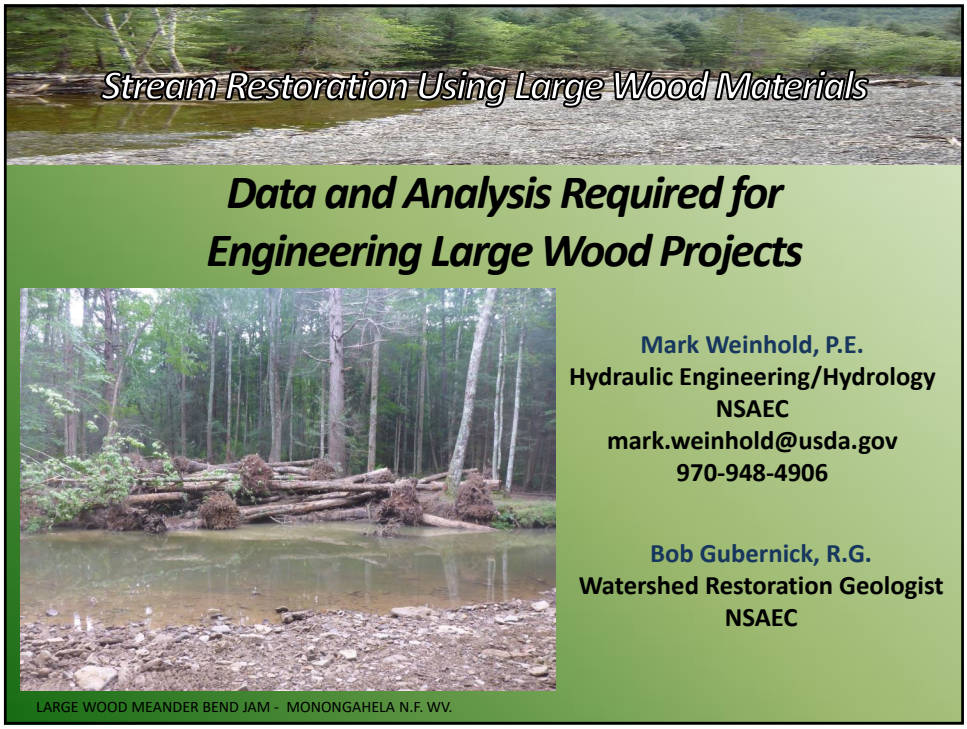
Stream Restoration Using Large Wood Materials
Data and Analysis Required for Engineering Large Wood Projects
LARGE WOOD MEANDER BEND JAM - MONONGAHELA N.F. WV.
Mark Weinhold, P.E.
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Watershed Restoration Geologist
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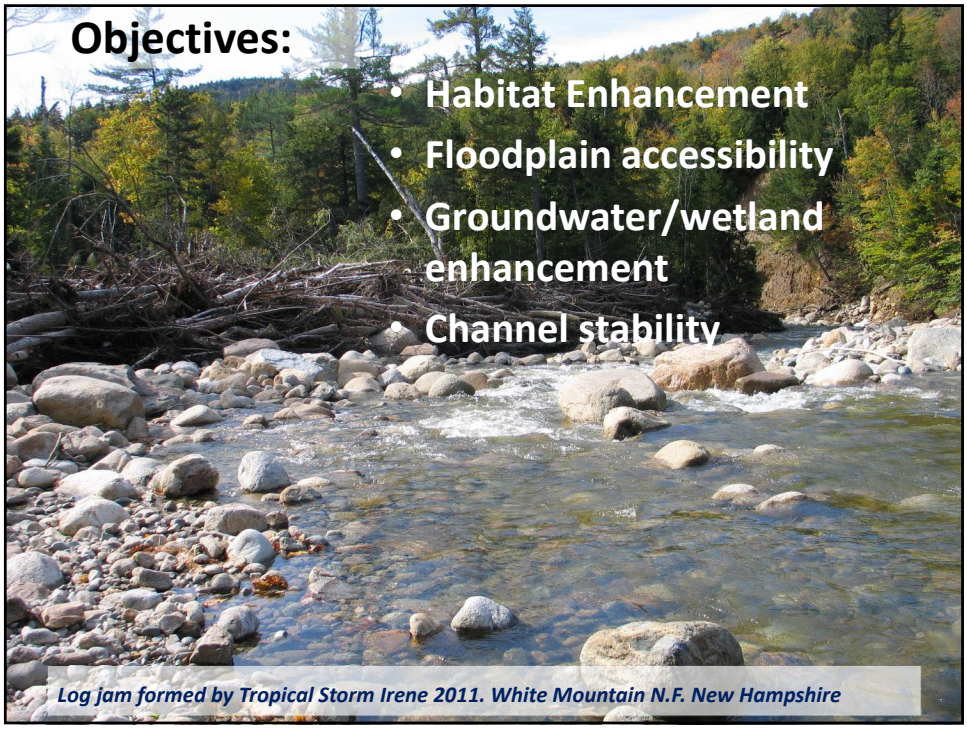
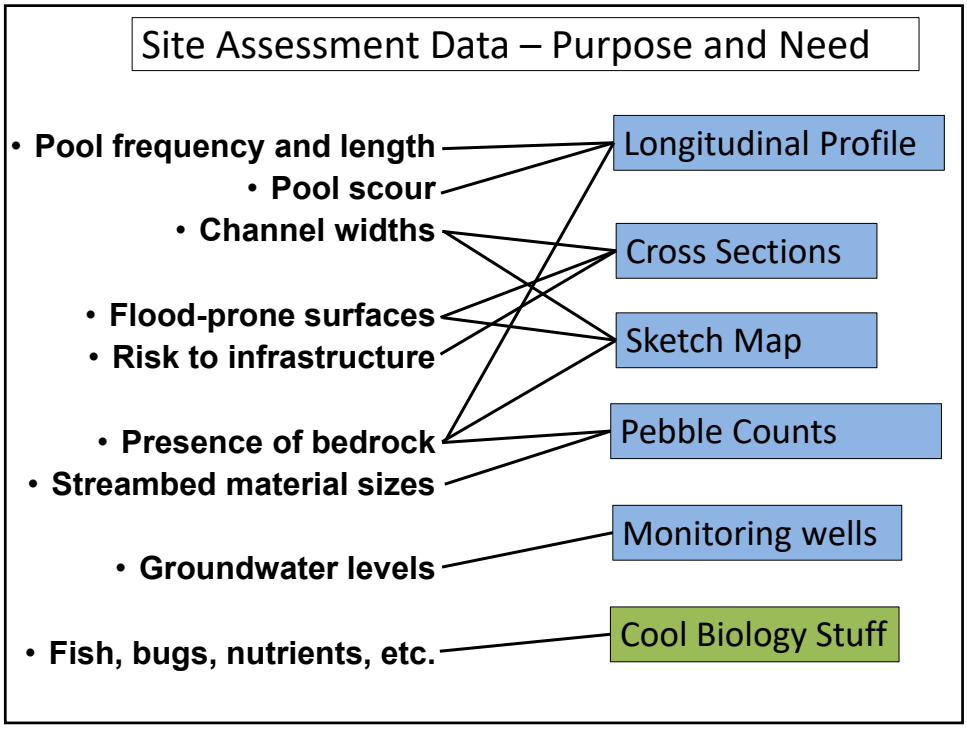
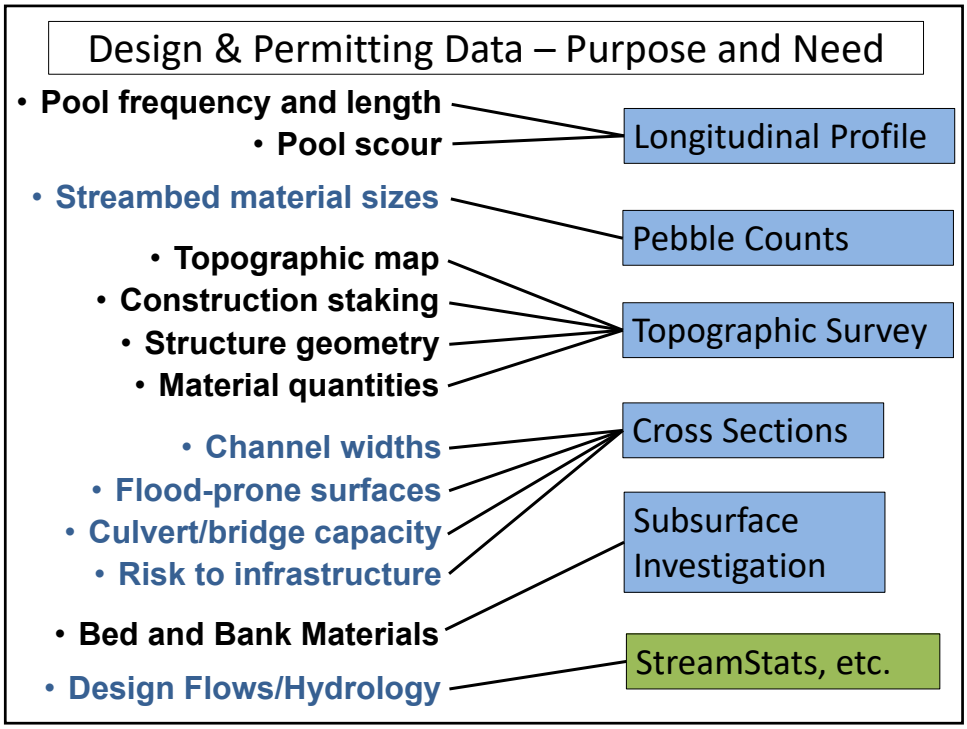
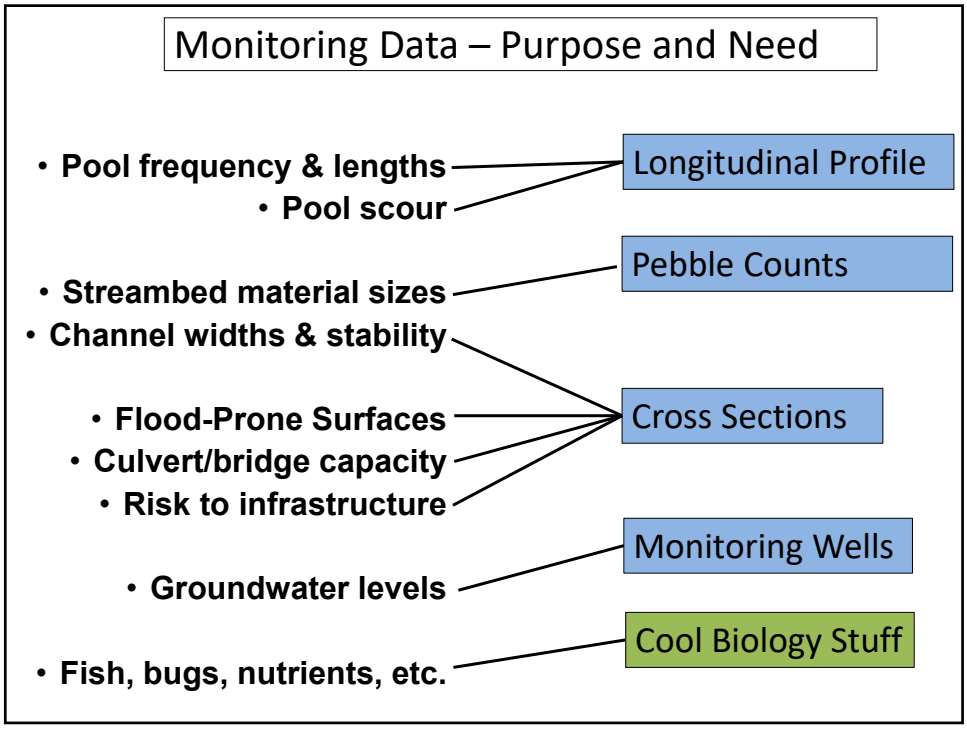

