7A. Site Assessment: Field Measurements and Interpretations

Channel Cross Sections, Channel-Bed Sediments and Channel-Bank Materials, Geotechnical Investigation, Risk Assessment

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Acknowledgements

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Stream Simulation Site Assessment Process

A

- Initial Site Assessment
- **Site Assessment**
  - Site Maps and Channel Planform Characteristics
  - Reference Reach
  - Roadway Considerations
  - Longitudinal Profile

B

  - **Channel Cross Sections**
  - Characterizing Channel-Bed Sediments and Channel-Bank Material
  - Preliminary Geotechnical Investigation
  - Project Site Risk Assessment

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What is the Purpose of a Channel Cross Section?

1) Establishes the natural dimensions of the channel (shape and range)
2) Delineates the width and depth of low flow, the stream bed, bankfull flow, floodplain inundation
3) Determines “reference reach” channel dimensions to be used in the channel-bed design through the structure
4) Identifies the lateral adjustment potential of the channel (channel migration zone).
5) Identifies bank and channel stability
6) Can be used for discharge and hydraulic calculations

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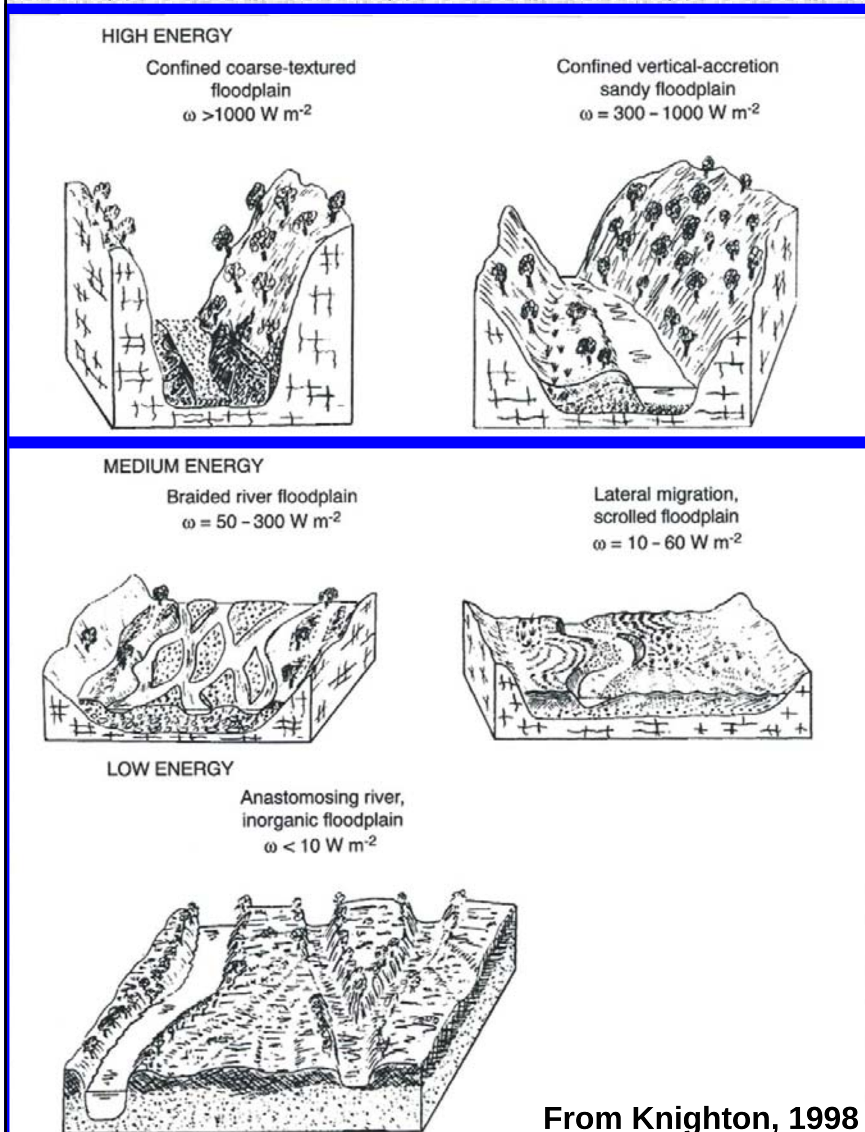
Confined and Unconfined Channels



From Knighton, 1998

Confined channels

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

Unconfined channels

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

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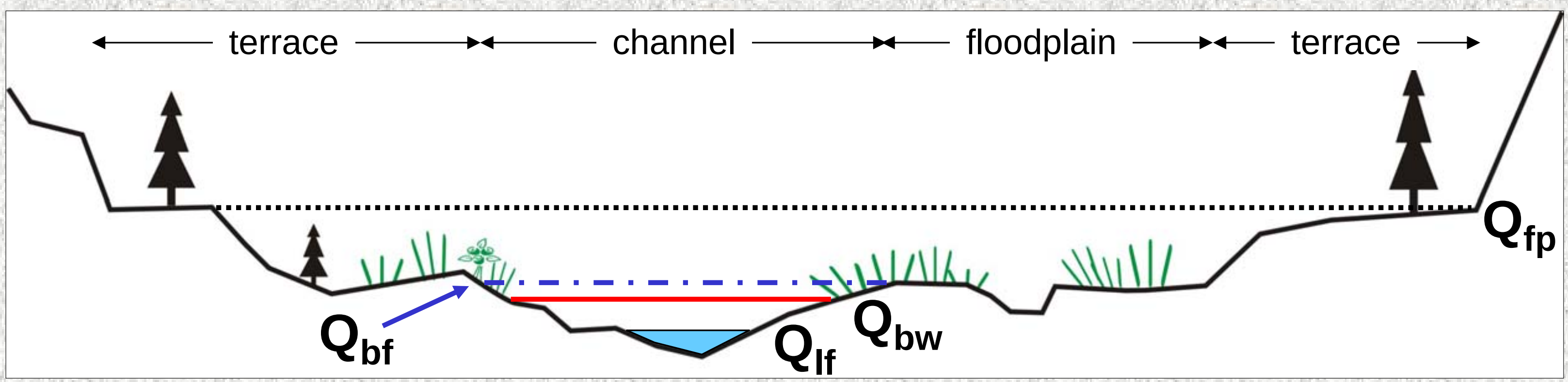
Definitions

Bankfull Flow Width (Q_{bf}): In streams with adjustable banks, it is the point at which a stream begins to overtop its banks and begins to spill onto the floodplain.

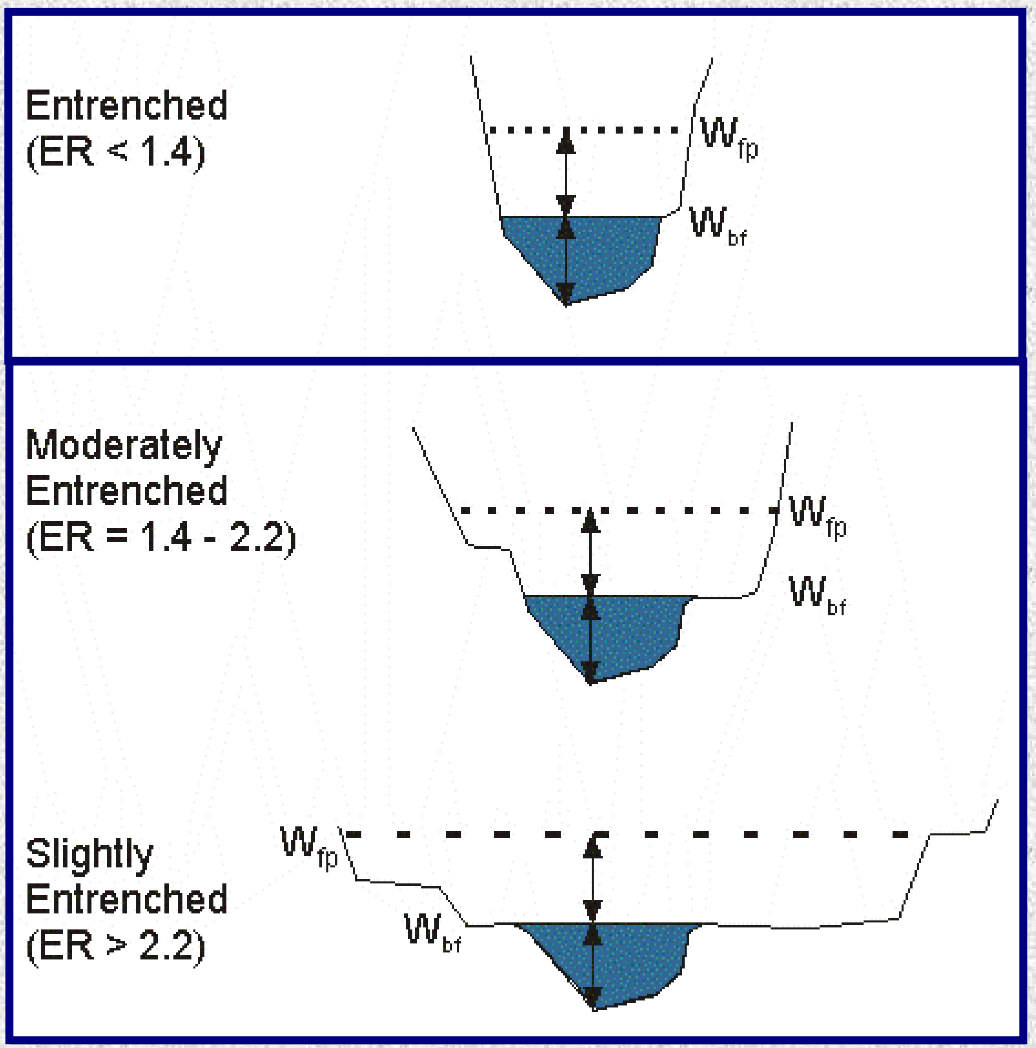
Stream Bed Width (Q_{bw}): The zone of annual scour in the channel.

Low Flow Width (Q_{lf}): The wetted width of the channel during drier conditions.

Flood Prone Width (Q_{fp}): The flood prone area for flows greater than bankfull.



Flood Prone Width, Channel Entrenchment



$$ER = \frac{W_{fp}}{W_{bf}}$$

ER is entrenchment ratio

W_{bf} is bankfull width

W_{fp} is the flood prone width of the valley bottom at two times the maximum bankfull depth

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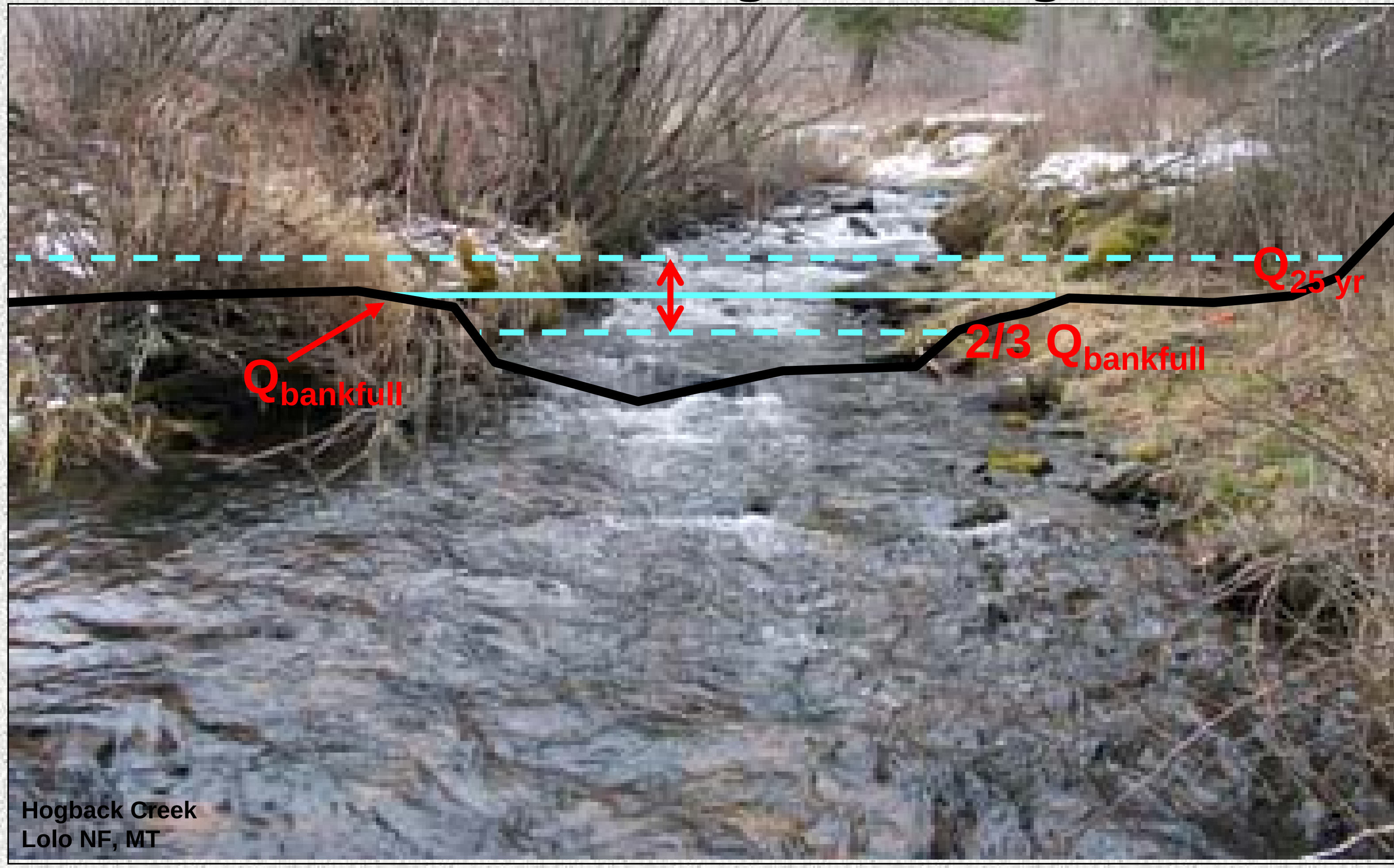
Channel-Forming Discharges



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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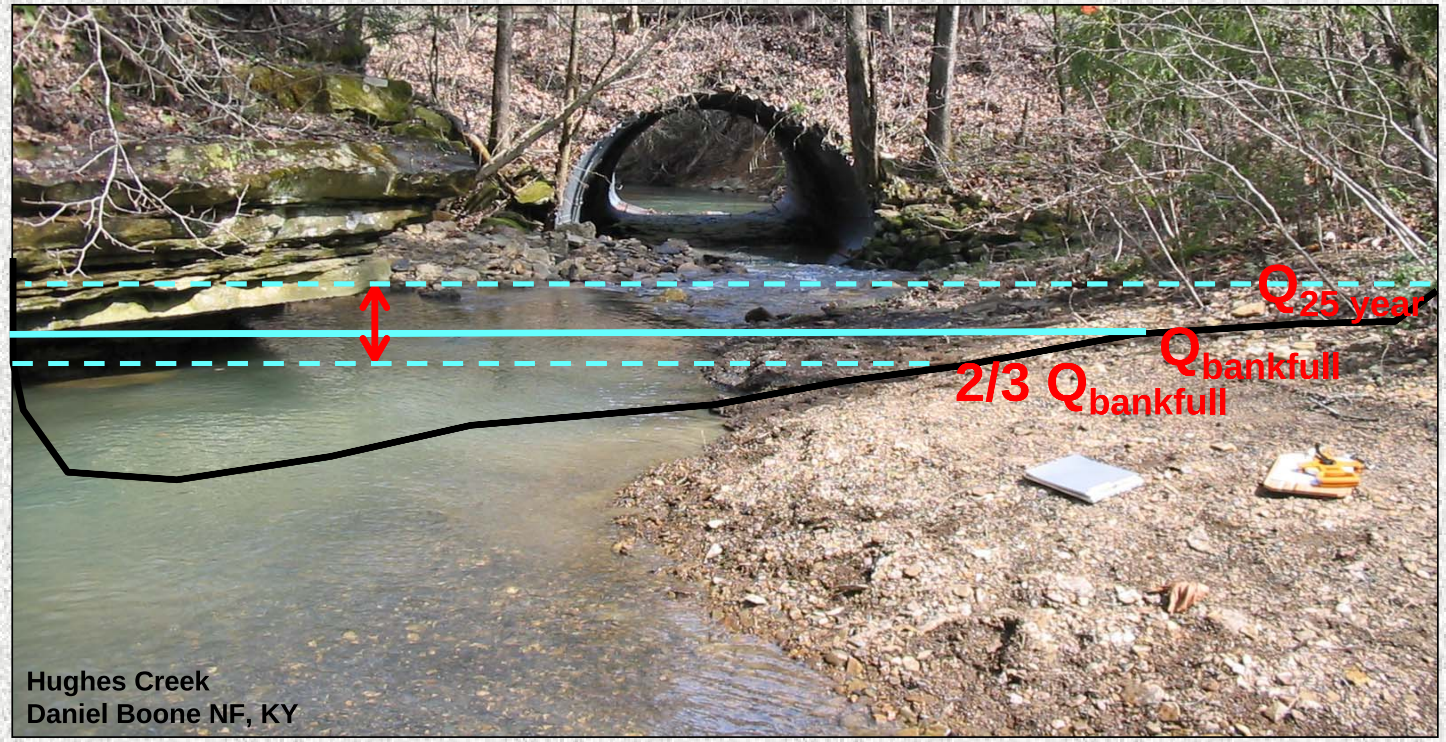
Purpose/Significance of Identifying Bankfull Flow



- **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**

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Bankfull Flow Indicators

- Elevation of the active floodplain margin adjacent to the channel (floodplain may be present as discontinuous patches).
- Elevation associated with the top of the highest depositional feature (point bars and mid-channel bars in active channels).
- Slope or topographic breaks along channel banks.
- Change in particle-size distribution of bank sediments (boundary between coarse and fine sediments).
- Change in vegetation types (especially the lower limit of perennial species).
- Stain lines or the lower extent of moss and lichens on boulders and large cobbles in the channel.

Stream Bed Width Indicators

- The area of the channel devoid of vegetation.

