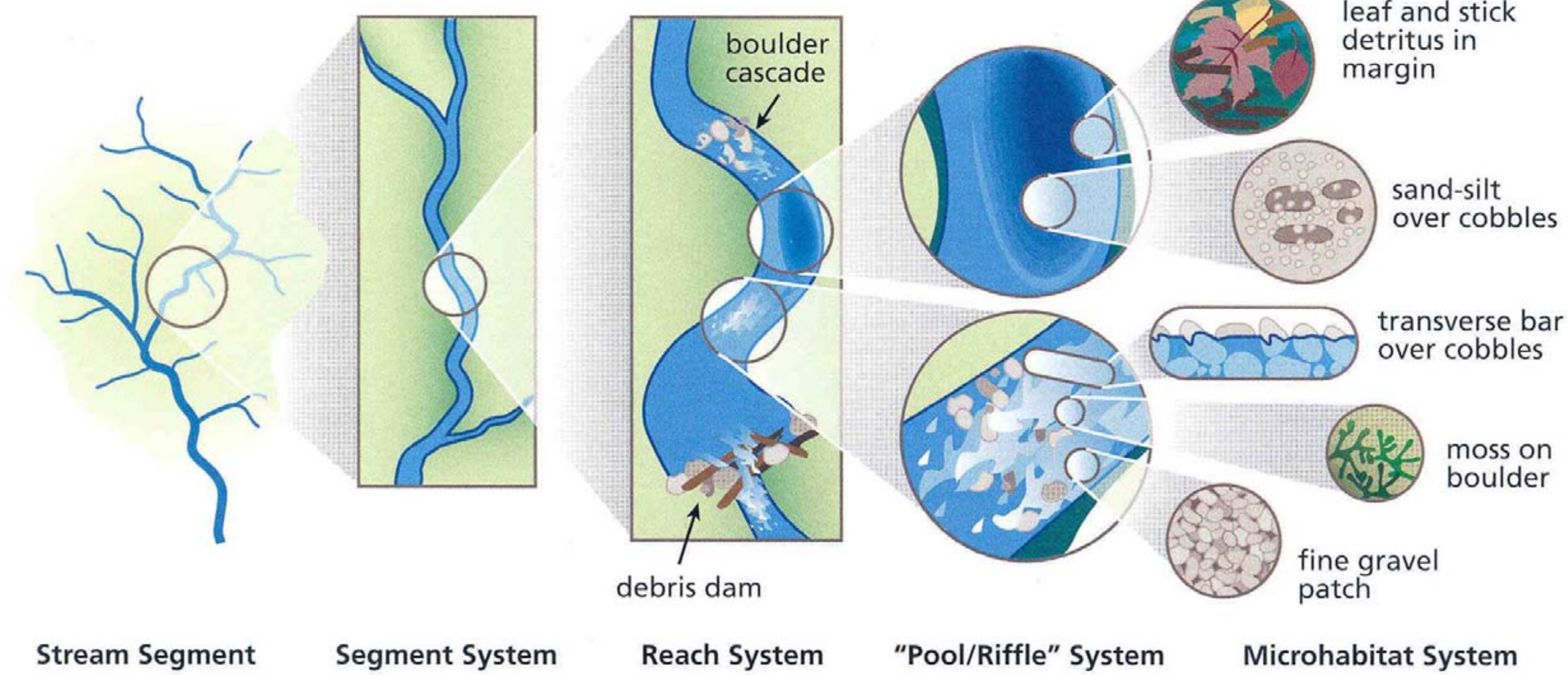

Response Reach,
Pool-Riffle (C) channel
Debris Flows
initiation
scour
deposition
hill-
slope
hollow
Large Woody Debris
largely immobile:
traps sediment
mobile:
acts as sediment
colluvial
cascade
Aa
step-pool
A,B,G
plane-bed
B
pool-riffle
C,E,F
regime
S > .20
.30 > S > .10
.10 > S > .03
.03 > S > .01
.02 > S > .001
S < .001
diffusion
dominated
debris flow
dominated
fluvial
Source
Transport
Response
From Montgomery & Buffington, 1993


Response Reach,
Pool-Riffle (E) channel
Debris Flows
initiation
scour
deposition
hill-slope
hollow
Large Woody Debris
largely immobile: traps sediment
mobile: acts as sediment
colluvial
cascade
Aa
step-pool
A,B,G
plane-bed
B
pool-riffle
C,E,F
regime
S > .20
.30 > S > .10
.10 > S > .03
.03 > S > .01
.02 > S > .001
S < .001
diffusion dominated
debris flow dominated
fluvial
Source
Transport
Response
From Montgomery & Buffington, 1993


Watershed-Scale Processes
Watershed-Scale Processes
• Floods
• Fire
• Landslides/Debris Flows
• Debris Torrents
• Wind Throw
• Drought
• Anthropogenic Activities/ Impacts
What it means to the crossing design
• Water Transport
• Sediment Transport
• Wood Transport
• Organism Passage
19

Spatial Scale of Stream Channels

from FISRWG, 1998



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- **Channel Characteristics and Fluvial Processes**
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  - **Channel-bed material**
- **Channel Classifications**
- **Understanding and Predicting Channel Adjustments/Responses**

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Channel-Forming Discharges

A range of flows (2/3 bankfull to the 25-year flood) are most influential in forming and maintaining the channel

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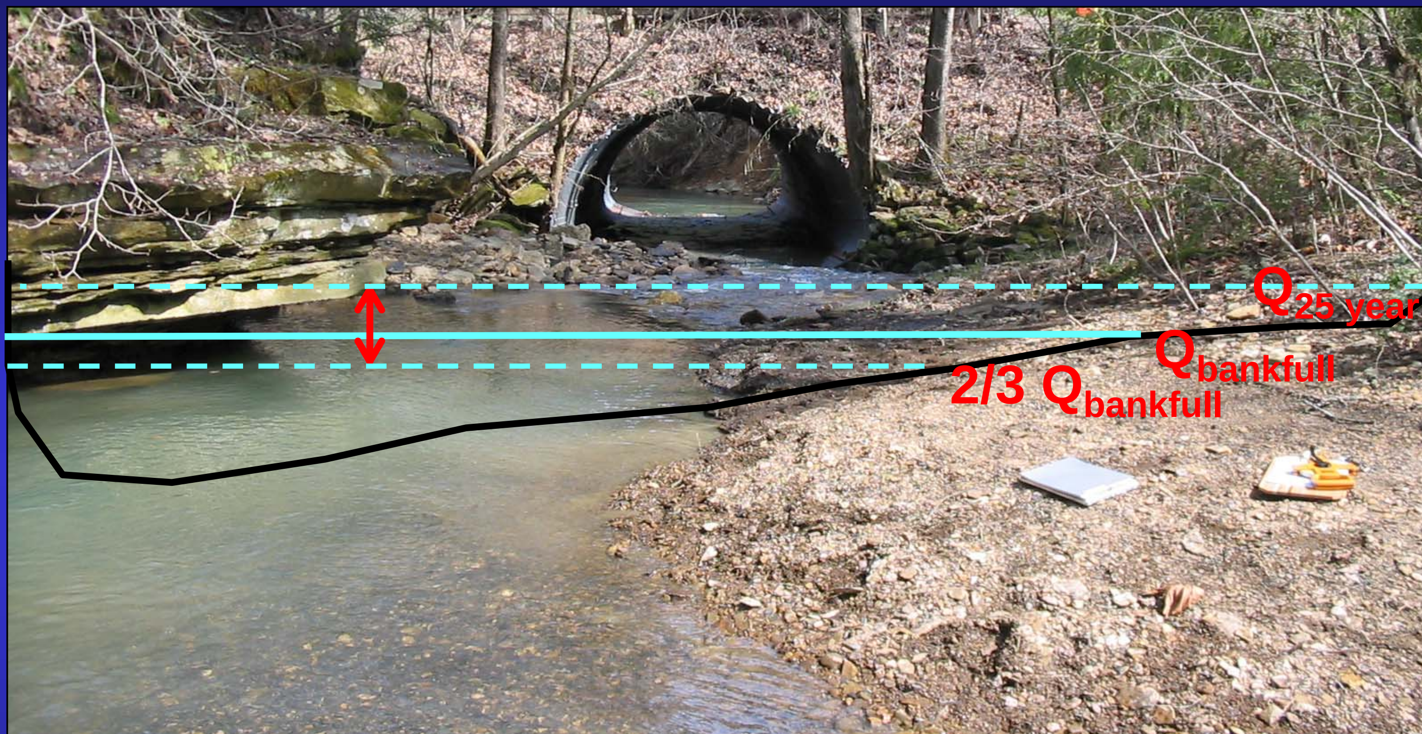
What is the Purpose/Significance of Identifying Bankfull Flow Conditions?



- **Bankfull discharge is an index of the range of flows that shape the channel and floodplain**
- **Usually transports more sediment over time than any other discharge**
- **Typically occurs on average every 1 – 3 years**

23

Why are bankfull discharge and bankfull width important at road-stream crossings?

Culverts less than bankfull width can lead to debris and/or bedload blockage and structure failure

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Why are bankfull discharge and bankfull width important at road-stream crossings?

- **Crossing widths less than bankfull width increase channel velocities through the structure and form perches at the culvert outlet, which in turn cause aquatic organism passage problems**

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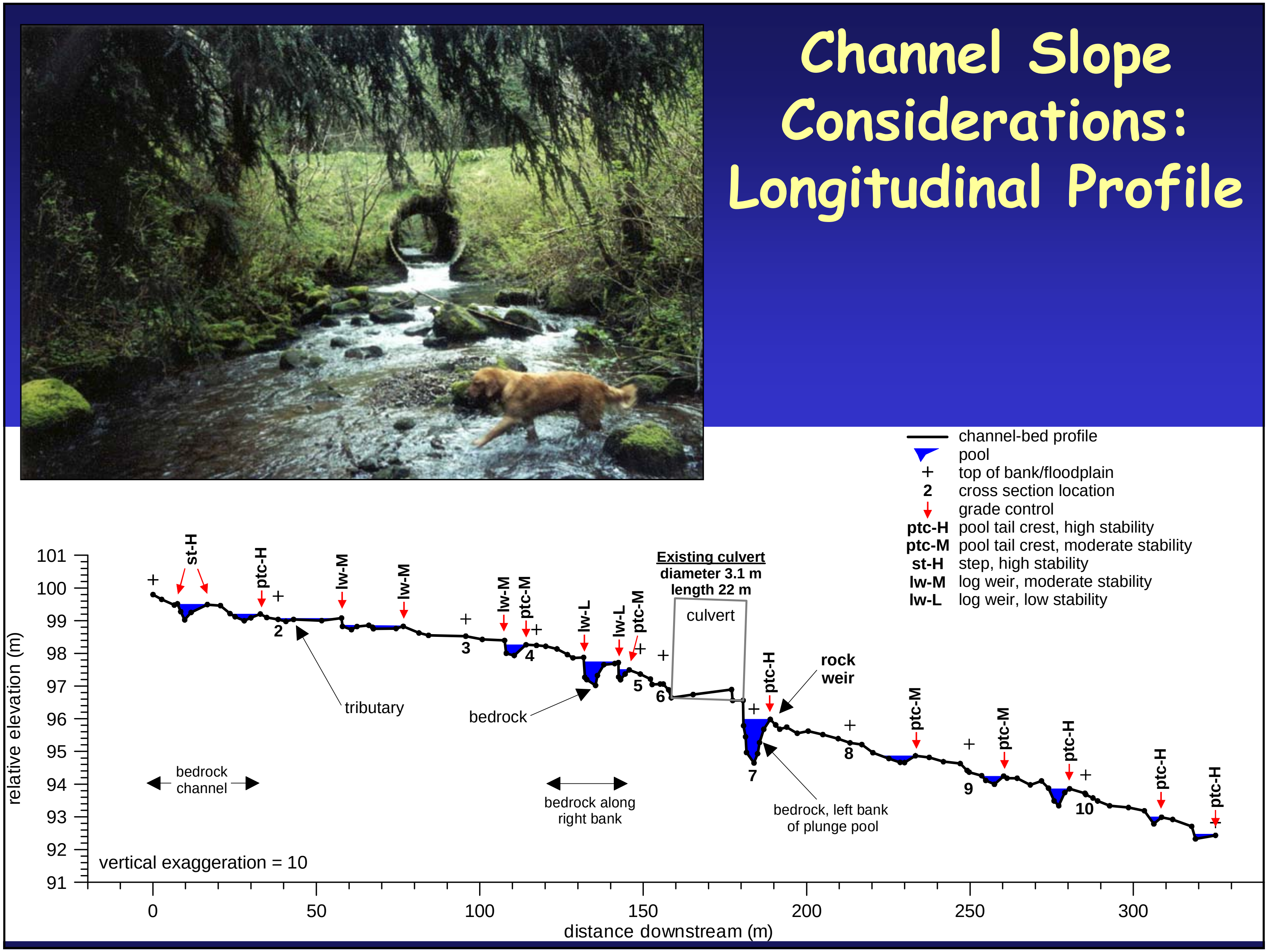
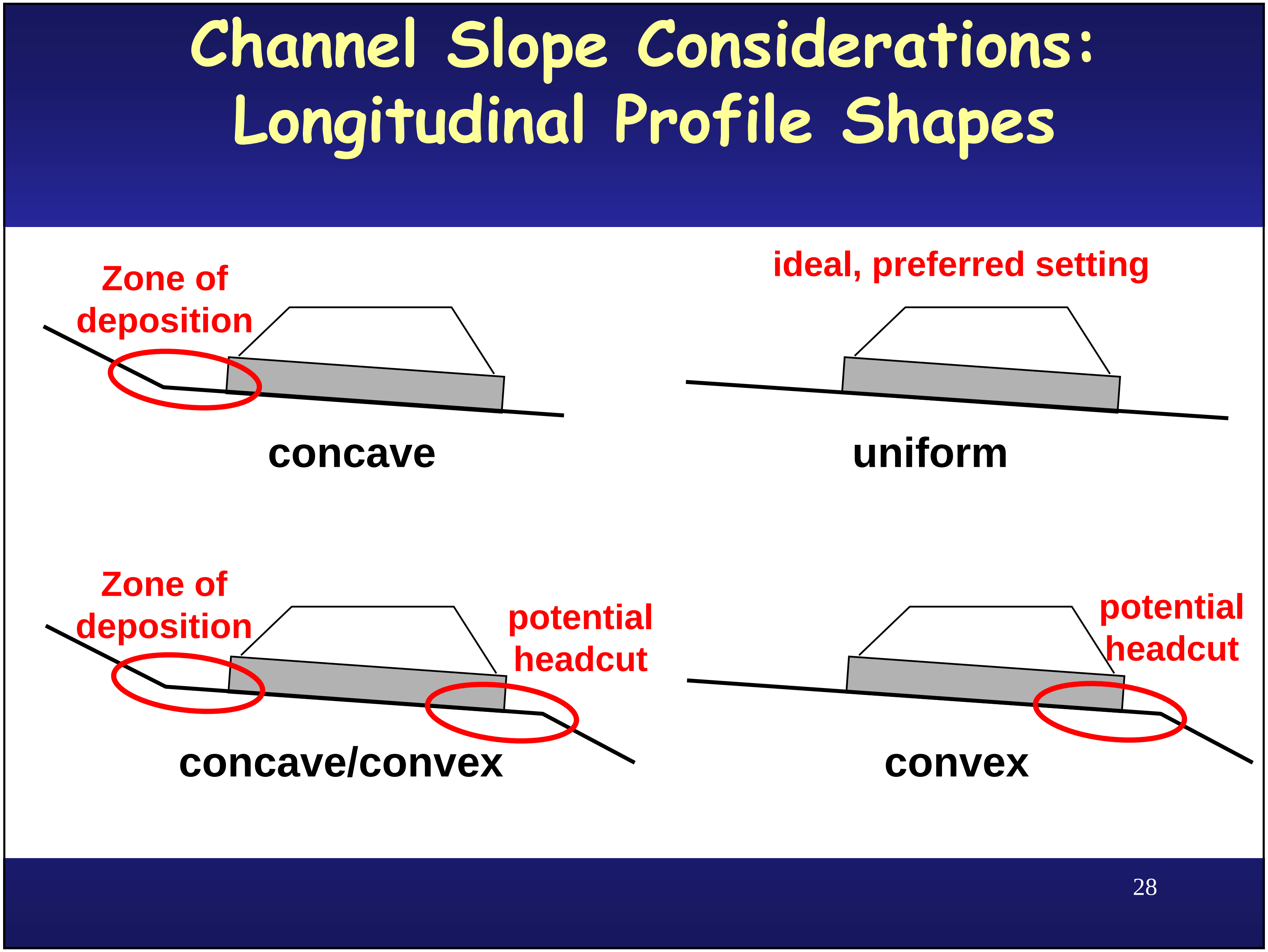
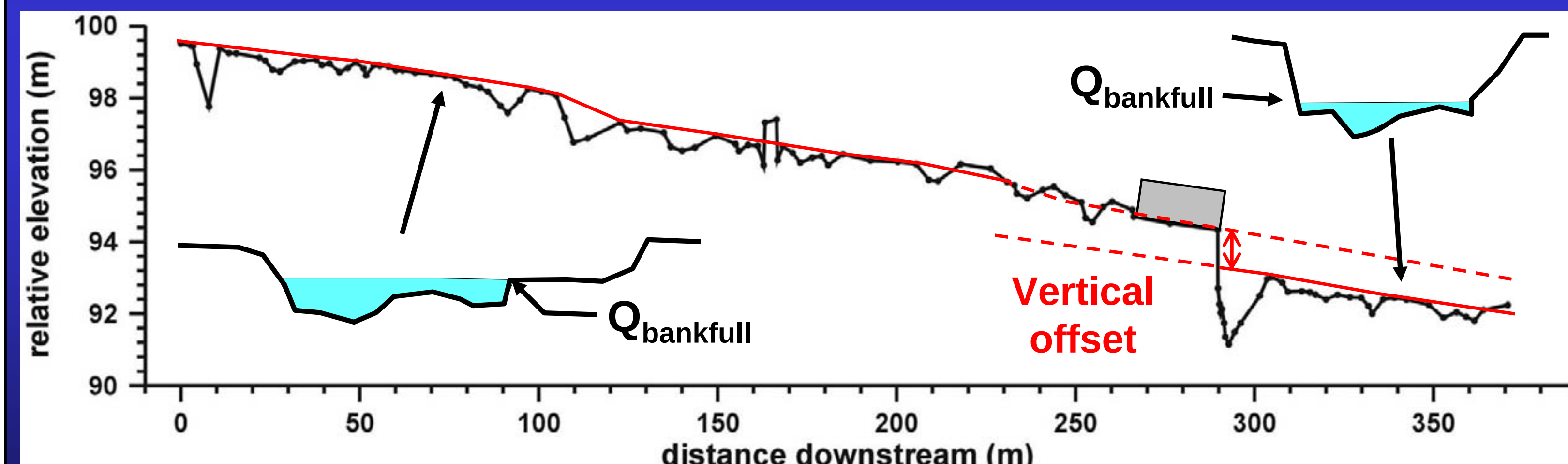

Channel Slope Considerations: Longitudinal Profile
channel-bed profile
pool
top of bank/floodplain
2 cross section location
grade control
ptc-H pool tail crest, high stability
ptc-M pool tail crest, moderate stability
st-H step, high stability
lw-M log weir, moderate stability
lw-L log weir, low stability
Existing culvert
diameter 3.1 m
length 22 m
culvert
rock weir
tributary
bedrock
bedrock channel
bedrock along right bank
bedrock, left bank of plunge pool
vertical exaggeration = 10
relative elevation (m)
distance downstream (m)

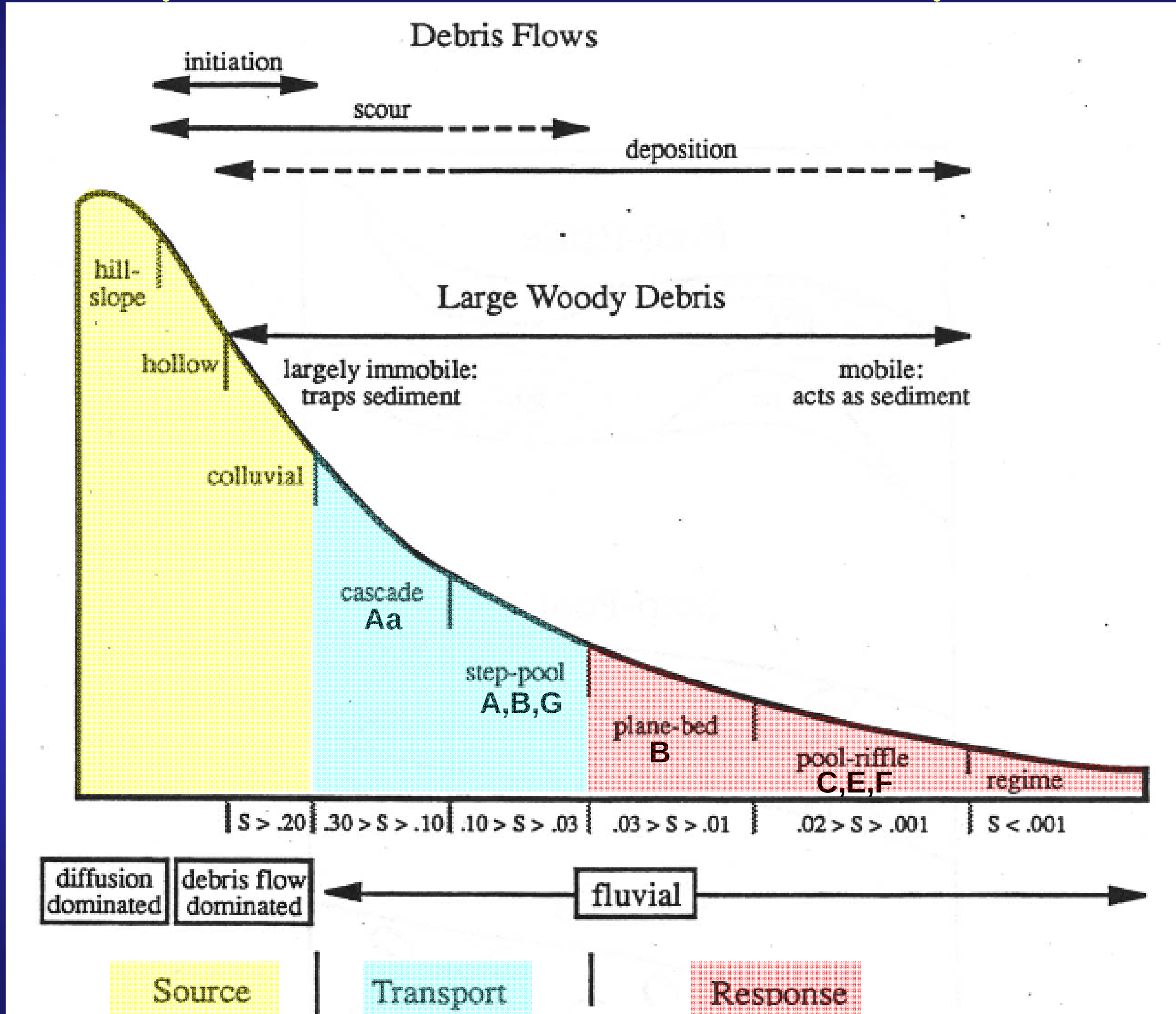

Channel Slope Considerations:
Longitudinal Profile Shapes
Zone of deposition
concave
ideal, preferred setting
uniform
Zone of deposition
potential headcut
concave/convex
potential headcut
convex
28

Channel Slope Considerations: Longitudinal Profile Shapes



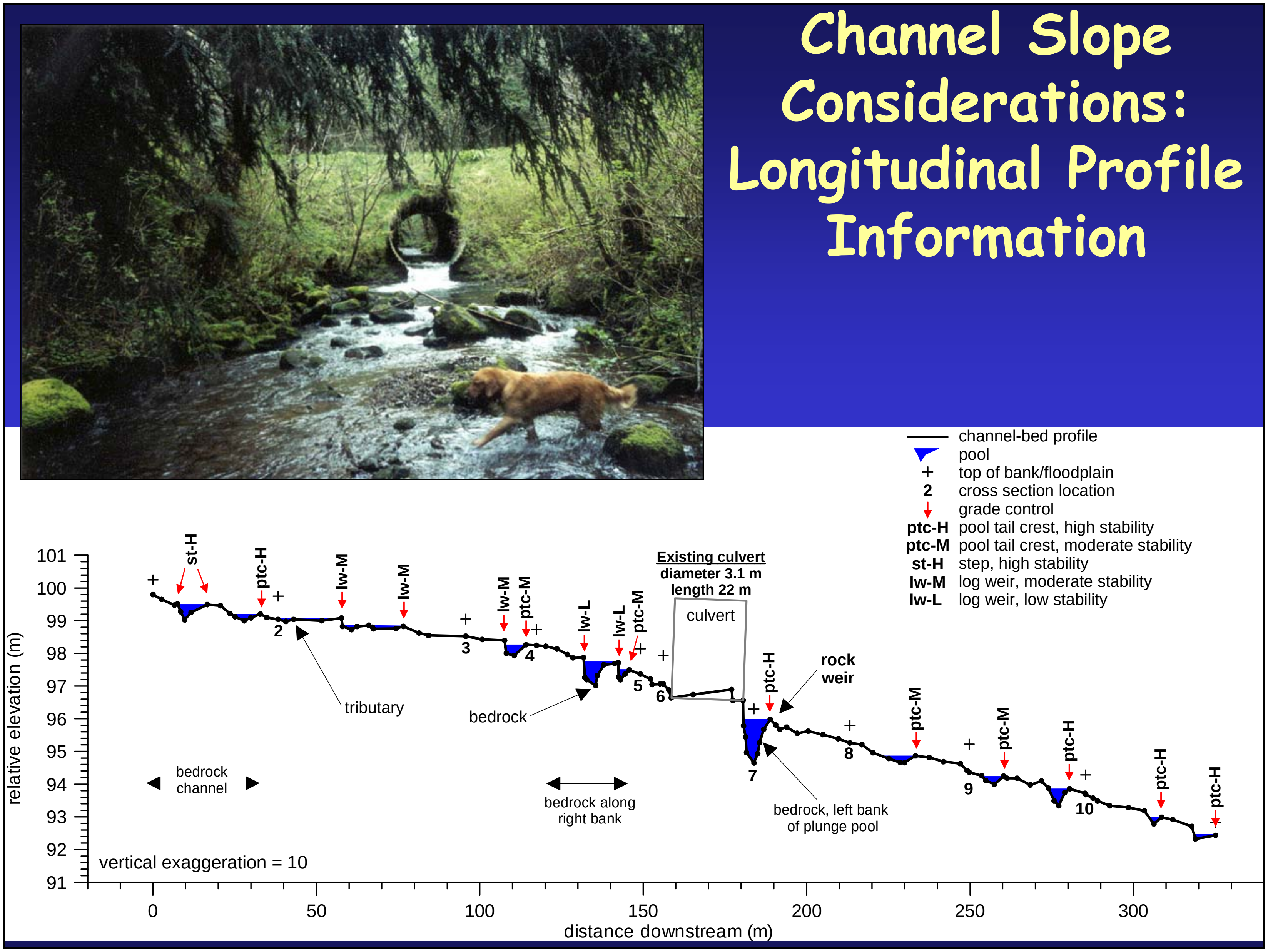
The longitudinal profile can identify possible system-wide channel degradation.