Objectives:
• Habitat Enhancement
• Floodplain accessibility
• Groundwater/wetland enhancement
• Channel stability
Log jam formed by Tropical Storm Irene 2011. White Mountain N.F. New Hampshire

Data and Analysis Required for Engineering Large Wood Projects



Data and Analysis Required for Engineering Large Wood Projects

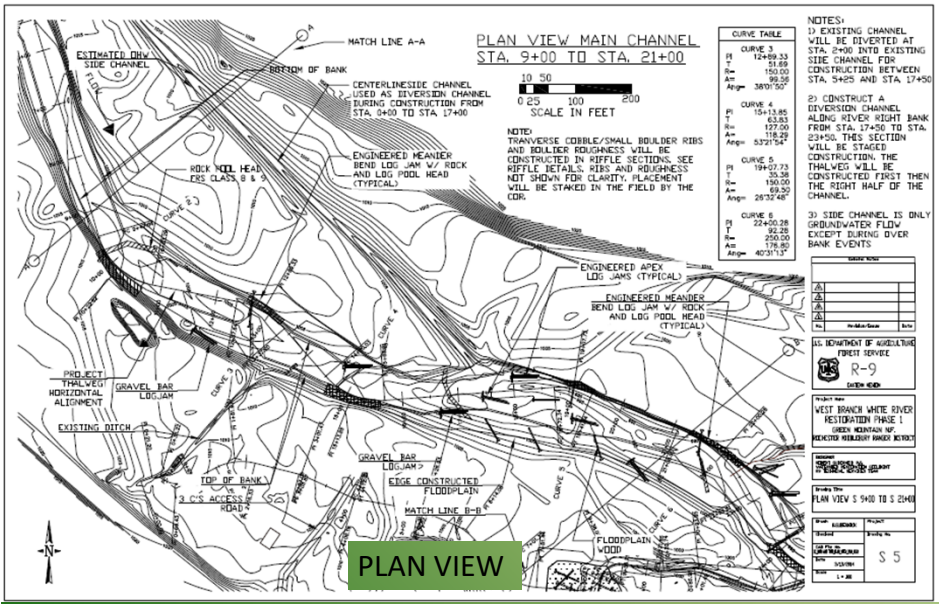




Data and Analysis Required for Engineering Large Wood Projects

- Topographic Map
- Sketch Map
- Longitudinal Profile
- Cross Sections
- Pebble Counts
- Subsurface Investigation
- Monitoring Wells

Topography | Long Profile | Cross Sections | Bed Material | Subsurface Material | Groundwater



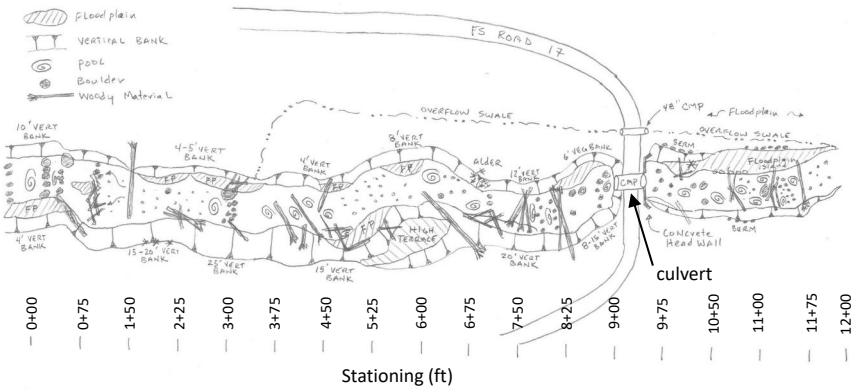
PLAN VIEW

SET BENCHMARKS AND CONTROL POINTS FOR CONSTRUCTION AND MONITORING

Data and Analysis Required for Engineering Large Wood Projects

Topography	Long Profile	Cross Sections	Bed Material	Subsurface Material	Groundwater

