Site Assessment: Field Measurements and Interpretations

Site Maps, Channel Planform Characteristics, and Longitudinal Profile

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Stream Simulation Design Process

6a

- **Initial Assessment**
  - **Review road context**
  - **Review resource values**
  - **Evaluate watershed-scale risk factors**
  - **Evaluate site risk factors**
  - **Develop project objectives**
- **Site Assessment**
  - **Collect data and develop Site Maps and Channel Planform Characteristics**
    - **Identify Preliminary Reference Reach**
    - **Roadway Considerations**
    - **Longitudinal Profile**
      - **Survey**
      - **Planform characteristics (structure)**
      - **Alignment**
      - **Interpretation**

Initial Assessment

The Big Picture View

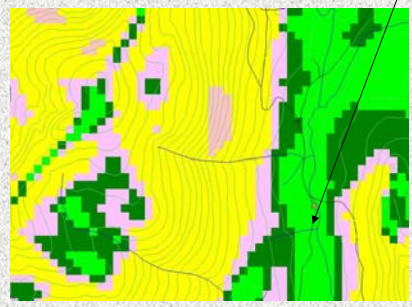
- **Necessary to view the site in the context of the watershed and future management to develop the realistic *project objectives* (possibilities) and minimize potential errors.**
- **Are there large scale events that can affect our site?**
  - **timber harvest, river base level adjustment, geo-hazards**
- **How valuable is the resource and what is at the site?**
- **What are the road issues?**
  - **Can it be moved? Are there ROW problems? What's the maintenance history?**
- **What are the site factors / concerns**
  - **Floodplain constriction?, channel stability?, etc?**

Large Scale Data Required to Determine Project Objectives

Watershed Information
- **Past/Present/Future Management Activities**
- **Road History**
- **Geology, Soils, Vegetation of Area**
- **Slope Stability/Hazard Assessment**
- **Air Photo Interpretation**

Channel Information
- **Channel Types**
- **Channel Stability**
- **Large Woody Debris**

Biological Information
- **Organisms Present**
- **Extent of Habitat**
- **Quality of Habitat**



What is the purpose of the reference reach?

- **The reference reach provides a template of the channel bed, banks, and floodplain characteristics and geomorphic processes along a stable, representative reach of the channel.**
- **The geomorphic characteristics of the reference reach can be utilized to develop an appropriate structure width and channel characteristics in the replacement structure that enables the natural fluvial processes to operate through the structure and allow for unimpeded aquatic organism passage.**

Selecting a Preliminary Reference Reach

- **The reference reach should be located in a channel segment that:**
  1) **is well beyond the influence of the culvert,**
  2) **is in a "stable" reach segment,**
  3) **has channel characteristics and geomorphic indicators that are representative of the channel and are interpreted to exist at the crossing if the culvert was not there.**
- **The longitudinal profile, channel cross sections, and plan view map for the site should be used in conjunction with the field reconnaissance to select the reference reach.**

Hint: Take a quick measurement of the stream / culvert elevation differential so you get an idea of the slope you need in a reference reach

Selecting a Preliminary Reference Reach

- **The channel design gradient through the structure should be similar to the channel gradient of the reference reach.**
- **The reference is typically selected upstream from the road-stream crossings, but a downstream reference reach can be selected depending on site conditions.**
- **If possible, avoid selecting areas that have extreme complexity.**
- **Do not select reference reaches upstream or downstream of tributary junctions because the change in discharge changes channel dimensions.**

During the collection of data for the site assessment, we are making the first attempt at determining the reference reach. The preliminary reference reach selected needs to be verified (or a new reference reach selected) after the longitudinal profile, channel cross sections, and plan view map are analyzed and interpreted.

What is the purpose of considering the roadway?

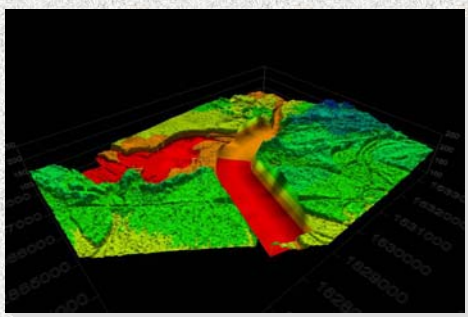
1) **Can the alignment, grade, fill height, and width of the road be changed to improve the culvert/stream alignment and/or reduce the length of the structure?**
2) **Does type of vehicle use, utilities, property boundaries, etc. limit the ability to reconfigure the roadway?**
3) **How will your answers to questions 1 and 2, affect your design recommendations for the site?**

What is the Purpose of a Site Map?