Channel Slope Considerations: Geomorphic Processes



From Montgomery & Buffington, 1993

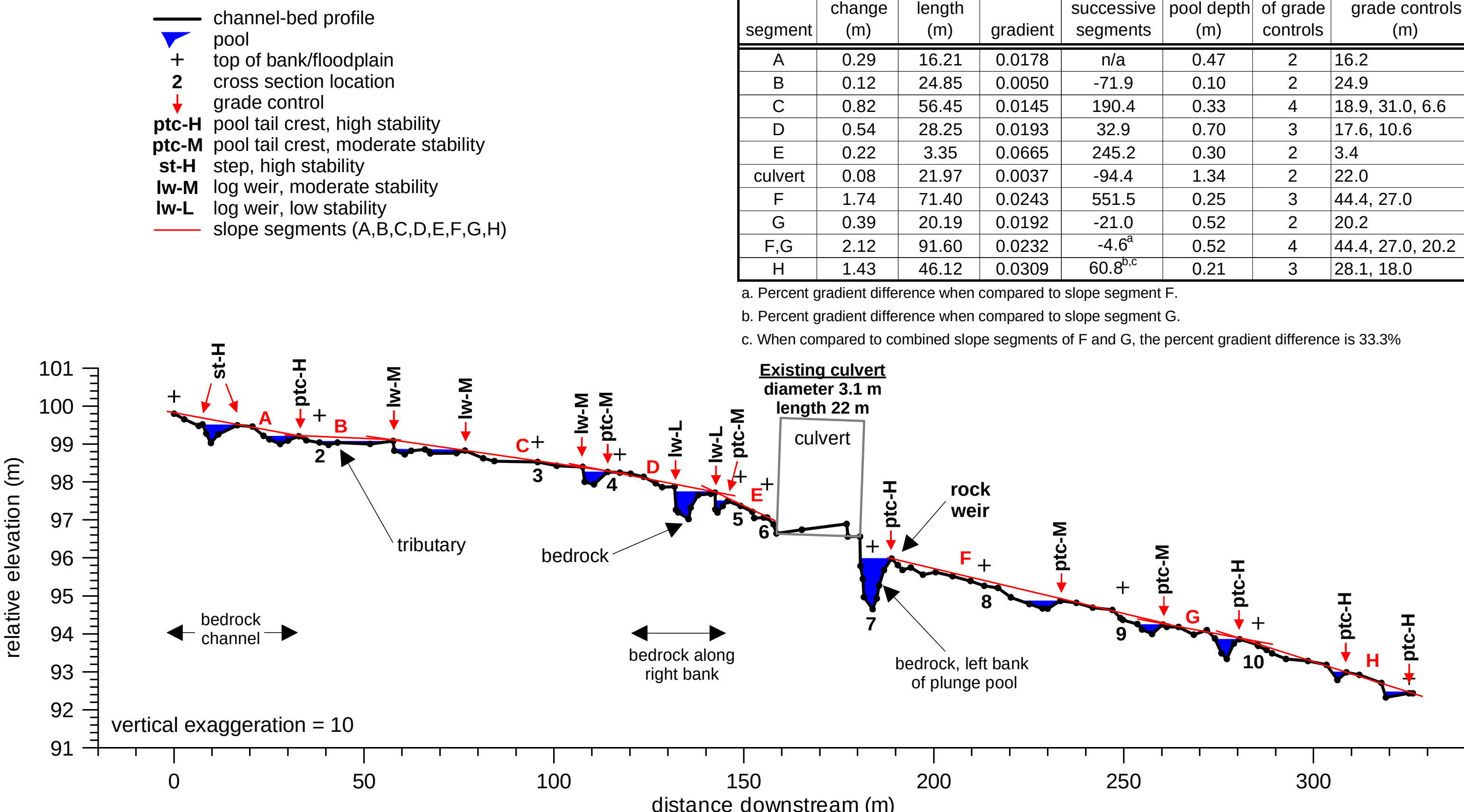
30


Channel Slope Considerations: Longitudinal Profile Information
channel-bed profile
pool
+ top of bank/floodplain
2 cross section location
grade control
ptc-H pool tail crest, high stability
ptc-M pool tail crest, moderate stability
st-H step, high stability
lw-M log weir, moderate stability
lw-L log weir, low stability
Existing culvert
diameter 3.1 m
length 22 m
culvert
rock weir
tributary
bedrock
bedrock channel
bedrock along right bank
bedrock, left bank of plunge pool
vertical exaggeration = 10
relative elevation (m)
distance downstream (m)
st-H
ptc-H
lw-M
lw-M
lw-M
ptc-M
lw-L
lw-L
ptc-M
ptc-H
ptc-M
ptc-M
ptc-H
ptc-H
ptc-H
2
3
4
5
6
7
8
9
10
101
100
99
98
97
96
95
94
93
92
91
0
50
100
150
200
250
300

Channel Slope Considerations: Longitudinal Profile Information

segment	elevation change (m)	segment length (m)	gradient	% gradient difference between successive segments	maximum residual pool depth (m)	number of grade controls	distance between grade controls (m)
A	0.29	16.21	0.0178	n/a	0.47	2	16.2
B	0.12	24.85	0.0050	-71.9	0.10	2	24.9
C	0.82	56.45	0.0145	190.4	0.33	4	18.9, 31.0, 6.6
D	0.54	28.25	0.0193	32.9	0.70	3	17.6, 10.6
E	0.22	3.35	0.0665	245.2	0.30	2	3.4
culvert	0.08	21.97	0.0037	-94.4	1.34	2	22.0
F	1.74	71.40	0.0243	551.5	0.25	3	44.4, 27.0
G	0.39	20.19	0.0192	-21.0	0.52	2	20.2
F,G	2.12	91.60	0.0232	-4.6[a]	0.52	4	44.4, 27.0, 20.2
H	1.43	46.12	0.0309	60.8[b,c]	0.21	3	28.1, 18.0

a. Percent gradient difference when compared to slope segment F.
b. Percent gradient difference when compared to slope segment G.
c. When compared to combined slope segments of F and G, the percent gradient difference is 33.3%



The longitudinal profile determines bedform spacing, key grade controls, gradient variability, and scour depth ranges

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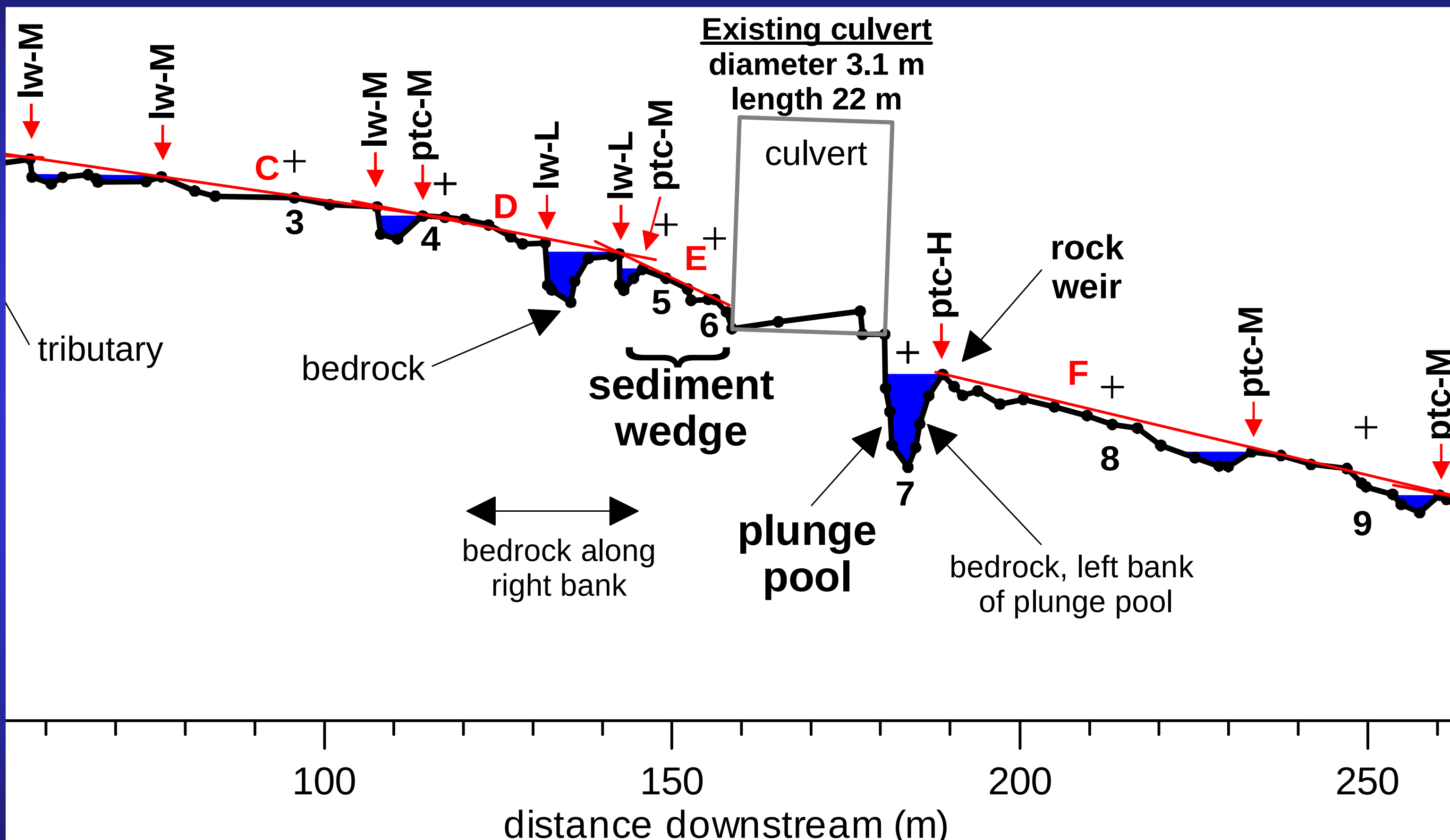
Channel Slope Considerations: Longitudinal Profile Information



The longitudinal profile determines local degradation and aggradation associated the culvert.

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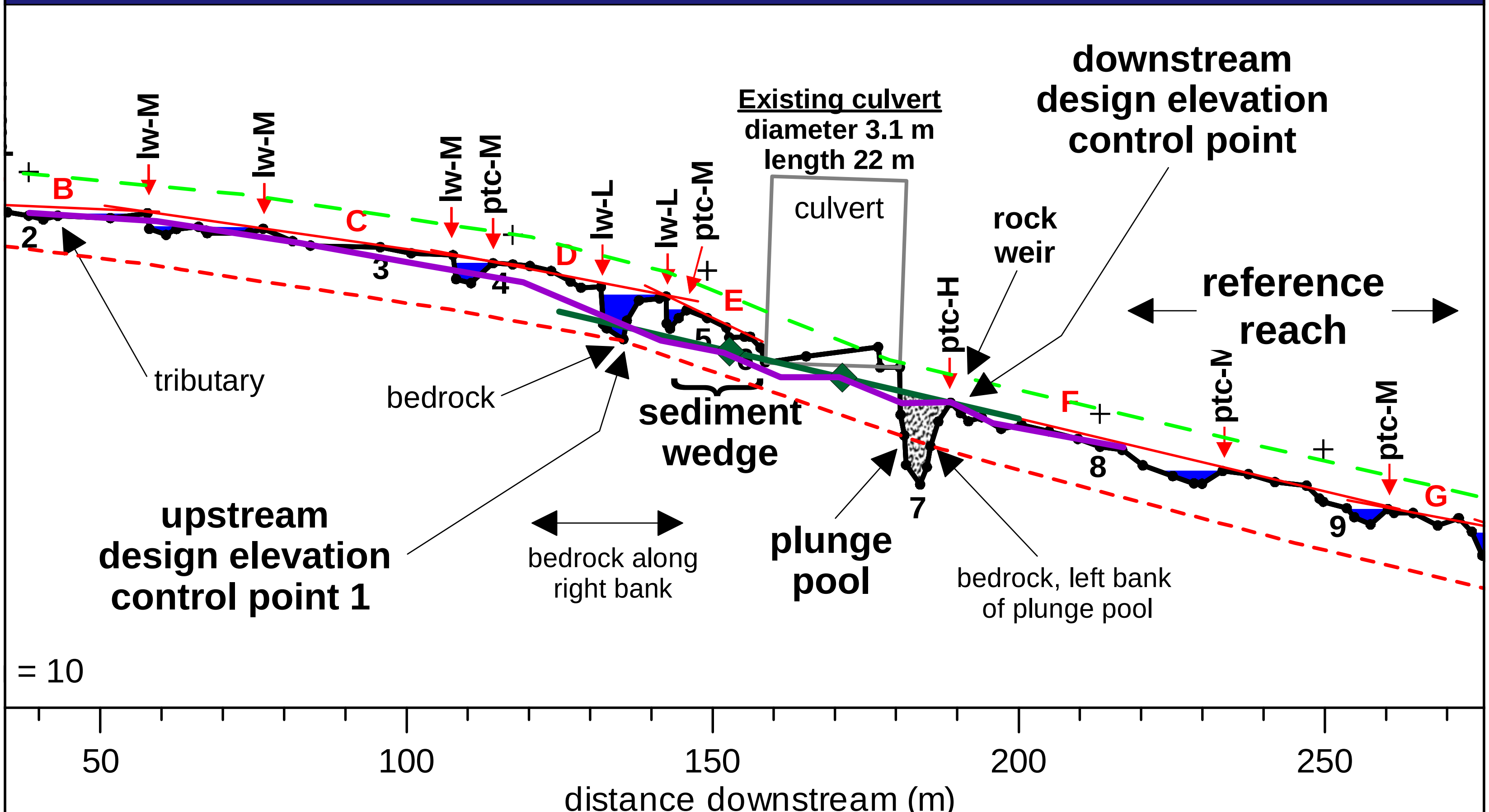
Channel Slope Considerations: Geomorphic Processes



The longitudinal profile is used to develop the design channel profile and spacing of bedforms through the structure.

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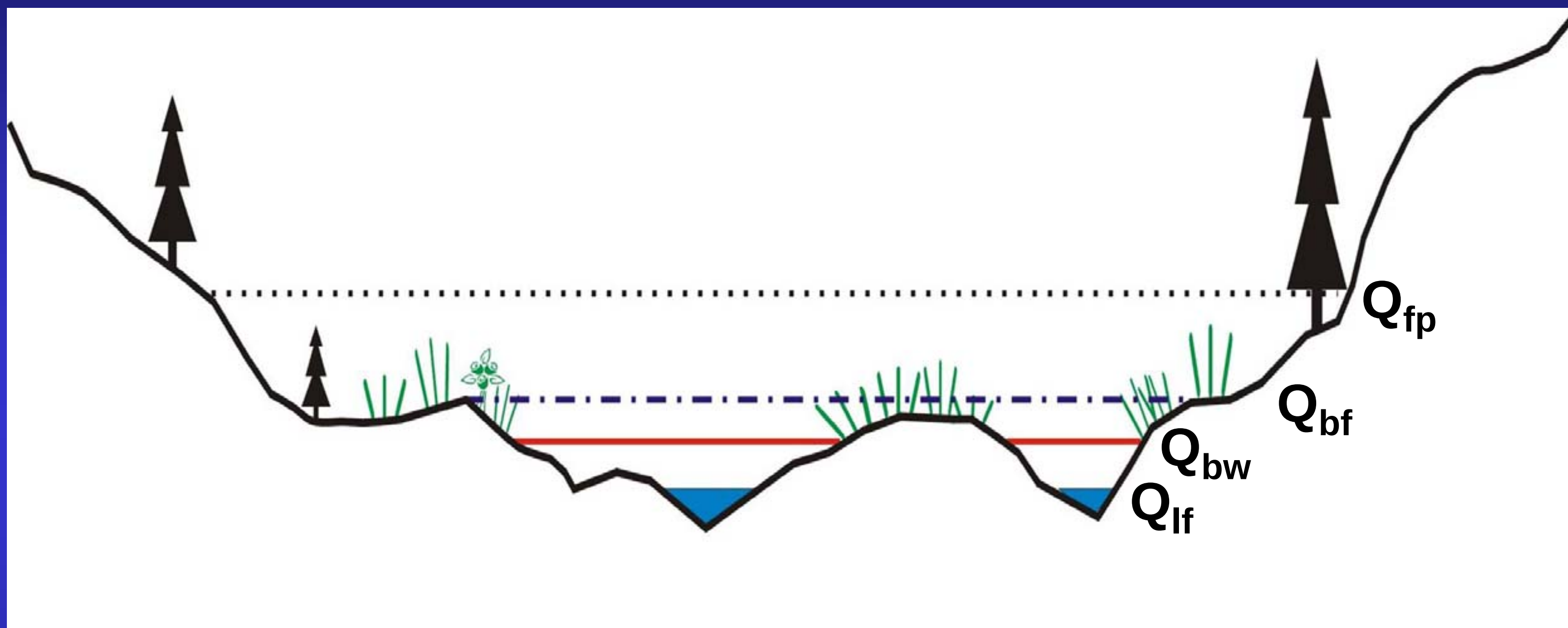
Channel Shape Considerations



- **Establishes the natural dimensions of the channel**
- **Delineates the width and depth of low flow, the streambed, bankfull flow, floodplain inundation, and channel/slope interactions**

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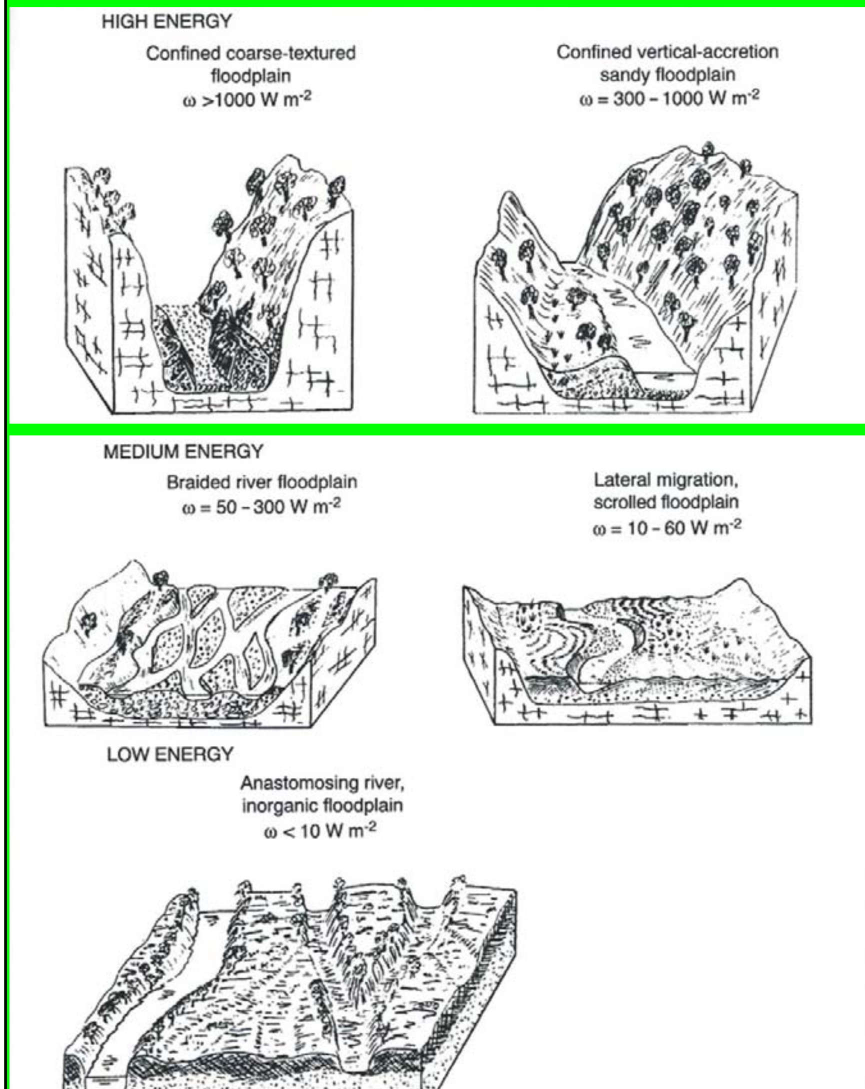
Channel Confinement Considerations



From Knighton, 1998

Confined channels
- High energy
- Straight, high gradient channels
- minimal floodplain development
- Channel migration low
- Slope/channel interactions high

Unconfined channels
- low energy
- Sinuous, low-gradient channels
- Well-developed floodplain
- Channel migration high
- Slope/channel interactions low

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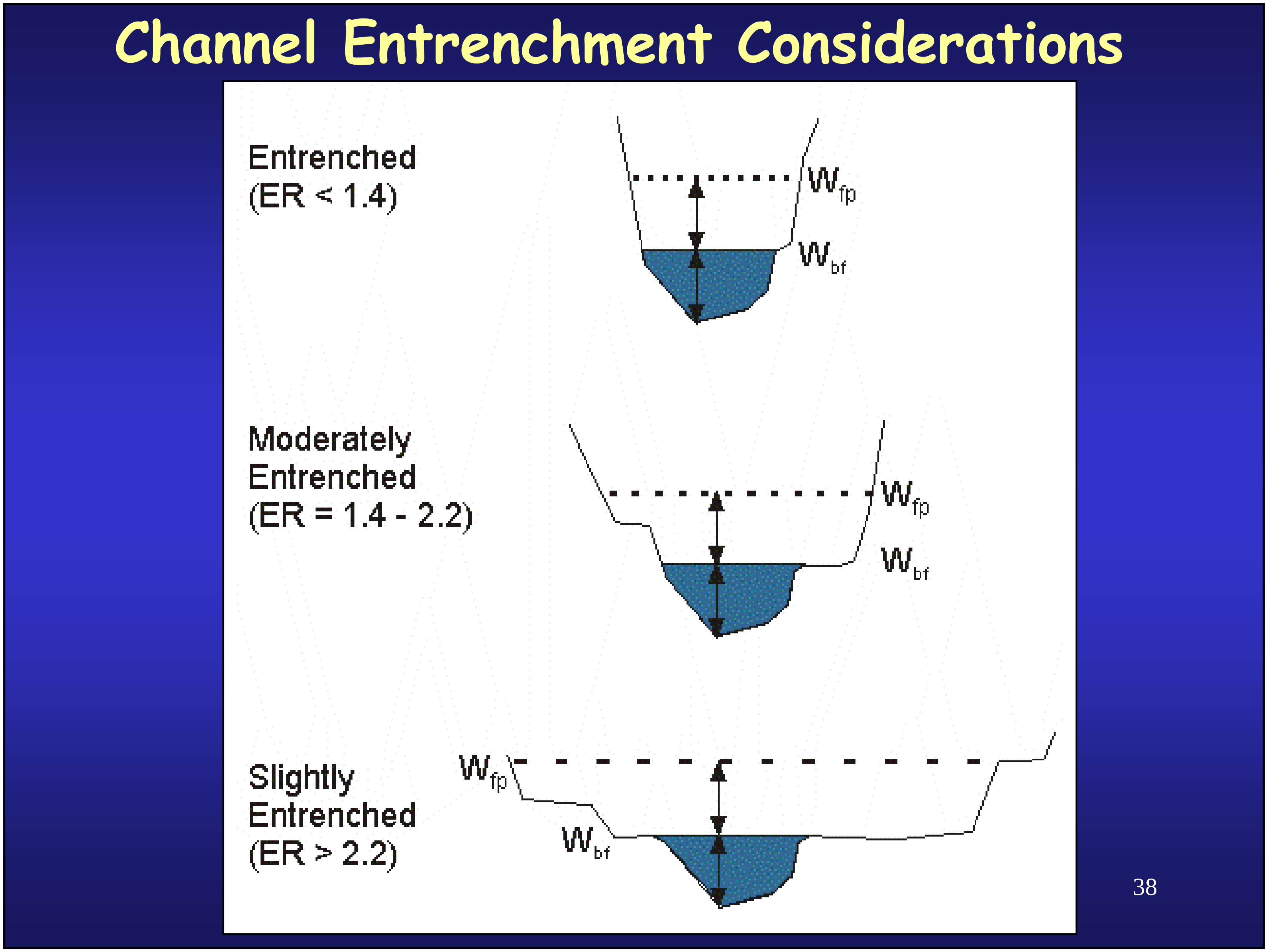
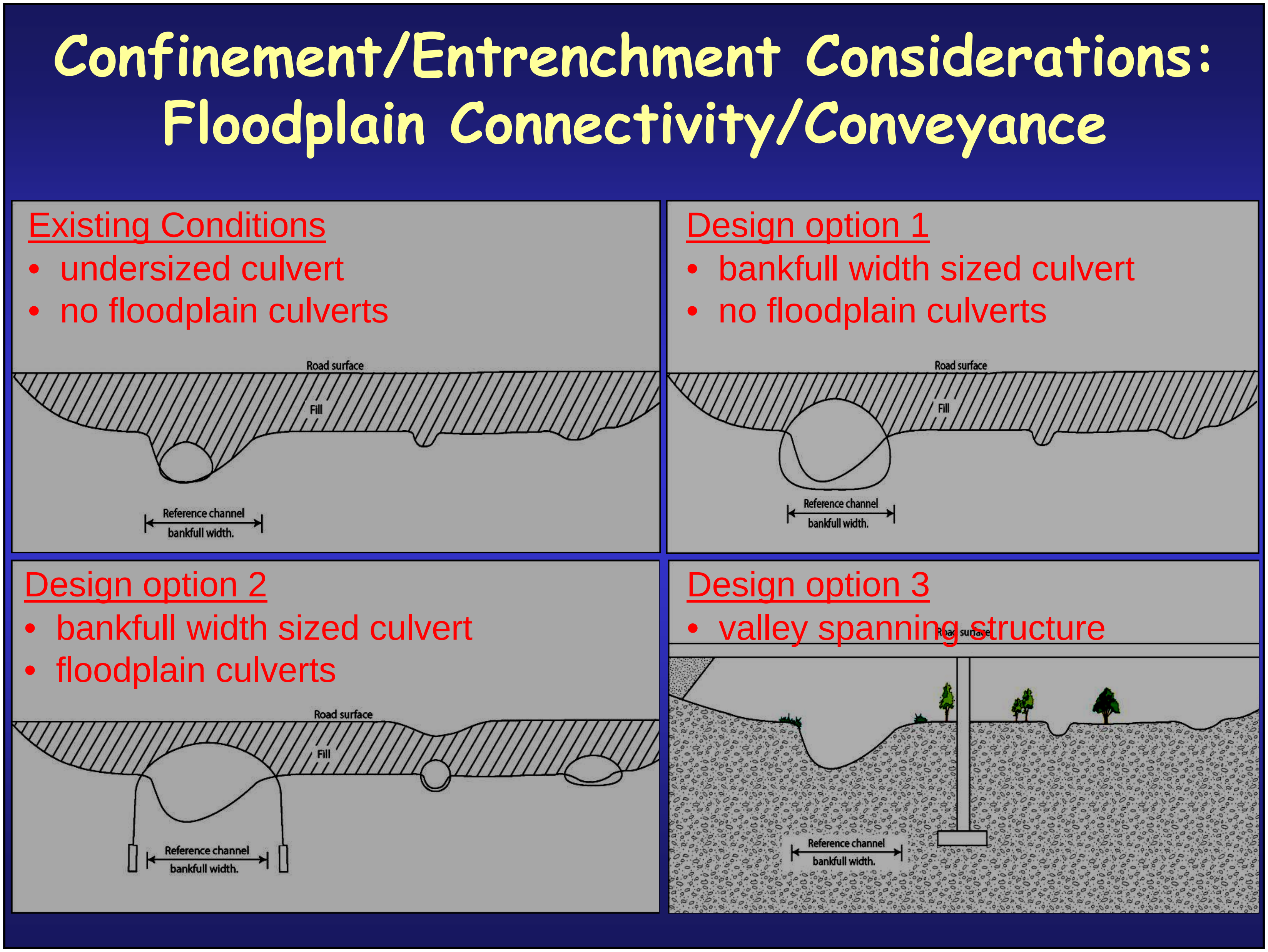