Recon Maps - Site Sketch

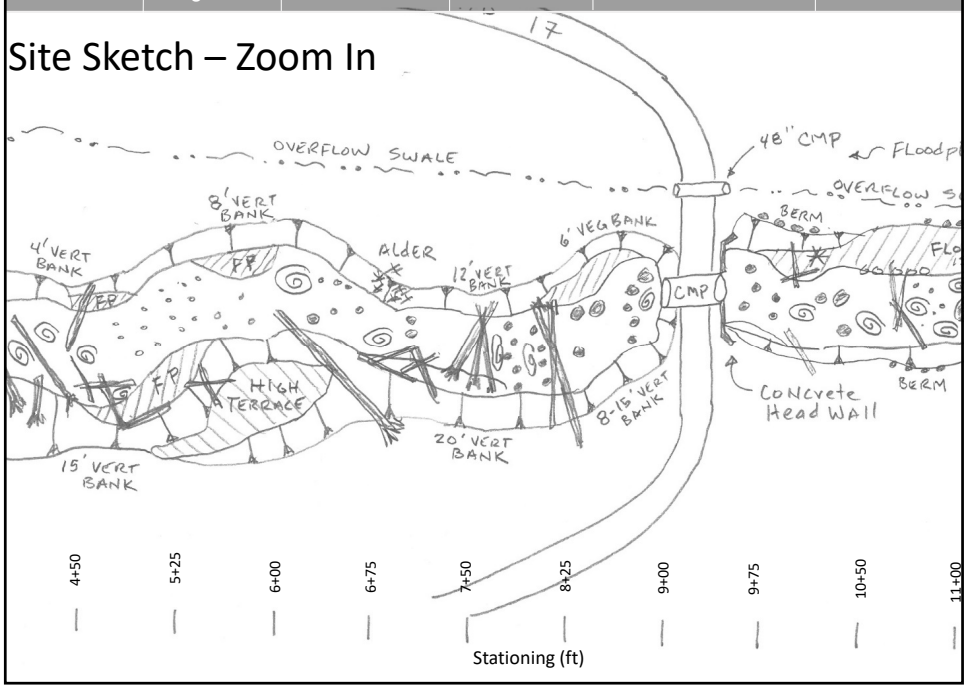


- **Captures critical information on channel dimensions, existing wood, bedrock exposures, floodplain, etc.**
- **Site sketch and photos aid in design decisions during the winter months.**
- **Provides comparison & data check for the survey drawings**

Data and Analysis Required for Engineering Large Wood Projects

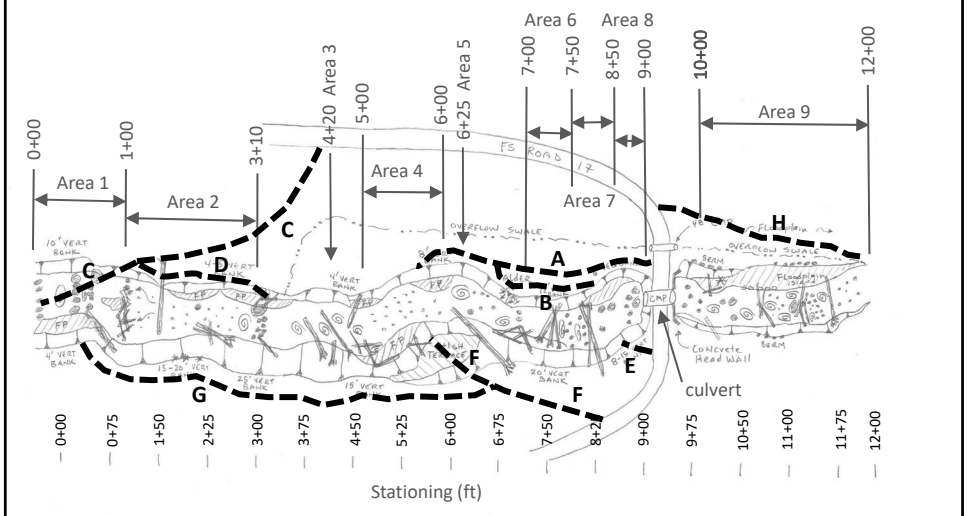
Topography | Long Profile | Cross Sections | Bed Material | Subsurface Material | Groundwater

Site Sketch – Zoom In



Topography | Long Profile | Cross Sections | Bed Material | Subsurface Material | Groundwater

Site Sketch – Broader Uses



Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater

Longitudinal Profile Provides:

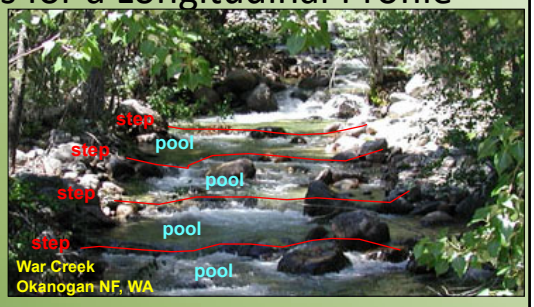
- Delineates channel grade controls upstream/downstream from each project area (both natural and human)
- Establishes the spacing and length of channel units
- Establishes natural channel gradient characteristics (average and variability)
- Determines the design channel gradient through the project area.
- Provides slopes for hydraulic modeling
- Identifies the vertical adjustment potential of the channel (pool scour depth and potential aggradation surfaces).
- Typically 20 to 30 bankfull widths on each side of structure - depending situation and project needs

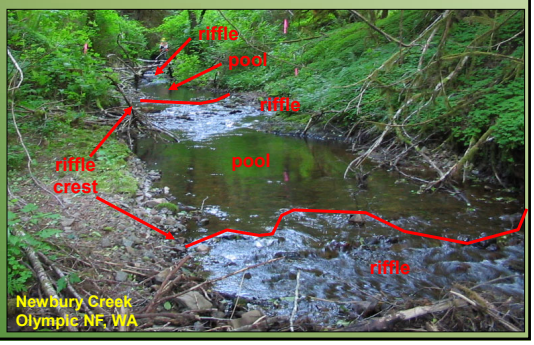
Depending on the action, long profile survey may not need to encompass the entire project length. If only large wood is placed then may only need it thru hydraulic modeled section

Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater

Typical Measuring Points for a Longitudinal Profile

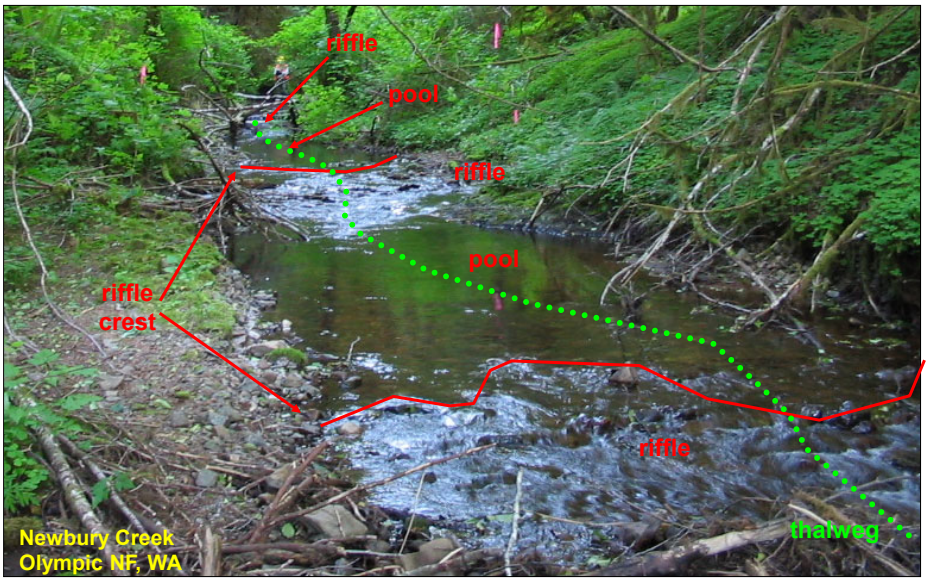
- Beginning, end, and maximum depth of pools.
- Crest and base of cobble, boulder, and LWD steps.
- Beginning and end of riffles, runs, cascades.
- Slope breaks in complex riffles
- Bedrock exposures: Falls, ledges, etc.
- Beginning and end of reach/channel types and other points of interest (changes in bed material size, bedrock, forcing features, etc.).