- **Characterizes and documents the spatial distribution of channel/floodplain features and their relation to the road crossing.**
- **The alignment of the channel and road can be evaluated. Provides a template for considering channel and road realignment options.**
- **The lateral migration characteristics of the channel can be evaluated (channel migration zone).**
- **Required for structure designs at road-stream crossings and assists in subsurface investigations at the site.**

Types of Maps

Watershed Scale Maps
- **USGS Quadrangle Maps**
- **Ortho Photos**
- **GIS Data Maps**
- **Geologic Maps**



Reach Scale Maps
- **Reconnaissance-Level Maps**
- **Engineering Maps**
- **Geomorphic Maps**

Watershed Scale Maps

Large Scale

- **Give you the watershed view**
- **Readily available (USGS quads, geologic maps)**
- **GIS maps may require construction (depending on size of site may not be necessary) can show proximity to managed area, slope hazards, etc.**

Reconnaissance-Level Site Maps

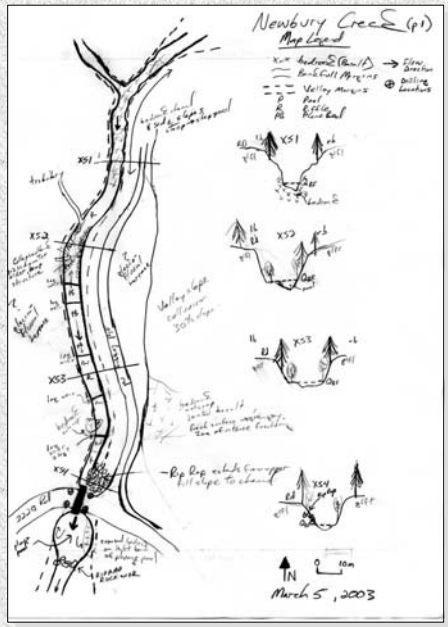
Sketch map that illustrates the spatial relationship of geomorphic features, road characteristics, and their relation to each other.

- **Geomorphic Features: Channel pattern, channel units, key grade control features, large woody debris, floodplain, terraces, valley wall, channel bars, vegetation changes, gravel bars, eroding banks, bankline pattern, etc.**
- **Engineering Features: Road alignment, road curvature, ditchline, inlet and outlet characteristics of existing structure, potential temporary roads and storage areas, hazard trees, utilities, property boundaries, etc.**

Allows various disciplines to share pertinent information with each other.

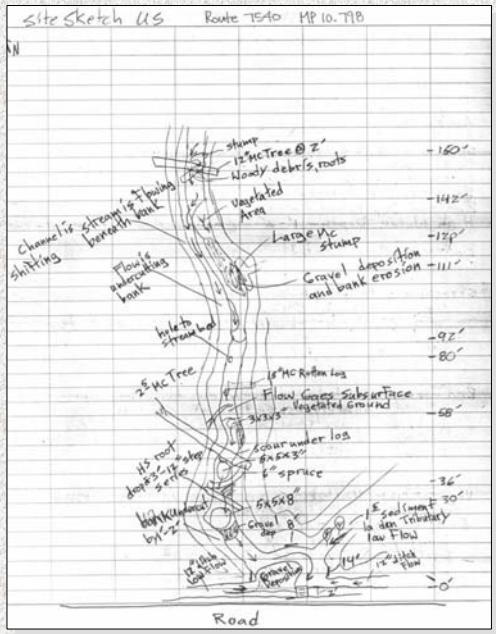
Example of a Reconnaissance-Level Site Map

Newbury Creek,
Olympic National Forest



Example of a Recon-Level Site Map

FDR7540-10.778MP
Tongass N.F.



Courtesy of

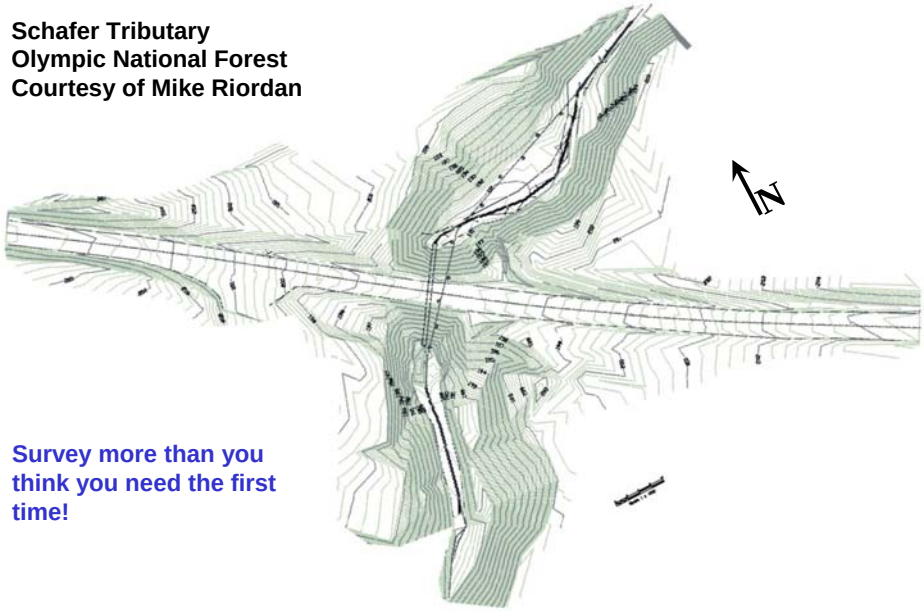
Bratslavsky Consulting Engineers, Anchorage AK.