Channel Entrenchment Considerations
Entrenched
(ER < 1.4)
Wfp
Wbf
Moderately
Entrenched
(ER = 1.4 - 2.2)
Wfp
Wbf
Slightly
Entrenched
(ER > 2.2)
Wfp
Wbf
38

Confinement/Entrenchment Considerations: Floodplain Connectivity/Conveyance

9


Confinement/Entrenchment Considerations: Floodplain Connectivity/Conveyance
Existing Conditions
• undersized culvert
• no floodplain culverts
Road surface
Fill
Reference channel
bankfull width.
Design option 1
• bankfull width sized culvert
• no floodplain culverts
Road surface
Fill
Reference channel
bankfull width.
Design option 2
• bankfull width sized culvert
• floodplain culverts
Road surface
Fill
Reference channel
bankfull width.
Design option 3
• valley spanning structure
Road surface
Reference channel
bankfull width.

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Channel Planform Considerations

Channel Planform Considerations

- If possible, locate crossings on straight channel segments
- Accept small skews in channel-road alignment and reinforce banks if necessary
- Interpret and predict the natural planform pattern at the crossing
- May need to perform channel restoration to recreate natural geometries

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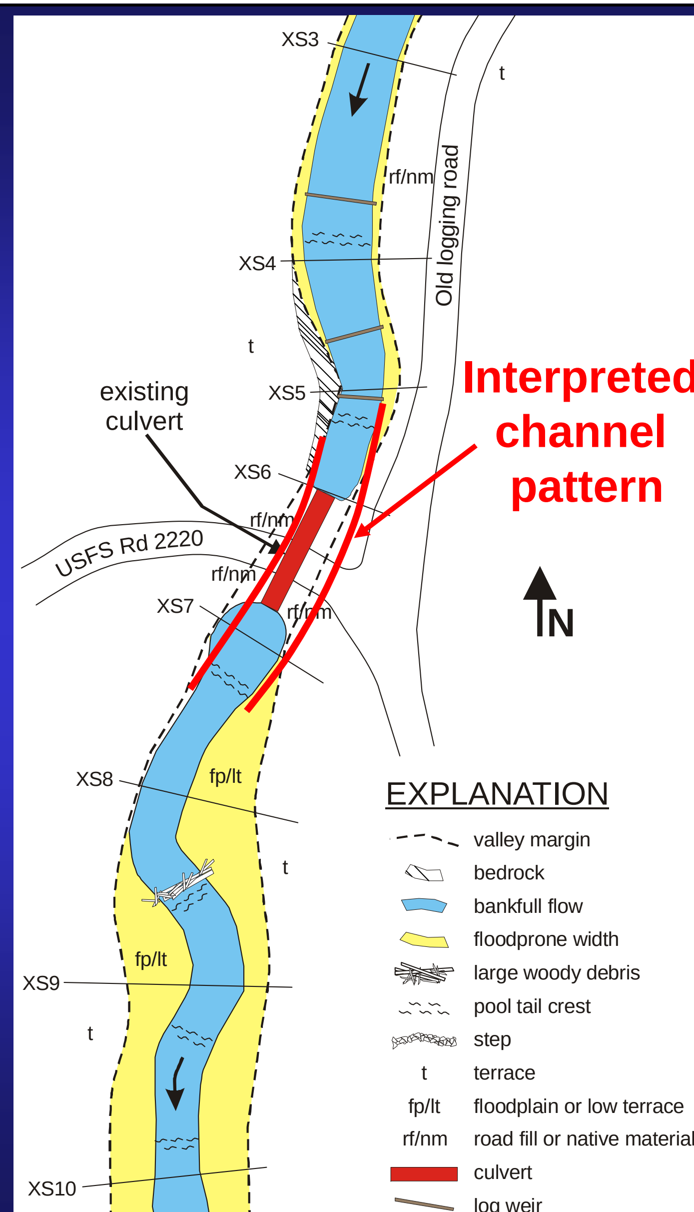
Channel Planform Considerations



Channel-Bank Patterns

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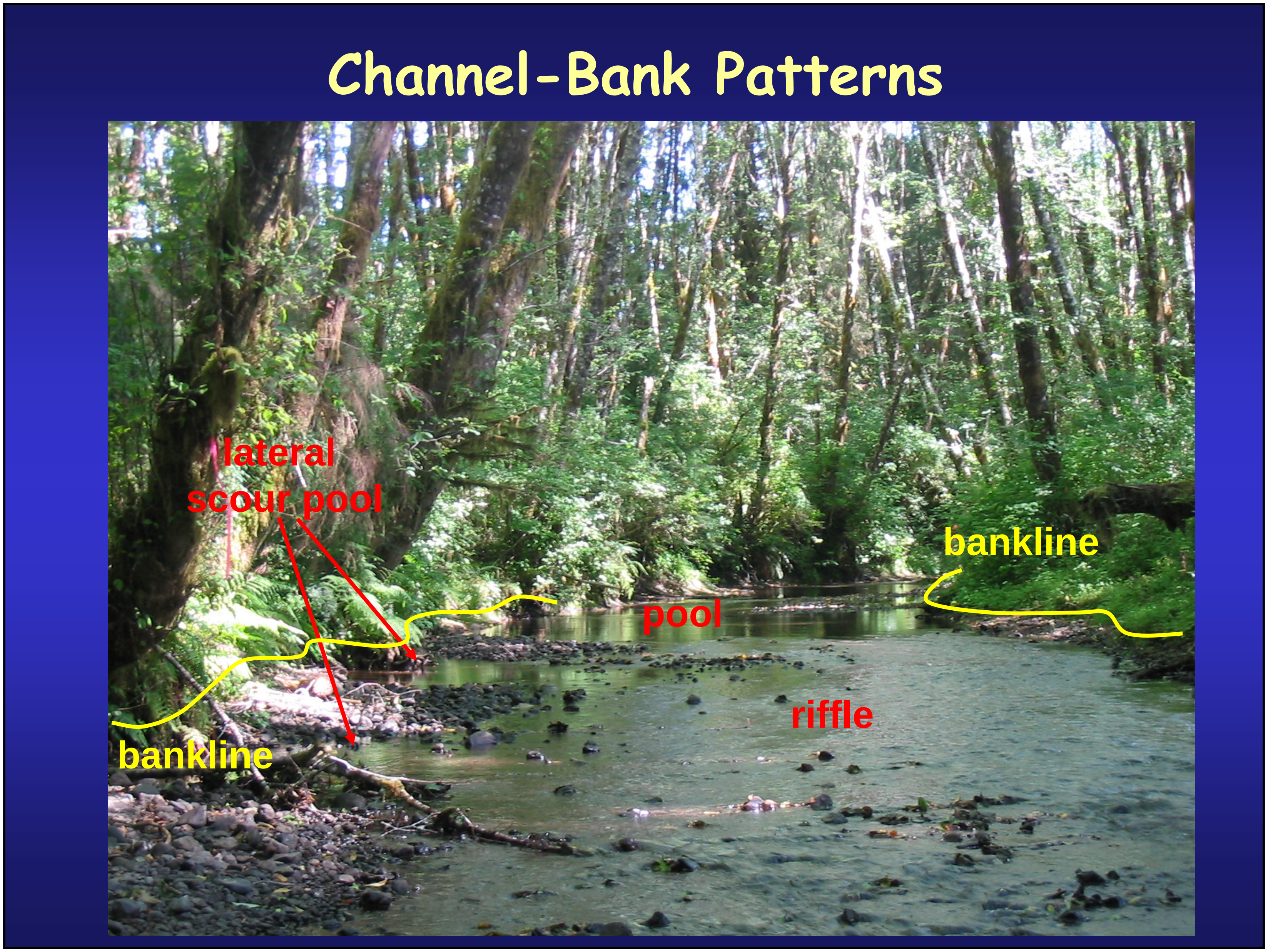
Channel-Bank Patterns
lateral
scour pool
bankline
pool
riffle
bankline

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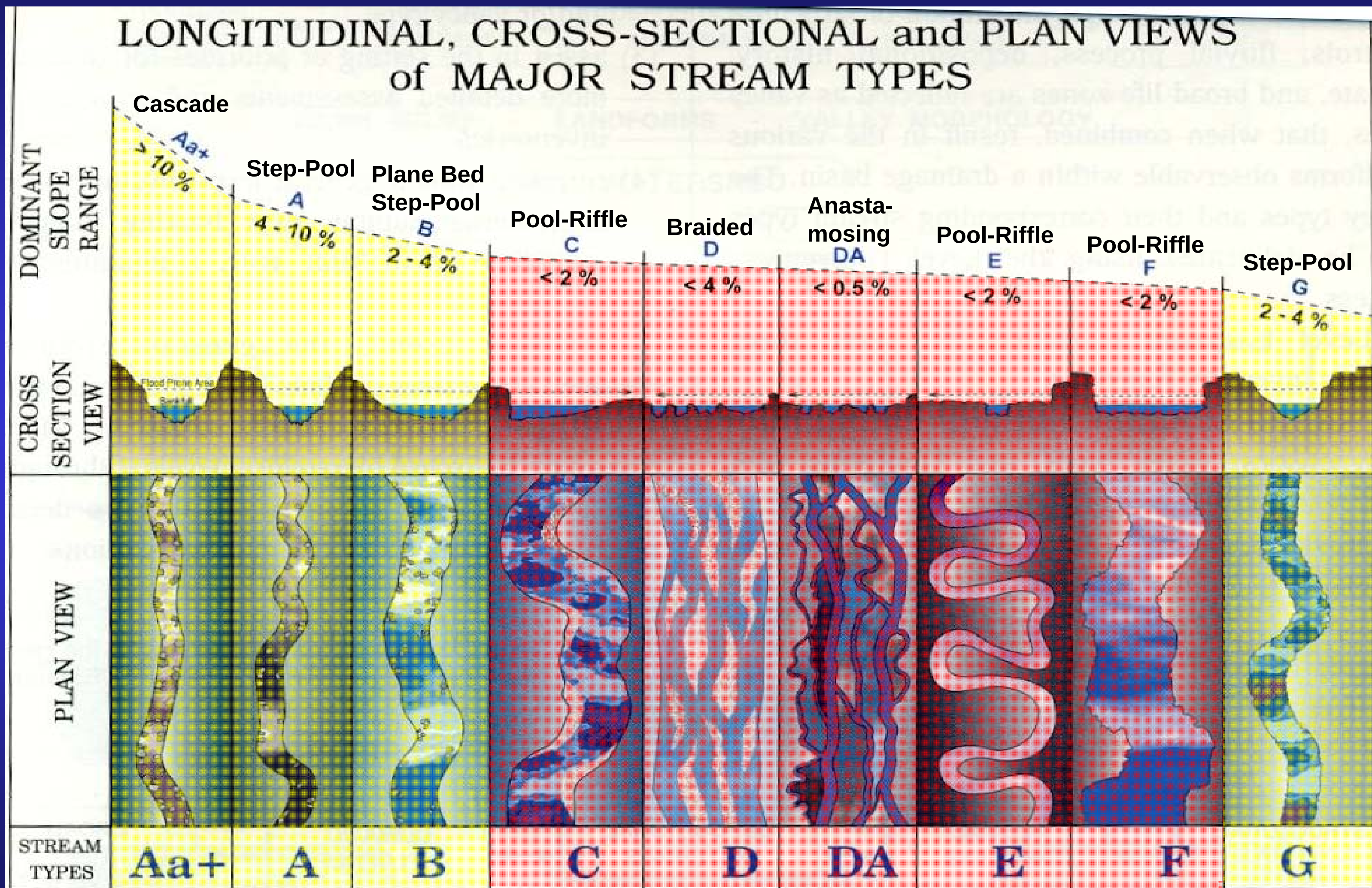
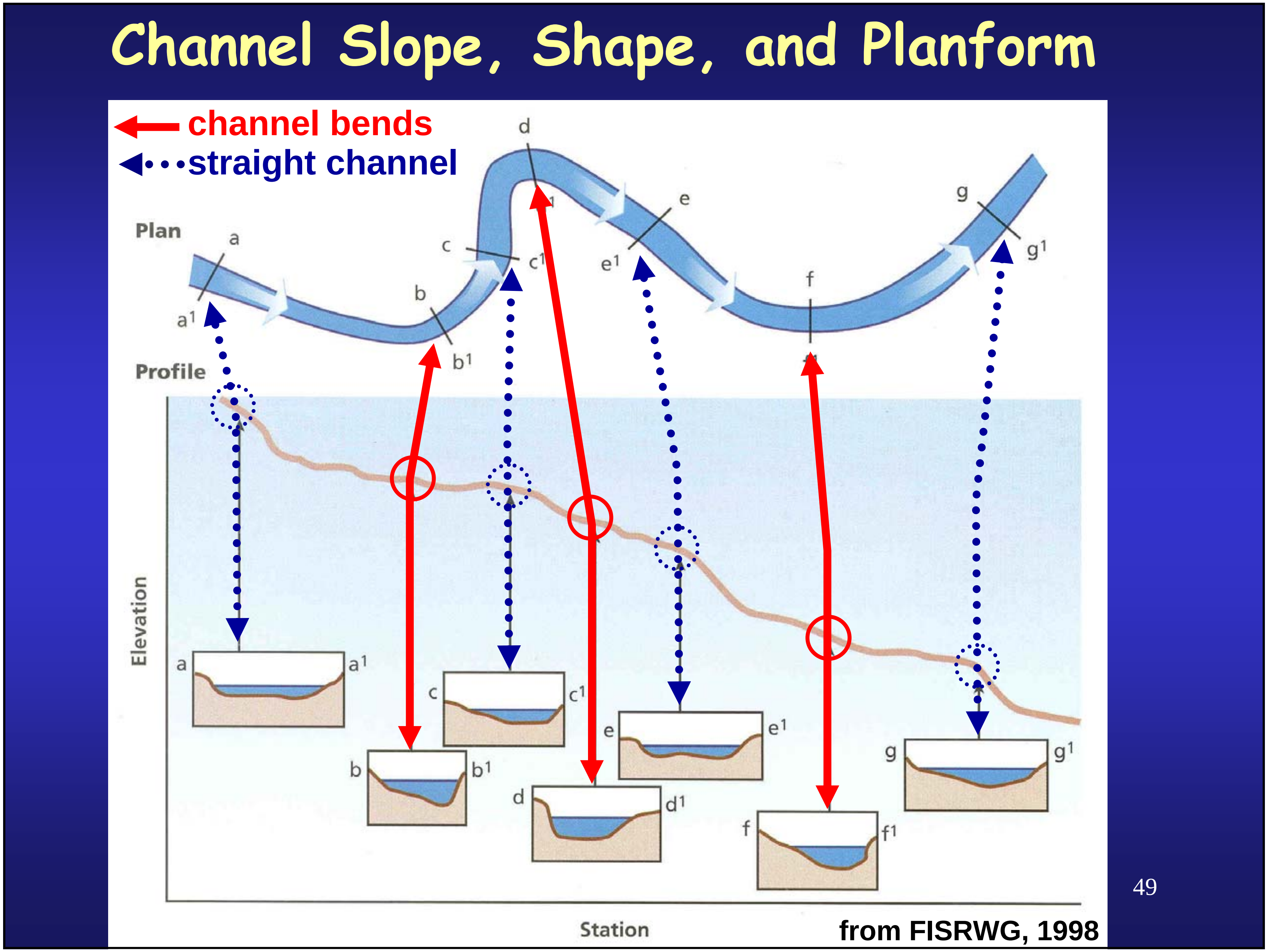
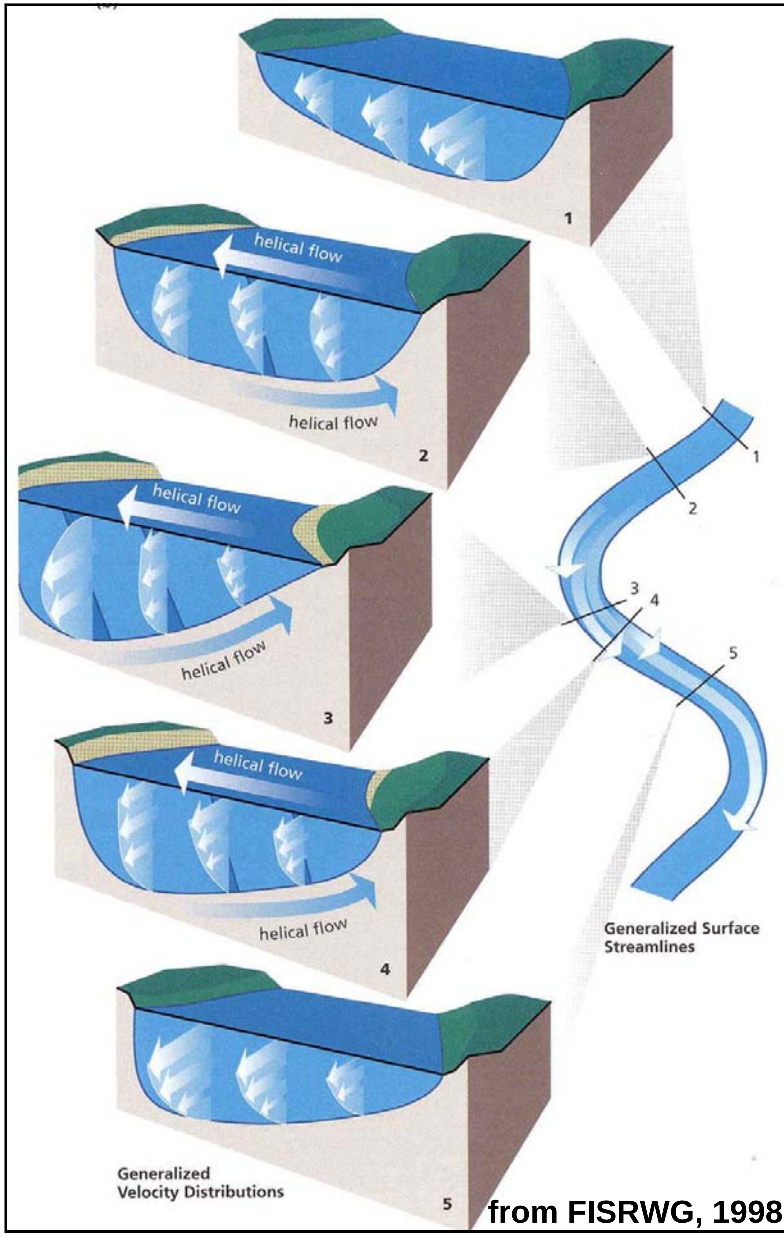
Channel Slope, Shape, and Planform



From Rosgen 1996


Channel Slope, Shape, and Planform
channel bends
straight channel
Plan
Profile
Elevation
Station
a
a1
b
b1
c
c1
d
e
e1
f
g
g1
d1
f1
from FISRWG, 1998
49



from FISRWG, 1998

Channel Slope, Shape, and Planform

- **Fluvial processes in meandering, pool-riffle channels**

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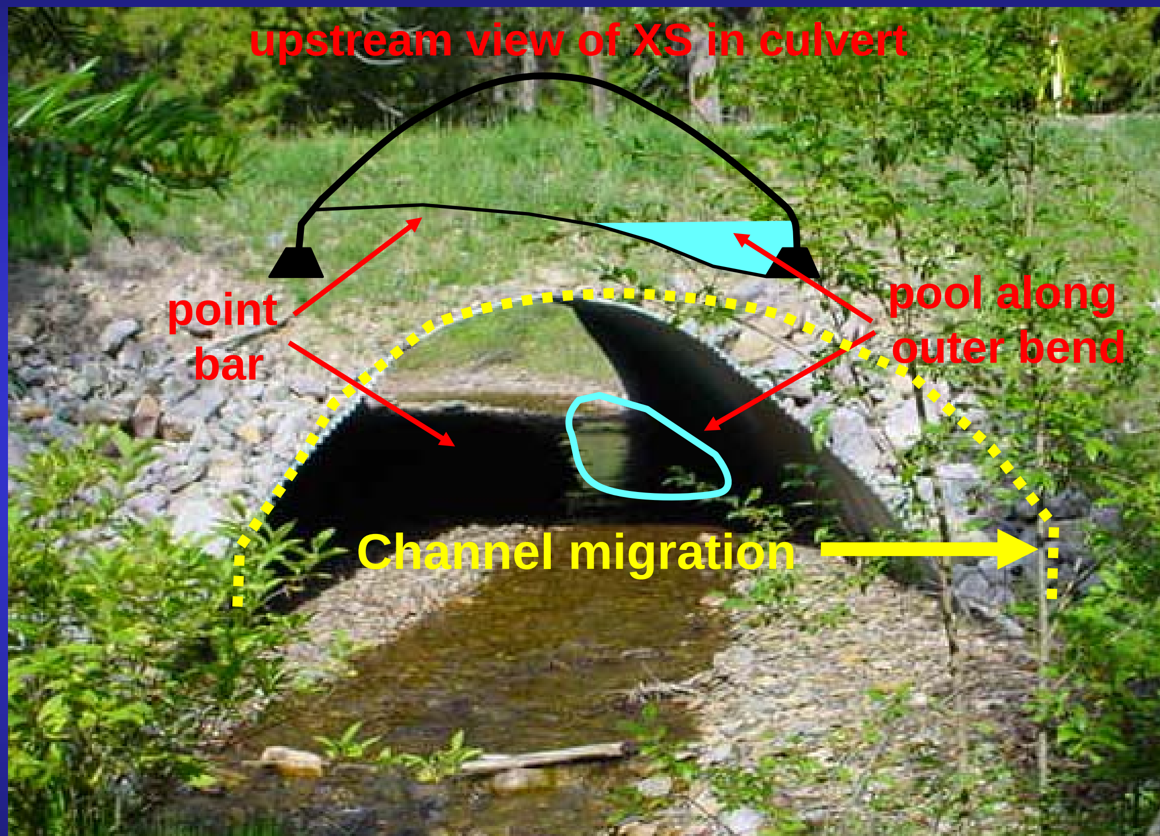
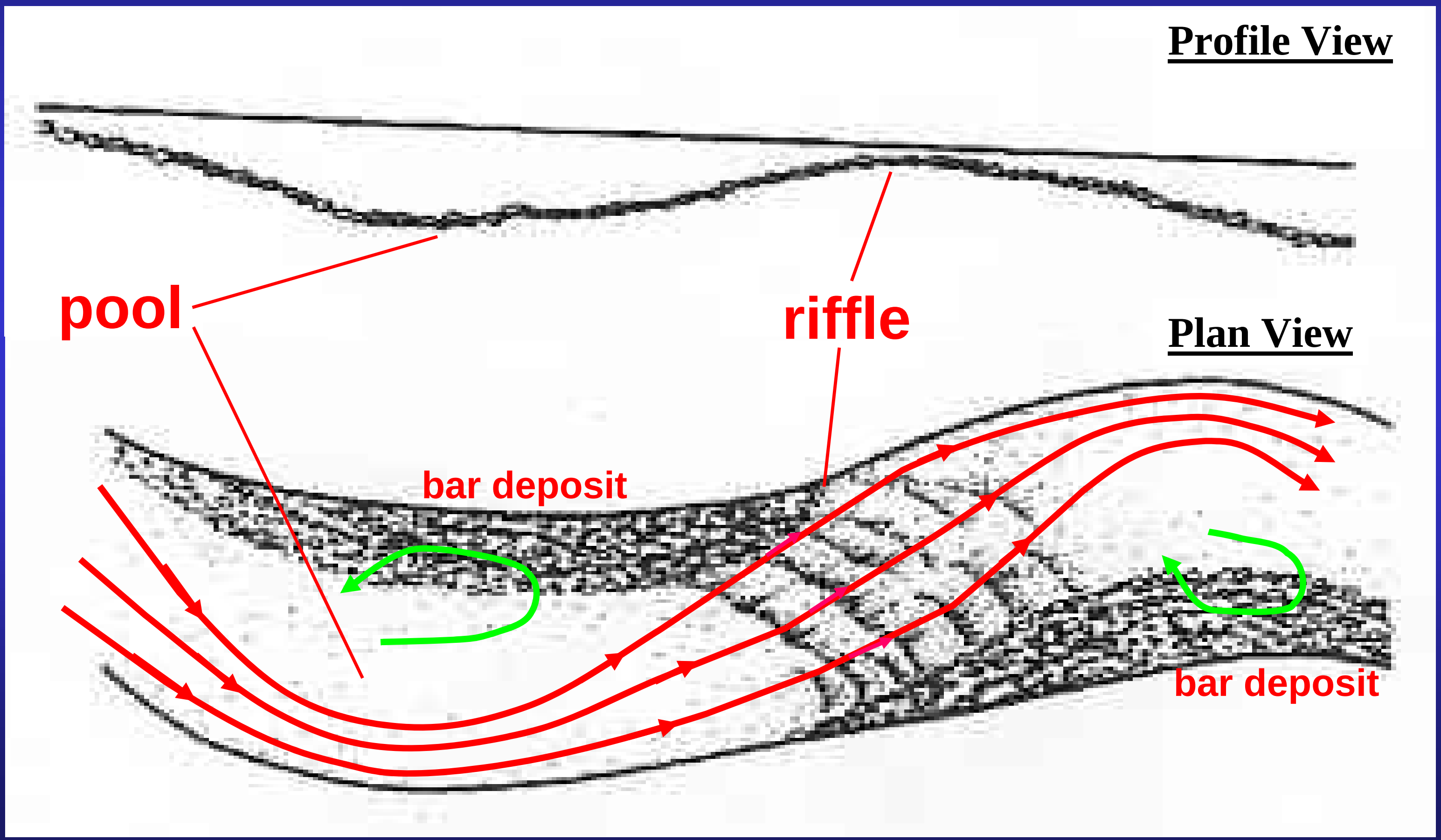
Channel Slope, Shape, and Planform