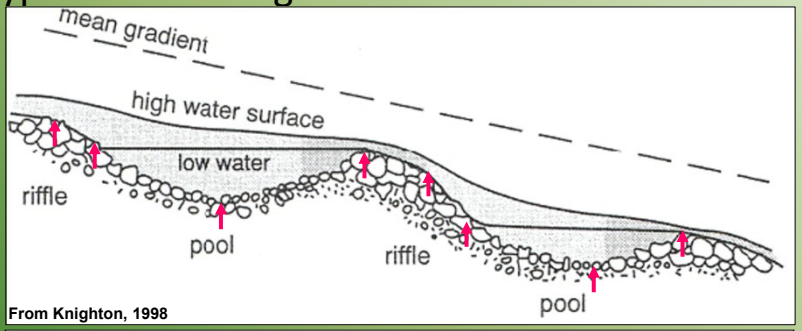
Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater

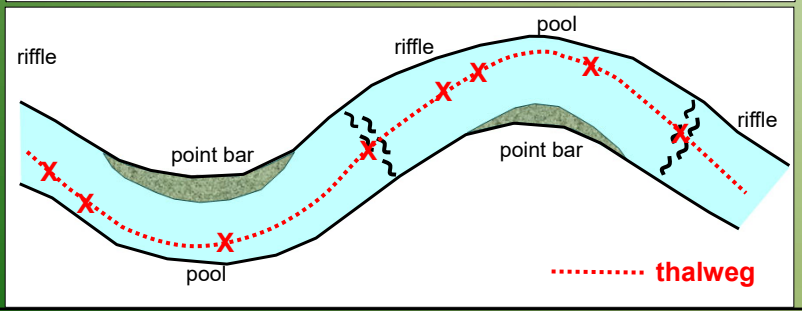
Longitudinal Profile: Pool-Riffle Channel



Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater

Typical Measuring Points for a Pool-Riffle Channel





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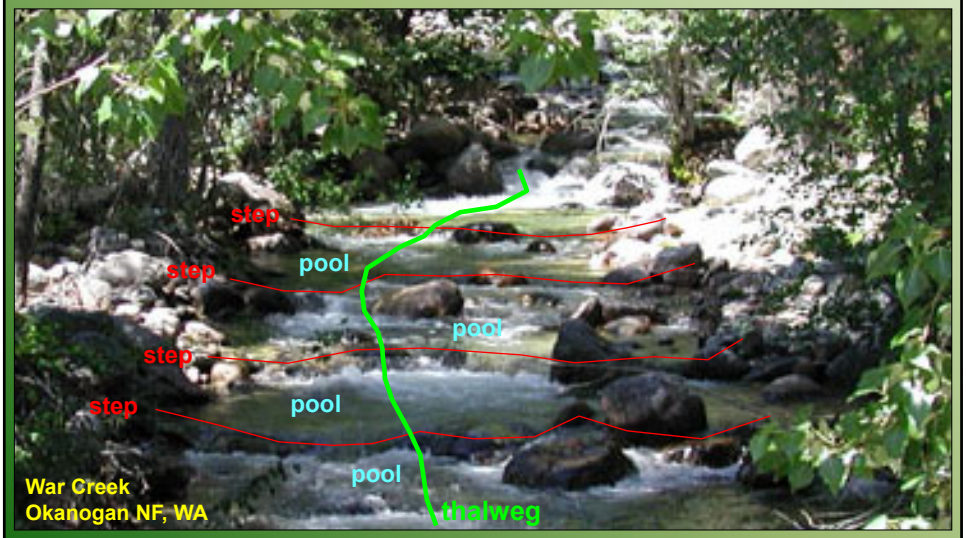
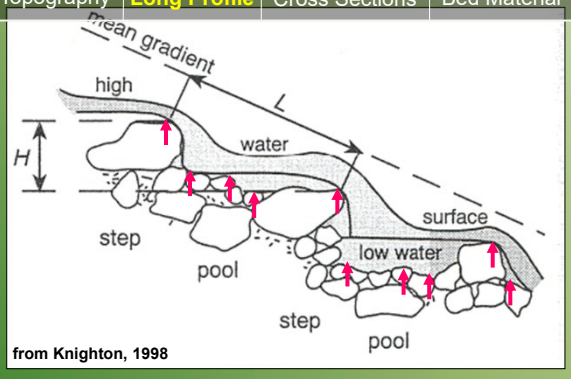
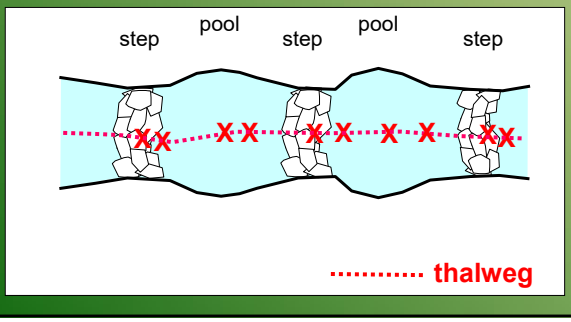
Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater

Longitudinal Profile: Step-Pool Channel



Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater





Typical Measuring Points for a Step-Pool Channel

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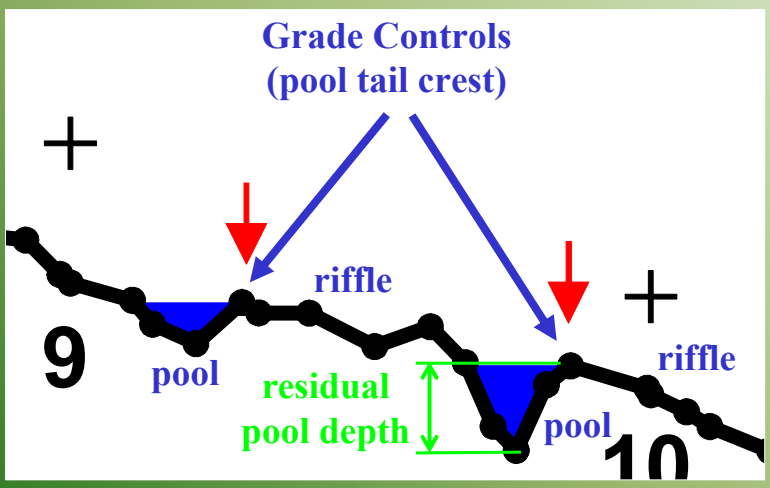
Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater

Hydraulic Grade Controls



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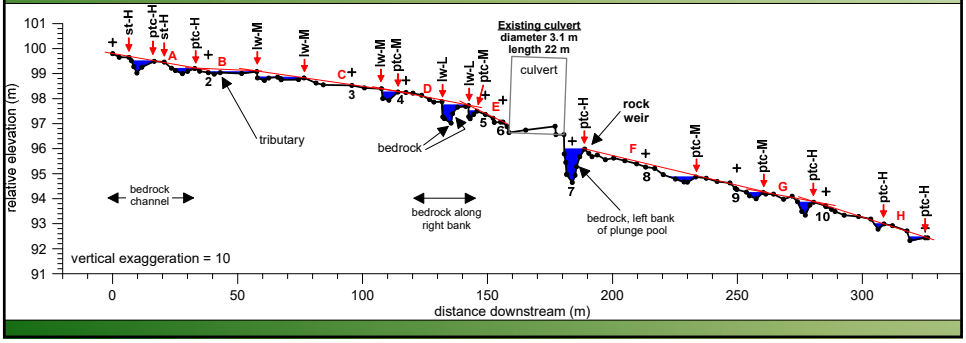
Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater

Longitudinal Profile Assessment – Slope Segments

- For reach average grades, work upstream to downstream and connect similar grade control features (Steps, Pool tail crests)
- Can show the influence of wood on profile