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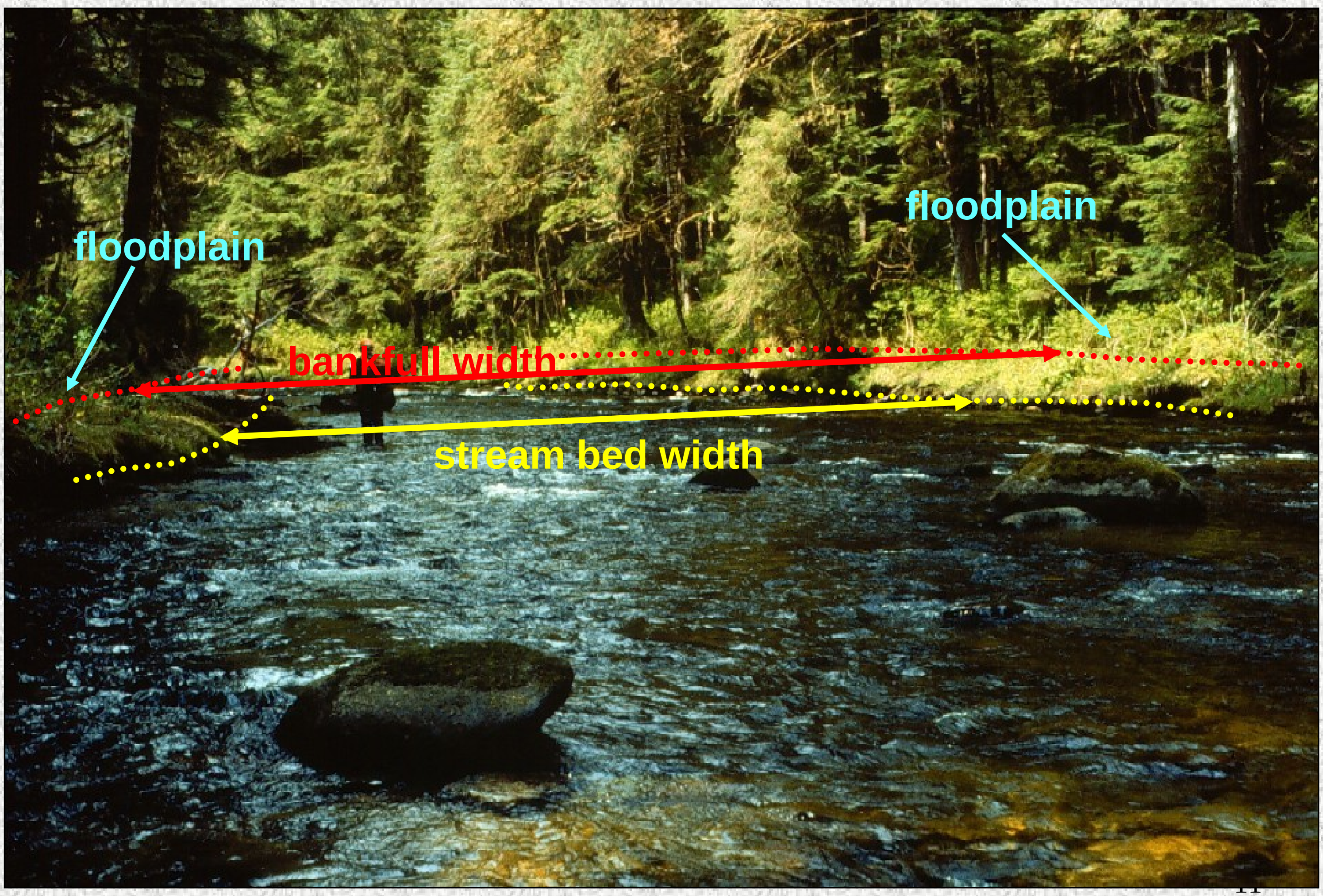
Stream Bed Width and Bankfull Width



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Stream Bed Width and Bankfull Width

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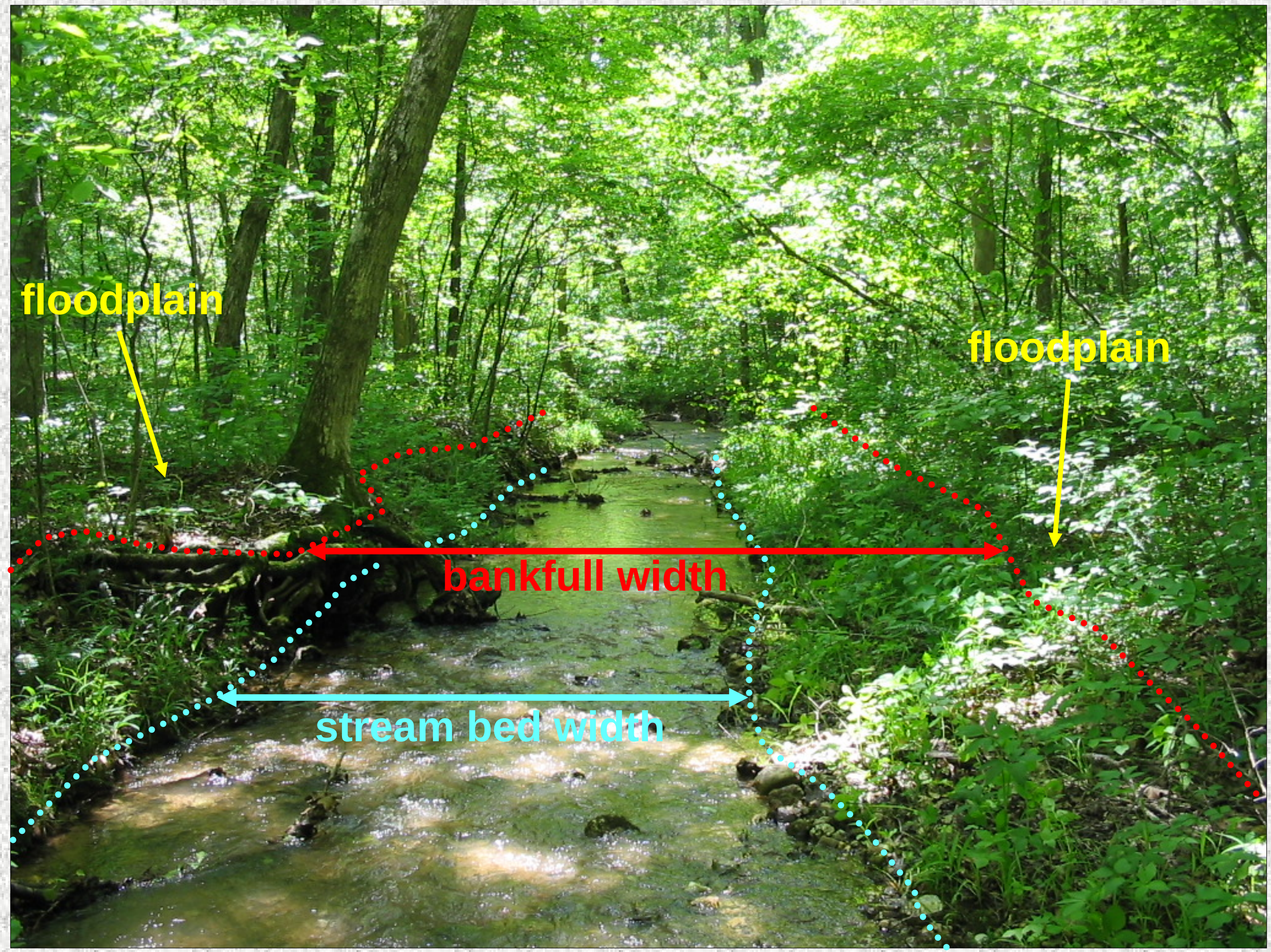
Stream Bed Width and Bankfull Width



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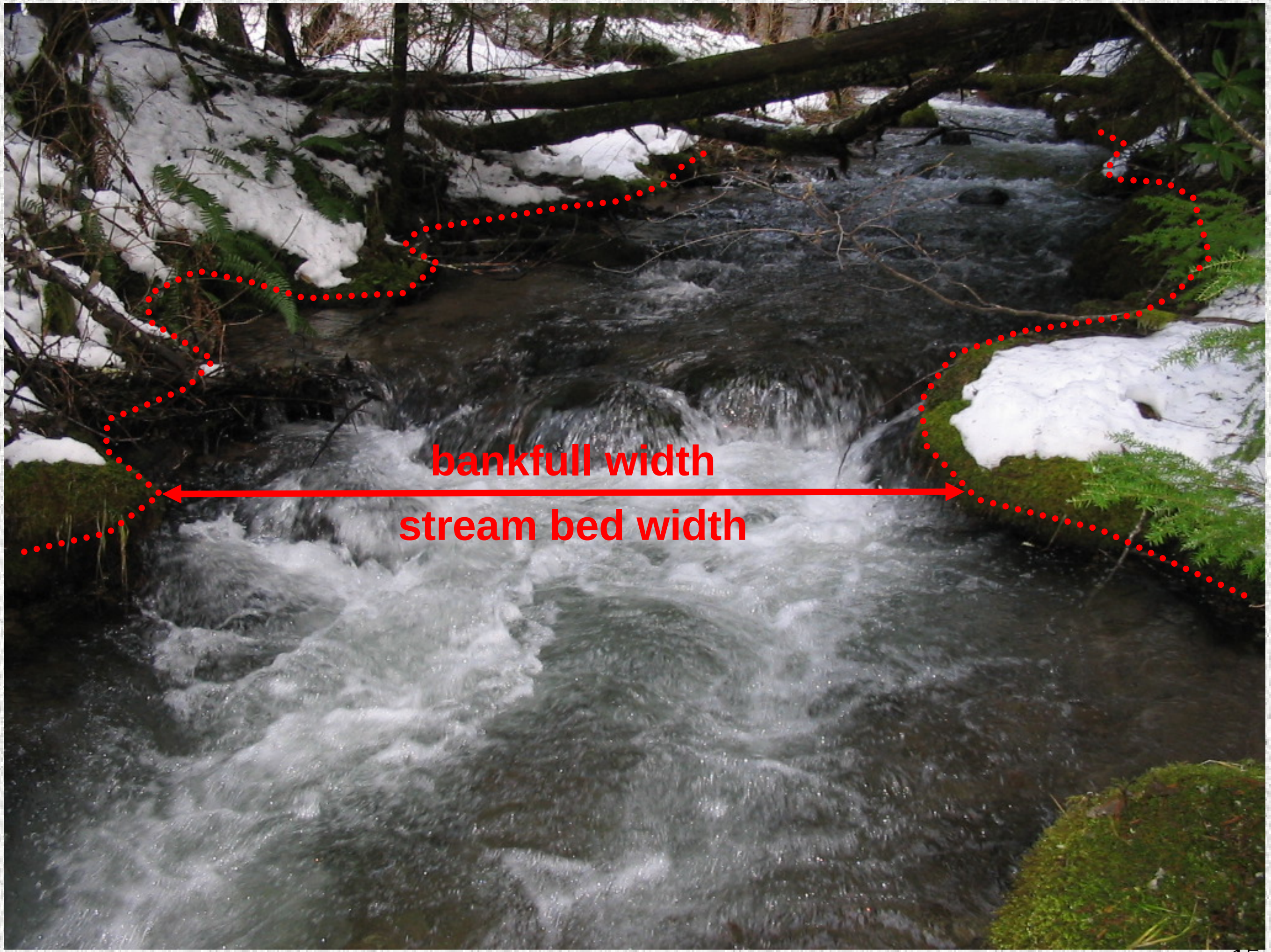
Stream Bed Width and Bankfull Width

Stream Bed Width and Bankfull Width



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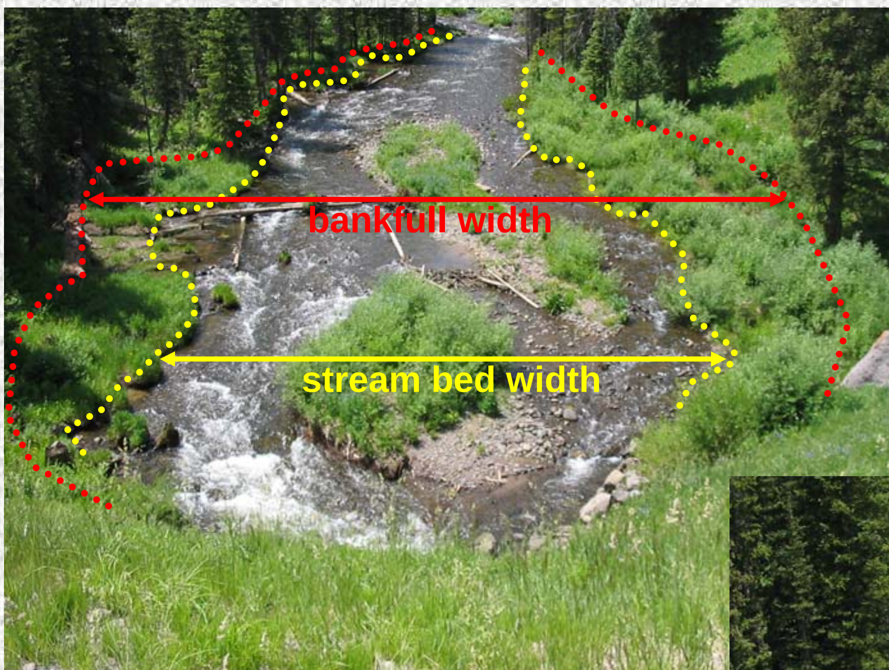
Stream Bed Width and Bankfull Width

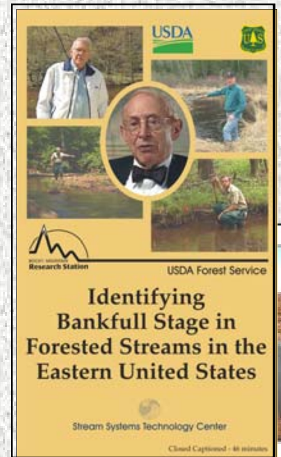


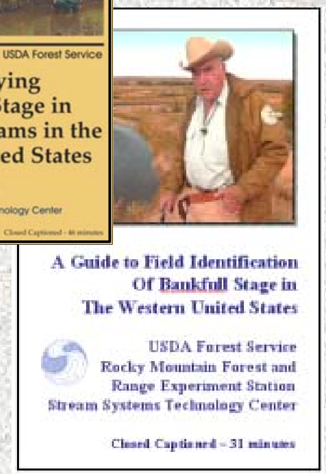
upstream view of culvert inlet

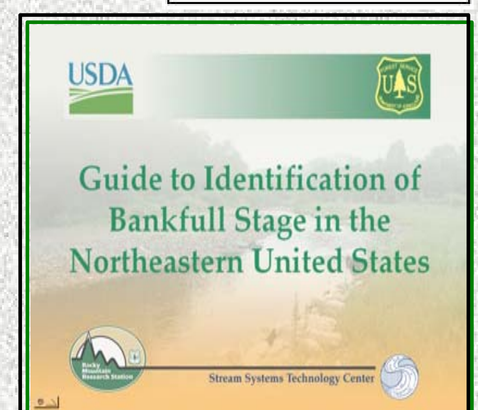
downstream view of culvert outlet

Where to get More Information on Identifying Bankfull Flow

- **The USDA Forest Service, Stream Systems Technology Center has produced multimedia presentations describing the techniques and procedures for identifying bankfull flow for different channel types:**
  - Identifying Bankfull Stage in the Eastern and Western United States (USDA Forest Service, 2003)
  - A Guide to Identification of Bankfull Stage in the Northeastern U.S. (USDA Forest Service, 2005)
- **Refer to the website below for information on how to obtain a copy of these multimedia presentations:**
  - http://www.stream.fs.fed.us/publications/videos.html







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Factors Influencing Channel Shape

- **Channel-Bed and Channel-Bank Materials**
  - Particle size, compaction, hardness, and cohesion of sediments
  - The type and rooting depth of vegetation
  - The size and burial depth of LWD
- **Position in Channel Planform**
  - Straight channel segments
  - Channel bends
- **Gradient**
  - High-gradient channel segments
  - Low-gradient channel segments
- **Flood History**
  - The effects of recent flooding
- **Sediment Supply**
  - High sediment supply versus low sediment supply

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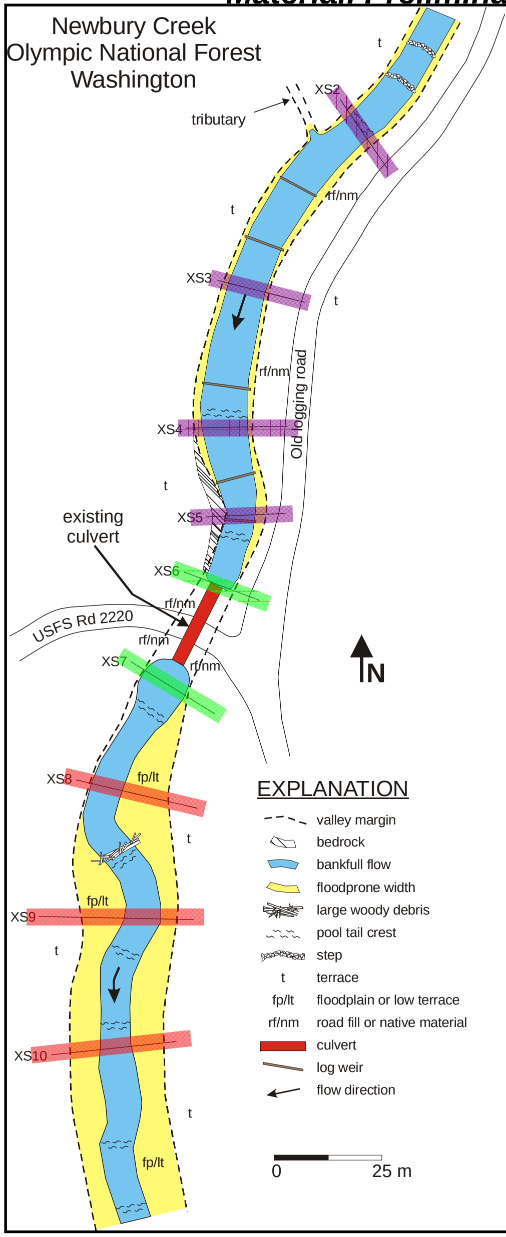

Cross Section Locations

- Immediately upstream and downstream from the culvert.
- At least two representative cross sections upstream from the culvert that best describe channel characteristics.
- At least two representative cross sections downstream from the culvert that best describe channel characteristics.
- If flow modeling is anticipated to determine flood hydrology and hydraulics, more cross sections will be needed to describe channel/valley transitions and dimensions.