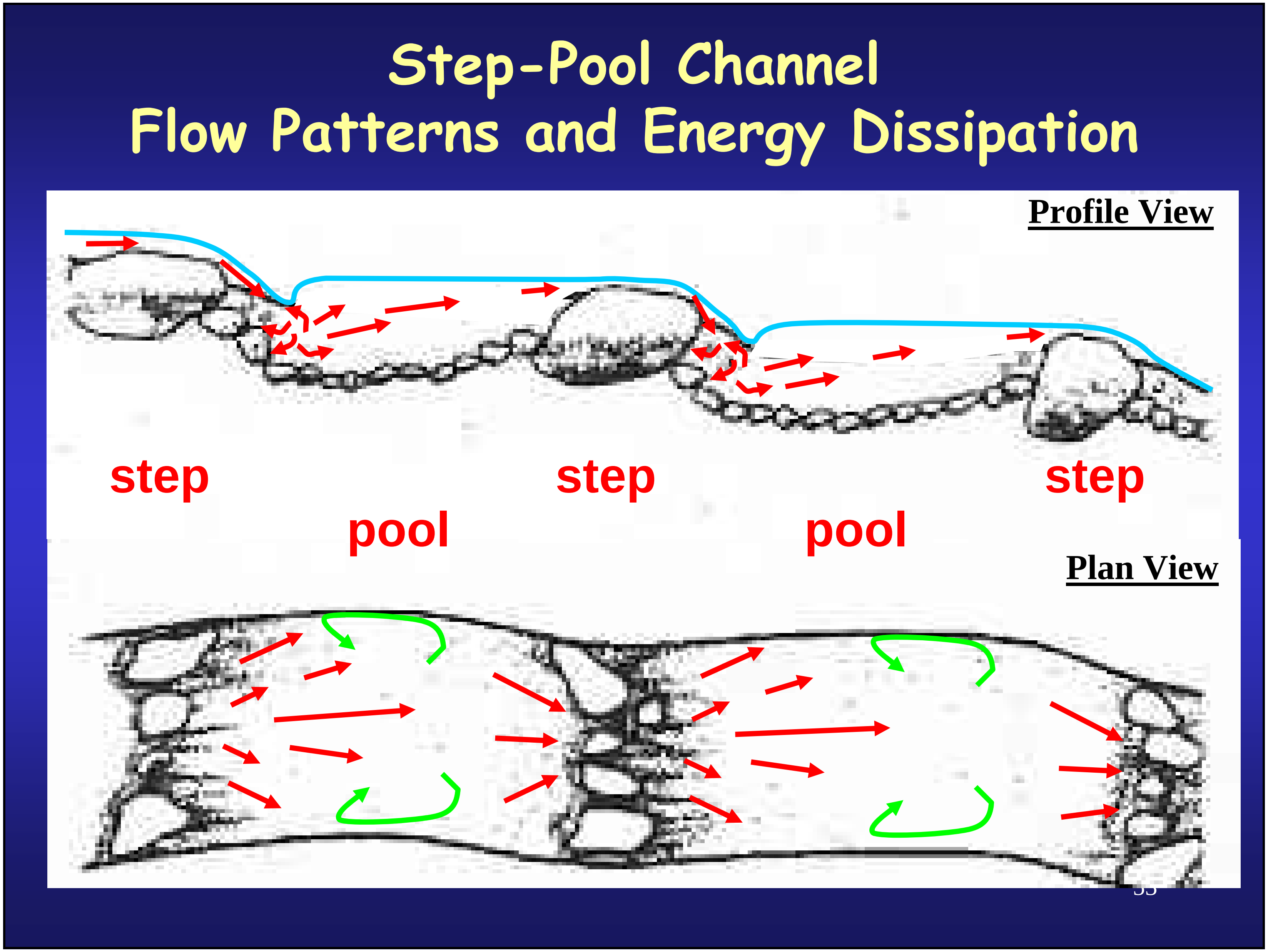


Fluvial processes and channel shape is dependant on where it occurs in the planform

51

Pool-Riffle Channel
Flow Patterns and Energy Dissipation




Step-Pool Channel
Flow Patterns and Energy Dissipation
Profile View
step
pool
step
pool
step
Plan View
53

Presentation Outline

- Watershed Context
- Discharge and Channel Characteristics
- Channel Characteristics and Fluvial Processes
  - Channel slope
  - Channel shape, confinement, entrenchment
  - Channel planform
  - Channel slope, shape, and planform
  - Channel bedforms
  - Channel-bed material
- Channel Classifications
- Understanding and Predicting Channel Adjustments/Responses

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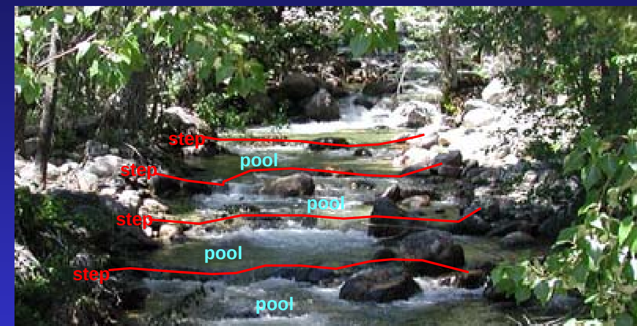
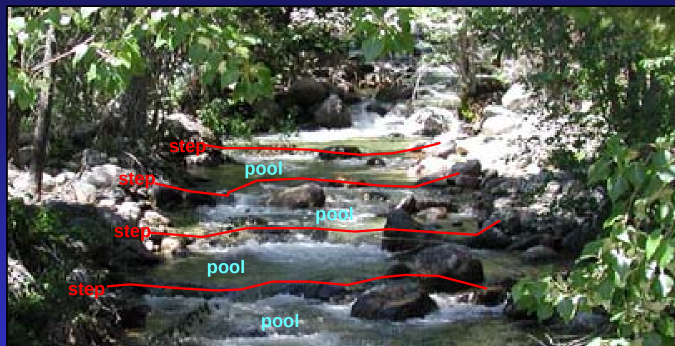
Channel Bedforms Considerations

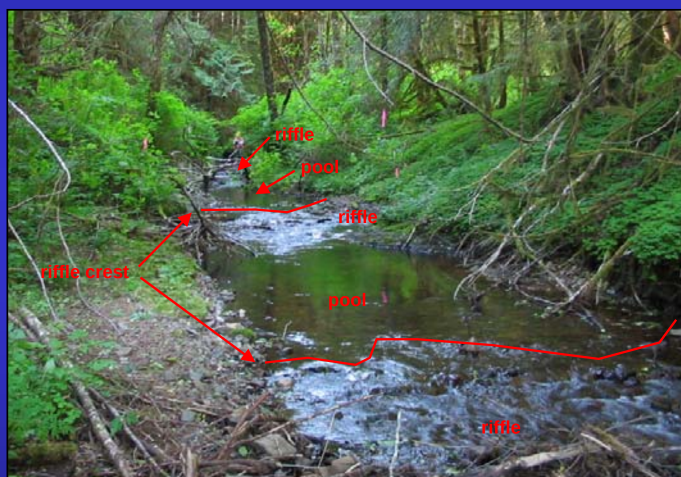
- **Are the bedforms significant along the longitudinal profile?**
- **Are the bedforms stable, permanent features or are they temporary features?**
- **Do the bedforms form step-pool or riffle-pool sequences along the channel?**
- **How do the bedforms affect channel roughness?**
- **Are the bedforms important for dissipating flow energy during floods?**



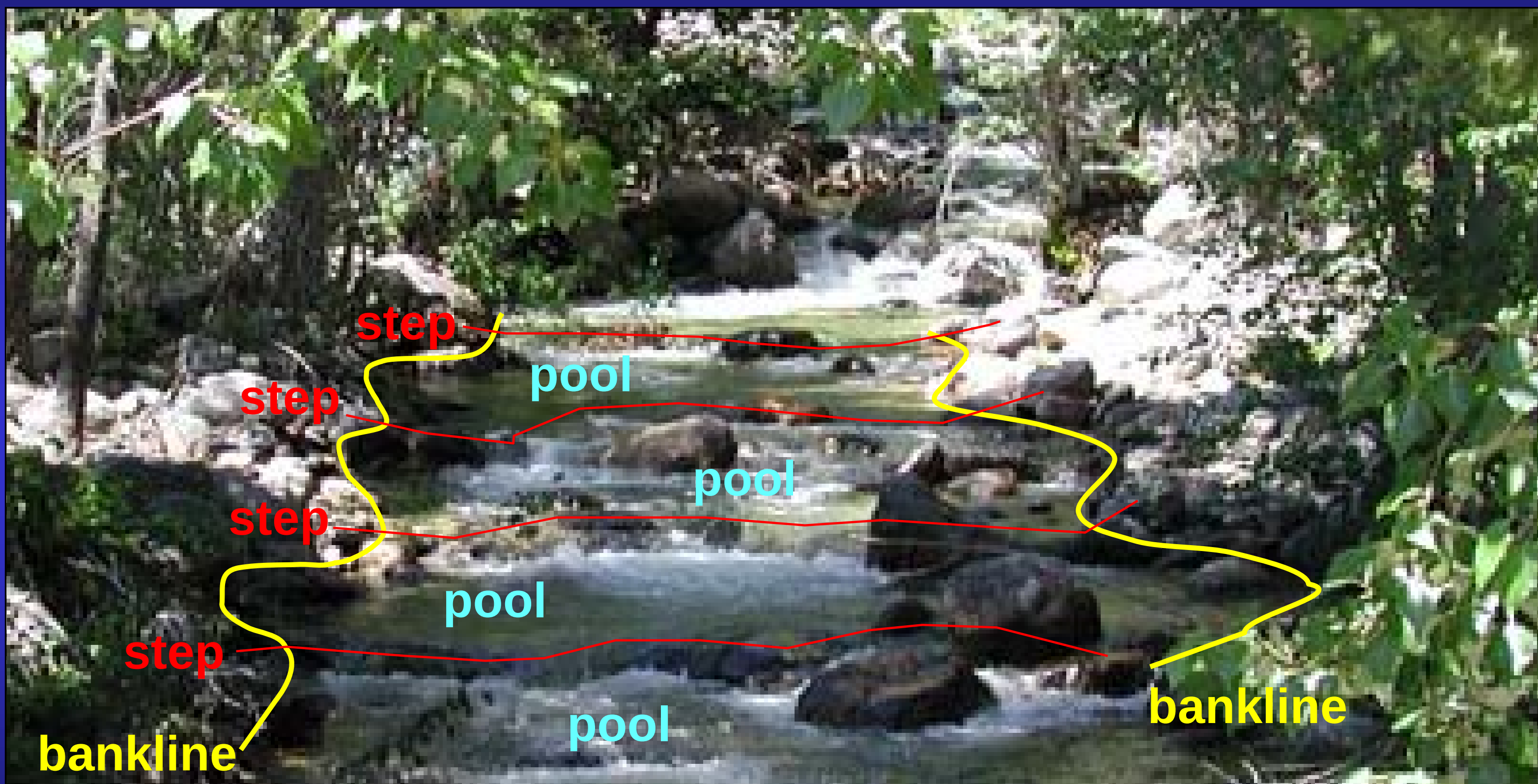
Channel Bedforms

- **Steps and Pools**
- **Riffles and Pools**
- **Large Woody Debris**
- **Transverse Ribs**
- **Particle Clusters**
- **Gravel Bars**



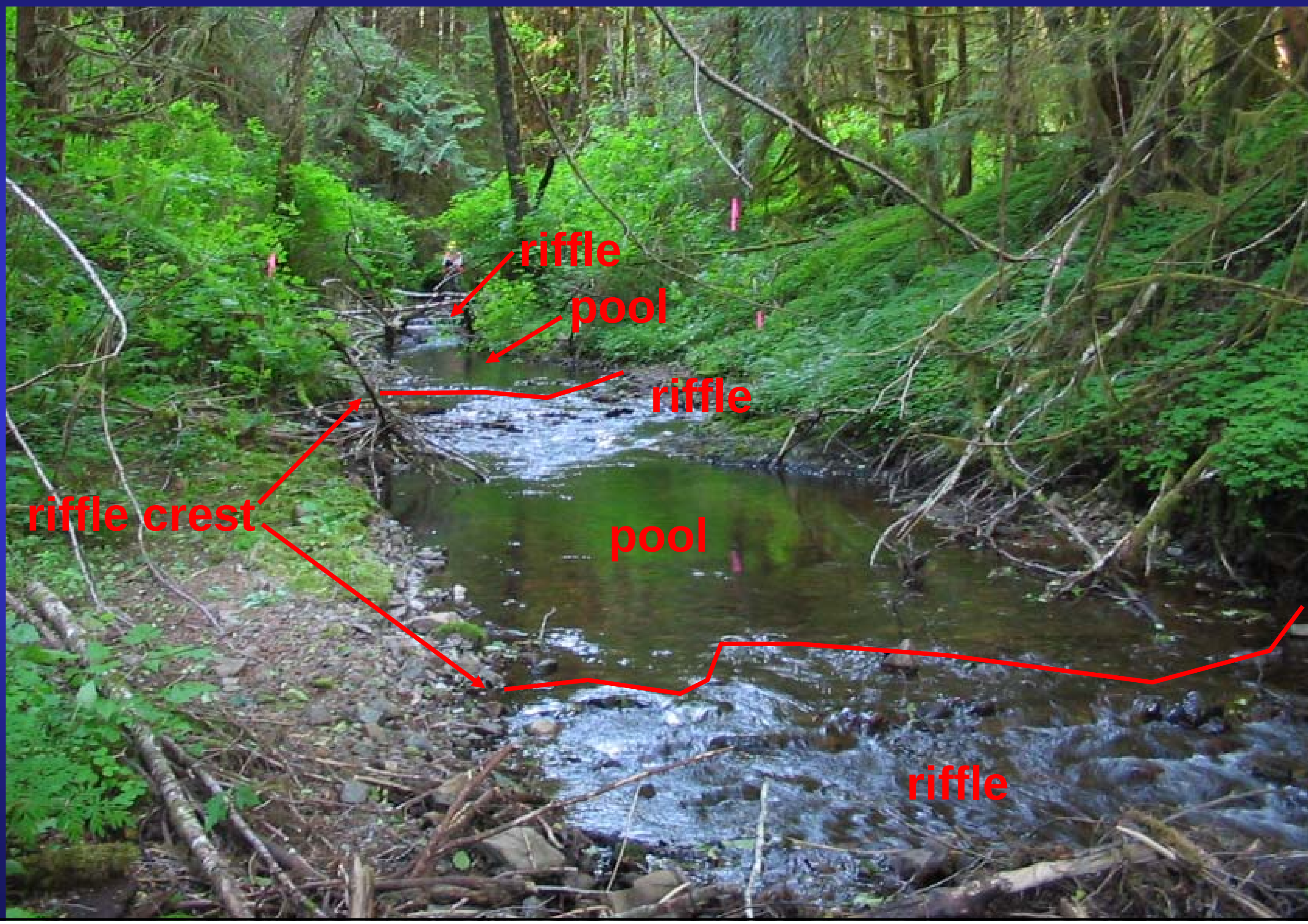


Channel Bedforms: Steps and Pools

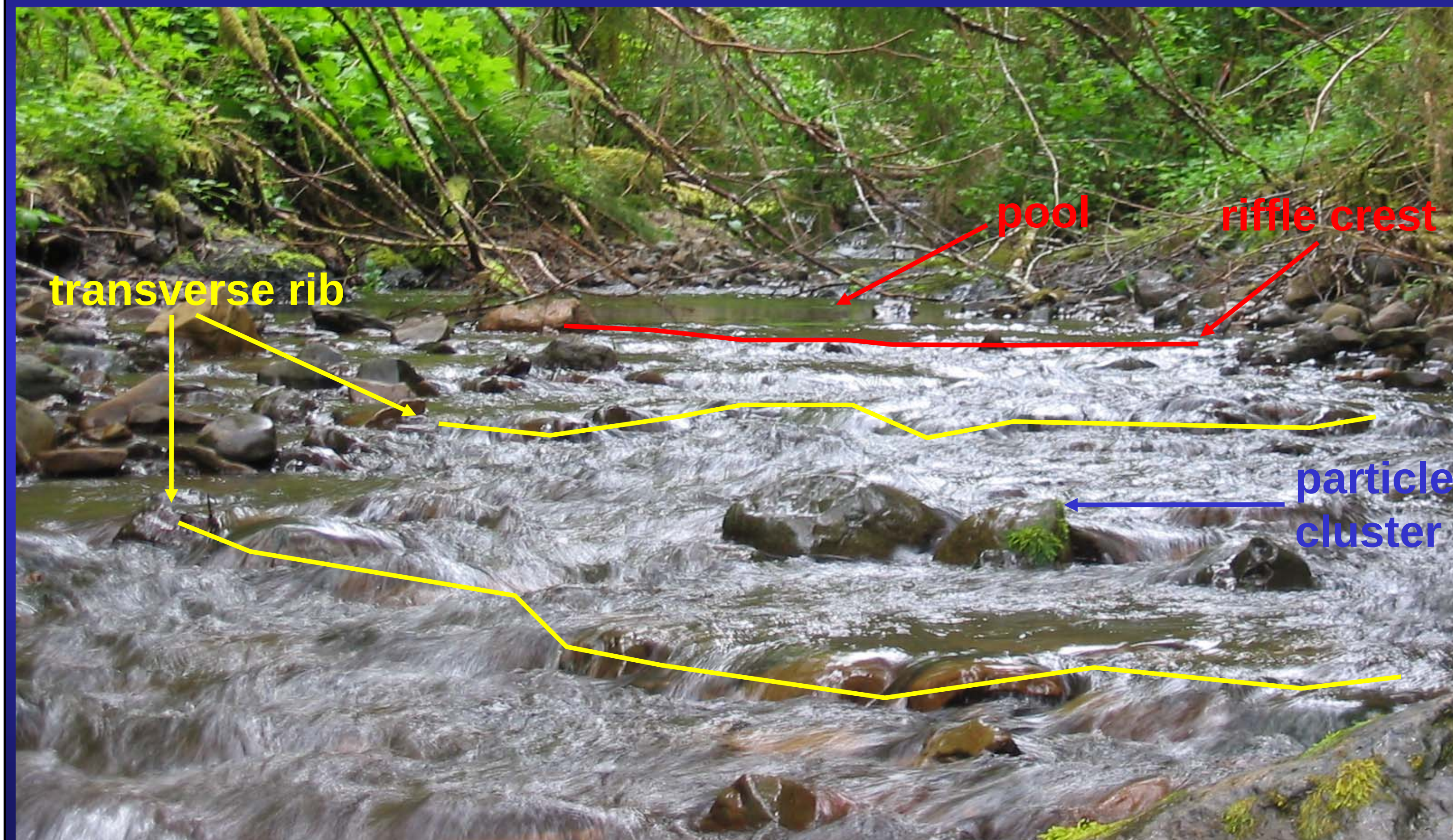


57

Channel Bedforms: Riffles and Pools



Channel Bedforms: Transverse Ribs and Particle Clusters



Channel Bedforms: Large Woody Debris

Channel Bedforms: Gravel Bars, Riffles, Pools

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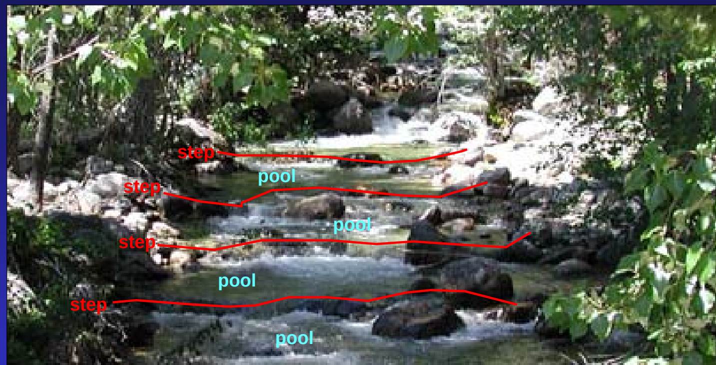
Channel-Bed Material Considerations



- Does channel-bed substrate size vary spatially between and within channel units (i.e., pools versus steps, riffles versus pools, within riffles)?
- Is the channel-bed substrate well sorted or poorly sorted (uniformly or non-uniformly graded)?
- Does the channel-bed substrate vary vertically (i.e., surface layer versus the subsurface layer)?