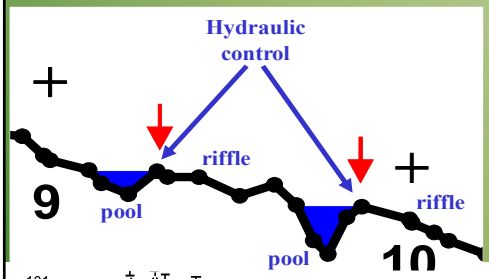
channel-bed profile
pool
top of bank/floodplain
2 cross section location
grade control
ptc-H pool tail crest, high stability
ptc-M pool tail crest, moderate stability
st-H step, high stability
lw-M log weir, moderate stability
lw-L log weir, low stability
slope segments (A,B,C,D,E,F,G,H)



Data and Analysis Required for Engineering Large Wood Projects

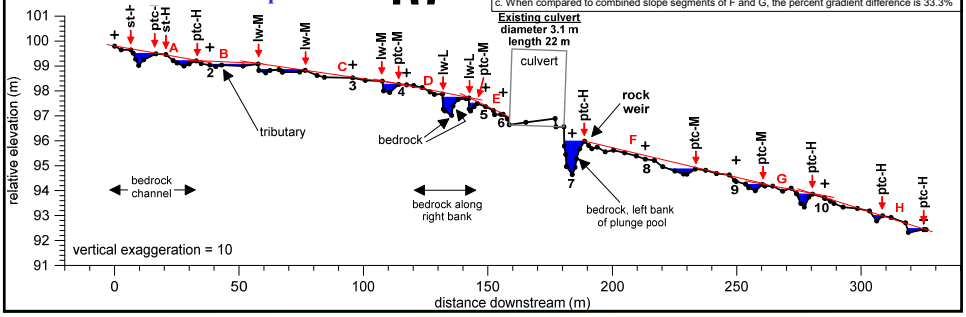
Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater

Profile gives maximum residual pool depth for each slope segment with pool length and spacing .



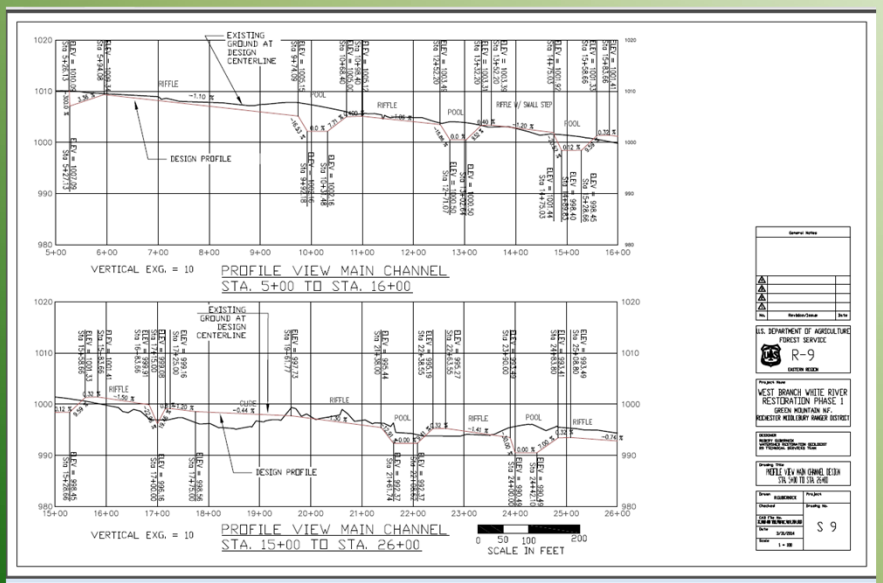
segment	elevation change (m)	segment length (m)	gradient	% gradient difference between successive segments	maximum residual pool depth (m)
A	0.29	16.21	0.0178	n/a	0.47
B	0.12	24.85	0.0050	-71.9	0.10
C	0.82	56.45	0.0145	190.4	0.33
D	0.54	28.25	0.0193	32.9	0.70
E	0.22	3.35	0.0665	245.2	0.30
culvert	0.08	21.97	0.0037	-94.4	1.34
F	1.74	71.40	0.0243	551.5	0.25
G	0.39	20.19	0.0192	-21.0	0.52
F,G	2.12	91.60	0.0232	-4.6[a]	0.52
H	1.43	46.12	0.0309	60.8[a,c]	0.21

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%



Topography | **Long Profile** | Cross Sections | Bed Material | Subsurface Material | Groundwater

Longitudinal Profile for Design Profile Development

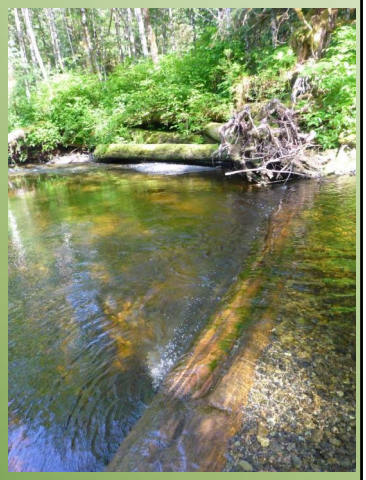


PROFILE VIEW

Topography | Long Profile | **Cross Sections** | Bed Material | Subsurface Material | Groundwater

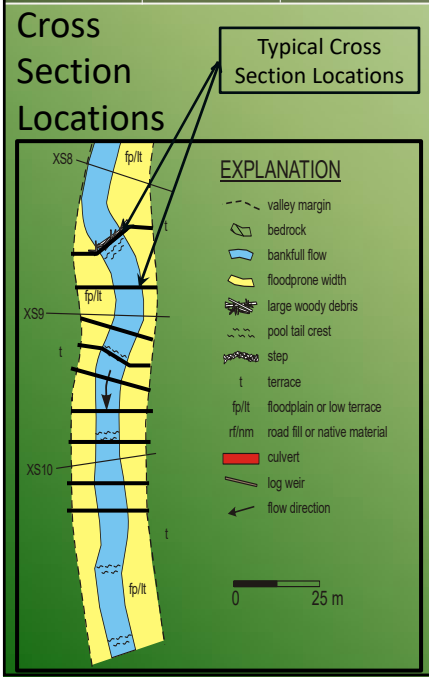
What is the Purpose of a Channel Cross Section?

- Delineates the width and depth of low flow, active stream bed, bankfull dimensions, floodplain and terraces
- Suggests "reference reach" channel dimensions to be used in the channel-bed design associated with the log jam
- Identifies remnant channels and the lateral adjustment potential of the channel (channel migration zone).
- Identifies bank and channel stability
- Necessary for hydraulic modeling



Topography | Long Profile | **Cross Sections** | Bed Material | Subsurface Material | Groundwater

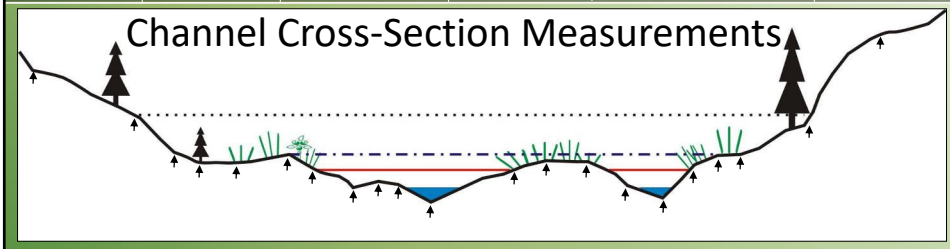
Cross Section Locations



- Number and spacing depend on intended use, topography and channel gradient.
- Section orientation should reflect flood flow direction on floodplains
- Representative cross sections in each channel unit in reference reach
- Above and below critical infrastructure (bridges, buildings…)
- Hydraulic modeling requires more cross sections. Spacing ~ 1 cross section per bankfull width thru the section to be modeled. Some of the cross sections can be interpolated.
- Single cross sections taken in uniform reach (e.g. riffle or GC)

Data and Analysis Required for Engineering Large Wood Projects

Topography | Long Profile | **Cross Sections** | Bed Material | Subsurface Material | Groundwater



- Width should cover flood-prone area (width at 2x maximum bankfull riffle depth) to characterize channel and valley bottom dimensions.
- Capture topographic breaks/transitions between the channel bed, channel deposits, the channel bank, the floodplain, and terraces.
- 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, deposits of woody debris or fine sediments on the floodplain or low terrace).
- Measure and note bankfull and stream bed width indicators.