Engineering Map: Topographic Surveys

- **Detailed survey of features identified on the reconnaissance-level map of the road-stream crossing (~12 mm accuracy).**
- **Needed for determining best horizontal and vertical alignments for road and stream.**
- **Need for developing contract quantities.**
- **Dimensions of existing culvert are surveyed.**
- **Road surface centerline, shoulders, and ditch line are surveyed**
- **Benchmarks and RP's are established and surveyed.**
- **Utilities, property lines, hazard trees, etc. are surveyed.**
- **Channel features (thalweg, waters edge, lower channel banks, upper channel banks, foot of valley slope or terraces, key grade control features, cross section locations, etc.) should be surveyed farter than the anticipated regrade upstream and downstream from crossing.**

Example of an Engineering Topographic Map

Schafer Tributary
Olympic National Forest
Courtesy of Mike Riordan



Survey more than you think you need the first time!

Geomorphic Maps

- **Detailed topographic survey map of the road-stream crossing (~12 mm accuracy)**
- **Needed for determining the spatial relationship of channel features (channel pattern, channel units, key grade control features, large woody debris, floodplain, terraces, valley wall, channel bars, vegetation changes, gravel bars, eroding banks, bankline pattern, etc. at least 20 to 30 channel widths upstream and downstream from the crossing**
- **Mapping is based on extrapolation between the surveyed cross sections, longitudinal profile, and other pertinent geomorphic features**

Newbury Creek, Olympic National Forest

Newbury Creek, Olympic National Forest

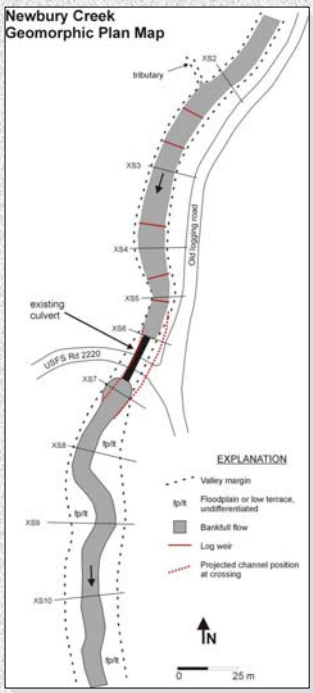
Downstream Channel

Upstream Channel

Geomorphic Map Example

Newbury Creek
Olympic National Forest

This can be the recon level map. Gage your level of effort based on risk, the cost of being wrong at the site, and the level of review for your project (State DOT or regulators)



Evaluate & Advance the Science

Phase 1
Initial
Assessment

Phase 2
Site Assessment

Phase 3
Stream Simulation
Design

Phase 4
Final Design &
Contract Preparation

Phase 5
Construction

Phase 6
Maintenance
& Monitoring

Stream
Simulation
Project
Phases

Stream Simulation Design Process

6a

- Initial Assessment
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  - Evaluate watershed-scale risk factors
  - Evaluate site risk factors
  - Develop project objectives
- Site Assessment
  - Collect data and develop Site Maps and Channel Planform Characteristics
    - Identify Preliminary Reference Reach
    - Longitudinal Profile
      - Survey
      - Planform characteristics (structure)
      - Alignment
      - Interpretation

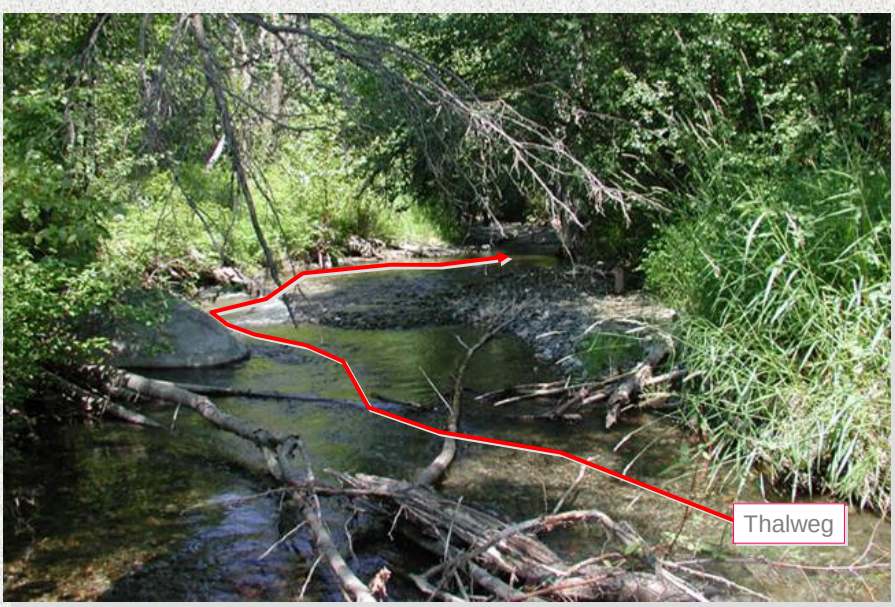
What is the Purpose of a Longitudinal Profile?