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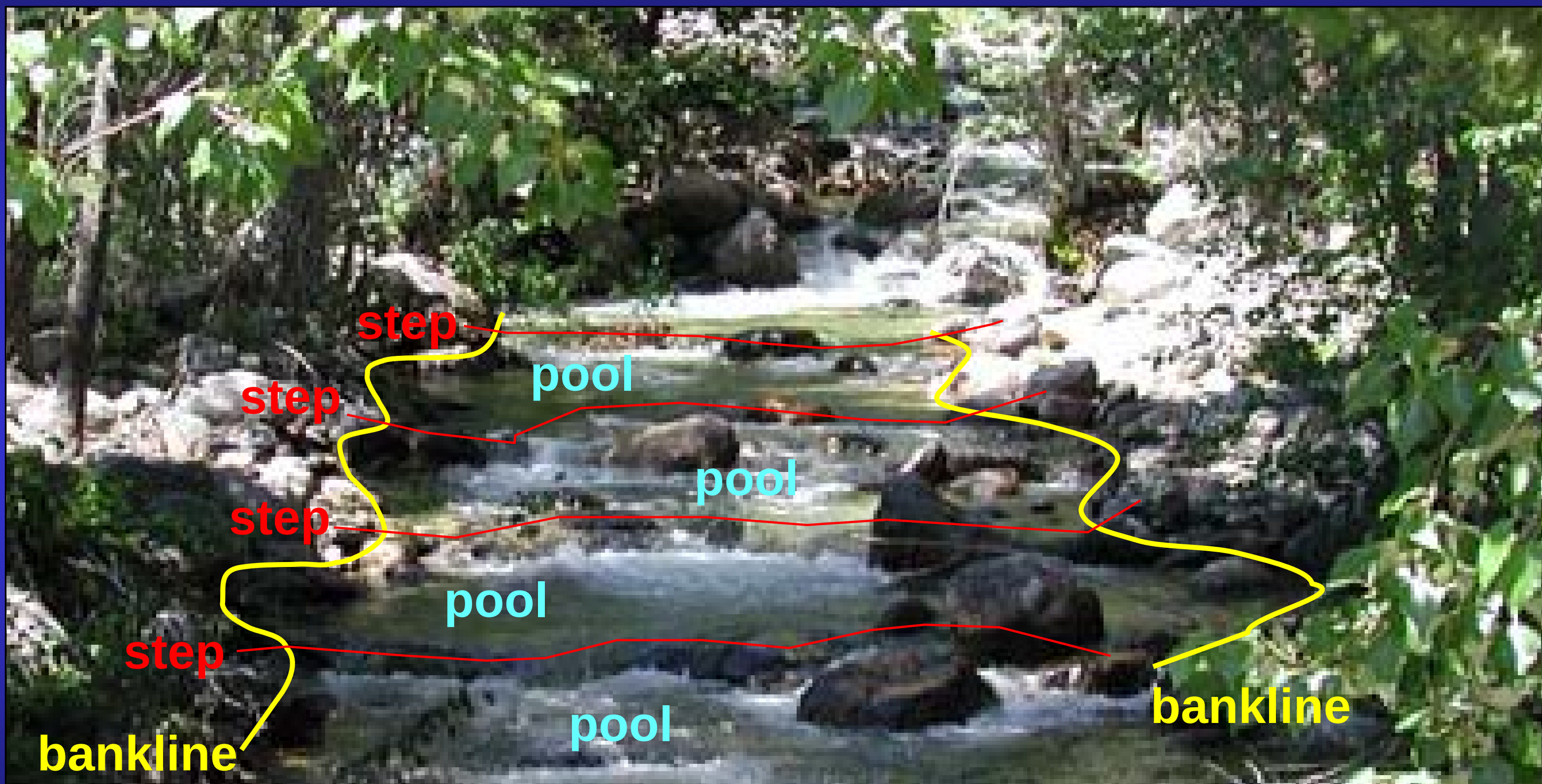
Channel-Bed Material: Steps and Pools



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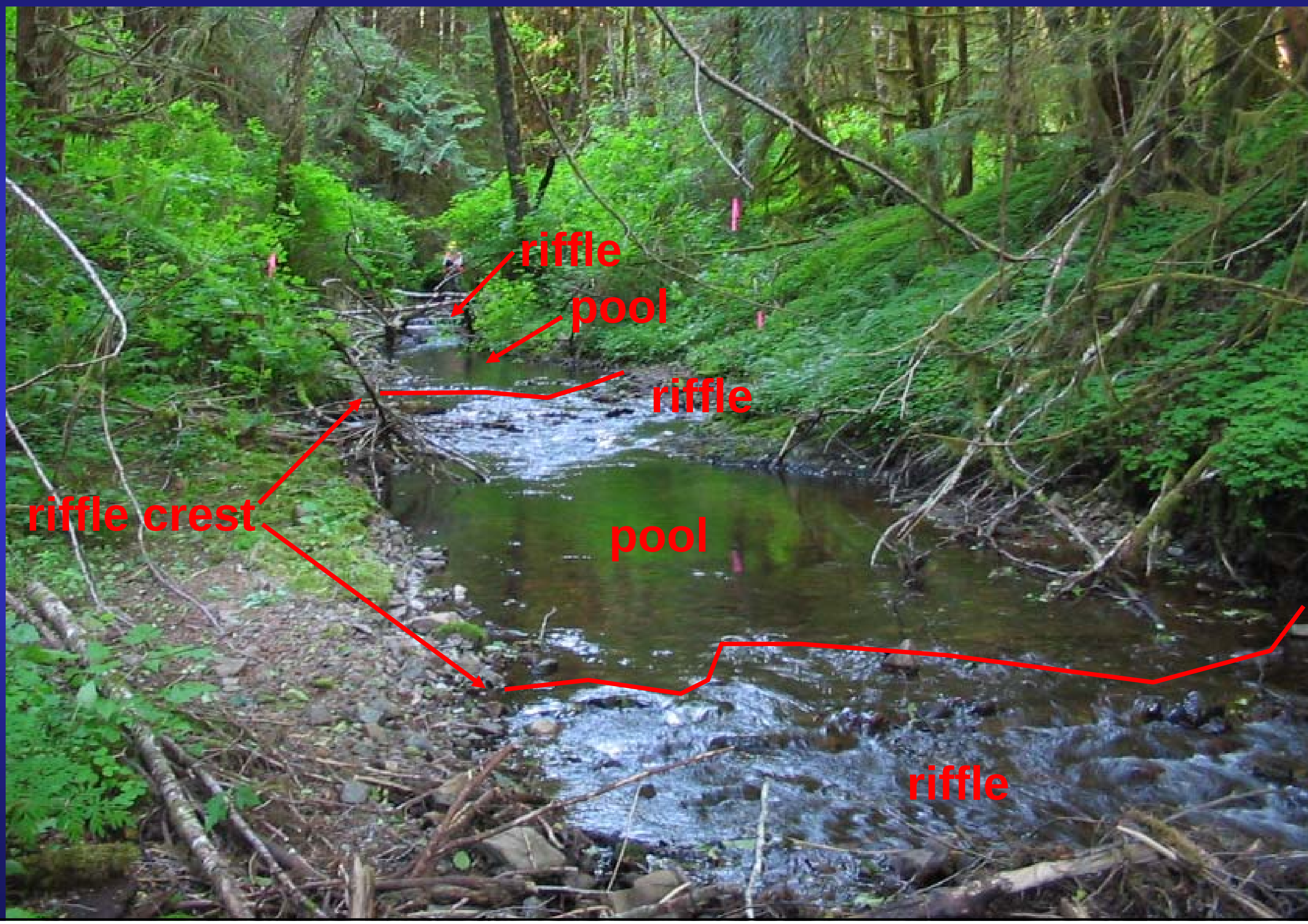
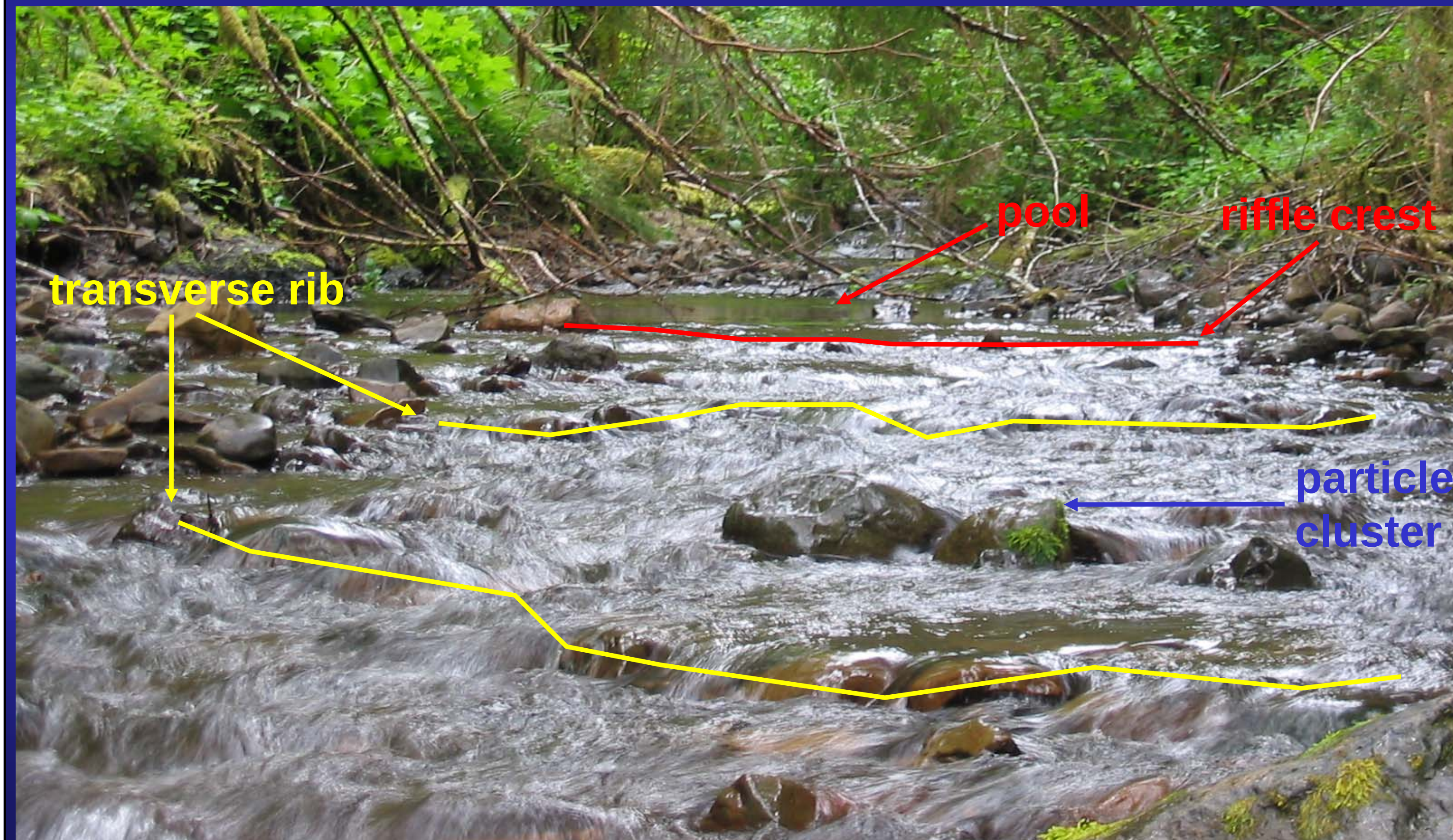
Channel-Bed Material: Riffles and Pools

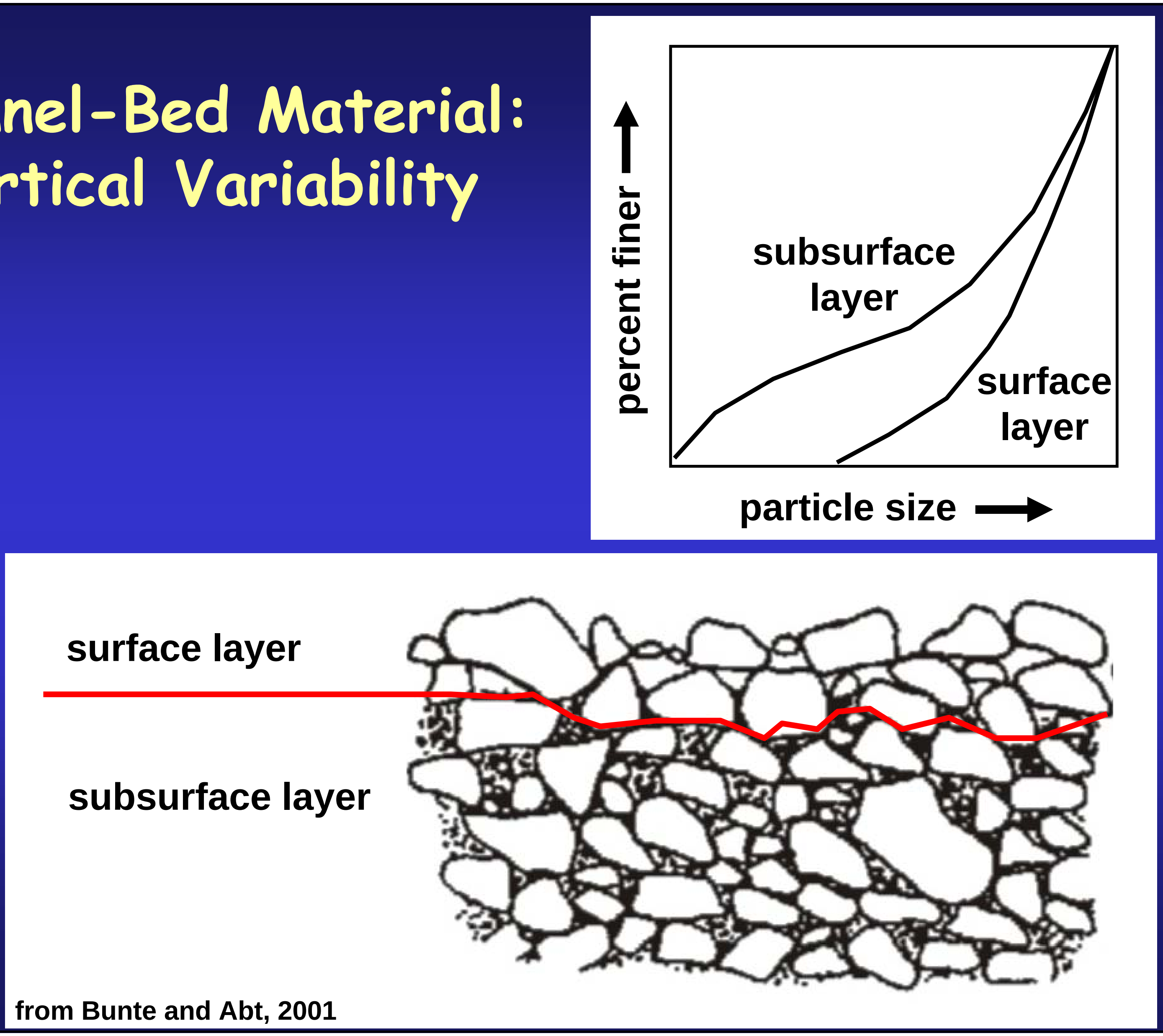


Channel-Bed Material: Transverse Ribs and Particle Clusters



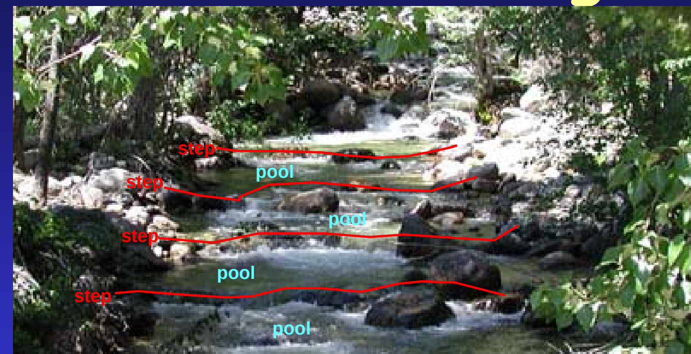
Channel-Bed Material: Vertical Variability

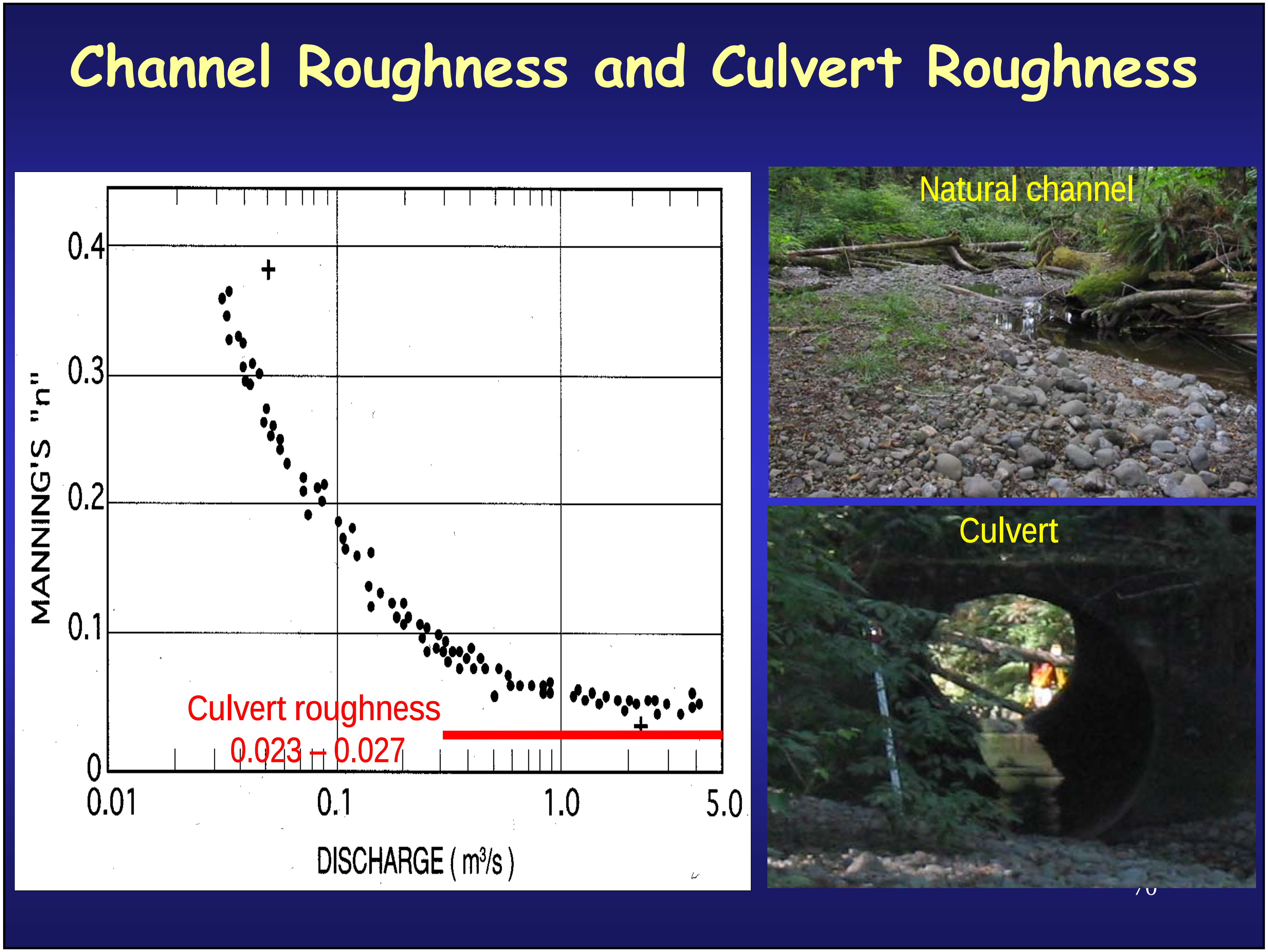
Channel-Bed Material: Vertical Variability

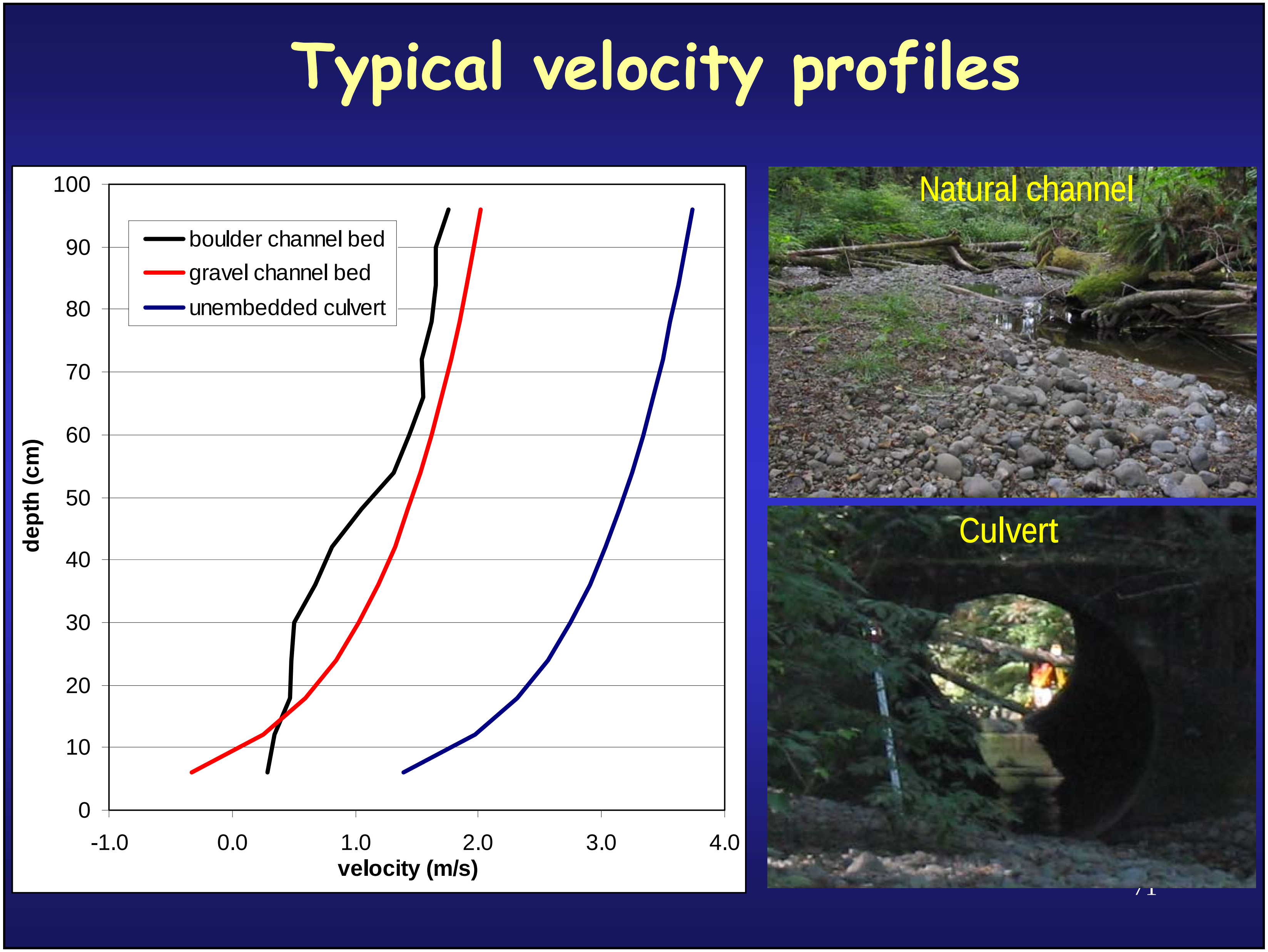


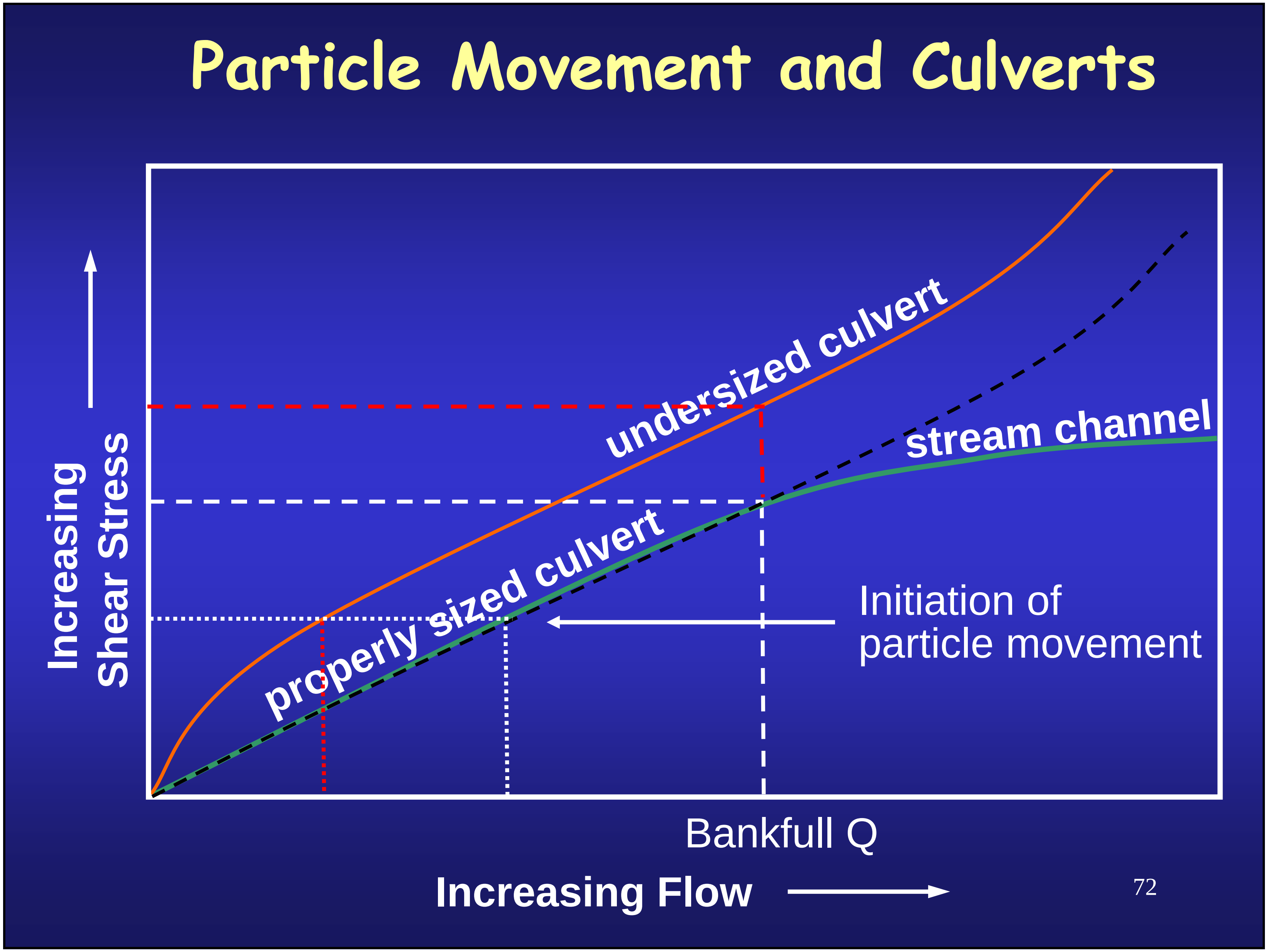
Types of Flow Resistance or Channel Roughness

- <u>Boundary Resistance</u>
  - Particle roughness (particle size, sorting, etc.)
  - Vegetation roughness
- <u>Channel Resistance</u>
  - Slope variability
  - Bedform sequences
  - (step-pool, pool-riffle, etc.)
  - Bank irregularity
  - Channel alignment
- <u>Free Surface Resistance</u>
  - Surface waves
  - Hydraulic jumps




Channel Roughness and Culvert Roughness
MANNING'S "n"
0.4
0.3
0.2
0.1
0
0.01
0.1
1.0
5.0
DISCHARGE (m³/s)
Culvert roughness
0.023 – 0.027
Natural channel
Culvert


Typical velocity profiles
boulder channel bed
gravel channel bed
unembedded culvert
depth (cm)
100
90
80
70
60
50
40
30
20
10
0
-1.0
0.0
1.0
2.0
3.0
4.0
velocity (m/s)
Natural channel
Culvert


Particle Movement and Culverts
Increasing Shear Stress
undersized culvert
stream channel
properly sized culvert
Initiation of particle movement
Bankfull Q
Increasing Flow
72

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Channel Classification

- Many of the channel features and fluvial processes discussed in this presentation are encompassed in the channel classification systems developed by Montgomery and Buffington (1993, 1997) and Rosgen (1994, 1996).
- Both of these classification systems provide a common framework for:
  - understanding channel morphology and fluvial processes
  - predicting channel responses to natural or anthropogenic disturbances
- Classifying channels encourage and require field observations of channel characteristics and interpretation fluvial processes and channel dynamics.
- Don't limit yourself to one channel classification: Each have strengths and weaknesses.