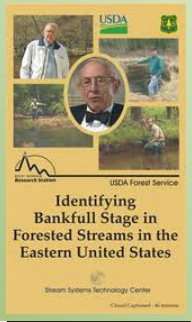
Topography | Long Profile | **Cross Sections** | Bed Material | Subsurface Material | Groundwater

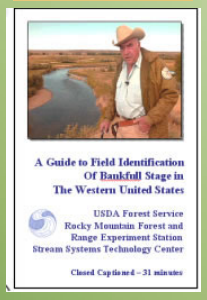
Bankfull Flow Indicators

- Floodplain presence
- Elevation associated with the top of the highest depositional feature (point bars and mid-channel bars in active channels)
- Break in slope of the banks and/or change in particle-size distribution
- Staining on rocks, moss, lichens
- Changes in vegetation types (perennial)

Stream Bed Width Indicators

- The area of the channel devoid of vegetation between banks



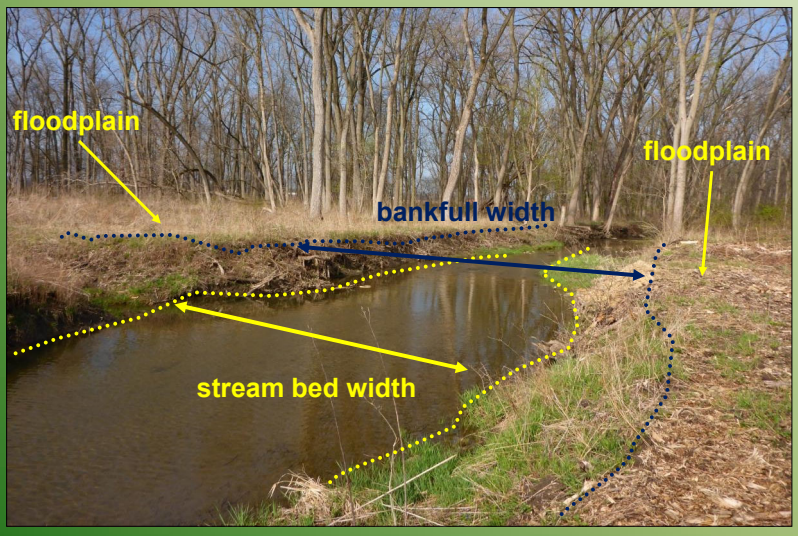


USFS Videos on Bankfull ID available from San Dimas T&D center

Data and Analysis Required for Engineering Large Wood Projects

Topography | Long Profile | **Cross Sections** | Bed Material | Subsurface Material | Groundwater

Stream Bed Width and Bankfull Width



Low gradient (< 1%) example - Grant Creek, Midewin Prairie, Illinois

Topography | Long Profile | **Cross Sections** | Bed Material | Subsurface Material | Groundwater

Stream Bed Width and Bankfull Width

Moderate gradient (1-3%) example - Hogback Creek, Lolo N.F. Montana

Topography | Long Profile | **Cross Sections** | Bed Material | Subsurface Material | Groundwater

Stream Bed Width and Bankfull Width

High gradient (>3%) example
Unnamed tributary to Abe's Run, Monongahela N.F. West Virginia

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

Channel-Bed Sediments

- **Typically measured in riffles 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. are important**
- **The subsurface material immediately below the channel bed should at a minimum be qualitatively described.**

- **Suitable for channels composed of boulders, cobbles, and gravels**
- **Sample channel bed between the base of the banks (i.e., do not include banks)**
- **Needed for scour assessment, incipient movement (if designing new channel)**

Data and Analysis Required for Engineering Large Wood Projects

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

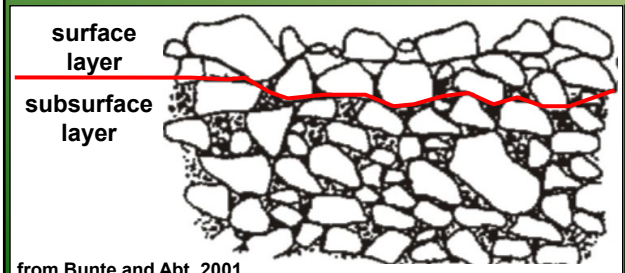
Channel-Bed Material

Surface layer

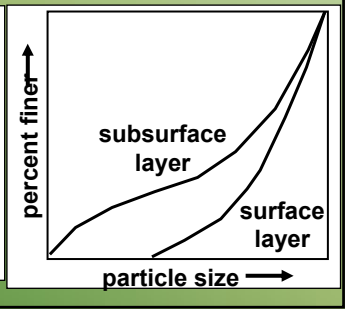
- Typically coarser than subsurface layer - fines scoured leaving the larger particles
- Thickness defined by the depth of the largest particles

Subsurface layer

- Fine material in the voids between the larger particles
- Dense gradation limits permeability

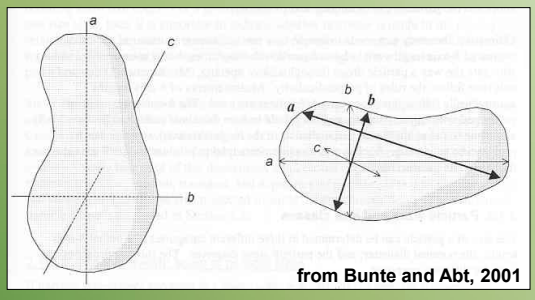


from Bunte and Abt, 2001



Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

Surface Sampling: Pebble Counts



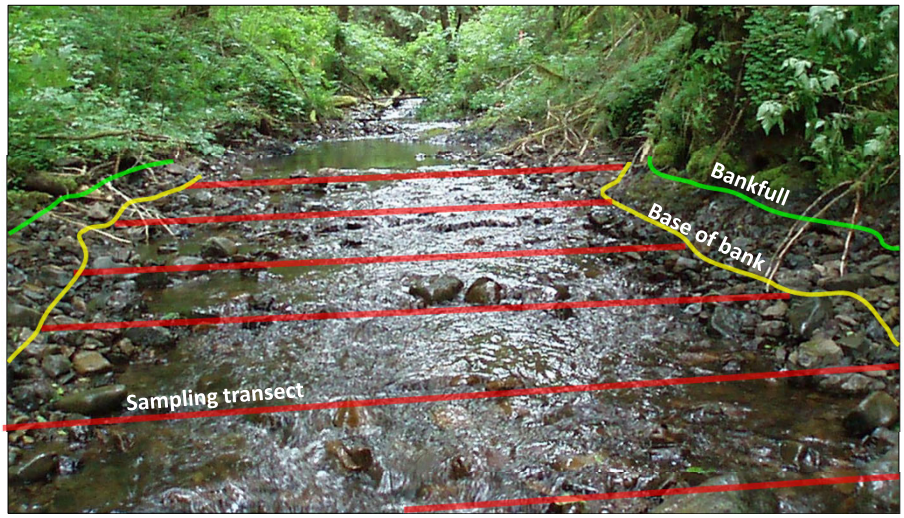
from Bunte and Abt, 2001

- **Substitutes for a volumetric sample at a lab**
- **Measure the particle diameter (intermediate- or b-axis)**
- **Measure 200+ particles in MILLIMETERS**
- **Sample along evenly spaced tape transects across stream**
- **Space multiple transects based on particle size, length of riffle, with a minimum 2-3 ft apart**
- **Can be measured by heal-to-toe, linear tape, or grid method depending on substrate size**

Data and Analysis Required for Engineering Large Wood Projects

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

Surface Sampling: Pebble counts along transects



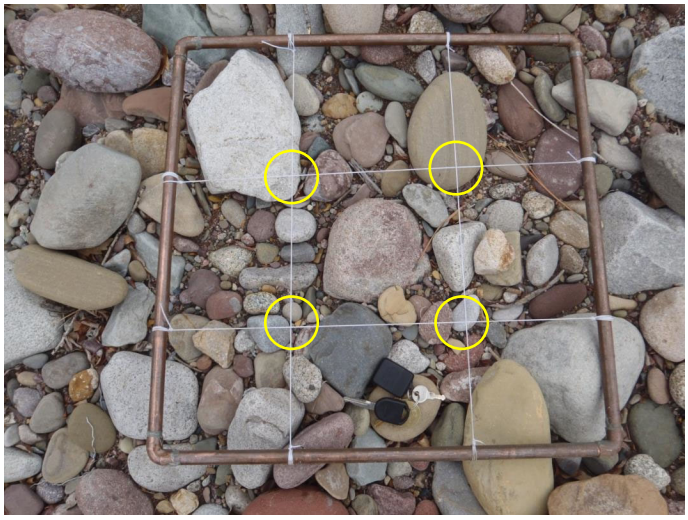
Number of transects is selected to collect a minimum of 200 particle measurements over the length of the channel unit.