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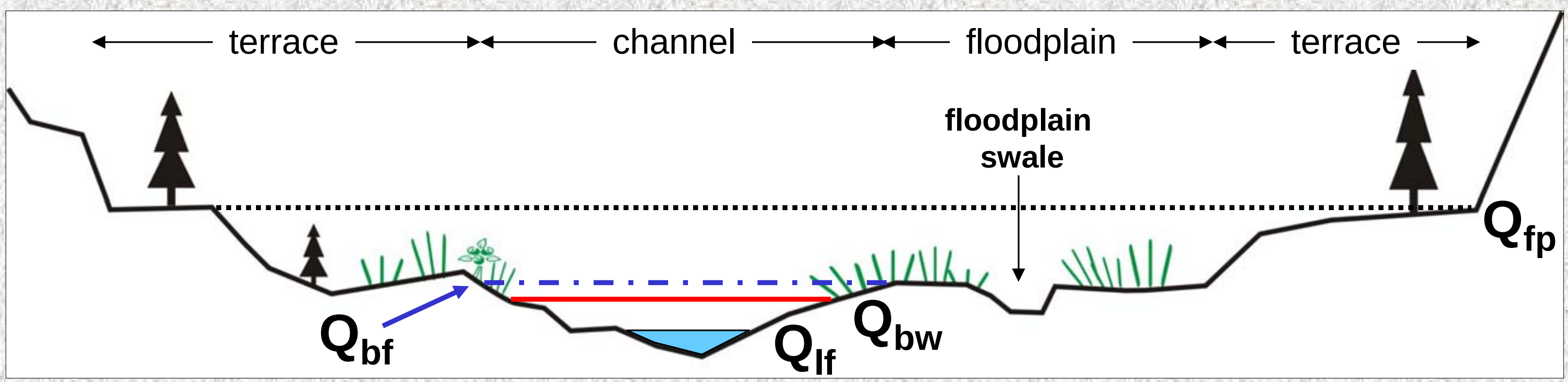
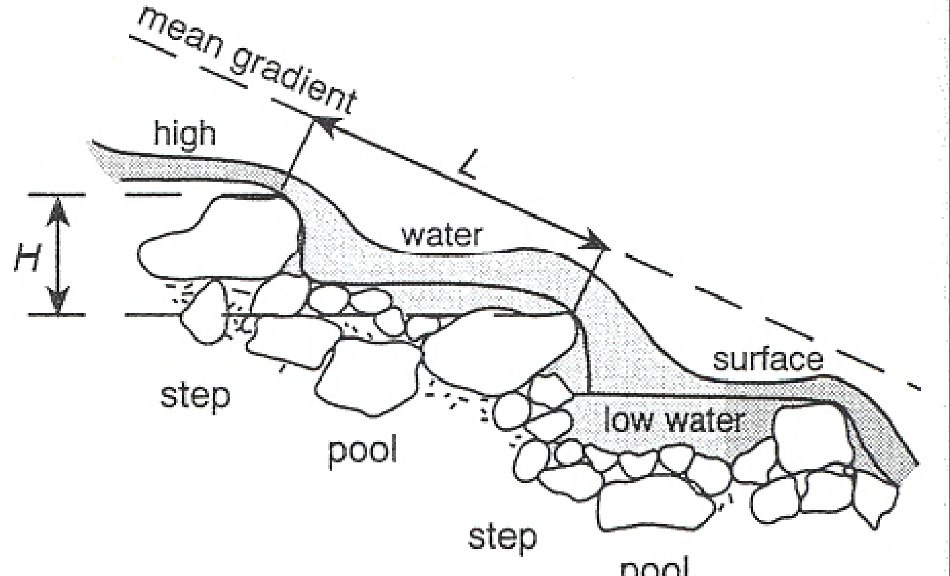
Typical Measuring Points for a Cross Section

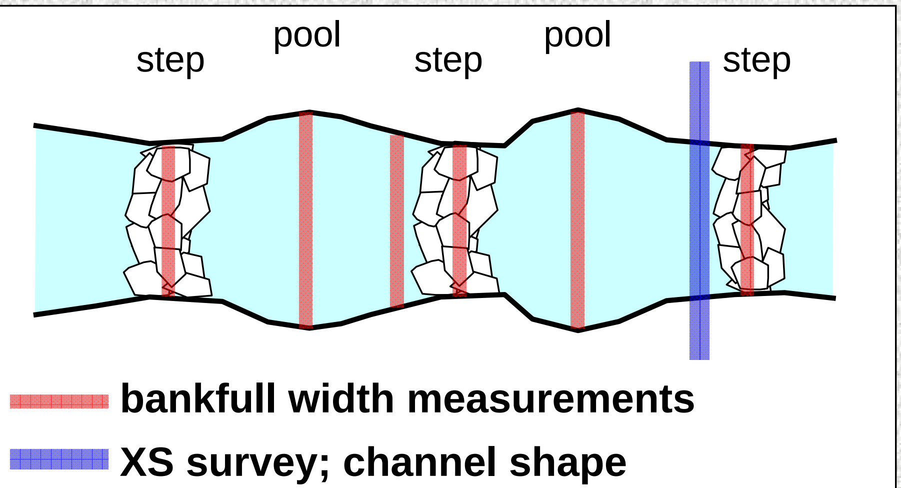
- The width of the cross section should extend at least two times the maximum bankfull depth to characterize channel and valley bottom (floodplain, terraces, etc.) dimensions.
- At bankfull and stream bed width flow indicators.
- At topographic breaks/transitions between the channel bed, channel deposits, the channel bank, the floodplain, terraces, and the valley slope.
- At changes in particle sizes along the channel bed and channel banks.
- At changes in vegetation types along the bank margin, floodplain, and terraces.
- Field evidence of past floods (e.g., scoured flood-plain swales or surfaces, accumulations of woody debris or fine sediments on the floodplain or low terrace).



Measuring Bankfull Width and Cross Section Shape in Step-Pool Channels



from Knighton, 1998



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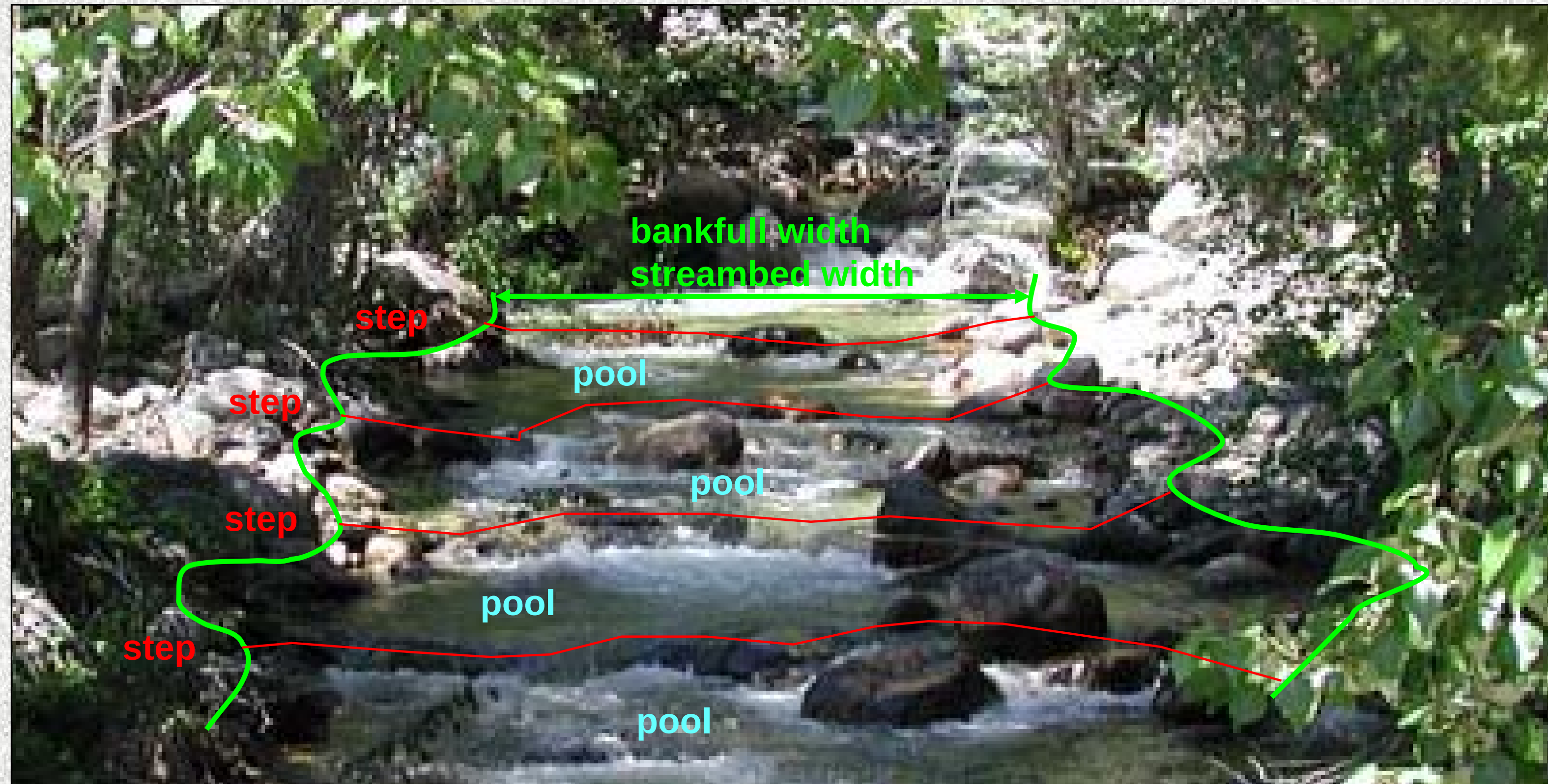

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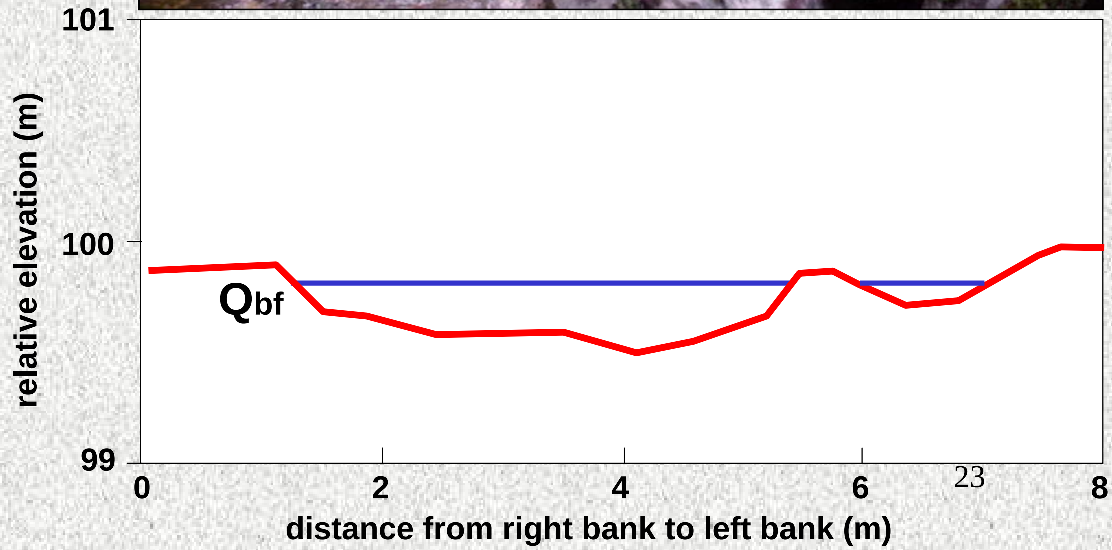
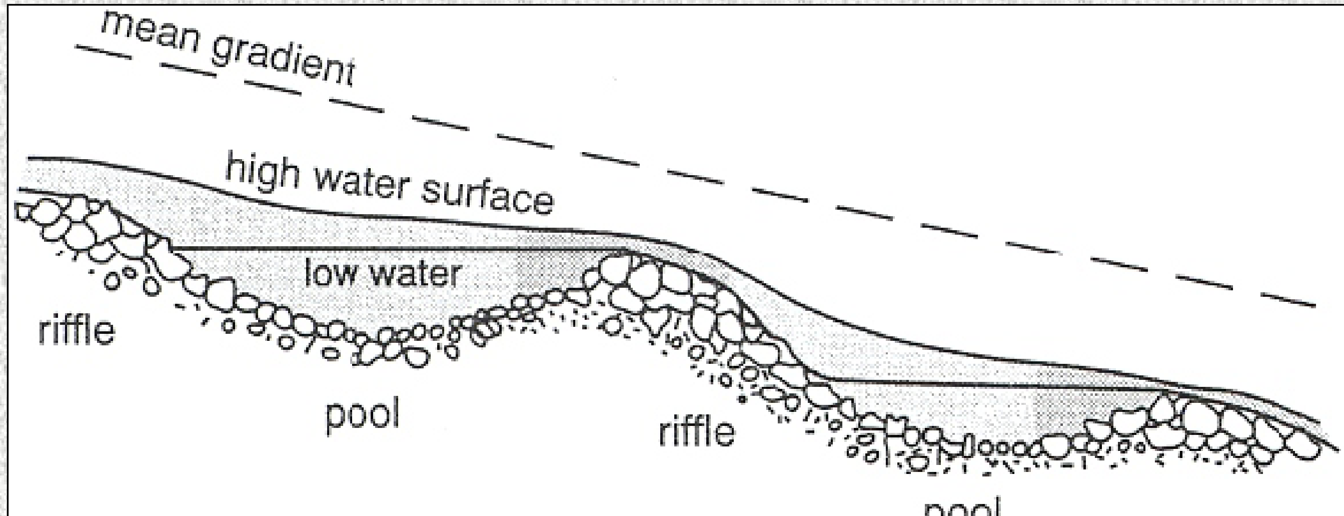
Step-pool Channel Cross Section Example

Cross-section in the riffle or run portion of the step-pool channel.

Collect multiple bankfull width measurements from different channel units; maximum width of pool, step crest.



Measuring Bankfull Width and Cross Section Shape in Pool-Riffle Channels



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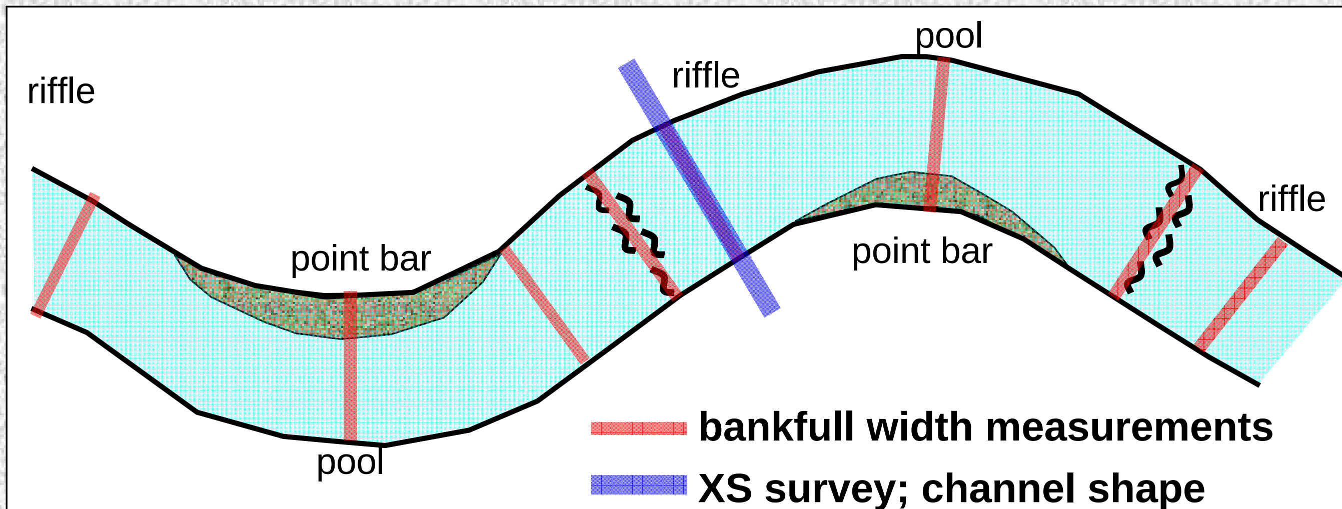

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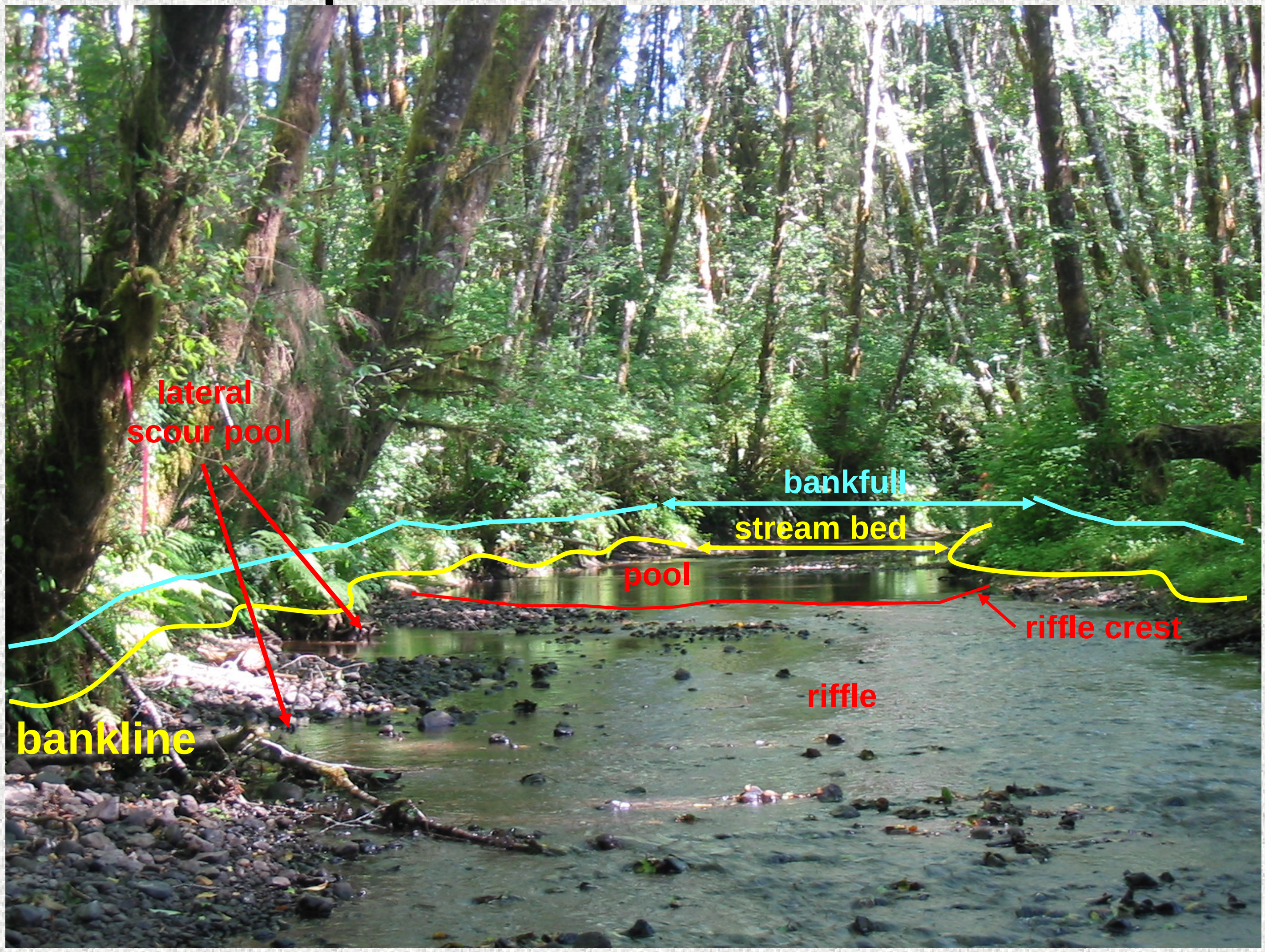
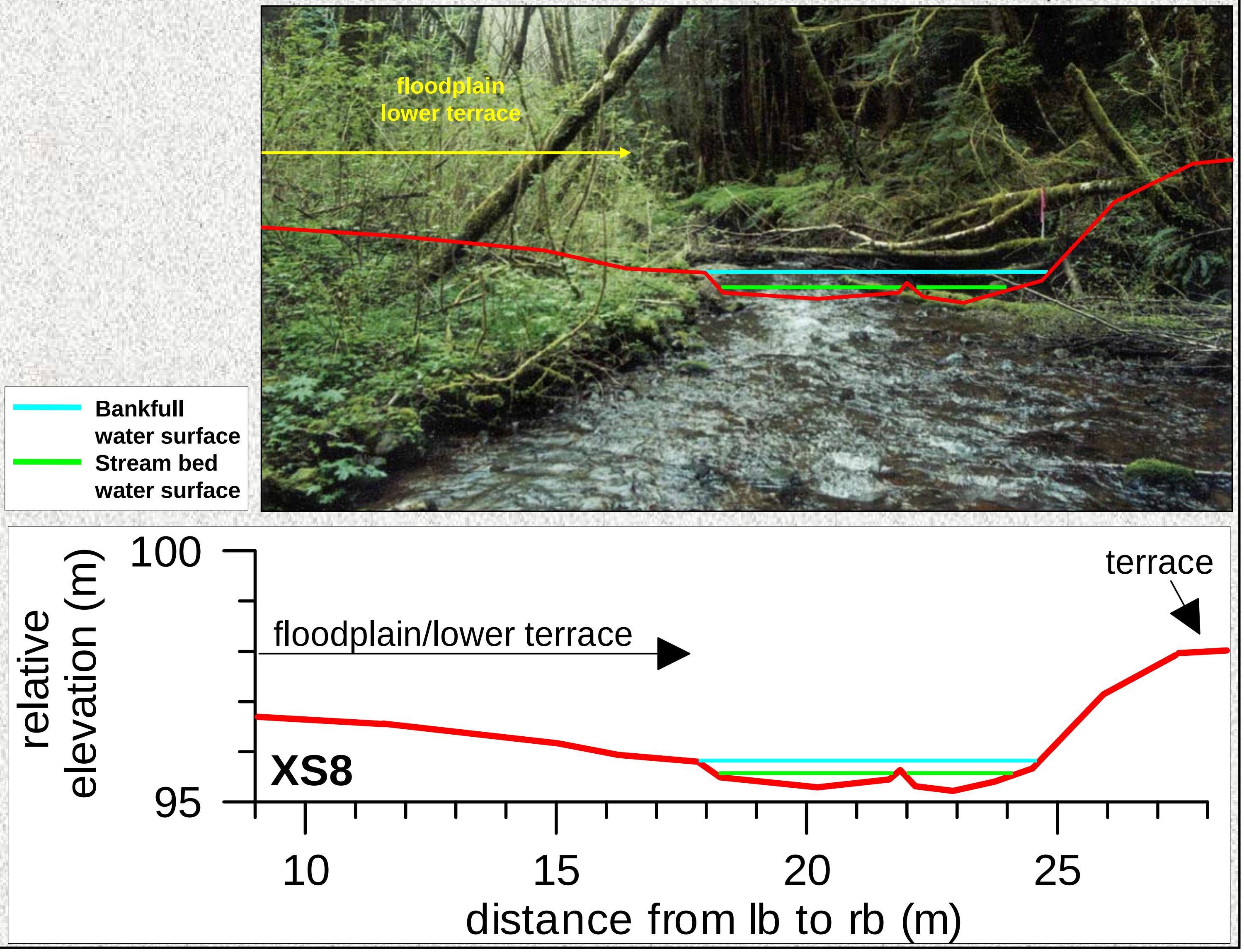
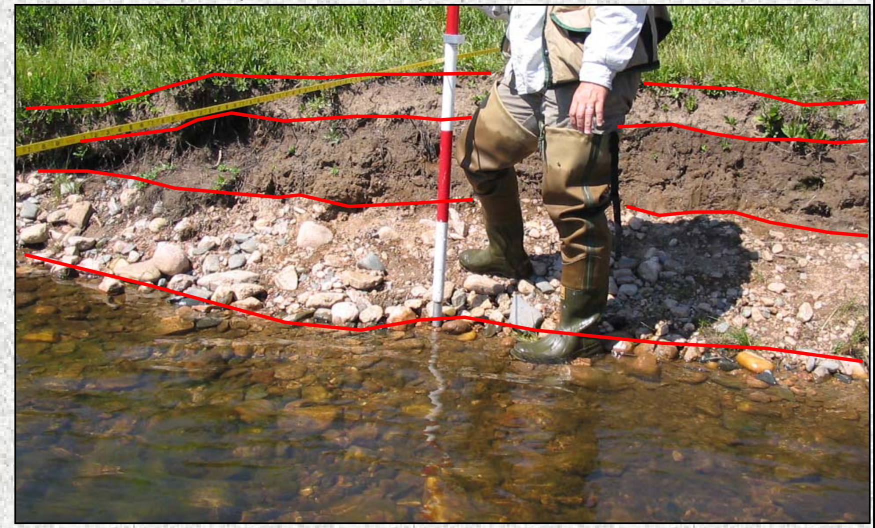