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Montgomery and Buffington Channel Classification (1993, 1997)

- **Reach-scale classification based on channel morphology, flow hydraulics, and fluvial processes**
- **Classification developed for mountain channels in the Pacific Northwest, but applicable in other mountainous environments**
- **Six alluvial channel types: Braided, dune-ripple, pool-riffle, plane bed, step-pool, and cascade**
- **Two non-alluvial channel types: bedrock and colluvial**
- **Channels are distinguished from each other based based on characteristics such as bed-material size, channel slope, dominant roughness elements, pool spacing, bedform pattern, channel confinement, sediment supply, and transport capacity**
- **Provides a framework for predicting the degree and style of channel response to changes in sediment and water inputs or local controls for different channel types**

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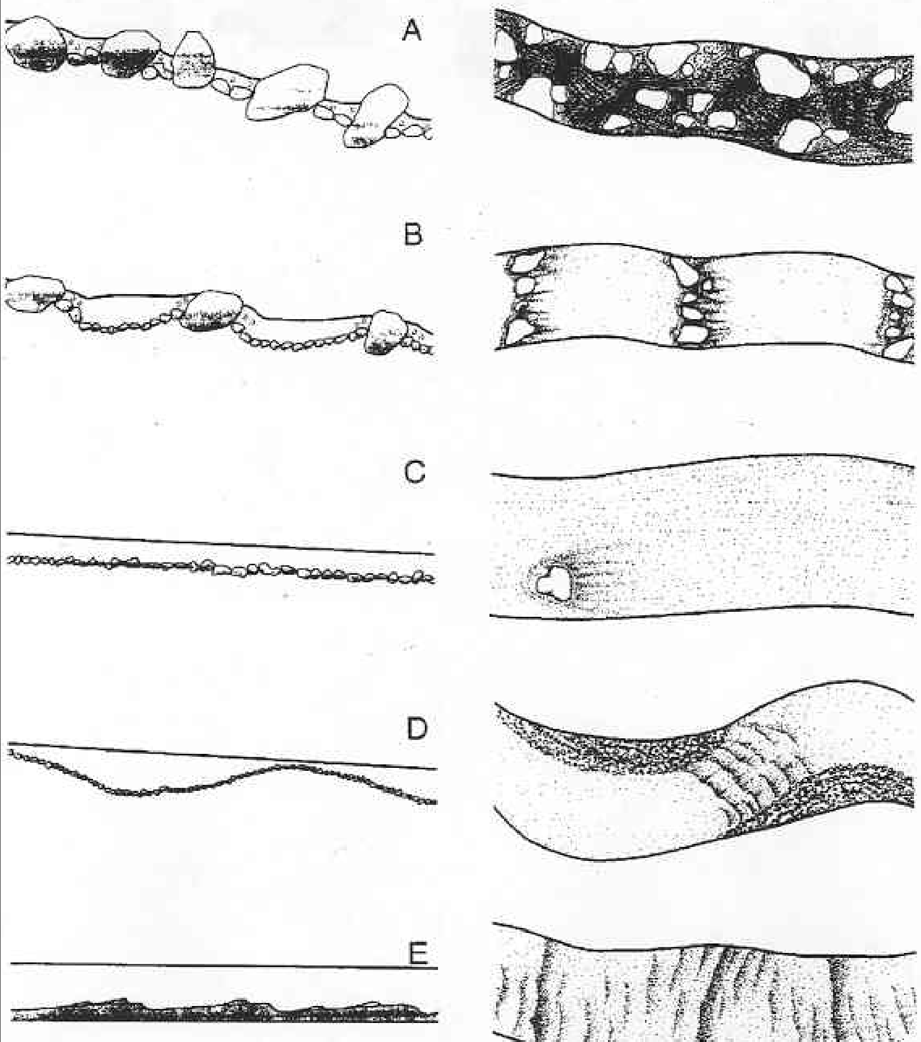
Montgomery & Buffington Alluvial Channel Types

Profile View | **Plan View**



From Montgomery & Buffington, 1993

A. Cascade

B. Step-pool

C. Plane bed

D. Pool-riffle

E. Dune-ripple

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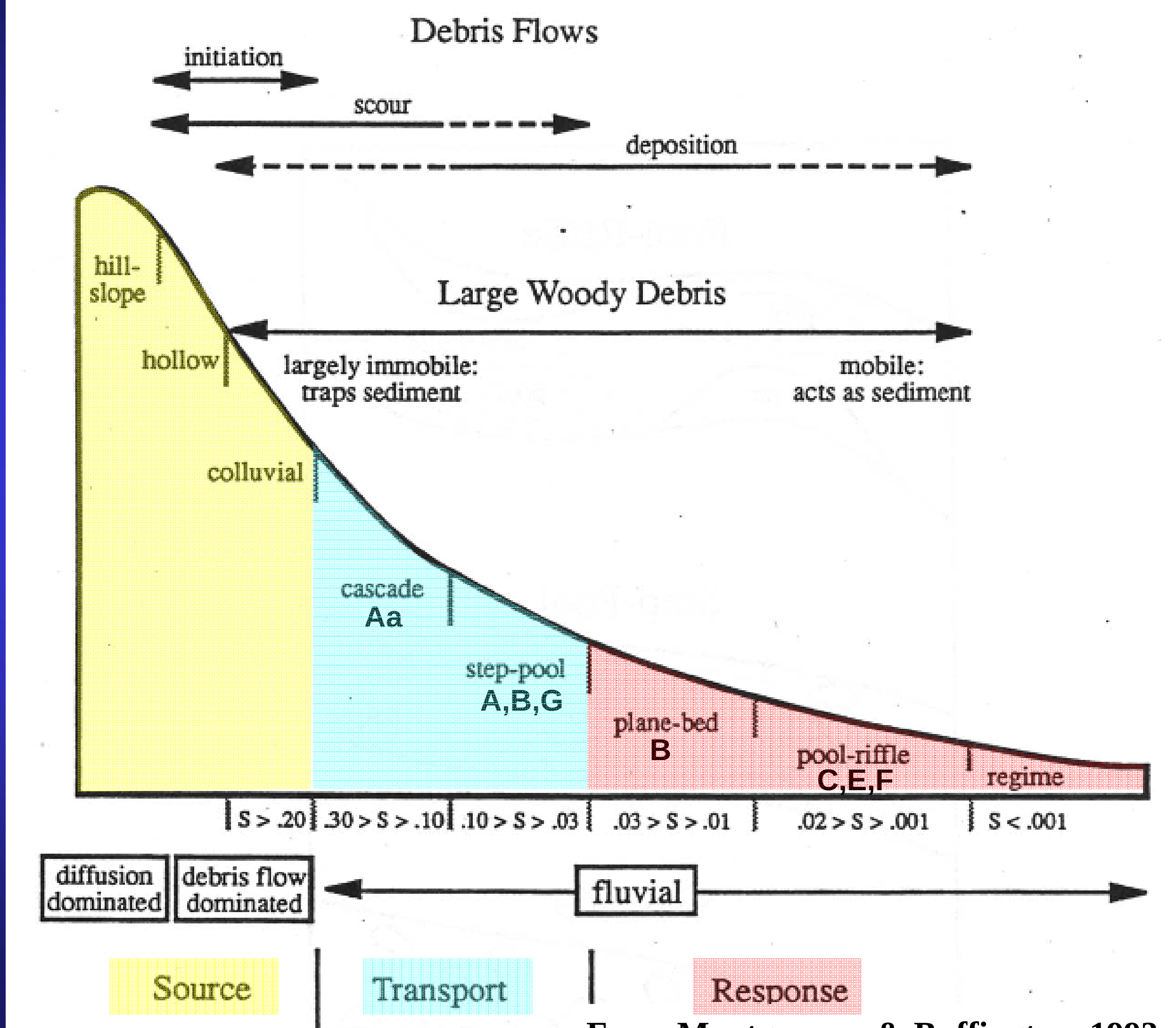
General Channel Characteristics for Channel Types of Montgomery and Buffington

Type of channel	Typical bed material	Typical slope	Dominant roughness elements	Pool spacing (channel widths)	Typical Confinement	Typical reach type	Typical sediment supply conditions	Typical transport capacity of stream	Frequency of effective bedload transport (mobile bed)
nonalluvial									
-colluvial	variable	> 0.20	grains, LWD	variable	confined	source	high	high	infrequent
-bedrock	bedrock	variable	not applicable	variable	confined	transport	low	high	not applicable
alluvial									
-cascade	boulder	0.10 to 0.30	grains, banks	< 1	confined	transport	low	high	infrequent
-step-pool	cobble, boulder	0.03 to 0.10	bedforms, grains, LWD,	1 to 4	confined	transport	low	high	infrequent
-plane bed 1	cobble	0.01 to 0.03	grains, banks	none	variable	transport	low	high	infrequent
-plane bed 2	gravel	0.01 to 0.03	grains, banks	none	variable	response	moderate	moderate	frequent
-pool-riffle	gravel	0.001 to 0.02	bedforms, grains, LWD, sinuosity,	5 to 7	unconfined	response	moderate	moderate	frequent
-dune-ripple	sand	< 0.001	sinuosity, bedforms	5 to 7	unconfined	response	high	low	very frequent
-braided	sand, gravel, cobble	< 0.030	bedforms	variable	unconfined	response	high	low	frequent

Montgomery & Buffington Channel Classification



From Montgomery & Buffington, 1993

78

Rosgen Channel Classification (1994, 1996)

- Reach-scale classification based on channel entrenchment, width to depth ratio, sinuosity, channel slope, and channel-bed material
- Classification developed from measurements of 450 streams in different geographic settings
- Identifies and differentiates eight major channel types (referred to as A, B, C, D, DA, E, F, or G channels) on the basis of degree of entrenchment, gradient, width to depth ratio, and sinuosity
- Identifies six subcategories within each major channel type based on the dominant material composing the channel bed
- Provides a framework for interpreting the various channel types in terms of sensitivity or responsiveness to disturbance, recovery potential after disturbance, sediment supply, susceptibility to bank erosion, and influence of vegetation on channel form

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Channel characteristics of Rosgen Channel Types

Stream Type	Channel characteristics
A	**Step-pool, or cascading:** plunge and scour pools, high energy, low sediment storage, stable;
B	**Riffles and rapids:** some scour pools, bars rare, stable;
C	**Pool-riffle sequences:** meandering, point bars, well-developed floodplain, banks stable or unstable;
D	**Braided:** multiple channels, shifting bars, scour, deposition, high sediment supply, eroding banks;
DA	**Anastomosing:** multiple channels, pool-riffle, vegetated floodplain, adjacent wetlands, stable banks;
E	**Meadow meanders:** well-developed floodplain, riffle-pool, relative high sediment conveyance;
F	**Valley meanders:** incised into valleys, poor floodplain, pool-riffle, banks stable or unstable;
G	**Gullies:** incised into hillslopes and meadows, high sediment supply, unstable banks, step-pool.

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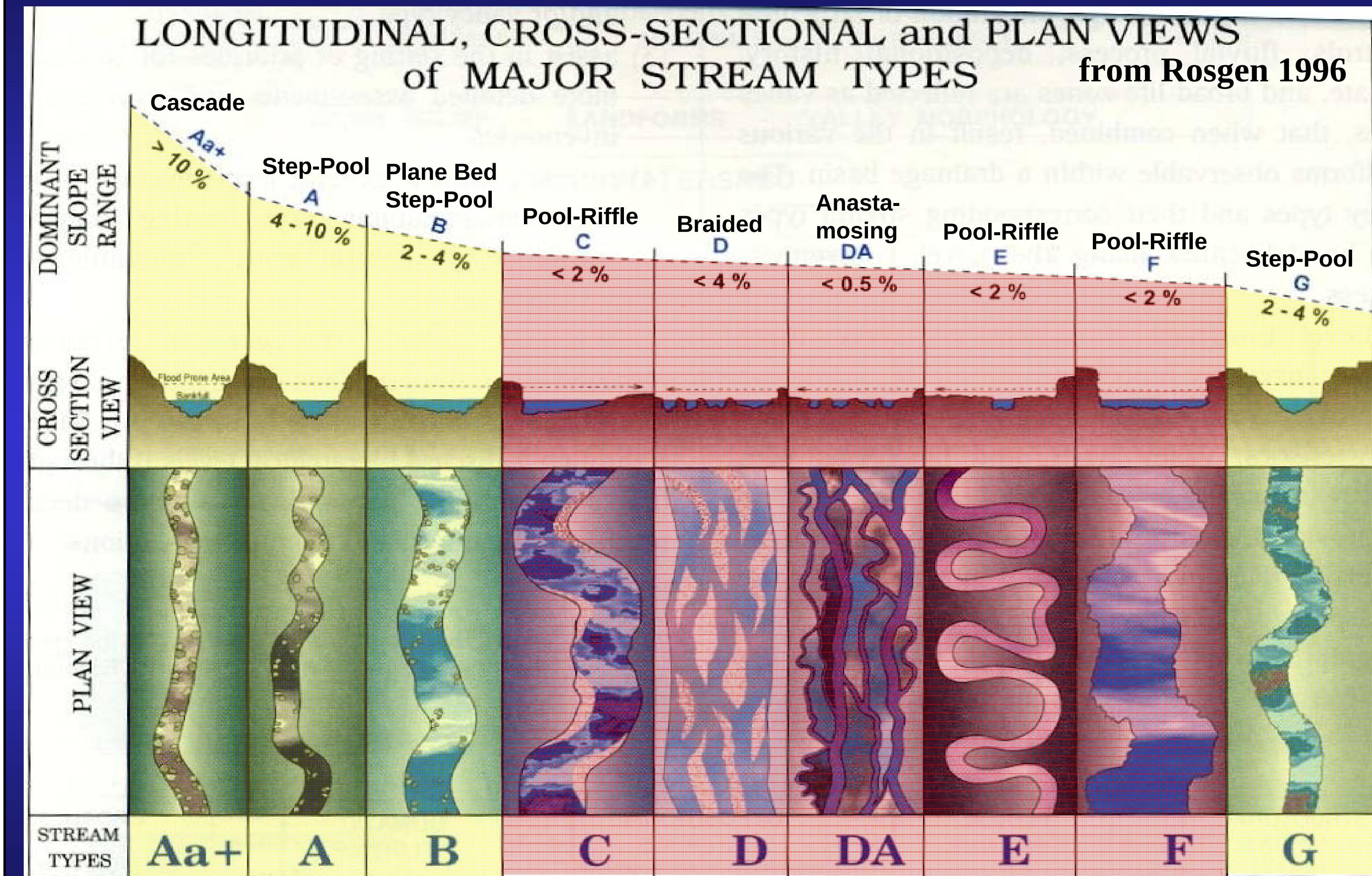
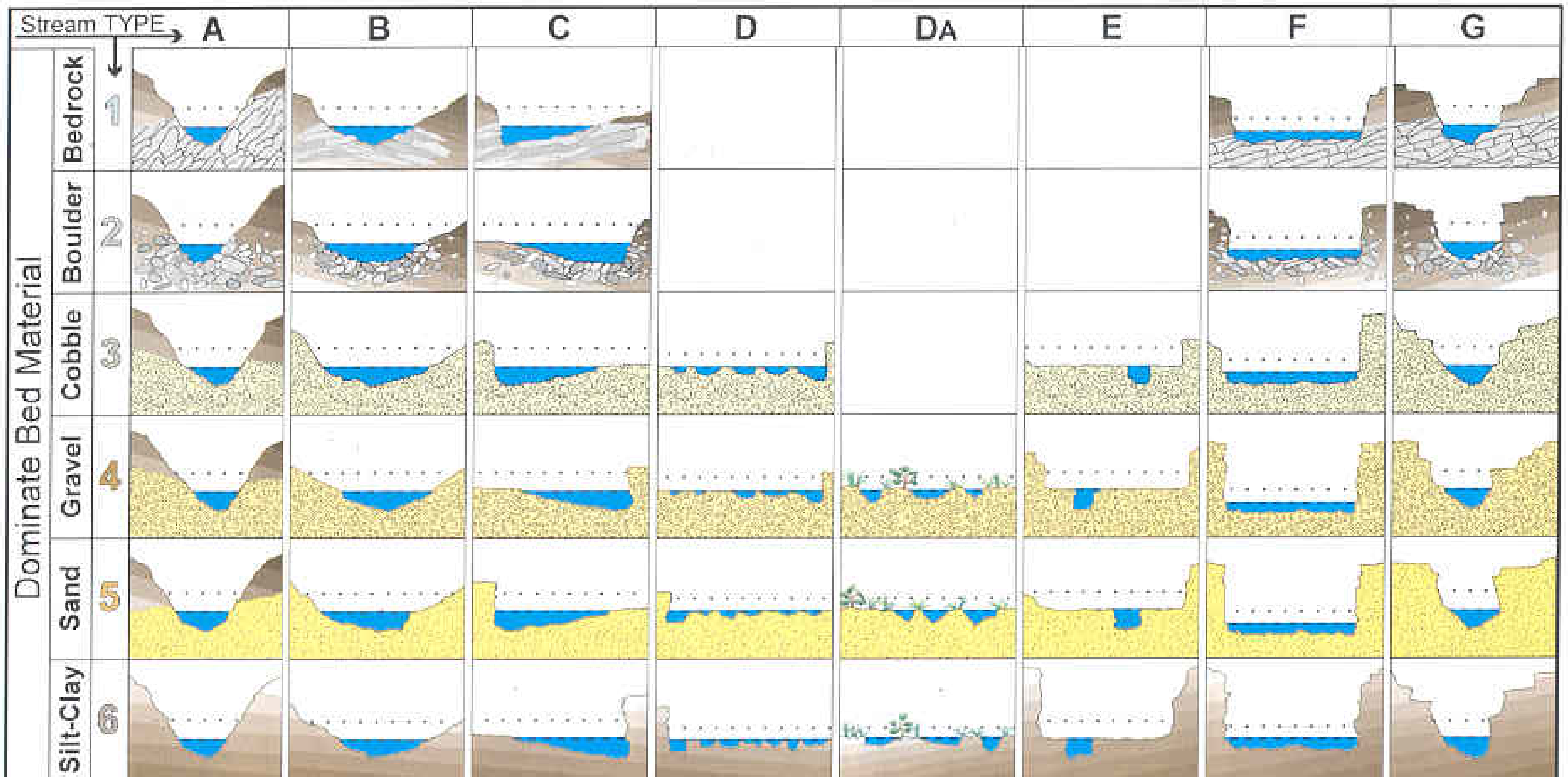
Rosgens Channel Classification



Rosgen's Channel Classification



Stream TYPE	A	B	C	D	DA	E	F	G
Entrchmnt.	< 1.4	1.4 - 2.2	> 2.2	n/a	> 4.0	> 2.2	< 1.4	< 1.4
W/D Ratio	< 12	> 12	> 12	> 40	< 40	< 12	> 12	< 12
Sinuosity	1 - 1.2	> 1.2	> 1.2	n/a	variable	>1.5	> 1.2	>1.2
Slope	.04-.099	.02-.039	< .02	< .04	< .005	< .02	< .02	.02-.039

from Rosgen, 1996

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Channel Adjustments and Responses

- **Channels adjust their bedform configuration, width, depth, slope, and meander pattern in response to changes in discharge, sediment supply, and/or base level changes**
- **Channel adjustments occur in response to naturally occurring events such as floods, landslides, etc. or land-use activities such as logging/road building, mining, urbanization, dam building, etc.**
- **The rate of channel adjustment varies spatially and temporally along the channel in response to a disturbance; this reflects watershed- and local-scale differences in geomorphic setting, fluvial processes, channel characteristics, and past disturbances**

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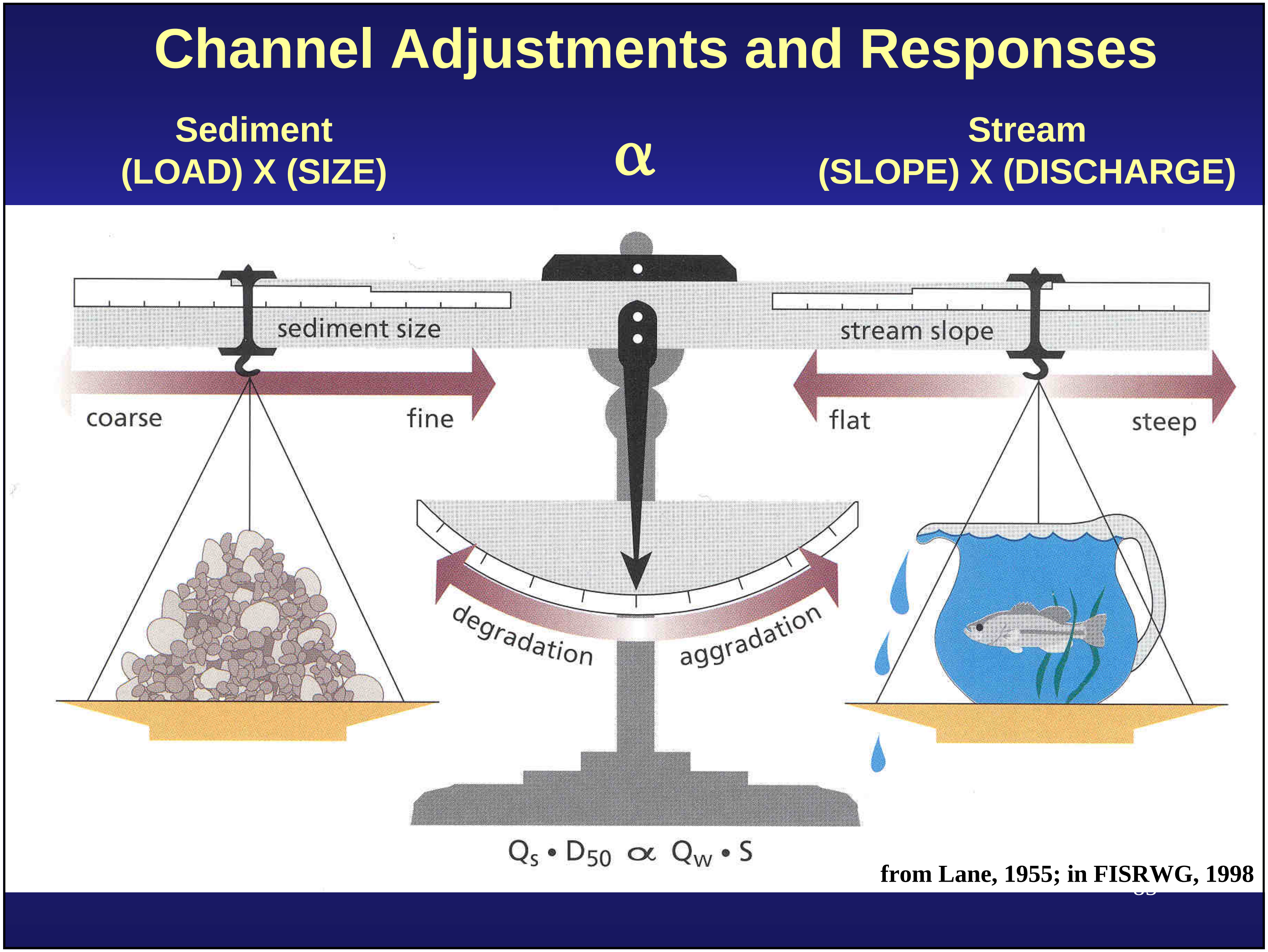
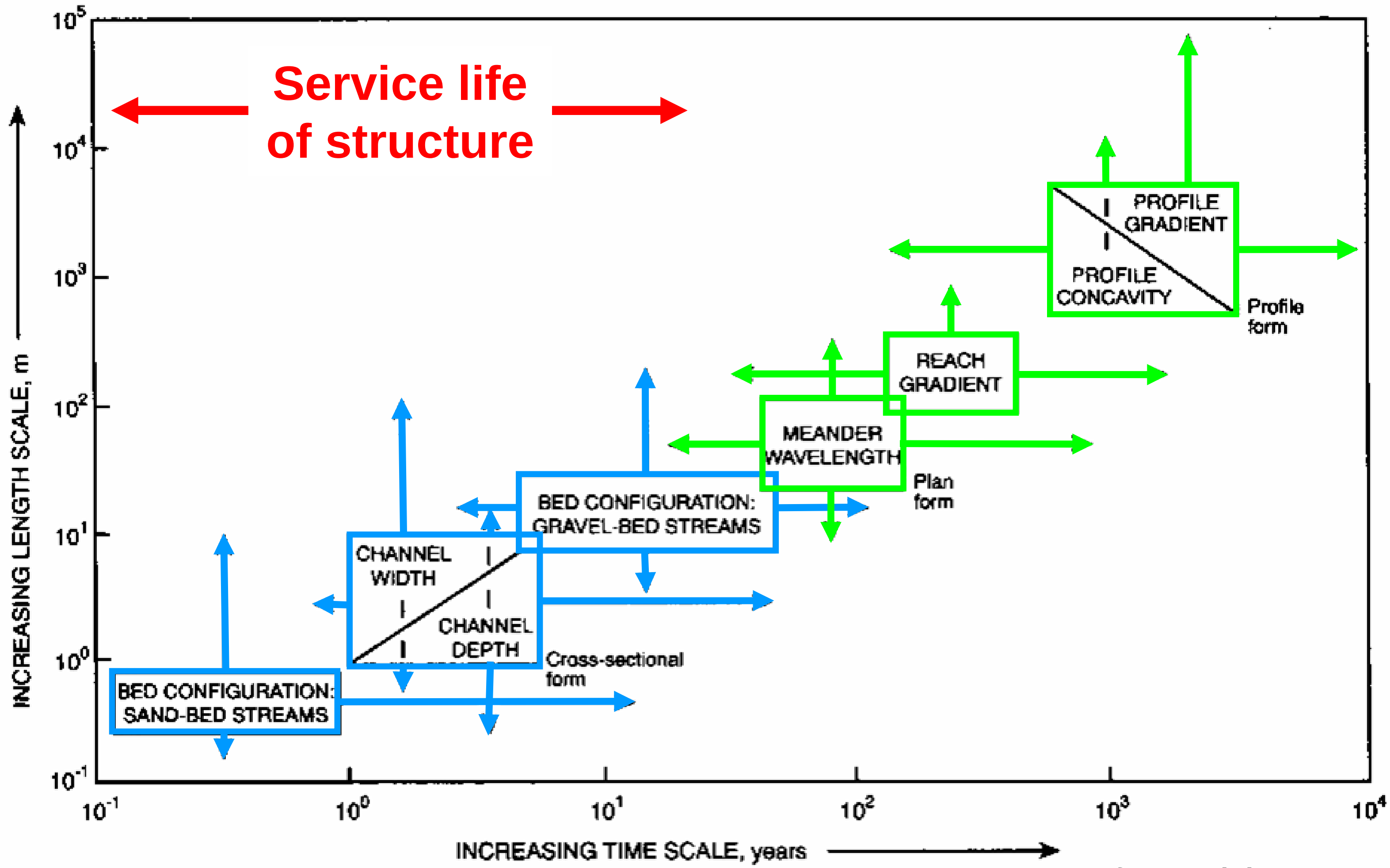
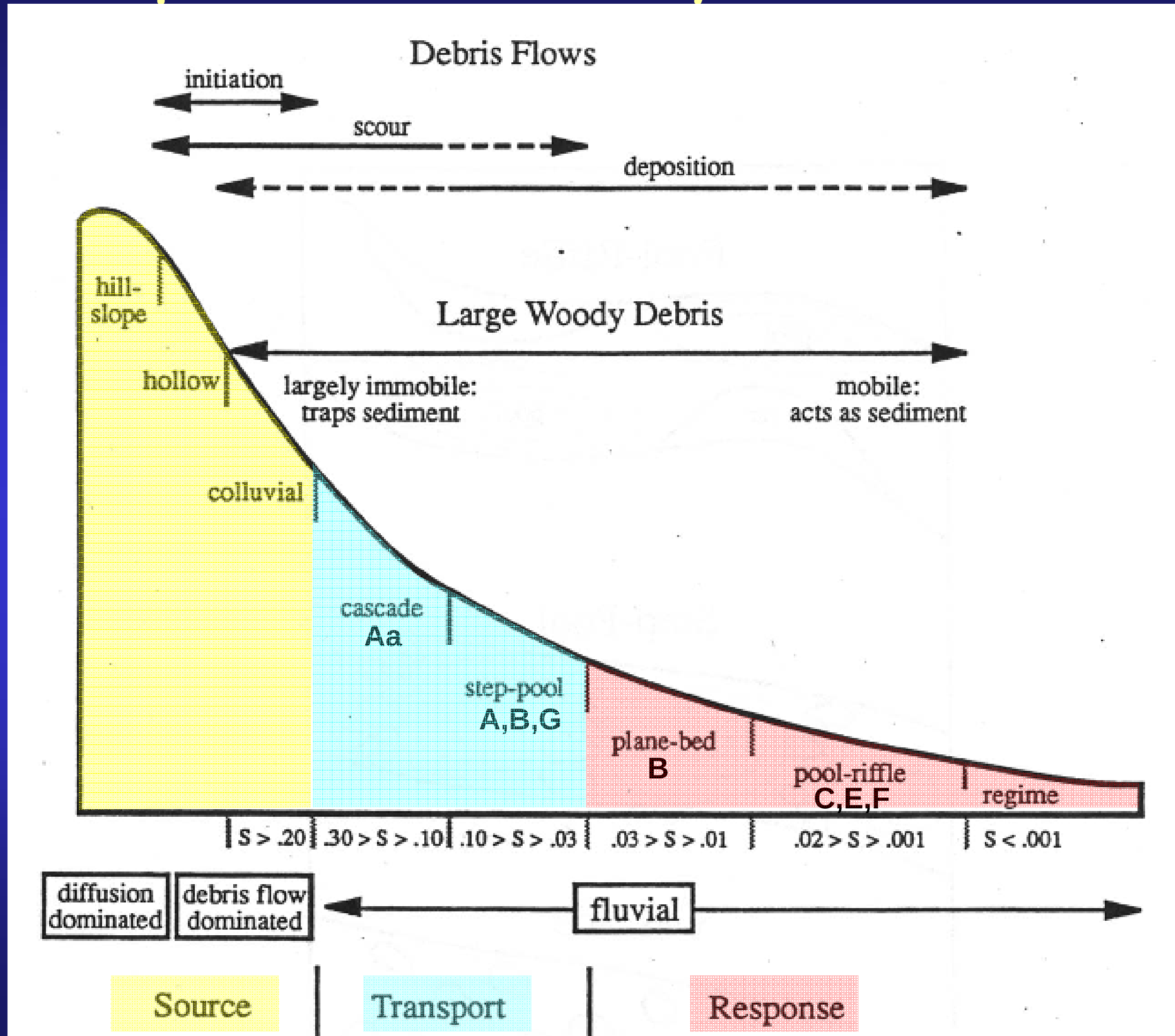