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

Option – Measuring at equal intervals along a tape at each transect

Data and Analysis Required for Engineering Large Wood Projects

Option – Measuring with a grid along each transect

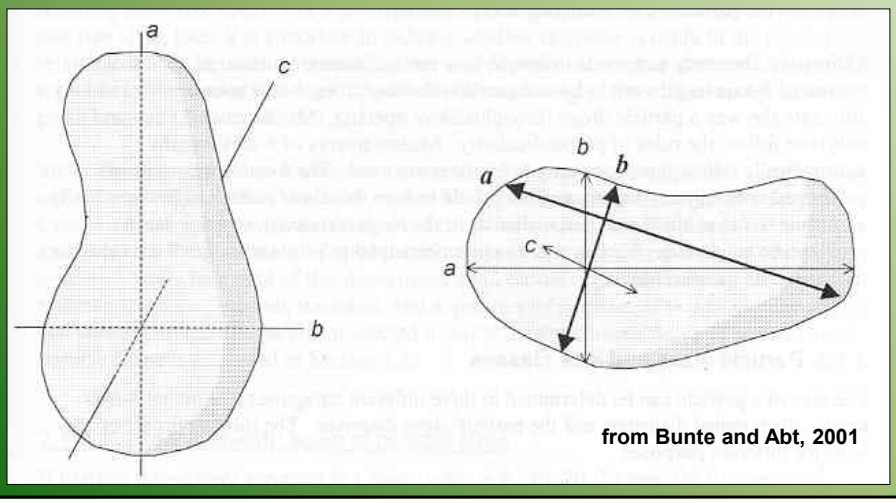


Grid sampling method reduces sampling bias (heal-to-toe method can be biased against sampling sands, small gravels, and large boulders).

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

Surface Sampling: Particle Measurements

- **For channel bed measure the intermediate-axis (b) of the particles**
- **For key features (steps, roughness elements such as boulders measure the length of the particle's long-axis (a), intermediate-axis (b), and short axis (c)**



from Bunte and Abt, 2001

Data and Analysis Required for Engineering Large Wood Projects

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

Binned or Individual Measurements

Measure and place in bins or record the actual B-axis measurement in a notebook to use in EXCEL (percentile function)

particle size interval name	size interval (mm)
medium boulders	512 to 724
	362 to 512
small boulders	256 to 362
	181 to 256
large cobbles	128 to 181
	90.5 to 128
small cobbles	64.0 to 90.5
	45.2 to 64.0
very coarse gravel	32.0 to 45.2
	22.6 to 32.0
coarse gravel	16.0 to 22.6
	11.3 to 16.0
medium gravel	8.0 to 11.3
	5.7 to 8.0
fine gravel	4.0 to 5.7
	2.8 to 4.0
very fine gravel	2.0 to 2.8
sand, silt, or clay	< 2
	Total count

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

Particle-Size Distributions – Binned Data

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

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
d30	40
d16	24
d10	15
d5	10
% boulders	6.19
% cobbles	47.79
% gravels	45.13
% sands,silts,clays	0.88

Example: Newbury Creek, (Olympic NF, WA)

Data and Analysis Required for Engineering Large Wood Projects

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

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)

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

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
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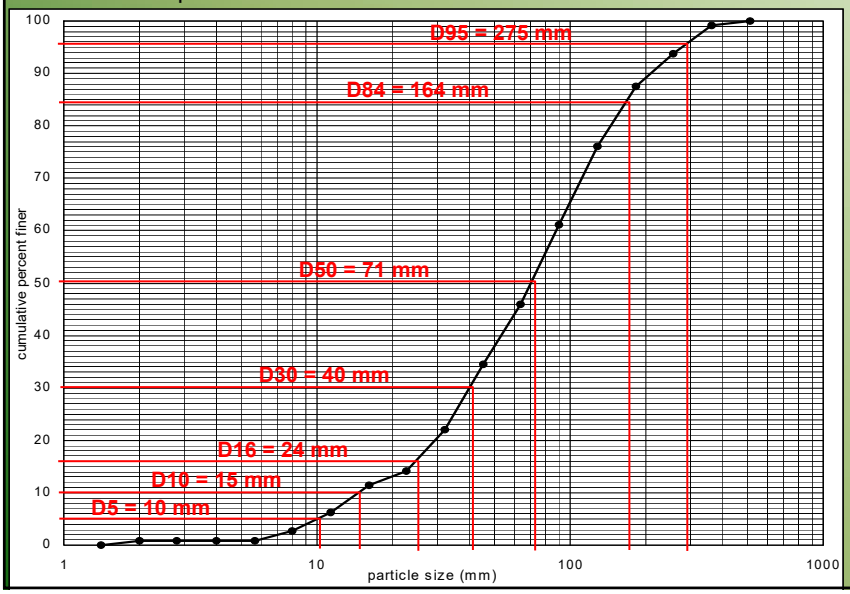
Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

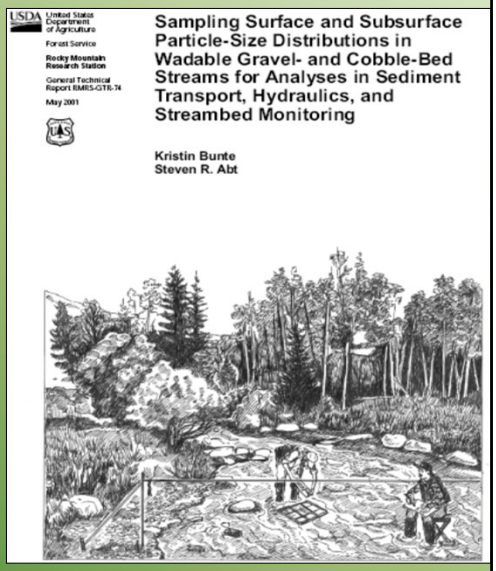
- Plot cumulative percent finer against the smallest value of a given size interval
- Use plot to obtain percentile particle sizes (D95, D84, D50, D30, D16, D10, D5, etc.) and calculate particle-size distribution statistics



Data and Analysis Required for Engineering Large Wood Projects

Bible for 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.