Pool-Riffle Channel Cross-Section Example

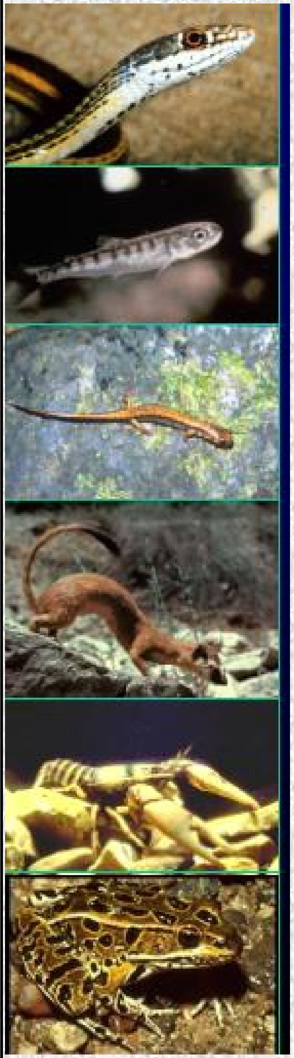


Channel Cross Sections: Bank Morphology and Stability

- **Survey and describe distinct bank layers**
- **Describe the size, depth, and density of exposed roots**
- **Measure the width and depth of bank undercutting (if applicable)**
- **Document any evidence of recent bank instability (slump blocks, detached bank margins, tensile cracks along bank margins, etc.)**



Stream Simulation Site Assessment Process



A
- Initial Site Assessment
- **Site Assessment**
  - Site Maps and Channel Planform Characteristics
  - Reference Reach
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  - Longitudinal Profile

B
  - Channel Cross Sections
  - **Characterizing Channel-Bed Sediments and Channel-Bank Material**
  - Preliminary Geotechnical Investigation
  - Project Site Risk Assessment

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What is the purpose of measuring and describing channel-bed and bank characteristics?

1) Establishes the range of sediment sizes, shapes, and roundness composing the natural channel bed and banks.
2) Sediment characteristics from the "reference reach" provides the basis for determining the characteristics and arrangement of channel-bed and bank sediments in the design channel.
3) Sediment characteristics are used to assess the mobility and stability of particles along the natural channel and design channel for different flows.

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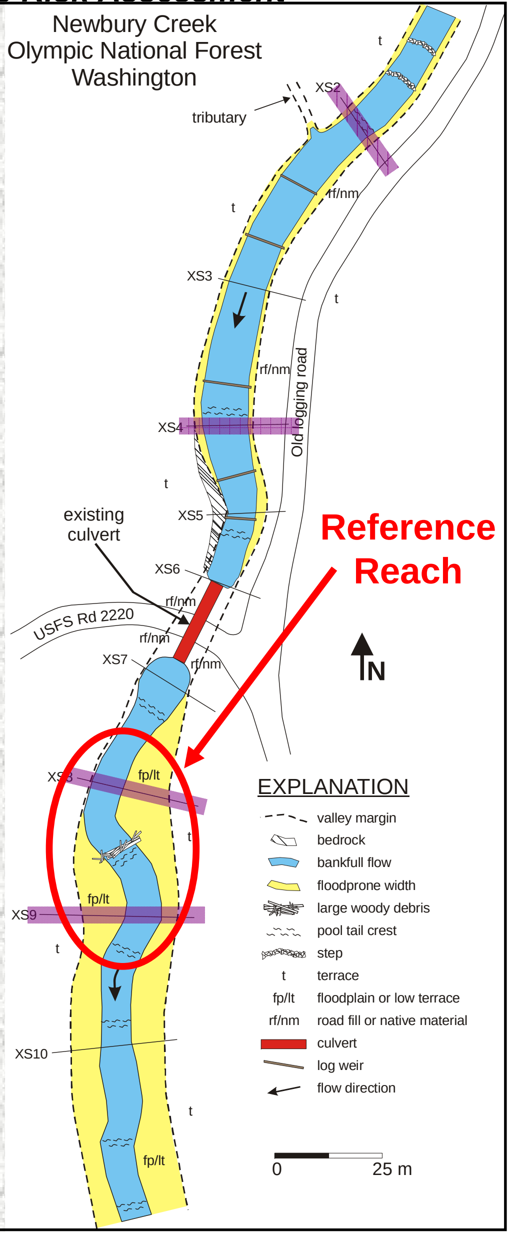
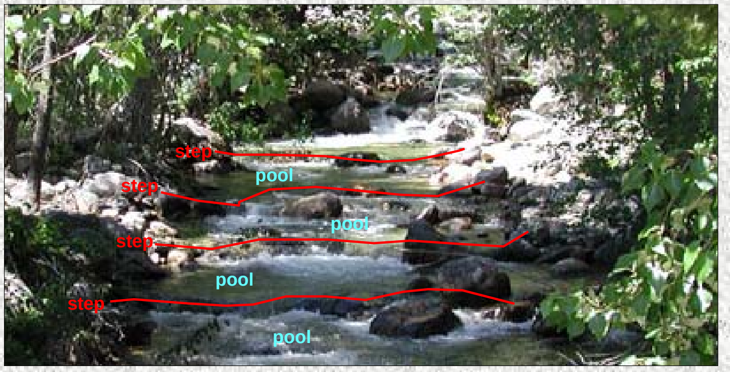
Sediment Sampling Strategies

1) Collect channel-bed and bank sediment data from several possible reference reaches while onsite and before the analysis of the longitudinal profile.
2) Wait to collect detailed channel-bed and bank sediment data until the reference reach has been selected after analyzing the longitudinal profile.
3) If the reference reach is downstream of the crossing, sediment characteristics upstream of the crossing are needed to determine the mobility and resupply of similar size sediments that are mobilized from the design channel at different flows.





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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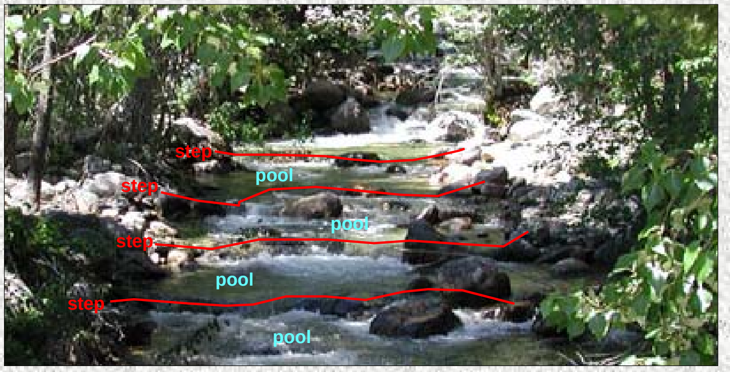

Channel-Bed Sediment Sampling Approaches

- Typically measure channel units such as riffles, pools, runs, and steps.
- Largest particles of individual channel-bed structures such as steps, pool-tail crests or head of riffles, particle clusters, transverse bars, isolated boulders, etc. should be measured.
- The subsurface material immediately below the channel bed should at a minimum be qualitatively described.

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Particle size intervals

particle size description	particle size (ø units)	particle size (mm)	particle size description	particle size (ø units)	particle size (mm)
	-12.0	4096			
very large boulder	-11.5	2896	fine gravel	-2.5	5.66
	-11.0	2048		-2.0	4.00
large boulder	-10.5	1448	very fine gravel	-1.5	2.83
	-10.0	1024		-1.0	2.00
medium boulder	-9.5	724	very coarse sand	-0.5	1.41
	-9.0	512		0.0	1.00
small boulder	-8.5	362	coarse sand	0.5	0.71
	-8.0	256		1.0	0.50
large cobble	-7.5	181	medium sand	1.5	0.35
	-7.0	128		2.0	0.25
small cobble	-6.5	90.5	fine sand	2.5	0.177
	-6.0	64.0		3.0	0.125
very coarse gravel	-5.5	45.3	very fine sand	3.5	0.088
	-5.0	32.0		4.0	0.063
coarse gravel	-4.5	22.6	silt		
	-4.0	16.0		8.0	0.0039
medium gravel	-3.5	11.3	clay		
	-3.0	8.00		12.0	0.00024

Conversion from mm to phi: $D_i = 2^{-\phi i}$

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Conversion from phi to mm: $-3.3219 \log (D_i)$

Bed Material Sampling Methods

Gravel-bed (8-64 mm), Cobble-bed (64-256 mm), and Boulder-bed (>256 mm) Channels

- Surface sampling
  - Grid counts, heal-to-toe walk
- Volumetric sampling
  - Extracting a predefined volume or mass of sediment from the surface layer for sieve analyses

Sand-bed (0.063 to 2 mm) and Fine Gravel-bed (2-8 mm) Channels

- Volumetric sampling
  - Extracting a predefined volume or mass of sediment from the surface layer for later sieve analyses
- Visual Estimates
  - Qualitative percentile estimates for different particle size classes; typically adequate for most design purposes

Subsurface Sediment Layer (Gravel-bed, Cobble-bed, and Boulder-bed Channels)

- Volumetric sampling
  - Extracting a predefined volume or mass of sediment from the surface layer for later sieve analyses
- Visual Estimates
  - Qualitative percentile estimates for different particle size classes; typically adequate for most design purposes

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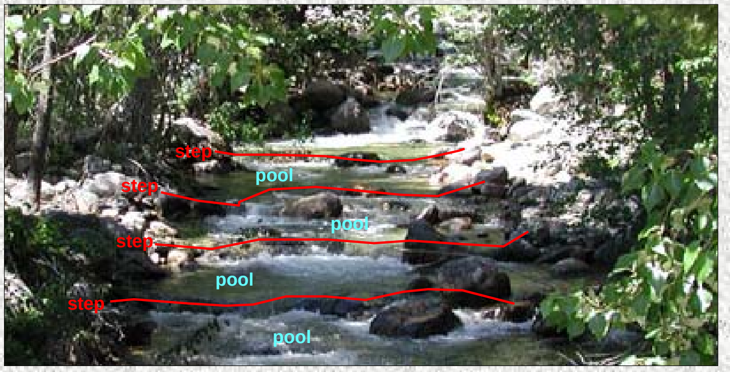

Channel-Bed Sediment Sampling Approaches

- **Typically measure channel units such as riffles, pools, runs, and steps.**
- Largest particles of individual channel-bed structures such as steps, pool-tail crests or head of riffles, particle clusters, transverse bars, isolated boulders, etc. should be measured.
- The subsurface material immediately below the channel bed should at a minimum be qualitatively described.

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Channel-Bed Sediment Sampling of Channels Composed of Fine Gravels and Sands

Volumetric or Bulk Samples

- Collect multiple samples to obtain a representative sample.
- Samples can be sieved in the field or the laboratory to determine the particle-size distribution.
- Normally not necessary to quantify for design purposes!

Visual Estimates

- Estimate relative abundance into three main constituents: gravels (2 to 8 mm), sands (0.063 to 2 mm), and silt/clay (<0.063 mm)
- Usually sufficient for design purposes

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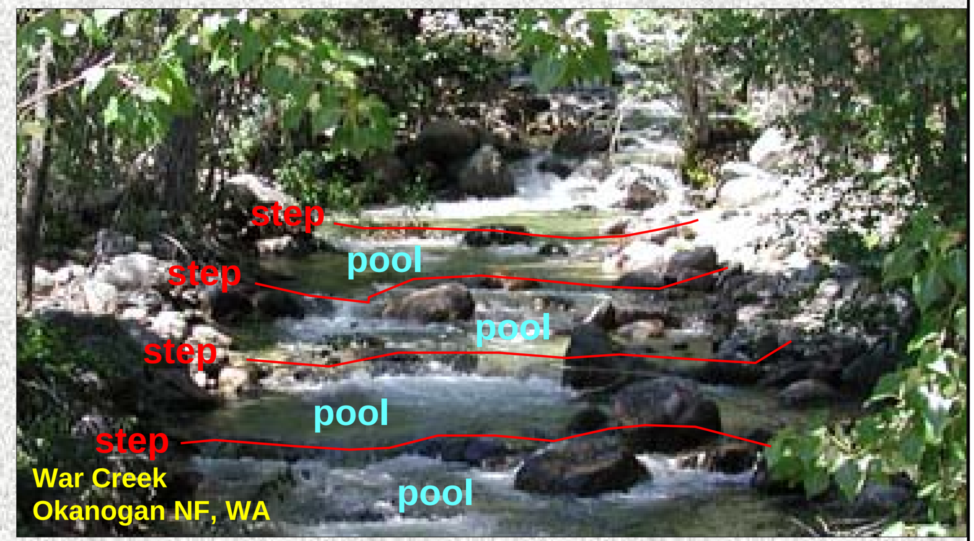
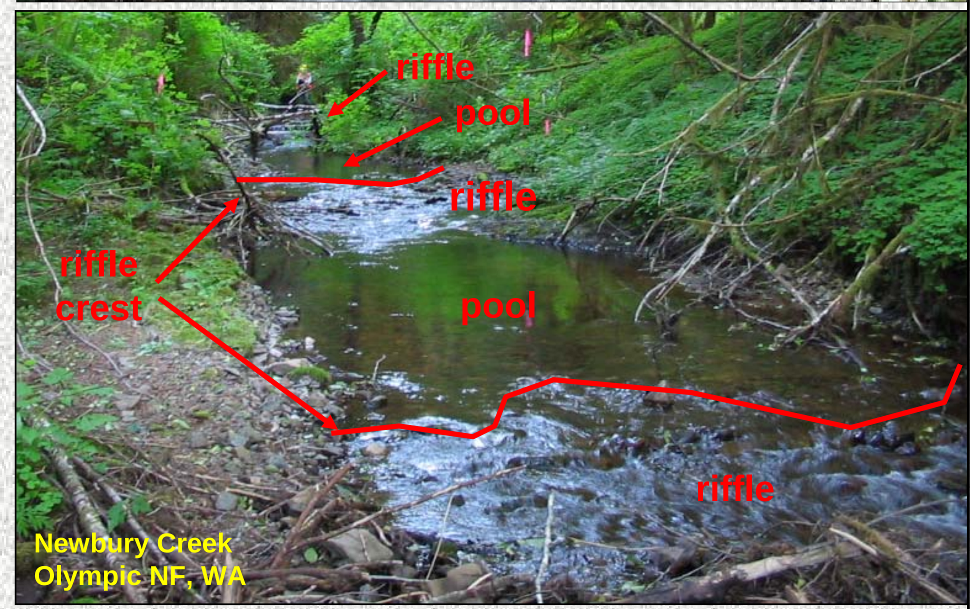
Surface Sampling: Pebble counts using the grid method

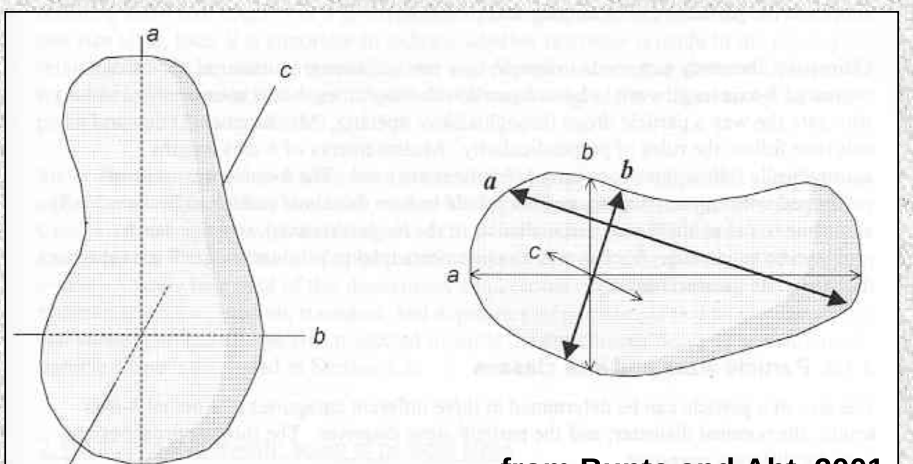
- **Suitable for channels composed of boulders, cobbles, and gravels**
- **Typically measure channel units such as riffles, pools, runs, and steps**
- **If bed composition is variable within a channel unit, sample those subunits separately and develop a composite grain-size distribution based on weighted area**
- **Sample channel bed between the base of the banks (i.e., do not include banks)**





Surface Sampling: Pebble counts using the grid method

- **Evenly spaced intervals along a tape transect: 1 to 2 times the D_{max} particle size of the bed material**
- **Measure the particle diameter (intermediate- or b-axis)**
- **Measure between 100 and 400 particles**
- **Space multiple transects at least 1 m apart**
- **Place measured particles in ½ phi intervals**