Channel Adjustments and Responses
Sediment
(LOAD) X (SIZE)
α
Stream
(SLOPE) X (DISCHARGE)
sediment size
coarse
fine
stream slope
flat
steep
degradation
aggradation
$Q_s \bullet D_{50} \propto Q_w \bullet S$
from Lane, 1955; in FISRWG, 1998

Timescales of adjustment



from Knighton, 1998

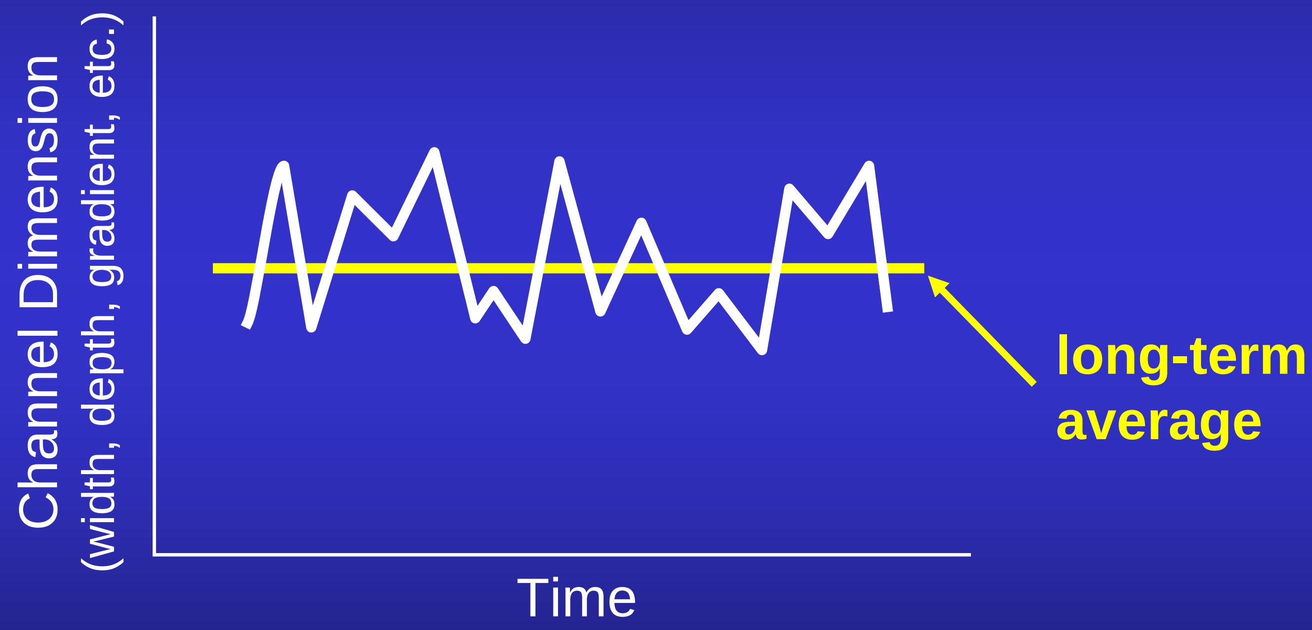
Channel Response: Influenced by Location in Watershed



87

from Montgomery & Buffington, 1993

Understanding and Predicting Channel Responses/Adjustments



Dynamic, Stable Channels: Steady State Equilibrium

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Channel Responses to an Undersized Culvert

$$\text{Inlet Constriction Ratio} = \frac{\text{Culvert Span}}{\text{Bankfull Width}} = \frac{2.1\ \text{m}}{9.7\ \text{m}} = 0.22$$

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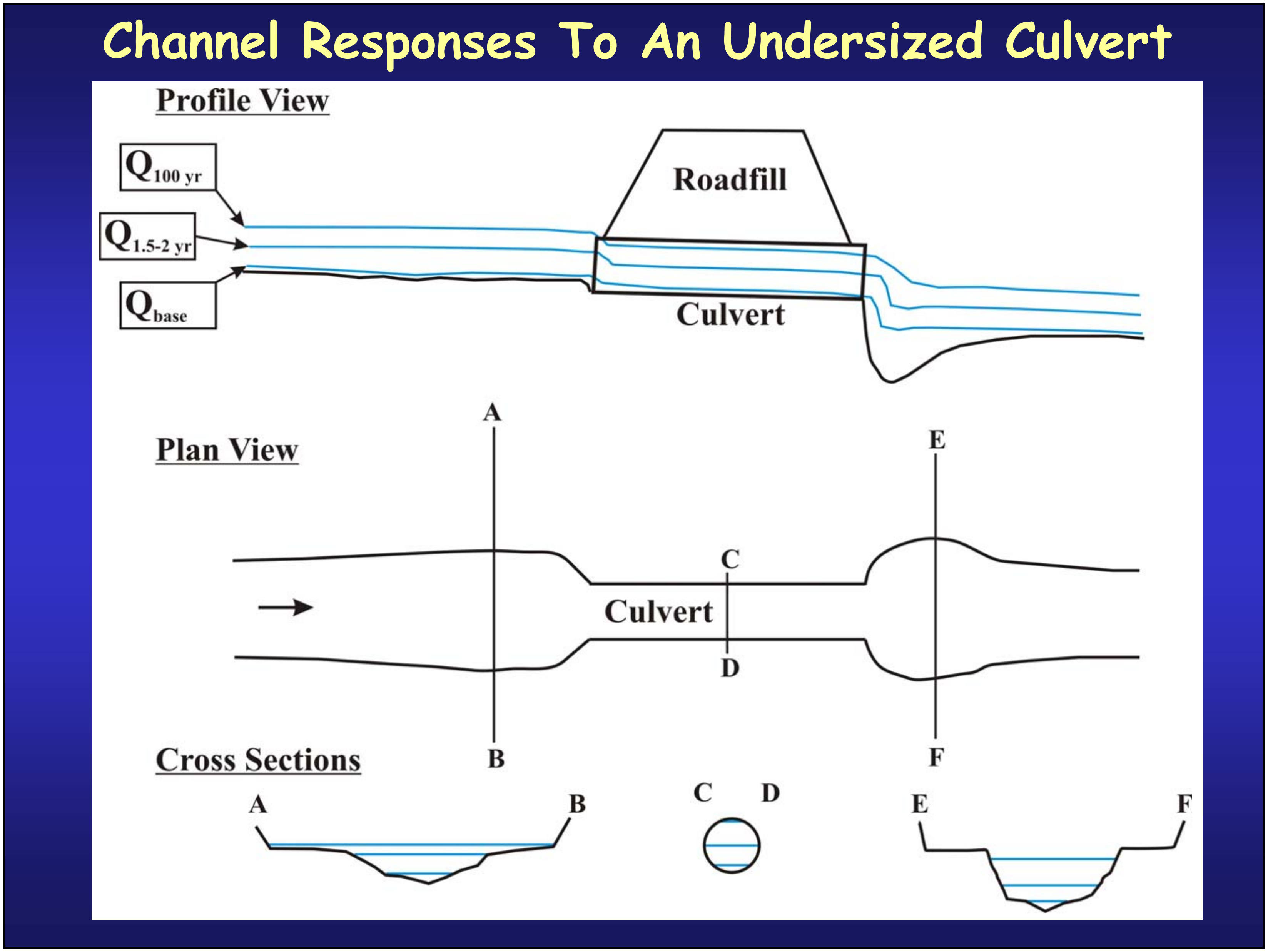
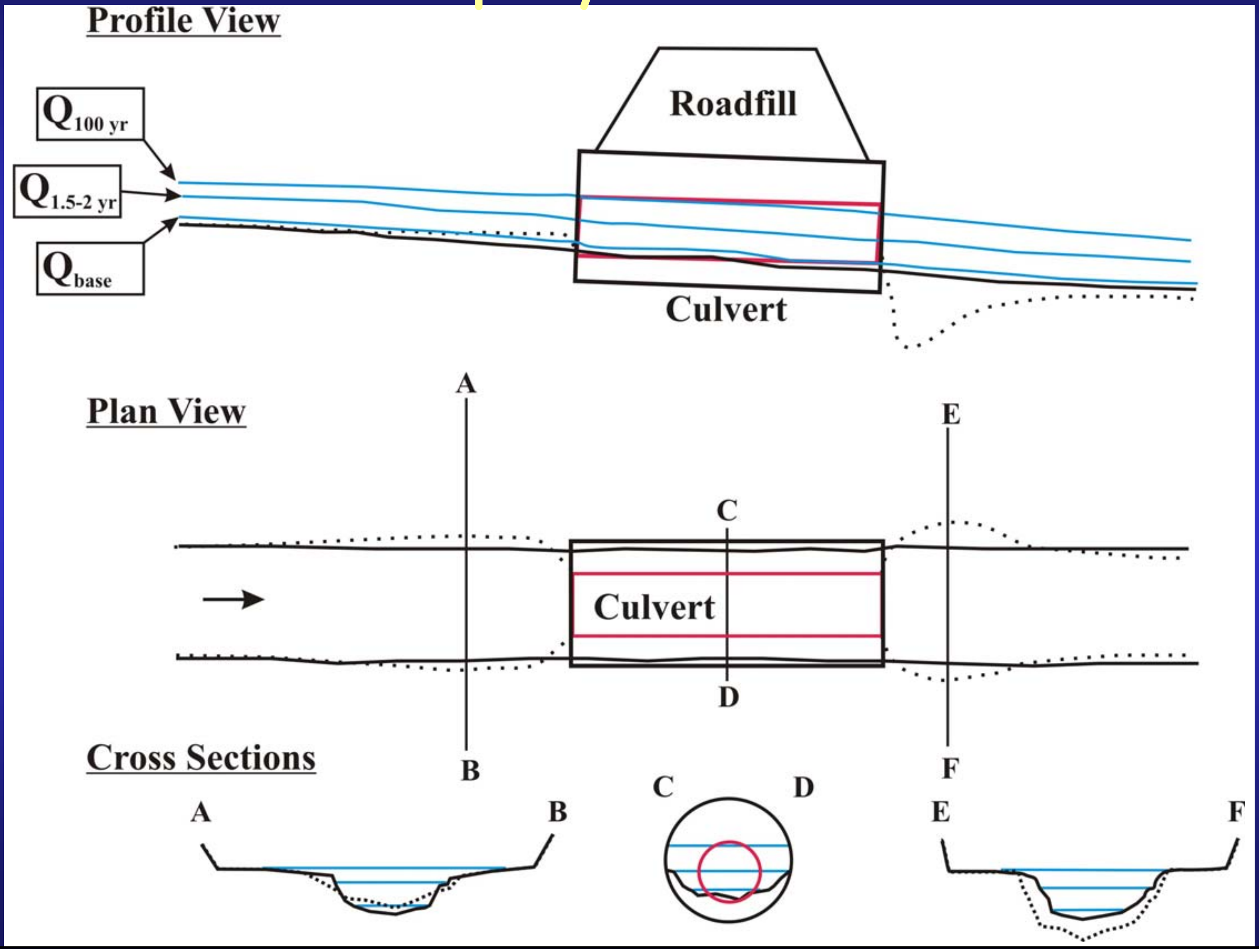
Channel Responses to an Undersized Culvert

$$\text{Outlet Expansion Ratio} = \frac{\text{Plunge Pool Scour Width}}{\text{Bankfull Width}} = \frac{12.8\text{ m}}{9.7\text{ m}} = 1.3$$

90

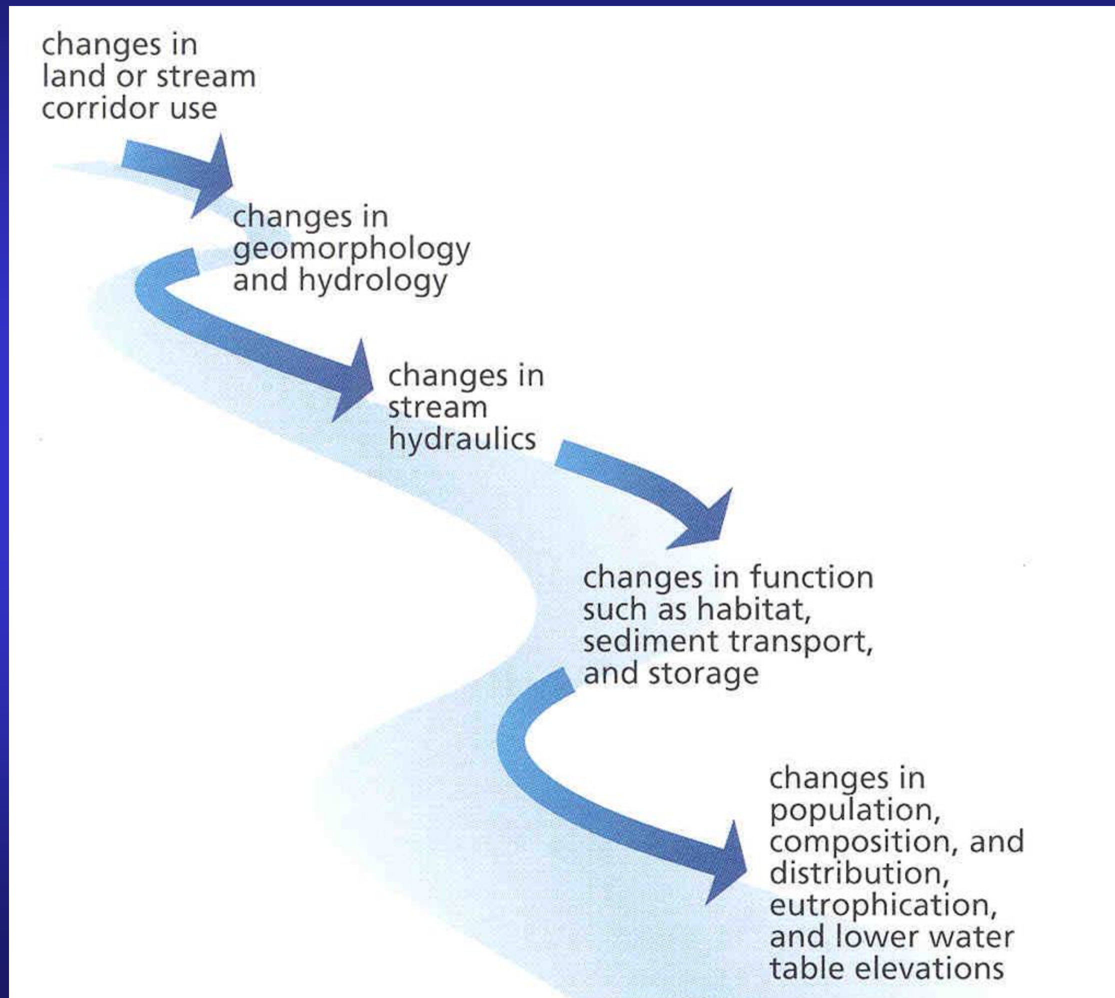

Channel Responses To An Undersized Culvert
Profile View
Q100 yr
Q1.5-2 yr
Qbase
Roadfill
Culvert
Plan View
A
B
C
D
E
F
Culvert
Cross Sections
A
B
C
D
E
F

Channel Responses After the Replacement of a "Properly-Sized" Culvert



Rate of Channel Adjustment

Channel Changes in Response to Undersized Culverts



from FISRWG, 1998

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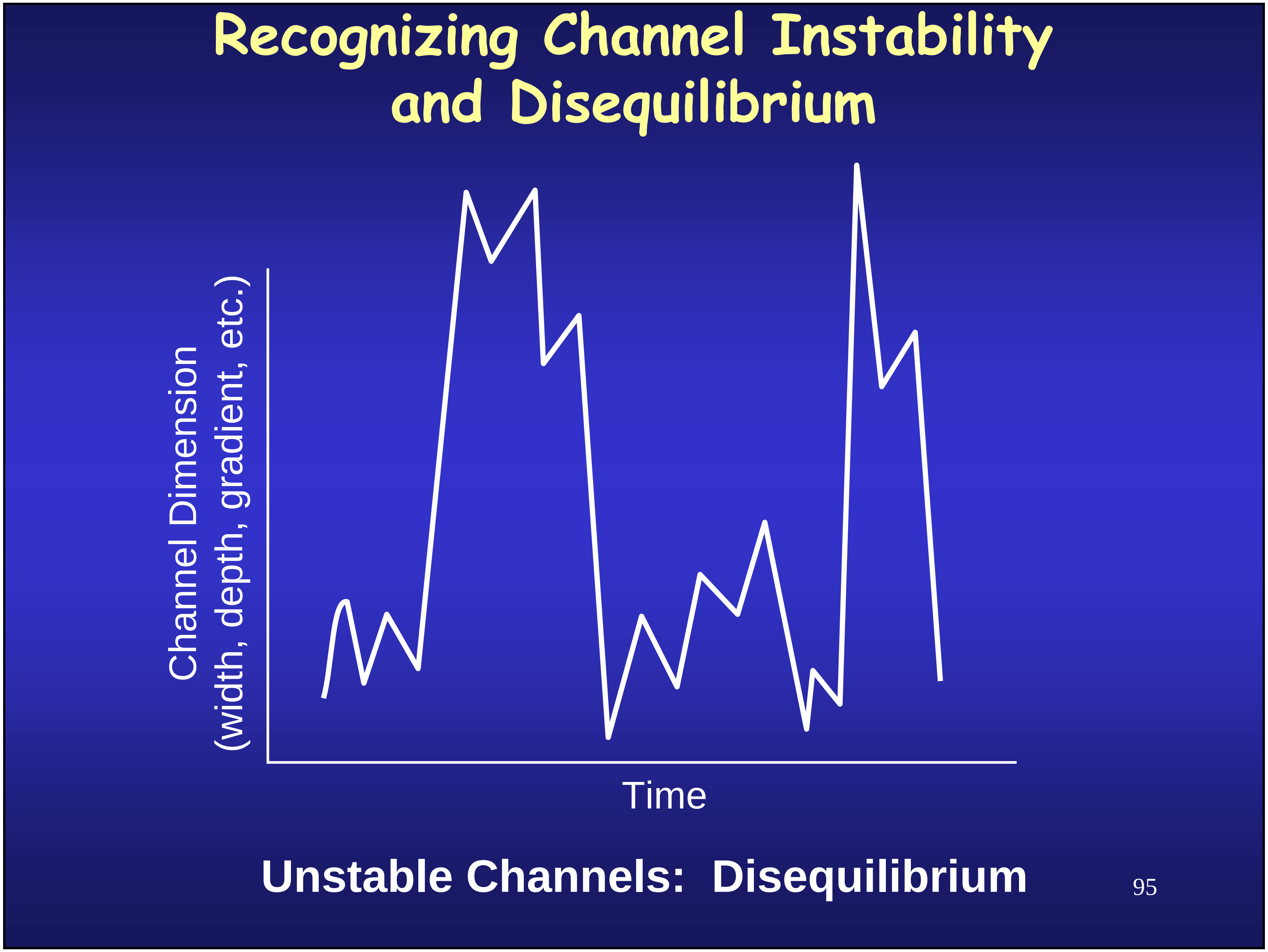
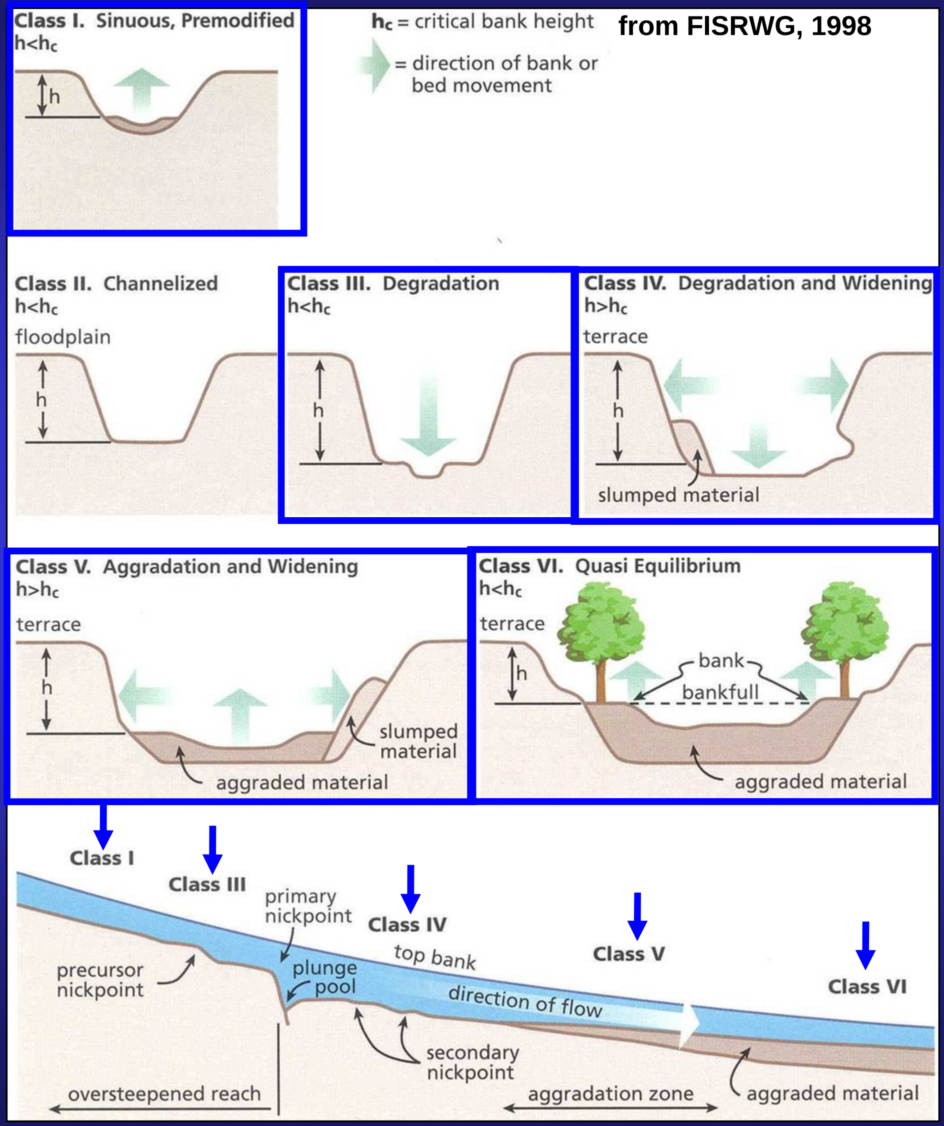

Recognizing Channel Instability
and Disequilibrium
Channel Dimension
(width, depth, gradient, etc.)
Time
Unstable Channels: Disequilibrium
95

Site Risk Assessment: Channel Instability

- **Important to recognize channel instability and disequilibrium**
- **Climate change, base-level changes, land-use practices, etc. can cause local and system-wide channel degradation and aggradation**

Site Risk Assessment: Channel Instability



- Channel Evolution Model

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Site Risk Assessment: Channel Instability

• Channel Evolution Model

Class No.	Class Name	Dominant Processes: Fluvial	Dominant Processes: Hillslope	Characteristic Forms	Geobotanical Evidence
I	Premodified	Sediment transport - mild aggradation; basal erosion on outside bends; deposition on inside bends.		Stable, alternate channel bars; convex top-bank shape; flow line high relative to top bank; channel straight or meandering.	Vegetated banks to flow line.
II	Constructed			Trapezoidal cross section; linear bank surfaces; flow line lower relative to top bank.	Removal of vegetation.
III	Degradation	Degradation; basal erosion on banks.	Pop-out failures.	Heightening and steepening of banks; alternate bars eroded; flow line lower relative to top bank.	Riparian vegetation high relative to flow line and may lean toward channel.
IV	Threshold	Degradation; basal erosion on banks.	Slab, rotational and pop-out failures.	Large scallops and bank retreat; vertical face and upper-bank surfaces; failure blocks on upper bank; some reduction in bank angles; flow line very low relative to top bank.	Riparian vegetation high relative to flow line and may lean toward channel.
V	Aggradation	Aggradation; development of meandering thalweg; initial deposition of alternate bars; reworking of failed material on lower banks.	Slab, rotational and pop-out failures; low-angle slides of previously failed material.	Large scallops and bank retreat; vertical face, upper bank, and slough line; flattening of bank angles; flow line low relative to top bank; development of new floodplain.	Tilted and fallen riparian vegetation; reestablishing vegetation on slough line; deposition of material above root collars of slough line vegetation.
VI	Restabilization	Aggradation; further development of meandering thalweg; further deposition of alternate bars; reworking of failed material; some basal erosion on outside bends deposition of flood-plain and bank surfaces.	Low-angle slides; some pop-out failures near flow line.	Stable, alternate channel bars; convex-short vertical face on top bank; flattening of bank angles; development of new floodplain; flow line high relative to top bank.	Reestablishing vegetation extends up slough line and upper bank; deposition of material above root collars of slough-line and upper-bank vegetation; some vegetation establishing on bars.

from FISRWG, 1998

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Site Risk Assessment: Channel Responses to Consider

- **Channel stability:** Is the overall channel stable or unstable because of system-wide degradation and aggradation?
- **Vertical adjustment potential:** What is the potential range of channel-bed elevations over the service life of the structure from scour and fill processes during floods, sediment and wood inputs from debris flows and/or debris torrents, loss or formation of debris jams, land-use changes, etc.?
- **Headcut potential:** What are the ecological implications for allowing headcutting to occur as the channel adjusts to establish a new equilibrium condition?
- **Lateral adjustment potential:** Can channel migration or lateral shifting over the service life of the structure affect stream/culvert alignment?
- **Floodplain inundation/connectivity:** Is floodplain function and connectivity important to the fluvial system and ecological processes?