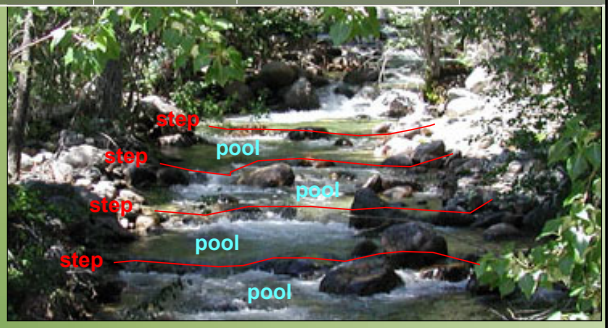
- **Available online at:**

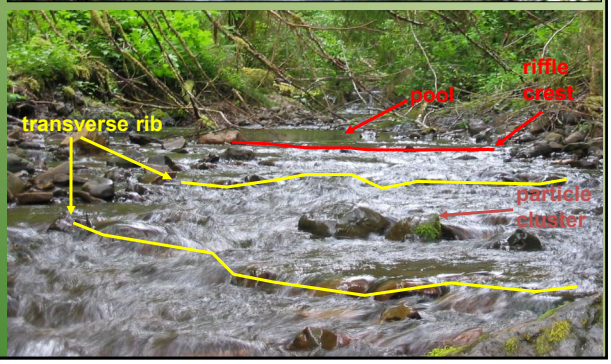
http://www.stream.fs.fed.us/publications/PDFs/rmrs_gtr74.pdf

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

Key Pieces

- Measure the largest particles making up key hydraulic features (e.g., steps, riffle crests, transverse ribs, particle clusters, etc.)
- Measure between 20 to 25 particles
- THIS IS NOT A RANDOM SAMPLE
- Measure all three axes to get shape





Data and Analysis Required for Engineering Large Wood Projects

Topography | Long Profile | Cross Sections | **Bed Material** | Subsurface Material | Groundwater

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/inter mediate 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
	552	**411**	**205**	**365**	**1.56**	d95 percentile (mm)
	374	**310**	**110**	**238**	**1.50**	d84 percentile (mm)
	308	**245**	**88**	**180**	**1.30**	d50 percentile (mm)
	260	**180**	**70**	**154**	**1.20**	d16 percentile (mm)

EXCEL percentile function

Topography | Long Profile | Cross Sections | Bed Material | **Subsurface Material** | Groundwater

Preliminary Geotechnical Investigation

- **Characterizes the sediment and stratigraphic properties of the material below the channel and in the banks (size, gradation, unit weights, etc.)**
- **Bank and subsurface observations and data are important in determining scour depth, depth to bedrock or unsuitable / problematic materials, deciding treatments for access roads, determining embedment and ballasting requirements for large wood structures**
- **Identifies potential subsurface conditions that may require further geotechnical analysis and design considerations.**
  - **Clay & cohesive soils (any problematic soils)**
  - **Organic-rich material**
  - **Bedrock**

Topography | Long Profile | Cross Sections | Bed Material | **Subsurface Material** | Groundwater

Preliminary Geotechnical Investigation - Soils

- **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

Topography | Long Profile | Cross Sections | Bed Material | **Subsurface Material** | Groundwater

Preliminary Geotechnical Investigation

•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

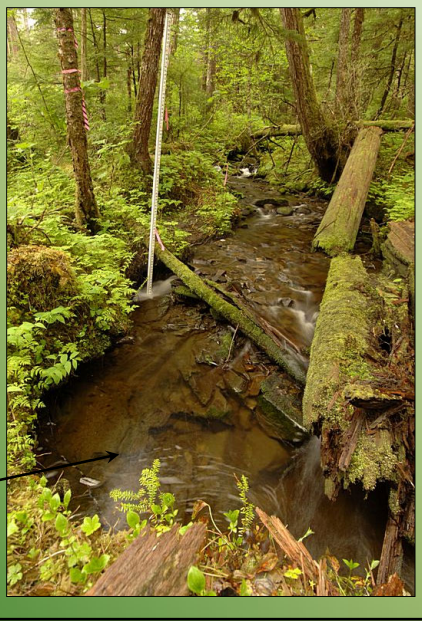
- –Locate areas on plan map, contour map, and longitudinal profile
- –Tie into existing survey data so elevation of units are known

Stumps found buried under 4 feet of gravel.
Buried by debris flow / landslide

Topography | Long Profile | Cross Sections | Bed Material | **Subsurface Material** | Groundwater

Preliminary Geotechnical Investigation - Bedrock

- **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.

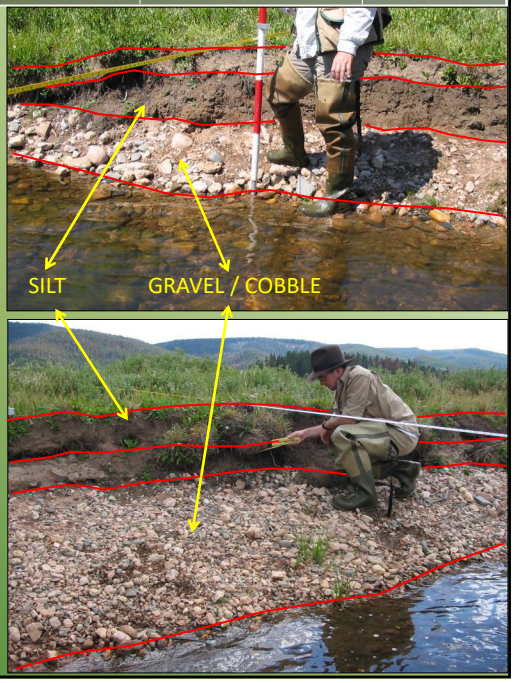


Bedrock exposed in pool bottom. Stream has a shallow veneer of gravel/cobble/boulders over bedrock. Bedrock limits deep pool development

Topography | Long Profile | Cross Sections | Bed Material | **Subsurface Material** | Groundwater

Characterizing Channel Bank Sediments

- Delineate distinct bank layers
- Characterize materials
- Cohesive soils, sand, silt, clay are more problematic
- Required to determine amount of work required to excavate trenches for key embedded logs and difficulty of constructing log jams.
- Estimate engineering properties of the bank materials and thickness of layers to be used in ballast in buoyancy calculations.
- Note critical bank heights if design includes a lowered channel bed elevation



Data and Analysis Required for Engineering Large Wood Projects

Topography | Long Profile | Cross Sections | Bed Material | **Subsurface Material** | Groundwater

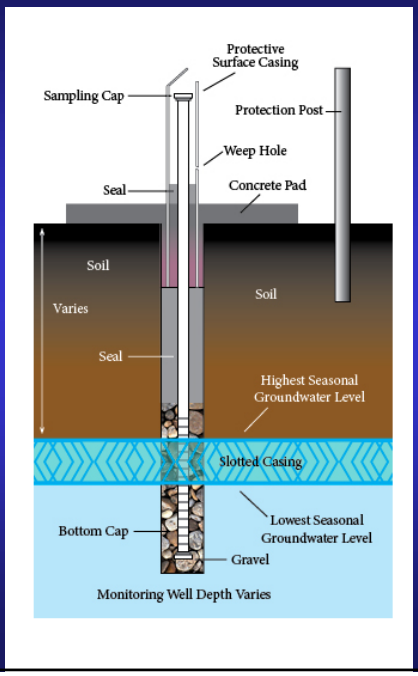
Engineering Properties of Bank Sediments for Buoyancy and Drag Calculations

Table 5-17. Typical compacted densities and optimum moisture contents for USCS soil types (after Carter and Bentley, 1991).

Soil Description	USCS Class	Compacted Dry Unit Weight (lb/ft3)	Compacted Dry Unit Weight (kN/m3)	Optimum Moisture Content (%)
Gravel/sand mixtures:				
well-graded, clean	GW	125-134	19.6-21.1	8-11
poorly-graded, clean	GP	115-125	18.1-19.6	11-14
well-graded, small silt content	GM	119-134	18.6-21.1	8-12
well-graded, small clay content	GC	115-125	18.1-19.6	9-14
Sands and sandy soils:				
well-graded, clean	SW	109-131	17.2-20.6	9-16
poorly-graded, small silt content	SP	94-119	15.7-18.6	12-21
well-graded, small silt content	SM	109-125	17.2-19.6	11-16
well-graded, small clay content	SC	106-125	16.7-19.6	11-19
Fined-grained soils of low plasticity:				
silts	ML	94-119	14.7-18.6	12-24
clays	CL	94-119	14.7-18.6	12-24
organic silts	OL	81-100	12.7-15.7	21-33
Fine-grained soils of high plasticity:				
silts	MH	69-94	10.8-14.7	24-40
clays	CH	81-106	12.7-18.6	19-36
organic clays	OH	66-100	10.3-15.7	21-45

Topography | Long Profile | Cross Sections | Bed Material | Subsurface Material | **Groundwater**

Keep it simple and let data needs drive the effort.




Summary:
All projects do not warrant significant survey data collection.
Let complexity and risk drive that decision.
The amount of survey data is a function of:
• Scale of the project (large or small)
• Risk (Close to private property or critical infrastructure)
• Permitting and modeling needs
• Reporting requirements (i.e. grants)


Questions?