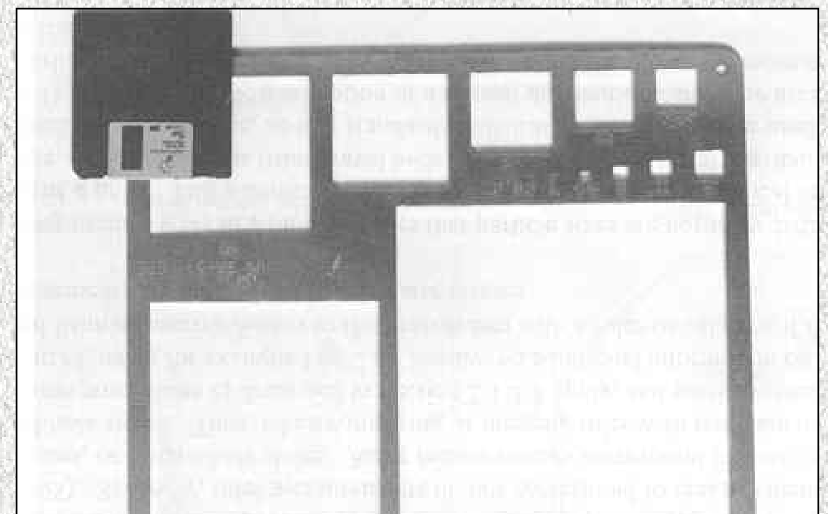


from Bunte and Abt, 2001

Surface Sampling: Pebble counts using the grid method

- **Grid method reduces sampling bias (heal-to-toe method can be biased against sampling sands, small gravels, and large boulders)**
- **Gravelometers and other measurement aids can improve accuracy**
- **Grid method is challenging to perform in flowing water, but can be done**

Newbury Creek
Olympic NF, WA



from Bunte and Abt, 2001

Surface Sampling: Pebble counts using the grid method

- **Example field data form**

project:	
sampling date:	sampling ID:
channel unit sampled:	sampling location:
pebble count method:	sampling interval (ft):
orientation of transect:	length of transects (ft):
general description of sediment sampled (embeddedness, imbrication, particle shape, particle roundness, etc.):	

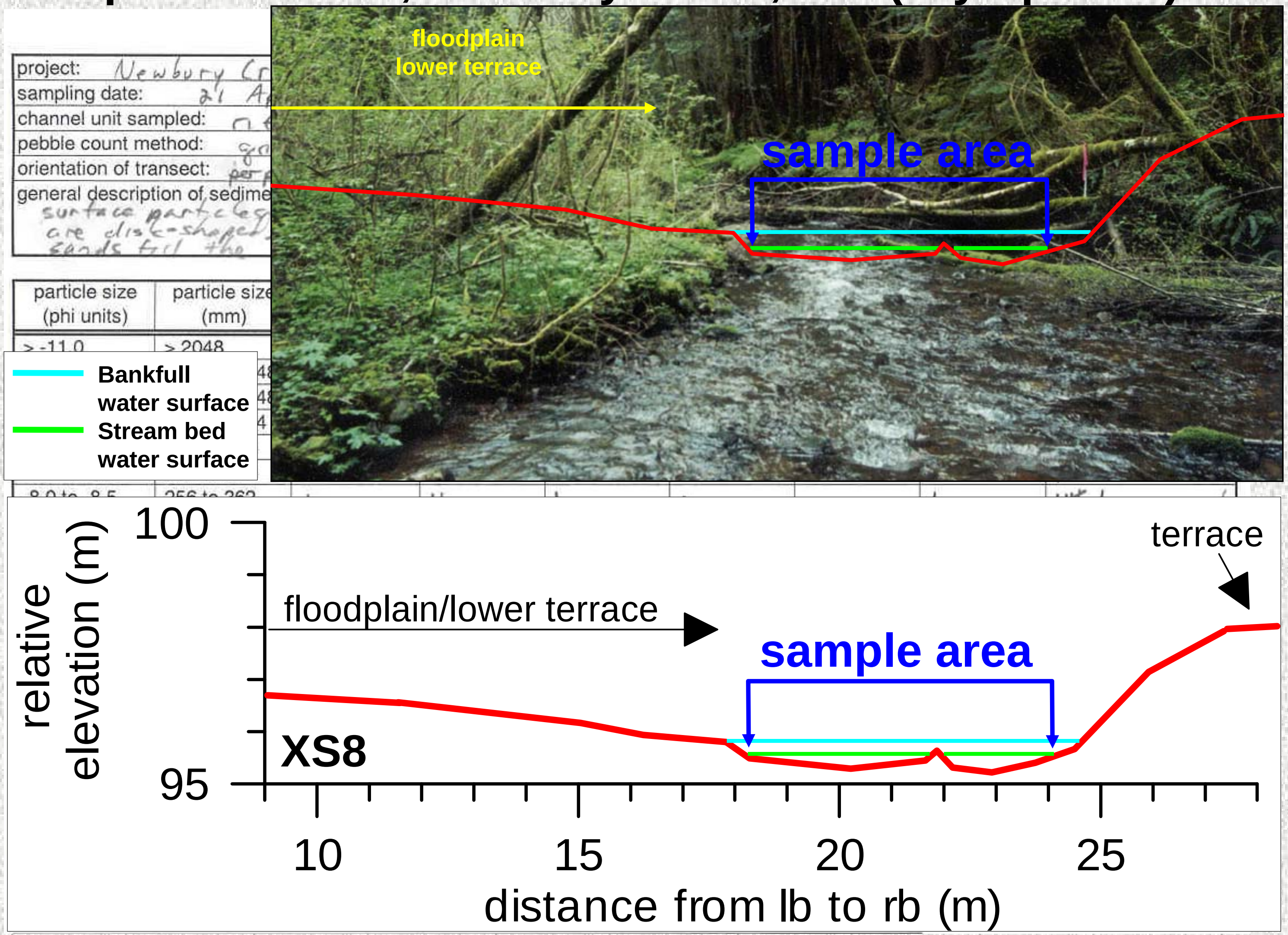
particle size (phi units)	particle size (mm)	transect 1	transect 2	transect 3	transect 4	transect 5	transect 6	total count
> -11.0	> 2048							
-10.5 to -11.0	1448 to 2048							
-10.0 to -10.5	1024 to 1448							
-9.5 to -10.0	724 to 1024							
-9.0 to -9.5	512 to 724							
-8.5 to -9.0	362 to 512							
-8.0 to -8.5	256 to 362							
-7.5 to -8.0	181 to 256							
-7.0 to -7.5	128 to 181							
-6.5 to -7.0	90.5 to 128							
-6.0 to -6.5	64.0 to 90.5							
-5.5 to -6.0	45.2 to 64.0							
-5.0 to -5.5	32.0 to 45.2							
-4.5 to -5.0	22.6 to 32.0							
-4.0 to -4.5	16.0 to 22.6							
-3.5 to -4.0	11.3 to 16.0							
-3.0 to -3.5	8.0 to 11.3							
-2.5 to -3.0	5.7 to 8.0							
-2.0 to -2.5	4.0 to 5.7							
-1.5 to -2.0	2.8 to 4.0							
-1.0 to -1.5	2.0 to 2.8							
< -1	< 2							
	sample size total							

largest particles sampled	long-axis (mm)	intermediate-axis (mm)	short-axis (mm)	particle shape, roundness

particle roundness, etc.):
ct 4 | transect 5 | transect 6 | total count

Surface Sampling: Pebble counts using the grid method

- **Example field form, Newbury Creek, WA (Olympic NF)**



Determining Particle-Size Distributions

- Pebble count measurements are placed in size intervals
- Calculate the percent frequency for each size interval

$$\text{Percent frequency} = \left\{\frac{\text{count in interval}}{\text{total count}}\right\}100$$

Example: Newbury Creek, (Olympic NF, WA)

particle size interval name	size interval (mm)	count or frequency	percent frequency	cumulative percent finer
medium boulders	512 to 724		0.00	100.00
	362 to 512	1	0.88	99.12
small boulders	256 to 362	6	5.31	93.81
	181 to 256	7	6.19	87.61
large cobbles	128 to 181	13	11.50	76.11
	90.5 to 128	17	15.04	61.06
small cobbles	64.0 to 90.5	17	15.04	46.02
	45.2 to 64.0	13	11.50	34.51
very coarse gravel	32.0 to 45.2	14	12.39	22.12
	22.6 to 32.0	9	7.96	14.16
coarse gravel	16.0 to 22.6	3	2.65	11.50
	11.3 to 16.0	6	5.31	6.19
medium gravel	8.0 to 11.3	4	3.54	2.65
	5.7 to 8.0	2	1.77	0.88
fine gravel	4.0 to 5.7		0.00	0.88
	2.8 to 4.0		0.00	0.88
very fine gravel	2.0 to 2.8		0.00	0.88
sand, silt, or clay	< 2	1	0.88	0.00
	Total count	113	100.00	

Project Name:	Newbury Creek Crossing
Sample ID:	PC (XS8, 4-21-03)
Sample Date:	4/21/2003
Sampler Name:	Cenderelli
Sample Locaton:	XS8, riffle mid-section
Sample Method:	grid method, 30 cm interval, 1 m spacing between transects, perpendicular to flow.

percentile	particle size (mm)
d95	275
d84	164
d50	71
d16	24
d5	10

% boulders	6.19
% cobbles	47.79
% gravels	45.13
% sands,silts,clays	0.88

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Determining Particle-Size Distributions

- At the largest size interval with NO measurements, set the cumulative percent finer interval to 100 % (100 % of the particles measured are smaller than this size interval)
- Subtract the next smallest size interval percent frequency by the cumulative percent finer value of the previous larger size interval to obtain the cumulative percent finer value for that particular interval.

Cumulative Percent Finer of Size Interval i = Cumulative Percent Finer of Previous Larger Size Interval - Percent Frequency of Size Interval i

Example: Newbury Creek, (Olympic NF, WA)

particle size interval name	size interval (mm)	count or frequency	percent frequency	cumulative percent finer
medium boulders	512 to 724		0.00	100.00
	362 to 512	1	0.88	99.12
small boulders	256 to 362	6	5.31	93.81
	181 to 256	7	6.19	87.61
large cobbles	128 to 181	13	11.50	76.11
	90.5 to 128	17	15.04	61.06
small cobbles	64.0 to 90.5	17	15.04	46.02
	45.2 to 64.0	13	11.50	34.51
very coarse gravel	32.0 to 45.2	14	12.39	22.12
	22.6 to 32.0	9	7.96	14.16
coarse gravel	16.0 to 22.6	3	2.65	11.50
	11.3 to 16.0	6	5.31	6.19
medium gravel	8.0 to 11.3	4	3.54	2.65
	5.7 to 8.0	2	1.77	0.88
fine gravel	4.0 to 5.7		0.00	0.88
	2.8 to 4.0		0.00	0.88
very fine gravel	2.0 to 2.8		0.00	0.88
sand, silt, or clay	< 2	1	0.88	0.00
	Total count	113	100.00	

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% cobbles	47.79
% gravels	45.13
% sands,silts,clays	0.88

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Determining Particle-Size Distributions

- Plot cumulative percent finer against the smallest value of a given size interval
- Use plot to obtain percentile particle sizes (D95, D84, D50, D16, D5, etc.) and calculate particle-size distribution statistics (mean, sorting, skewness, kurtosis)

Example: Newbury Creek, (Olympic NF, WA)

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medium gravel	8.0 to 11.3	4	3.54	2.65
	5.7 to 8.0	2	1.77	0.88
fine gravel	4.0 to 5.7		0.00	0.88
	2.8 to 4.0		0.00	0.88
very fine gravel	2.0 to 2.8		0.00	0.88
sand, silt, or clay	< 2	1	0.88	0.00
	Total count	113	100.00	

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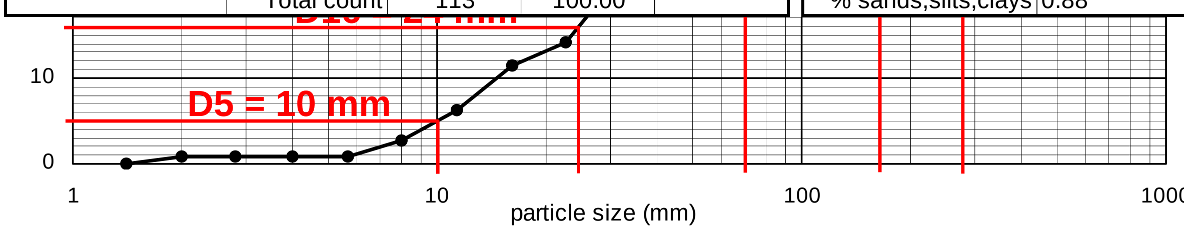

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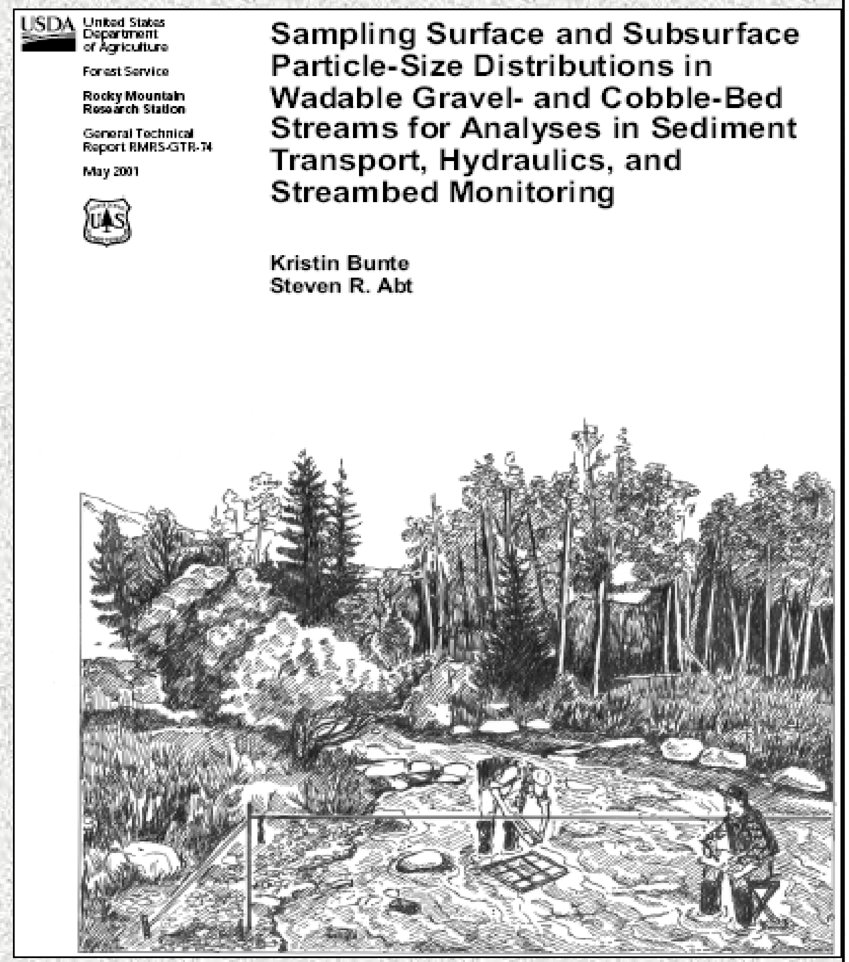
Where To Get More Information on Sampling and Analyzing Channel-Bed Sediments

- **Bunte, K., Abt, S.R. 2001**. Sampling Surface and Subsurface Particle-Size Distributions in Wadable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring. General Technical Report, RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p.


USDA United States Department of Agriculture

Forest Service

Rocky Mountain Research Station

General Technical Report RMRS-GTR-74

May 2001

Sampling Surface and Subsurface Particle-Size Distributions in Wadable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring

Kristin Bunte
Steven R. Abt

- **Available online at:**

http://www.stream.fs.fed.us/publications/PDFs/rmrs_gtr74.pdf

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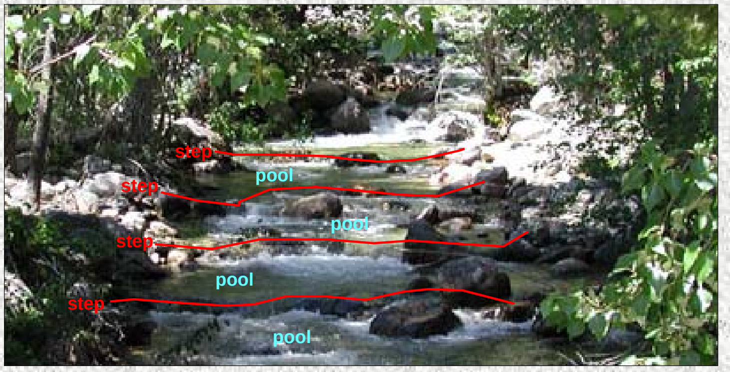

Channel-Bed Sediment Sampling Approaches

- Typically measure channel units such as riffles, pools, runs, and steps.
- **Largest particles of individual channel-bed structures such as steps, pool-tail crests or head of riffles, particle clusters, transverse bars, isolated boulders, etc. should be measured.**
- The subsurface material immediately below the channel bed should at a minimum be qualitatively described.