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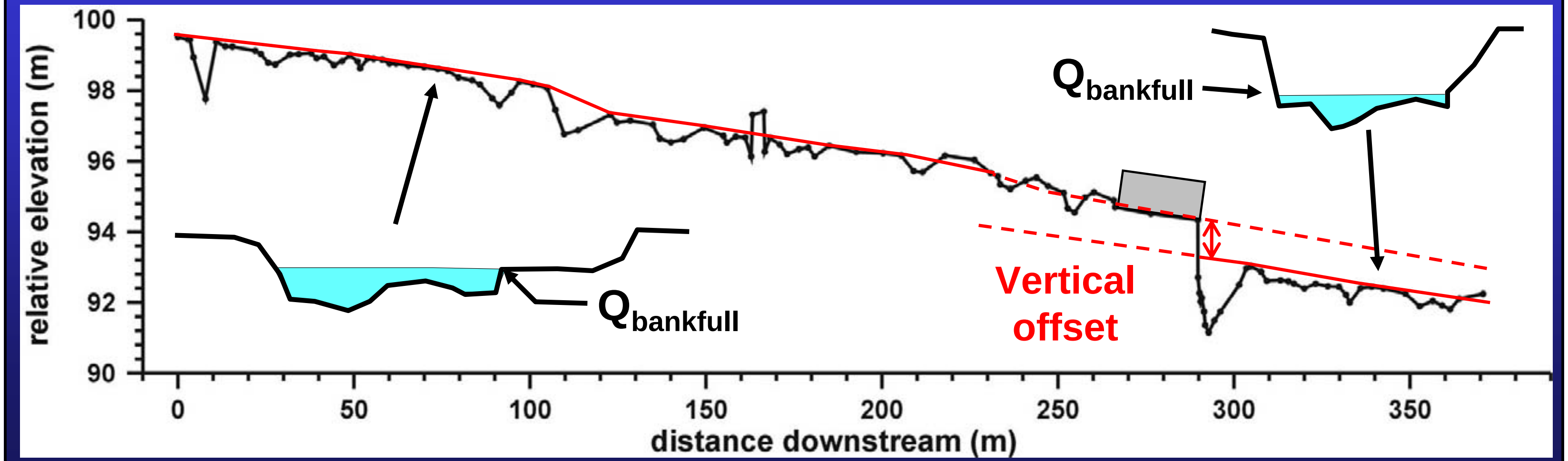
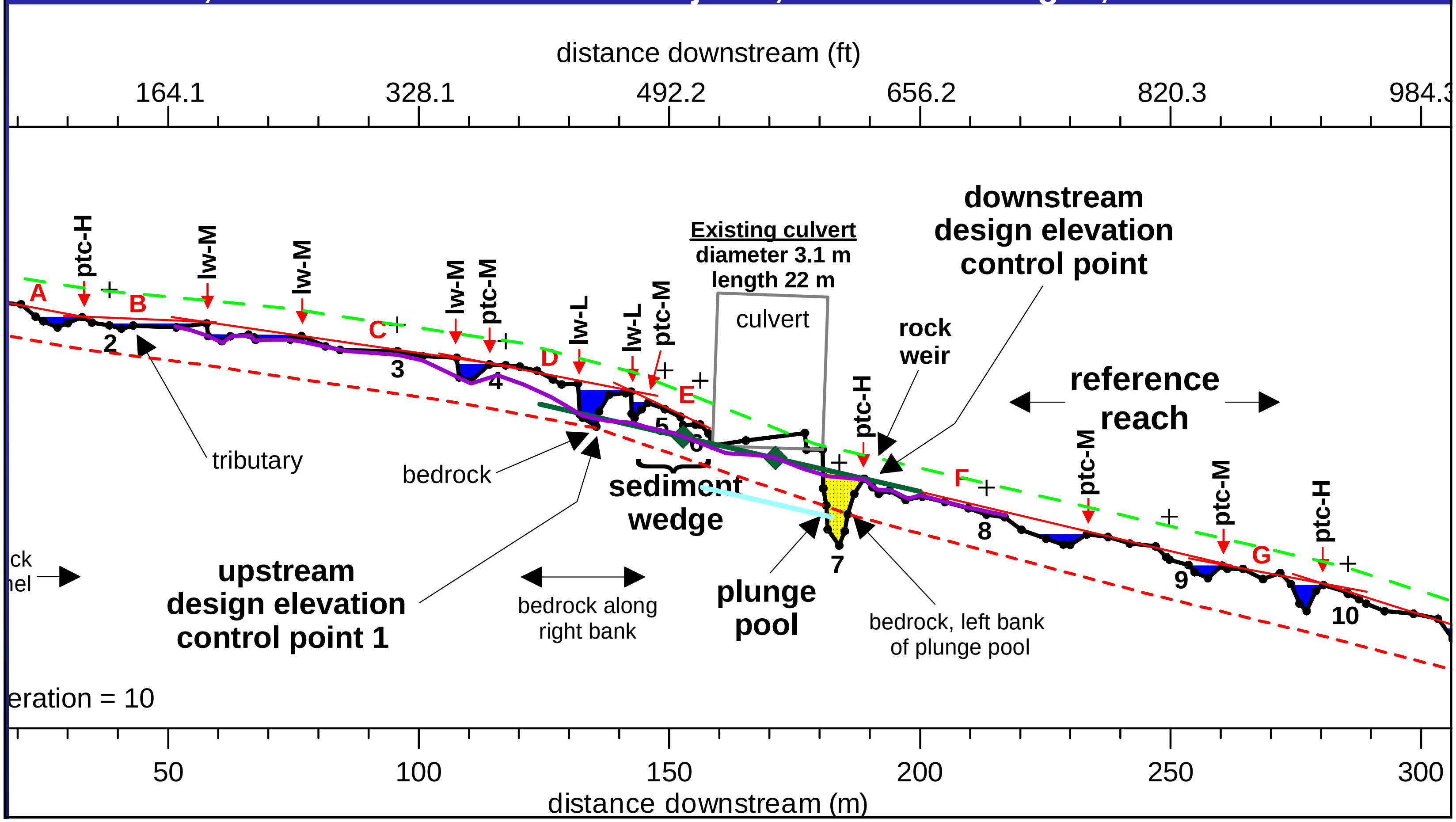
Predicting Channel Responses When Replacing a Structure

Channel stability: Is the overall channel stable or unstable because of system-wide degradation and aggradation?



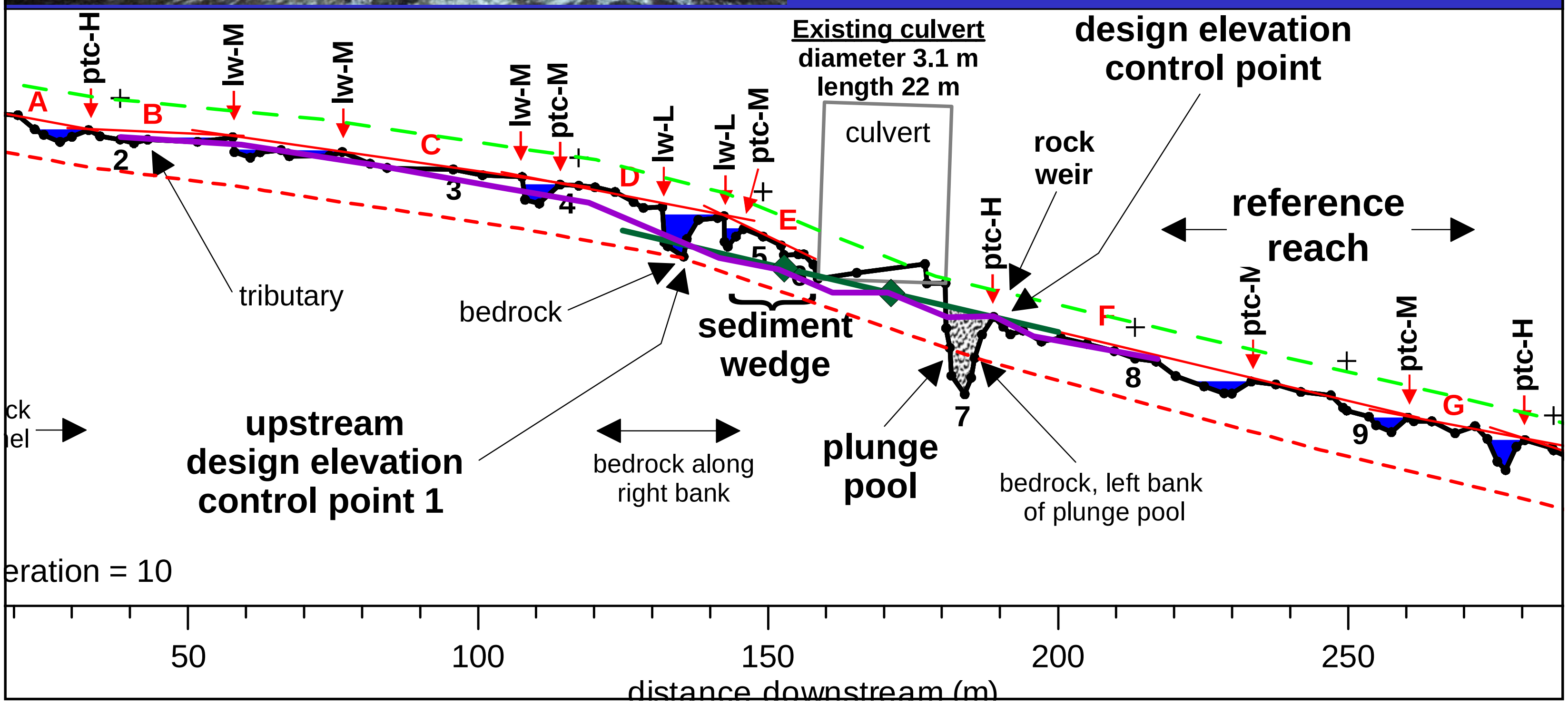
Predicting Channel Responses When Replacing a Structure

Vertical adjustment potential: What is the potential range of channel-bed elevations over the service life of the structure from scour and fill processes during floods, sediment and wood inputs from debris flows and/or debris torrents, loss or formation of debris jams, land-use changes, etc.?



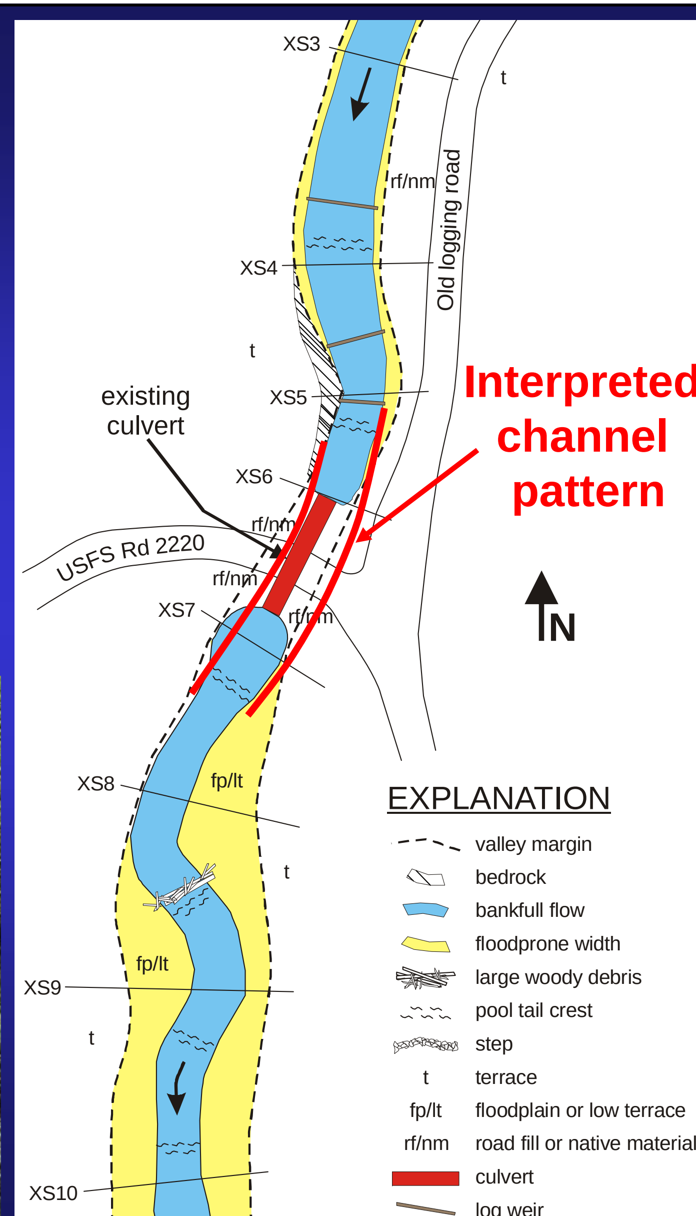
Predicting Channel Responses When Replacing a Structure

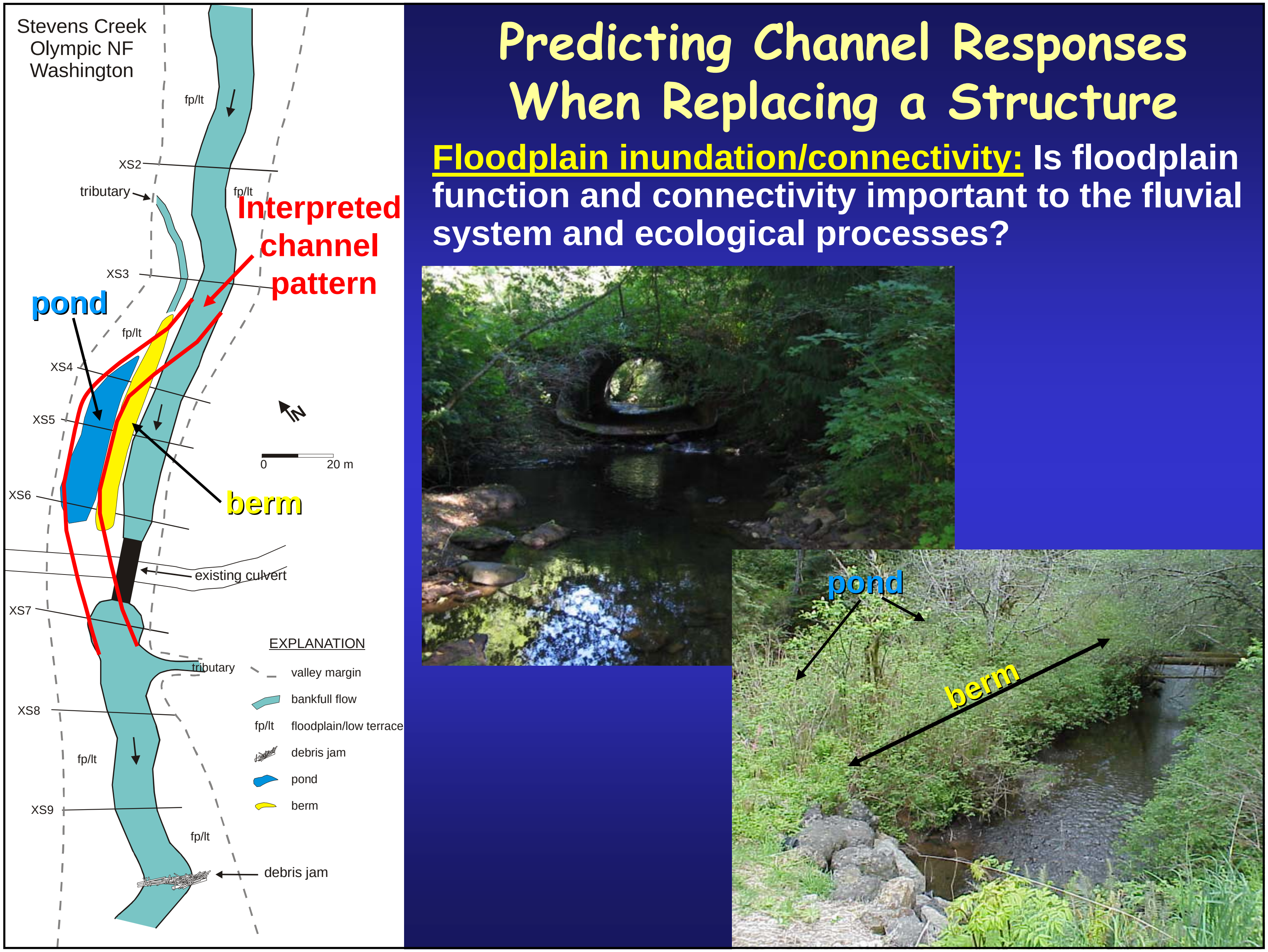
Headcut potential: What are the ecological implications for allowing headcutting to occur as the channel adjusts to establish a new equilibrium condition?

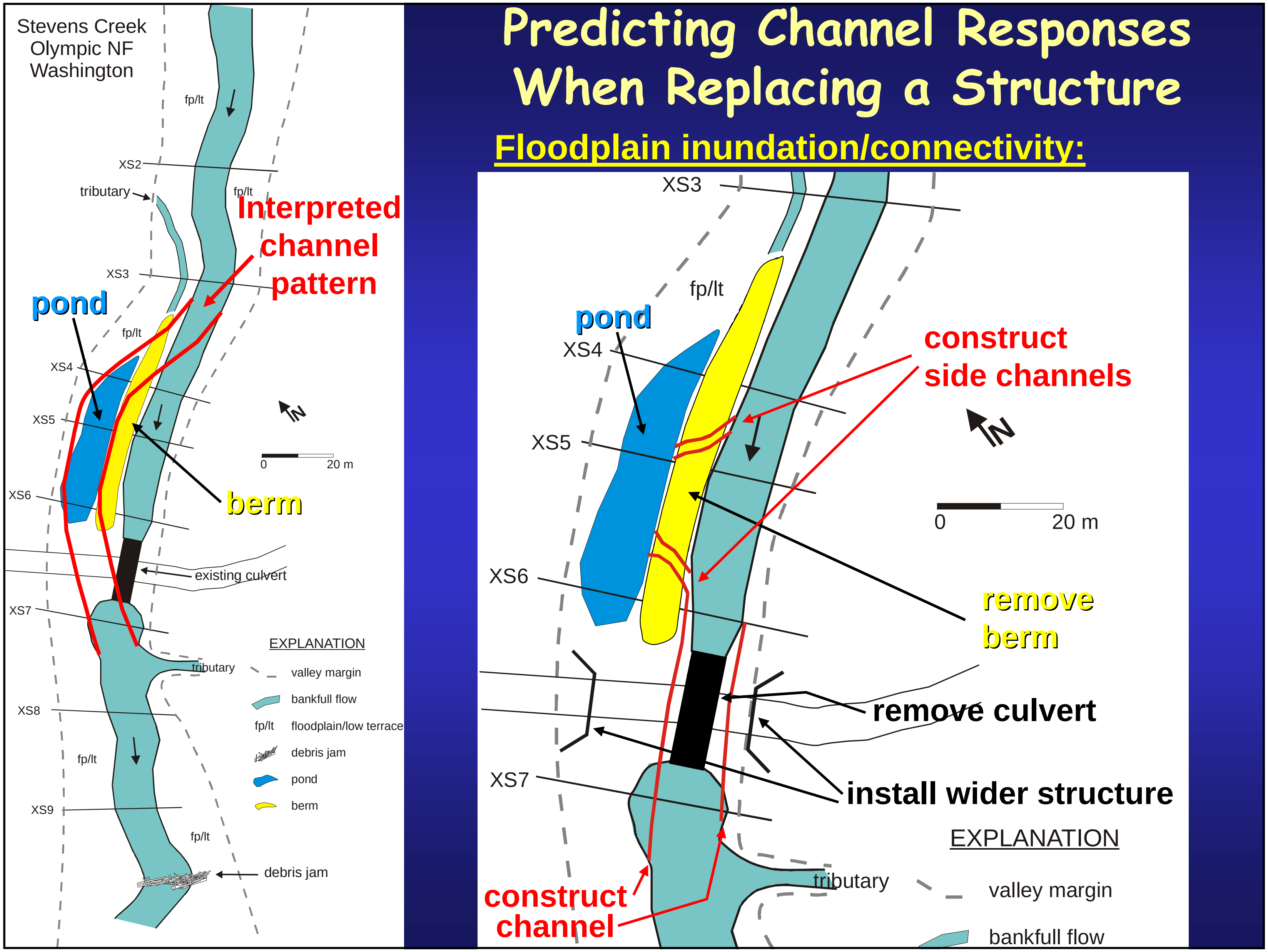


Predicting Channel Responses When Replacing a Structure

- **Lateral Adjustment Potential:** Can channel migration or lateral shifting over the service life of the structure affect stream/culvert alignment?




Predicting Channel Responses When Replacing a Structure
Floodplain inundation/connectivity: Is floodplain function and connectivity important to the fluvial system and ecological processes?
Stevens Creek
Olympic NF
Washington
fp/lt
XS2
tributary
fp/lt
Interpreted channel pattern
XS3
pond
fp/lt
XS4
XS5
N
0
20 m
XS6
berm
existing culvert
XS7
EXPLANATION
tributary
valley margin
bankfull flow
fp/lt floodplain/low terrace
debris jam
pond
berm
XS8
fp/lt
XS9
fp/lt
debris jam
pond
berm


Stevens Creek
Olympic NF
Washington
fp/lt
XS2
tributary
fp/lt
Interpreted channel pattern
XS3
pond
fp/lt
XS4
XS5
XS6
berm
0
20 m
existing culvert
XS7
EXPLANATION
tributary
valley margin
bankfull flow
fp/lt floodplain/low terrace
debris jam
pond
berm
XS8
fp/lt
XS9
fp/lt
debris jam
Predicting Channel Responses When Replacing a Structure
Floodplain inundation/connectivity:
XS3
fp/lt
pond
XS4
construct side channels
XS5
0
20 m
XS6
remove berm
remove culvert
XS7
install wider structure
EXPLANATION
tributary
valley margin
construct channel
bankfull flow

Summary

- Watershed-scale and local-scale processes influence channel conditions at the crossing; consideration of these processes at both scales are needed for understanding channel conditions, fluvial processes, and channel responses at the road-stream crossing.
- The gradient, planform pattern, dimensions, bedforms, and sediment size of the natural channel must be evaluated at the road-stream crossing in order to design a structure that contains a natural and dynamic channel.
- A road-stream crossing channel design that has dimensions and characteristics similar to those in the natural channel will ensure that the design channel will be able to laterally and vertically adjust its form to a wide range of floods and sediment/debris inputs without compromising the movement and habitat needs of fish and other aquatic organisms.

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