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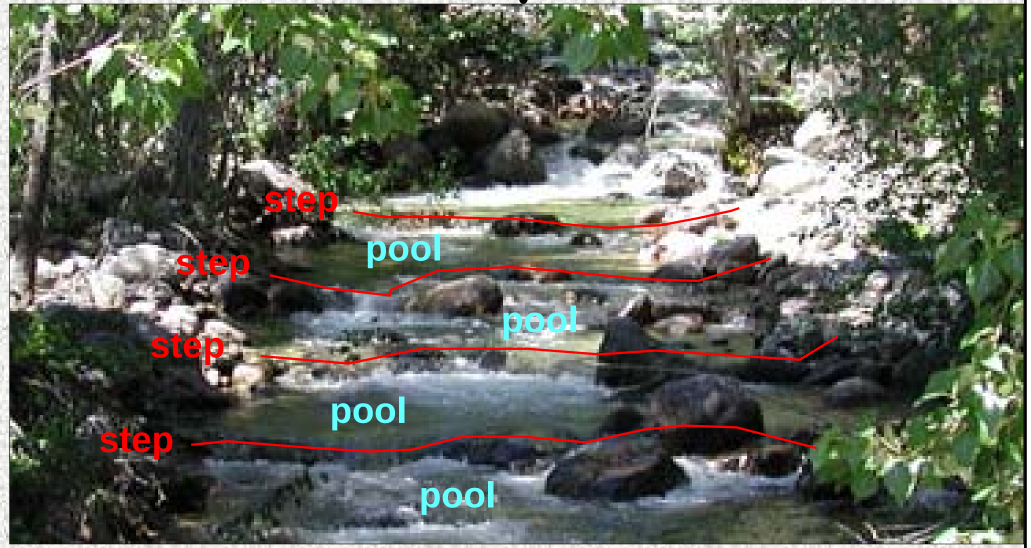
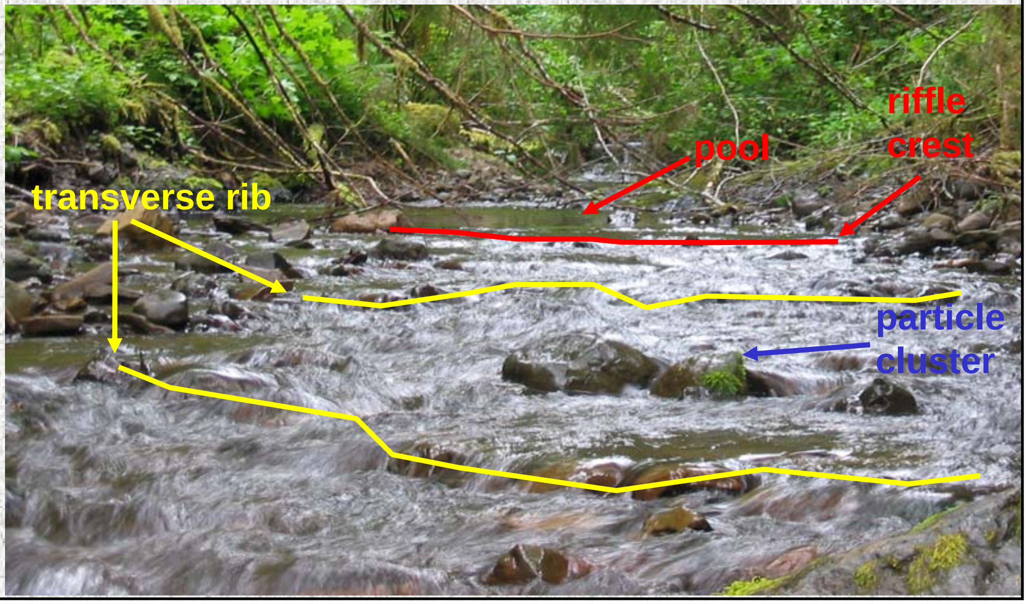
Surface Sampling: Measurement of Key Features

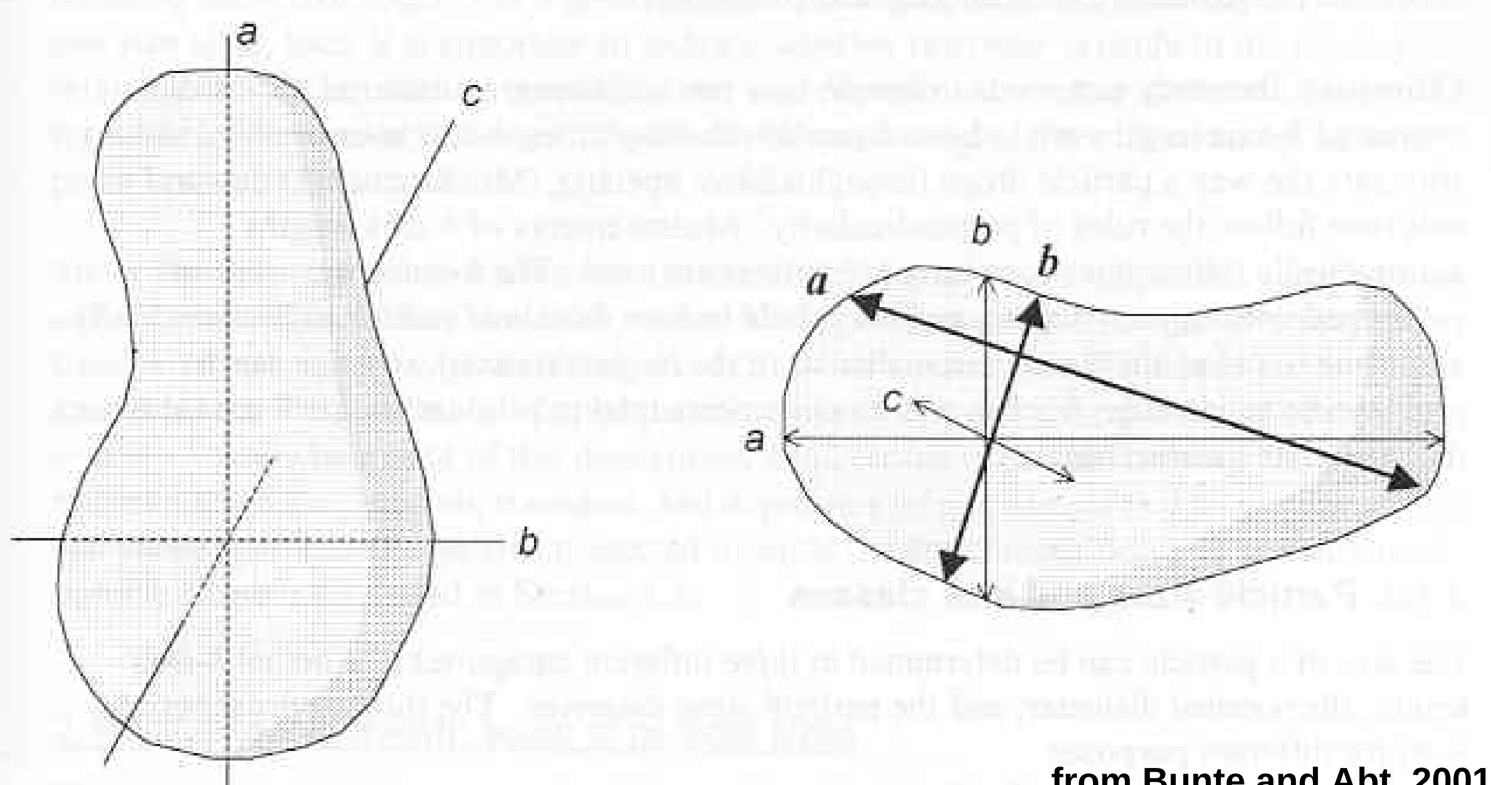
- **Measure the largest particles making up key hydraulic features (e.g., steps, riffle crests, transverse ribs or microsteps, particle clusters, etc.)**
- **Measure between 10 to 25 particles**
- **Measure the lengths of the particles long-, intermediate-, and short-axes**
- **Describe the shape and roundness of the particles measured**





Surface Sampling: Measurement of Key Features

- **Measure the length of the particle's long-axis (a), intermediate-axis (b), and short axis (c)**



from Bunte and Abt, 2001

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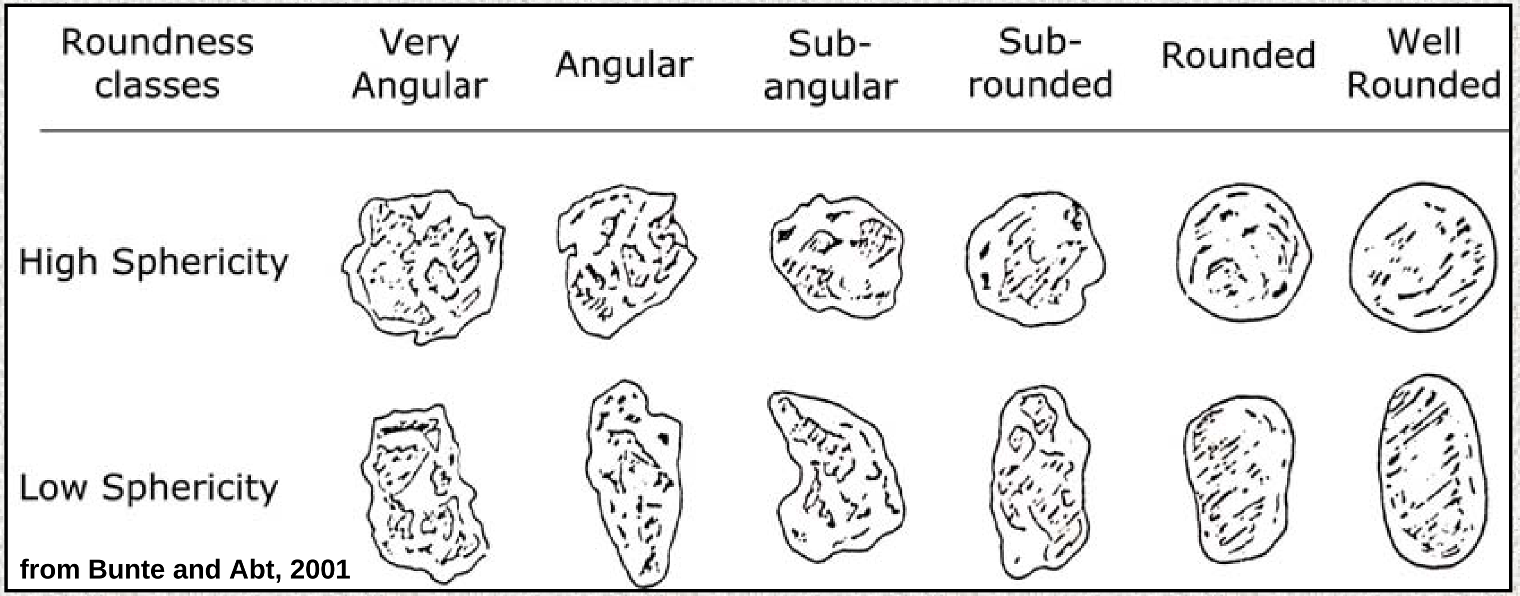
Surface Sampling: Measurement of Key Features

- **Describe the roundness of the particles measured**



from Bunte and Abt, 2001

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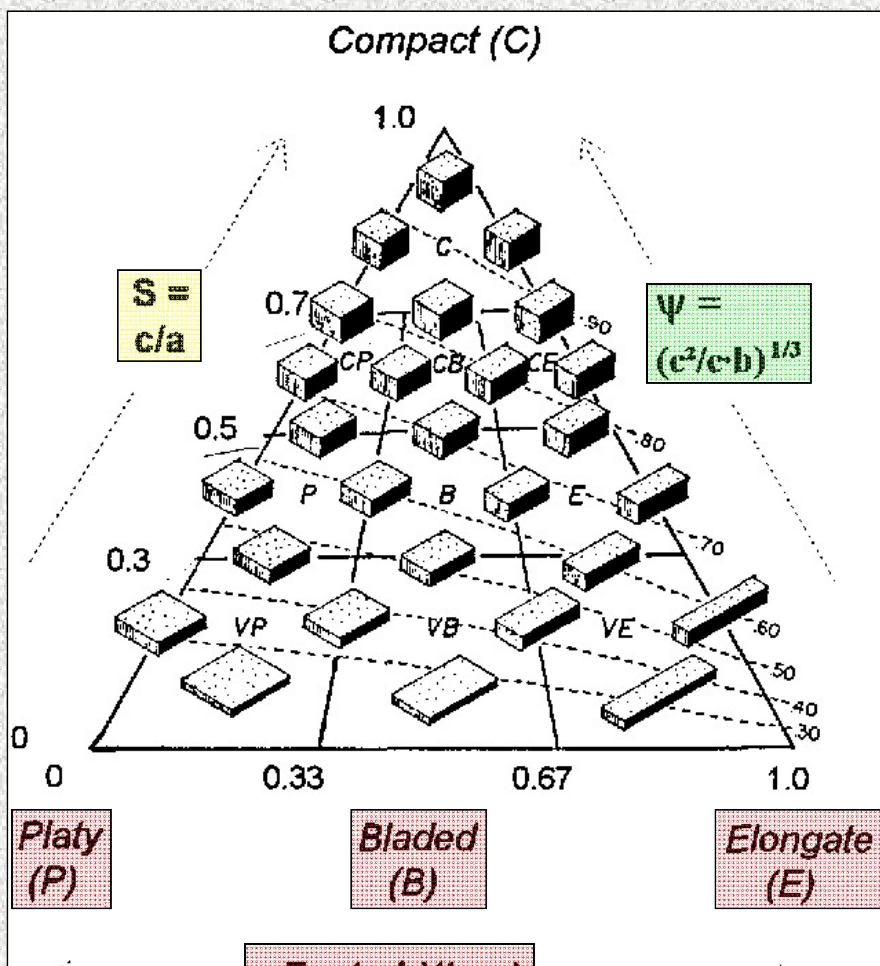
Surface Sampling: Measurement of Key Features

- **Describe the shape of the particles measured**
  - **F quantifies the particles form as platy (i.e., disc shaped), bladed (i.e., ellipsoid), or elongated (i.e., rod-shaped).**
  - **S quantifies the particle's degree of platyness, bladedness, and elongatedness or deviation from compactness**
  - **Ψ quantifies the particles sphericity**

a = particle long axis	
b = particle intermediate axis	
c = particle short axis	



from Bunte and Abt, 2001

Surface Sampling: Measurement of Key Features

• Example field form: Newbury Creek, WA (Olympic NF)

project:	
sampling date:	sampling ID:
channel unit sampled:	sampling location:
pebble count method:	sampling interval (ft):
orientation of transect:	length of transects (ft):
general description of sediment sampled (embeddedness, imbrication, particle shape, particle roundness, etc.):	

particle size (phi units)	particle size (mm)	transect 1	transect 2	transect 3	transect 4	transect 5	transect 6	total count
> -11.0	> 2048							
-10.5 to -11.0	1448 to 2048							
-10.0 to -10.5	1024 to 1448							
-9.5 to -10.0	724 to 1024							
-9.0 to -9.5	512 to 724							
-8.5 to -9.0	362 to 512							
-8.0 to -8.5	256 to 362							
-7.5 to -8.0	181 to 256							
-7.0 to -7.5	128 to 181							
-6.5 to -7.0	90.5 to 128							
-6.0 to -6.5	64.0 to 90.5							
-5.5 to -6.0	45.2 to 64.0							
-5.0 to -5.5	32.0 to 45.2							
-4.5 to -5.0	22.6 to 32.0							
-4.0 to -4.5	16.0 to 22.6							
-3.5 to -4.0	11.3 to 16.0							
-3.0 to -3.5	8.0 to 11.3							
-2.5 to -3.0	5.7 to 8.0							
-2.0 to -2.5	4.0 to 5.7							
-1.5 to -2.0	2.8 to 4.0							
-1.0 to -1.5	2.0 to 2.8							
< -1	< 2							
	sample size total							

largest particles sampled	long-axis (mm)	intermediate-axis (mm)	short-axis (mm)	particle shape, roundness

Procedure for determining the distribution of measured key pieces

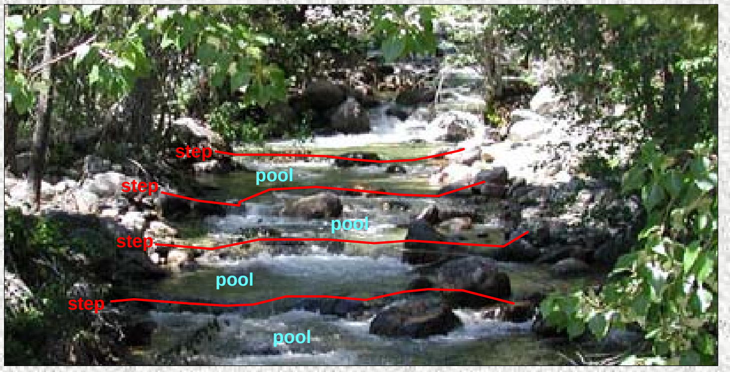
Summary of 20 largest particles measured along upper riffle (from XS8 to riffle crest).

particle number	long axis (mm)	inter-mediate axis (mm)	short axis (mm)	average cubic dimension (mm)	long axis/intermediate axis ratio	particle shape; roundness
1	580	410	205	365	1.41	disk shaped, subangular
2	550	420	210	365	1.31	disk shaped, subangular
3	525	350	105	268	1.50	blade shaped, subangular
4	350	270	110	218	1.30	disk shaped, subangular
5	350	290	90	209	1.21	disk shaped, subangular
6	375	300	120	238	1.25	disk shaped, subangular
7	340	310	100	219	1.10	disk shaped, subangular
8	360	300	105	225	1.20	disk shaped, subangular
9	350	290	110	224	1.21	disk shaped, subangular
10	300	250	70	174	1.20	disk shaped, subrounded
11	290	230	90	182	1.26	disk shaped, subrounded
12	260	200	80	161	1.30	disk shaped, subrounded
13	280	240	85	179	1.17	disk shaped, subrounded
14	280	230	80	173	1.22	disk shaped, subangular
15	315	210	60	158	1.50	blade shaped, subrounded
16	280	180	80	159	1.56	blade shaped, subrounded
17	270	180	75	154	1.50	blade shaped, subrounded
18	250	175	70	145	1.43	disk shaped, subangular
19	240	160	70	139	1.50	blade shaped, subrounded
20	250	155	55	129	1.61	blade shaped, subrounded
average				**204**	**1.34**	

552	**411**	**205**	d95 percentile (mm)
374	**310**	**110**	d84 percentile (mm)
308	**245**	**88**	d50 percentile (mm)
260	**180**	**70**	d16 percentile (mm)

365	average cubic dimension of d95 percentile
238	average cubic dimension of d84 percentile
180	average cubic dimension of d50 percentile
154	average cubic dimension of d16 percentile

1) **Determine the d95, d84, d50, and d16 percentile sizes for the axes of the particles measured (this can be done using the percentile function in Excel).**
2) **Determine the average cubic dimension and long-axis/intermediate axis ratio of each particle measured.**
3) **Determine the average cubic dimension d95, d84, d50, and d16 percentile sizes of the particles measured.**
4) **Determine the average of the particles long axis to intermediate axis ratio.**



Channel-Bed Sediment Sampling Approaches

- Typically measure channel units such as riffles, pools, runs, and steps.
- Largest particles of individual channel-bed structures such as steps, pool-tail crests or head of riffles, particle clusters, transverse bars, isolated boulders, etc. should be measured.
- **The subsurface material immediately below the channel bed should at a minimum be qualitatively described.**

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Channel-Bed Material

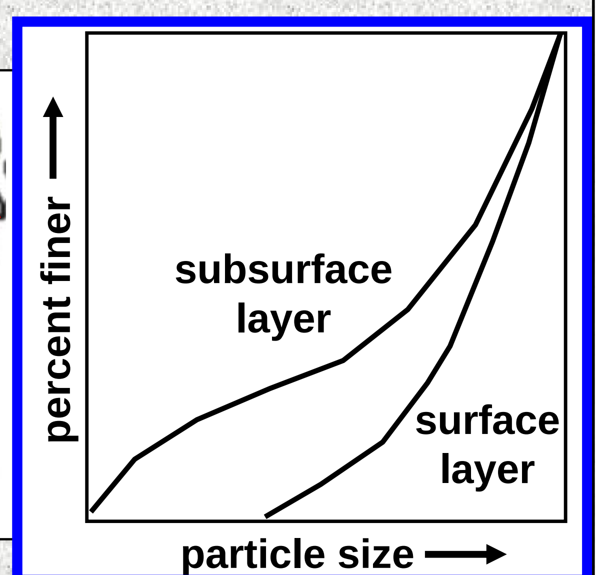
Surface layer

- Typically coarser than the subsurface layer because of the scour of fines between the larger particles
- Thickness is usually defined by the depth of the largest particle

Subsurface layer

- Typically finer than the surface layer because of the presence of fines in the voids between the larger particles
- Winnowing flows do not scour fines

from Bunte and Abt, 2001



Sampling Subsurface Channel-Bed Material

- Remove surface layer and sample subsurface layer at varying depths

Volumetric or Bulk Sampling

- Methods: grab samples, freeze cores, resin cores, frame and barrel samplers
- Multiple samples needed to obtain a representative sample.
- Samples can be sieved in the field or brought back to the laboratory to determine the particle-size distribution.
- Normally not necessary to quantify for design purposes!

Visual Estimates

- Estimate relative abundance by three main constituents: gravels (2 to 8 mm), sands (0.063 to 2 mm), and silt/clay (<0.063 mm)
- Usually sufficient for design purposes

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Characterizing Channel-Bank Sediments

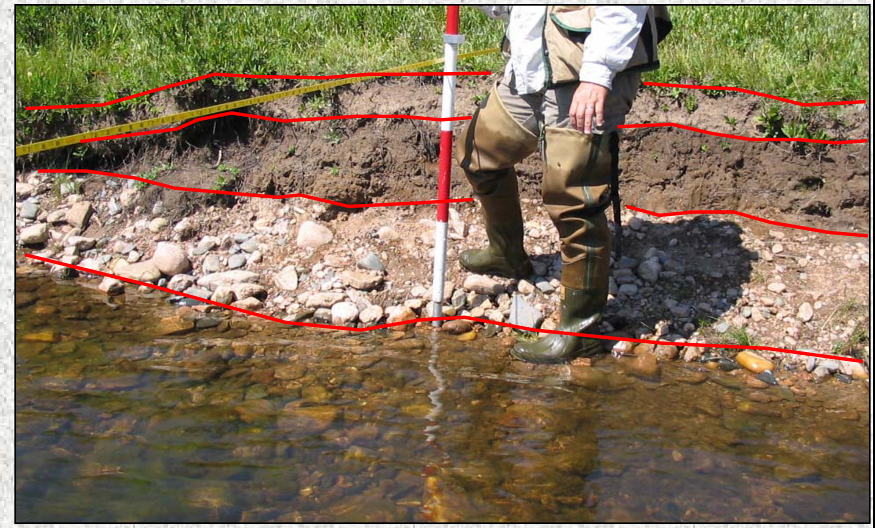
- Delineate distinct bank layers

Volumetric or Bulk Sampling

- Suitable for sand and fine gravel bank sediments
- Samples can be sieved in the field or in the laboratory to determine the particle-size distribution.
- Normally not necessary to quantify for design purposes!

Visual Estimates

- Estimate relative abundance by major particle constituents: boulders (>256 mm), cobbles (64 to 256 mm), gravels (2 to 64 mm), sands (0.063 to 2 mm), and silt/clay (<0.063 mm)
- Usually sufficient for design purposes



Assessing and Describing Wood Characteristics

- Describe and measure logs and trees where they are key channel features controlling fluvial processes.
- Delineate key wood features on the geomorphic map and longitudinal profile

Geomorphic Considerations

- Hydraulic grade control
- Channel and bank roughness
- Bank stability
- Constricts and deflects flow

Measurements, Descriptions

- Measure diameter, length, and depth of embedment.
- Describe the type and condition (minimal, moderate, extensive decay) of the wood.
- Assess overall stability

Nonalluvial Material

- **Mass Wasting**
  - Material transported by gravitational processes (e.g., rockfall, landslides, debris flows, debris torrents, etc.)
  - Potential substantial slope/stream interaction in confined channels
- **Glacial Erratics**
  - Material transported and deposited in channel under different hydrological conditions in the past

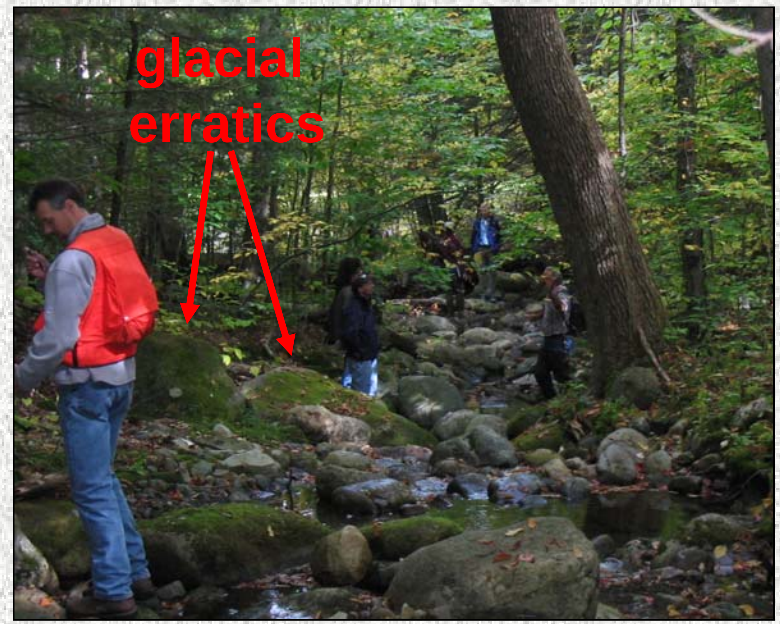
Nonalluvial Material

Properties

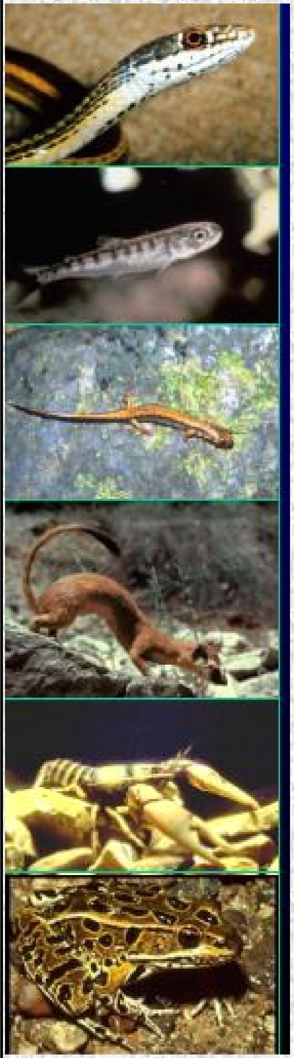
- Typically are the largest material present
- Particles are typically angular to subangular, but can be rounded
- Significant outliers on the particle-size distribution curve

Important Questions to Address

- Do the particles control channel form and stabilize the channel bed?
- Where is the source area of the particles?



Stream Simulation Site Assessment Process



A
- Initial Site Assessment
- **Site Assessment**
  - Site Maps and Channel Planform Characteristics
  - Reference Reach
  - Roadway Considerations
  - Longitudinal Profile

B
  - Channel Cross Sections
  - Characterizing Channel-Bed Sediments and Channel-Bank Material
  - **Preliminary Geotechnical Investigation**
  - Project Site Risk Assessment

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What is the purpose of a preliminary geotechnical investigation?

1) **Characterizes the sedimentologic and stratigraphic properties of the material below the channel.**
2) **Identifies potential subsurface conditions that may require further geotechnical analysis.**
   - **Clay soils**
   - **Organic-rich material**
   - **Saturated material**
   - **Bedrock**
3) **Subsurface observations and data are important for selecting the type of structure and designing the foundation for the structure.**

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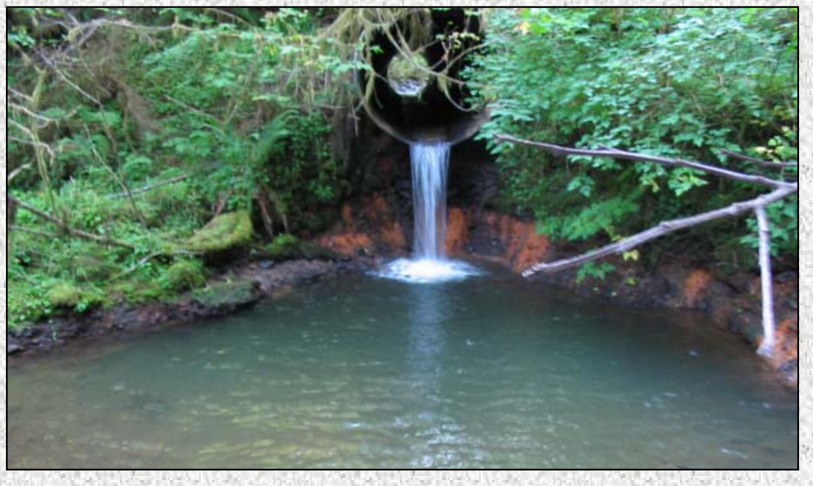
Preliminary Geotechnical Investigation for Soils (unconsolidated sediment)

- **Soil Auger-portable or Hand Shovel**
  - Hand samples; describe materials and thickness of units
- **Drive Probe**
  - Relative density of material; estimates material type and thickness of units
  - Probe pool scour holes and undercuts in banks

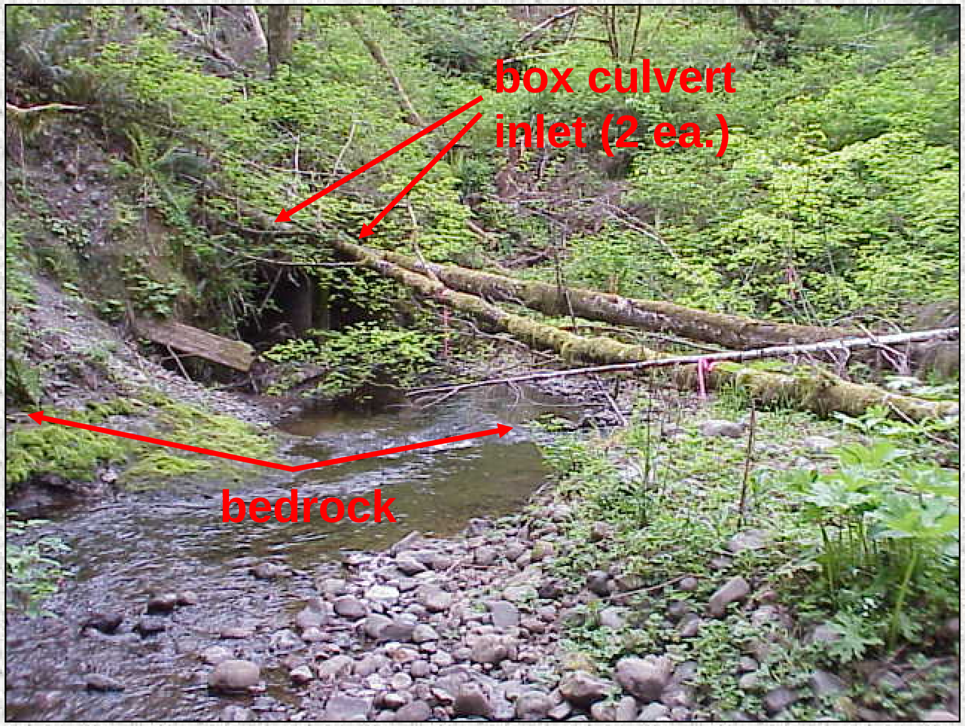
Preliminary Geotechnical Investigation for Soils (unconsolidated sediment)

- **Stratigraphic Descriptions**
  - At exposed surfaces, describe the materials (size, sorting, weathering, saturation, etc.)
  - measure the thickness and lateral extent of the units
- **Location and Extent**
  - Locate areas on plan map, contour map, and longitudinal profile
  - Tie into existing survey data so elevation of units are known



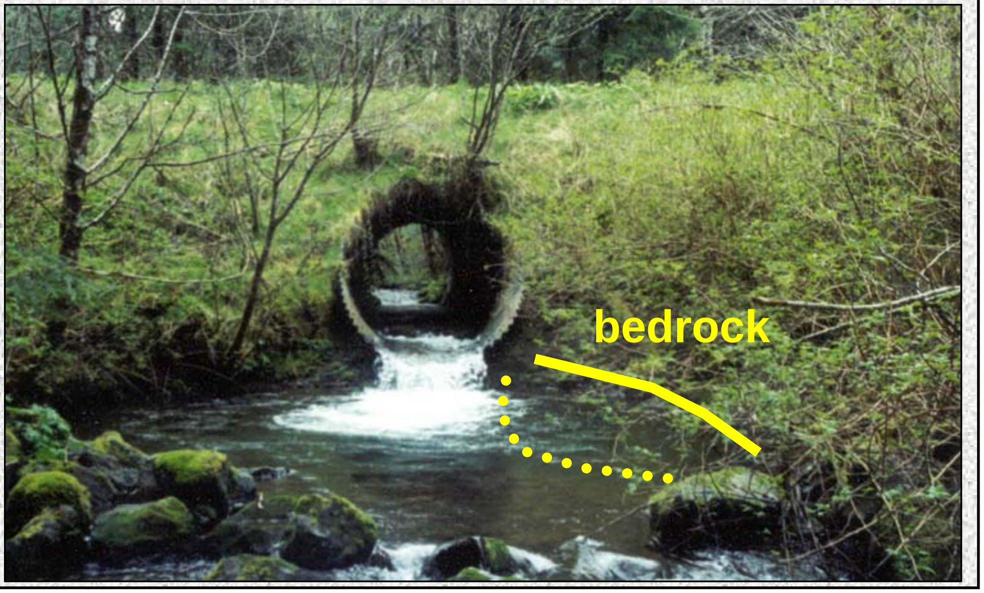
Preliminary Geotechnical Investigation (Bedrock)

- **Rock Hammer (outcrops)**
  - Universal Rock Classification System (URCS) compressive strength test for different rock types
- **Drive Probe**
  - Is bedrock shallow and covered by a veneer of material? Estimate the thickness of materials overlying the bedrock.
  - Probe pool scour holes and undercuts in banks.



Preliminary Geotechnical Investigation (Bedrock)

- **Description of Rock Type and Properties**
  - Igneous, sedimentary, metamorphic
  - Durability and weathering
  - Jointing and fracturing patterns
  - Unit weight
  - Make sure its bedrock; if probing or digging use multiple sites to verify
- **Location and Extent**
  - Locate areas on plan map, contour map, and longitudinal profile
  - Tie into existing survey data so elevation of units are known



Stream Simulation Site Assessment Process

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- **Site Assessment**
  - Site Maps and Channel Planform Characteristics
  - Reference Reach
  - Roadway Considerations
  - Longitudinal Profile

B
  - Channel Cross Sections
  - Characterizing Channel-Bed Sediments and Channel-Bank Material
  - Preliminary Geotechnical Investigation
  - **Project Site Risk Assessment**

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What is the purpose of performing a site risk assessment for the project?

1) **Predict past and potential channel changes at the road-stream crossing with respect to channel stability, channel-bed vertical adjustment, channel headcutting, channel lateral adjustment, and floodplain inundation/connectivity.**
2) **Identify potential channel changes that pose significant risks to the stability of the road-stream crossing, design channel bed, and aquatic organism passage so that they are accommodated for in the road-stream crossing design.**

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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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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**

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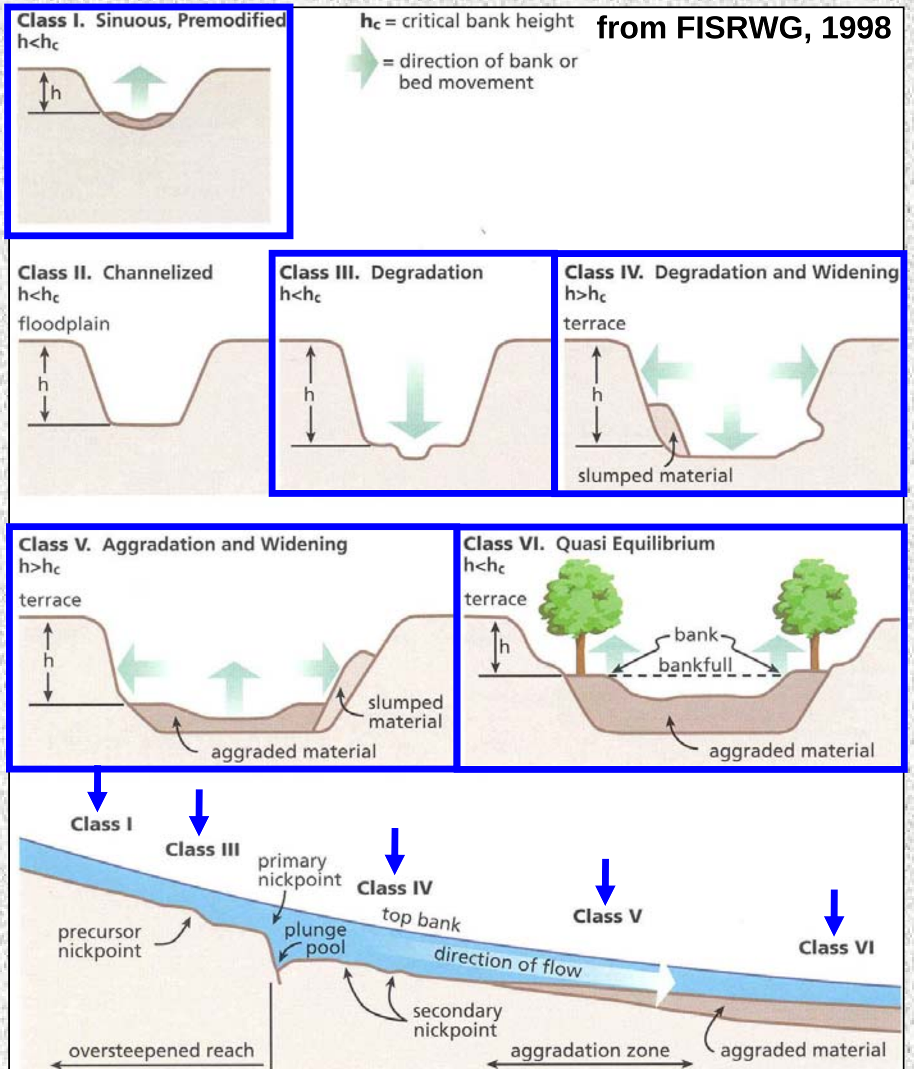
Site Risk Assessment: *Channel Instability*



Channel Evolution Model

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Site Risk Assessment: *Channel Instability*

Channel Evolution Model

Class		Dominant Processes		Characteristic Forms	Geobotanical Evidence
No.	Name	Fluvial	Hillslope		
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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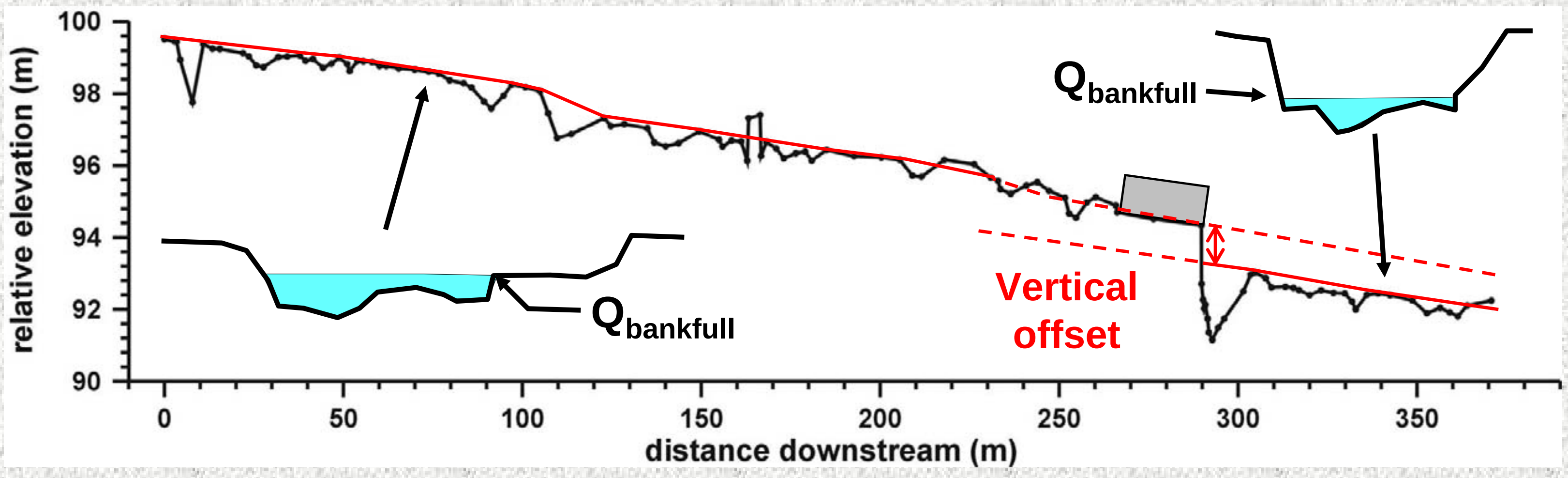
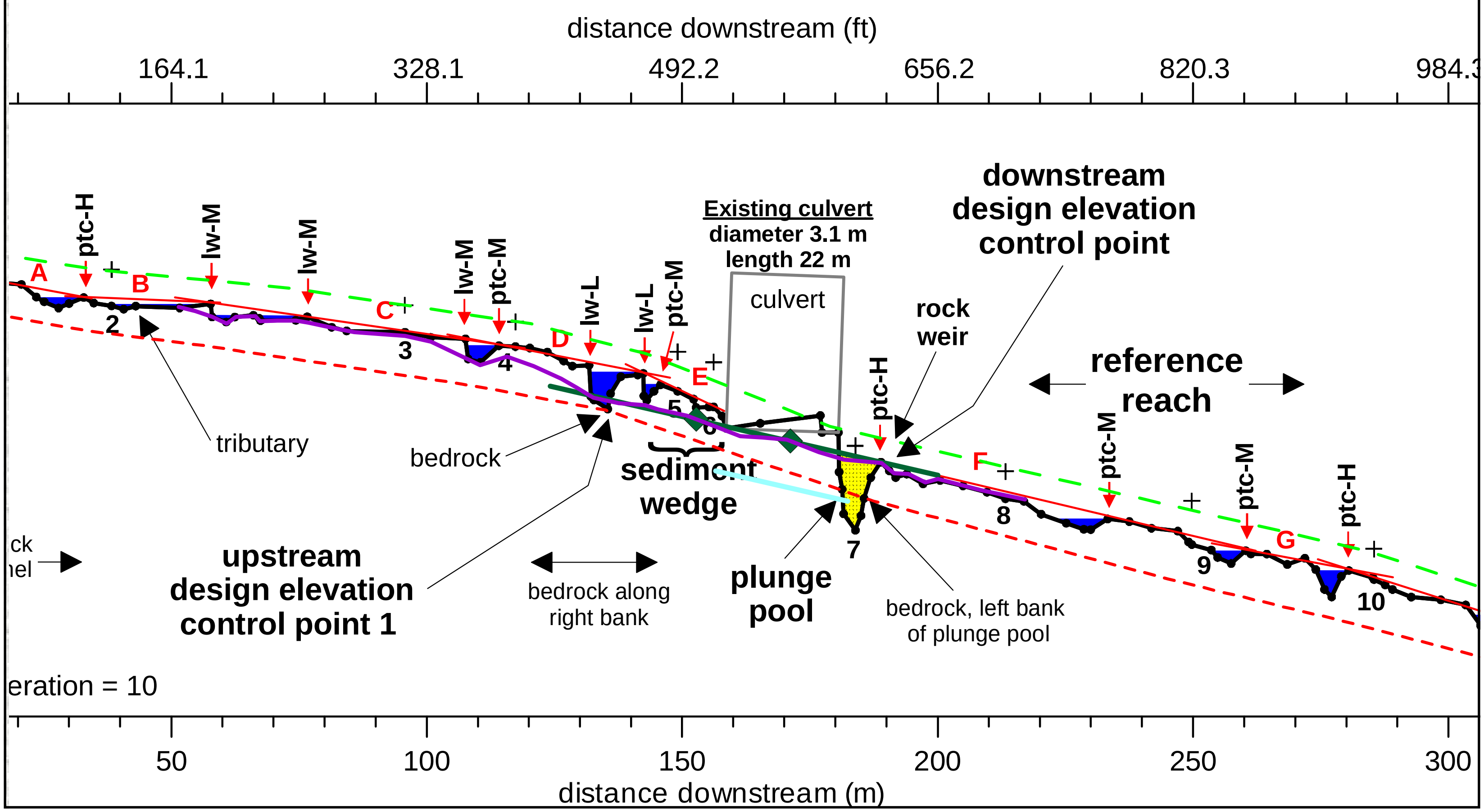
Site Risk Assessment: *Channel Stability*

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



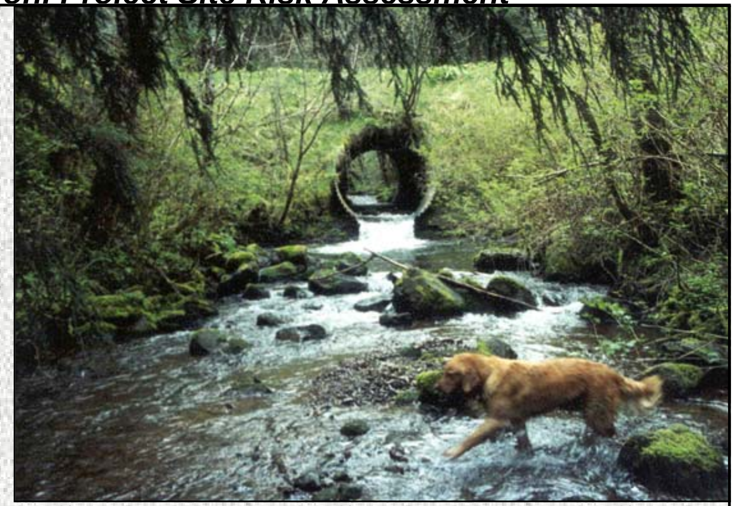
Site Risk Assessment: *Vertical Adjustment Potential*

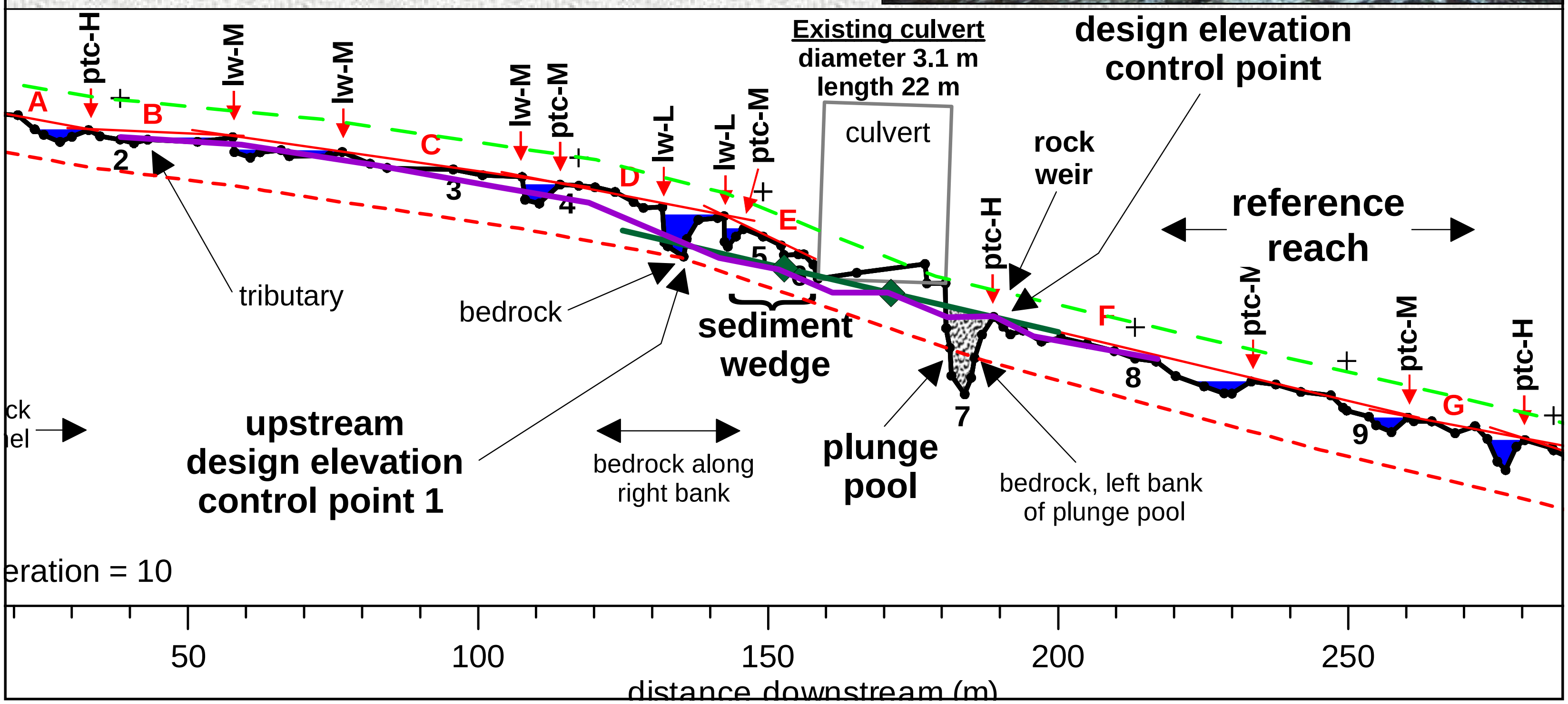
What is the potential range of channel-bed elevations over the service life of the structure from scour and fill processes during floods, sediment and wood inputs from debris flows and/or debris torrents, loss or formation of debris jams, land-use changes, etc.?



Site Risk Assessment:
Headcut Potential

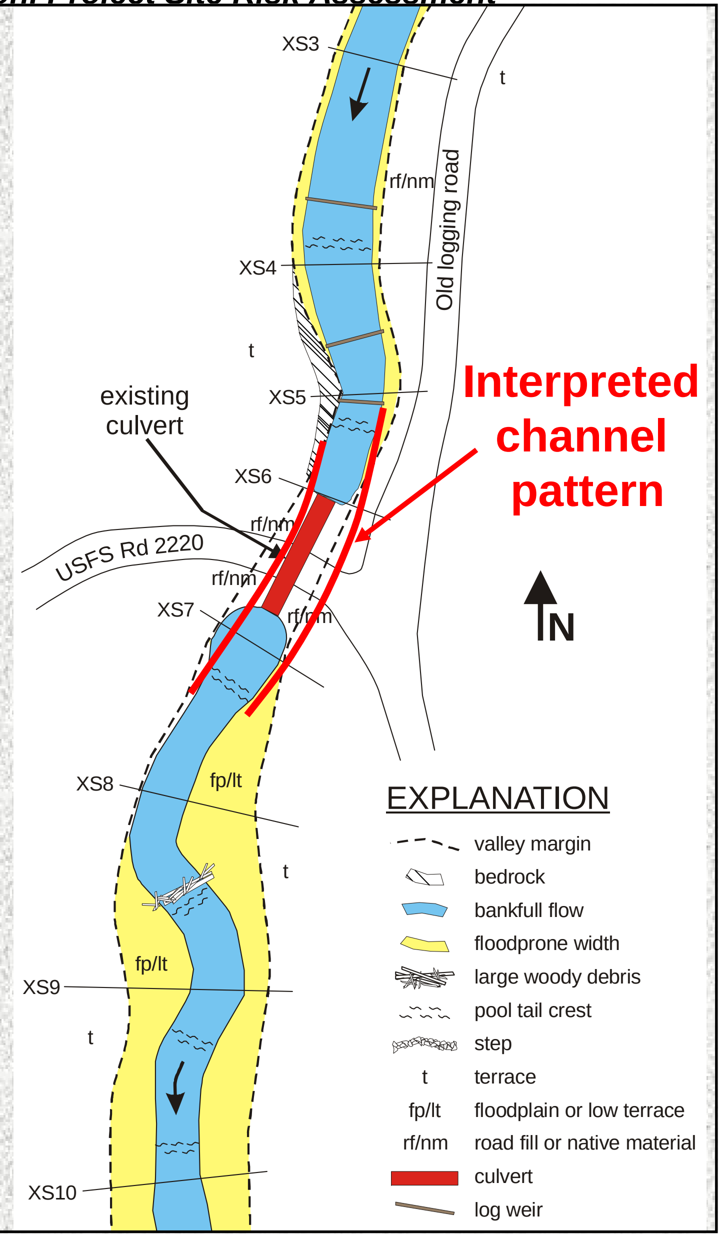
What are the ecological implications for allowing headcutting to occur as the channel adjusts to establish a new equilibrium condition?





Site Risk Assessment:
Lateral Adjustment Potential

Can channel migration or lateral shifting over the service life of the structure affect stream/culvert alignment?



Site Risk Assessment:
Floodplain Inundation/Connectivity

Is floodplain function and connectivity important to the fluvial system and ecological processes?

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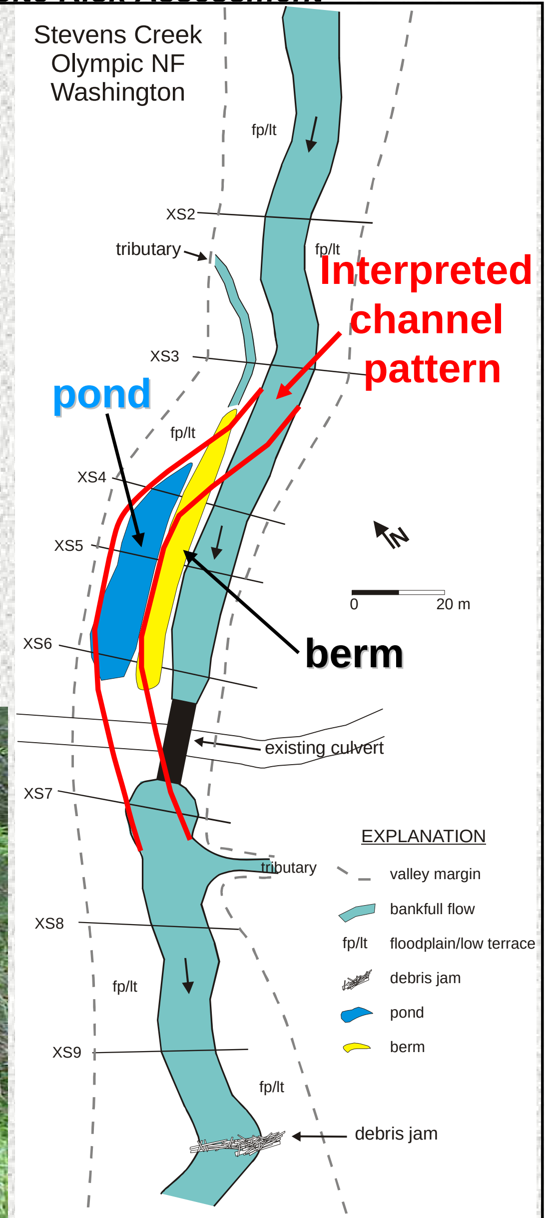
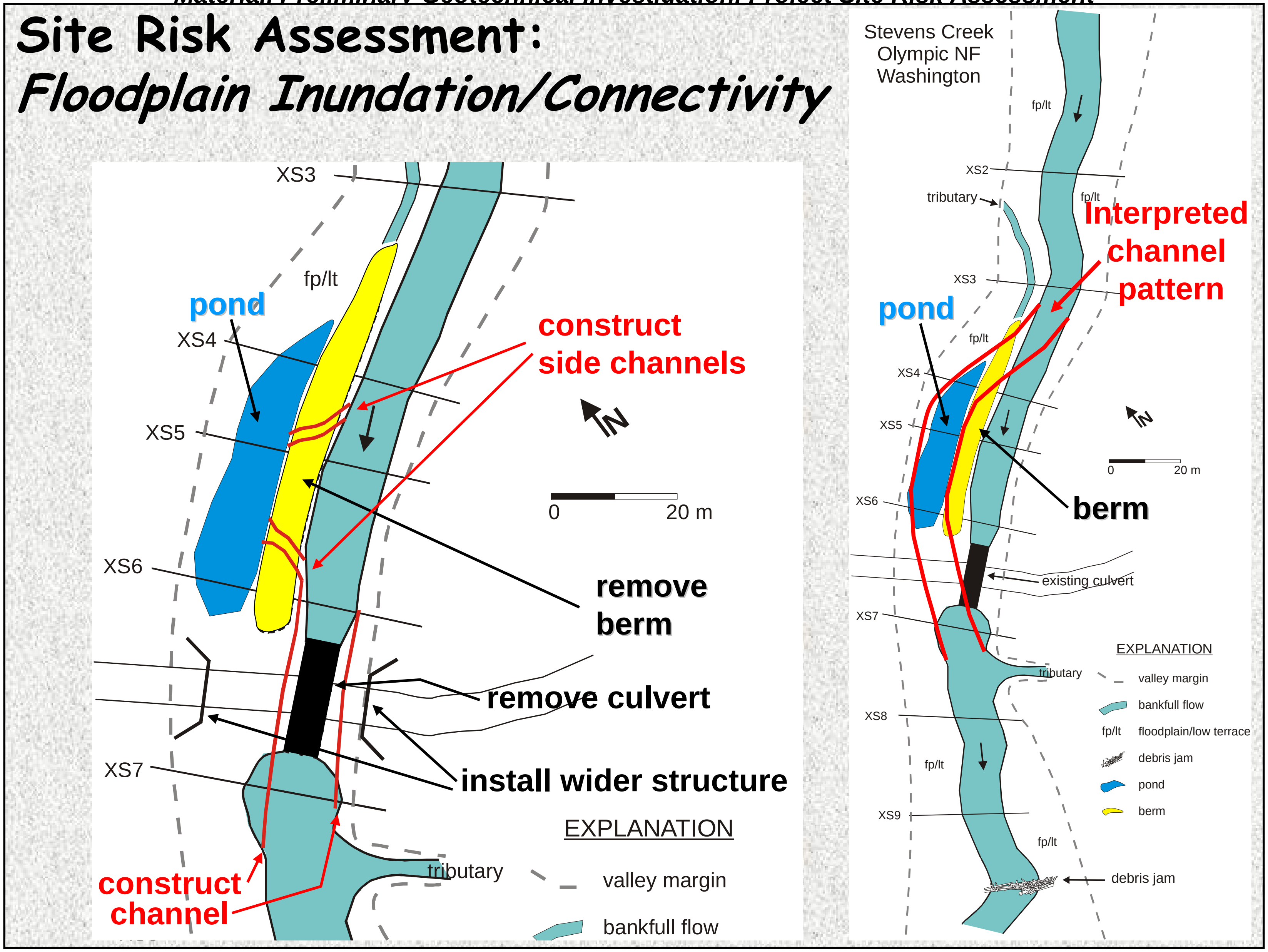
Site Risk Assessment:
Floodplain Inundation/Connectivity

Is floodplain function and connectivity important to the fluvial system and ecological processes?




Site Risk Assessment:
Floodplain Inundation/Connectivity
XS3
fp/lt
pond
XS4
XS5
XS6
XS7
construct side channels
N
0
20 m
remove berm
remove culvert
install wider structure
construct channel
tributary
EXPLANATION
valley margin
bankfull flow
Stevens Creek
Olympic NF
Washington
fp/lt
XS2
tributary
Interpreted channel pattern
XS3
pond
XS4
XS5
XS6
berm
existing culvert
XS7
XS8
XS9
debris jam
EXPLANATION
valley margin
bankfull flow
fp/lt floodplain/low terrace
debris jam
pond
berm

Site Assessment Summary

- **Describe channel features well upstream and downstream from the road crossing.**
- **Take the appropriate number of measurements that sufficiently represents site variability and complexity.**
- **Predict past and potential channel changes at the road-stream crossing with respect to channel stability, channel-bed vertical adjustment, channel headcutting, channel lateral adjustment, and floodplain inundation/connectivity.**
- **Integrate channel characteristics and dimensions from the natural channel in the design channel so it has the capability to laterally and vertically adjust to a wide range floods and sediment/wood inputs without compromising the movement and habitat needs of fish and other aquatic organisms.**

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Selected References and Recommended Readings

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