1) Establishes natural channel gradient characteristics (average and variability)
2) Delineates channel grade controls upstream/downstream from the road crossing (both natural and human)
3) Establishes the spacing and length of channel units
4) Determines the elevation difference of the channel immediately upstream and downstream from the "undersized" pipe.
5) Identifies the vertical adjustment potential of the channel (scour depth and potential aggradational surfaces).
6) Used to develop the design channel gradient (project profile & invert elevations) through the crossing.

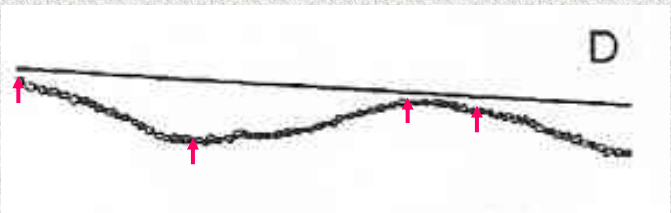
Typical Measuring Points for a Longitudinal Profile

- **Beginning, end, and maximum depth of pools.**
- **Crest and base of cobble, boulder, and LWD steps.**
- **Beginning and end of riffles, runs, lag deposits.**
- **Top and base of steps (LWD or rock), transverse bars.**
- **Bedrock exposures: Falls, ledges, etc.**
- **Beginning and end of reach/channel types and other points of interest (changes in bed material size, gradations, forcing features/ constrictions, etc.).**

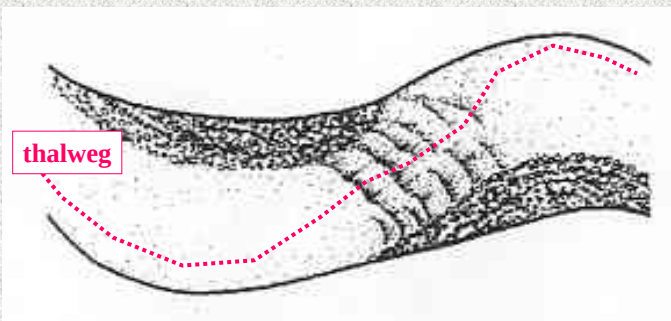
Longitudinal Profile: Pool-Riffle Channel



Typical Measuring Points of a Longitudinal Profile for a Pool-Riffle Channel



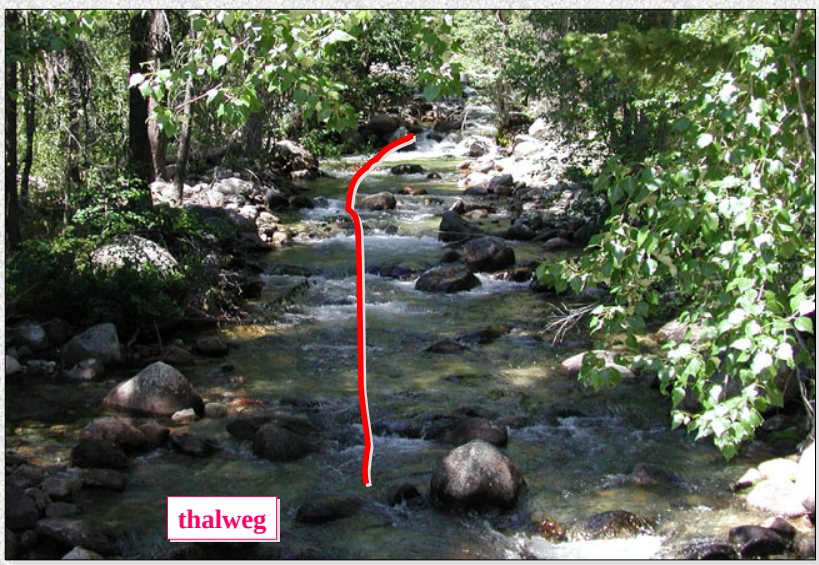
Profile View



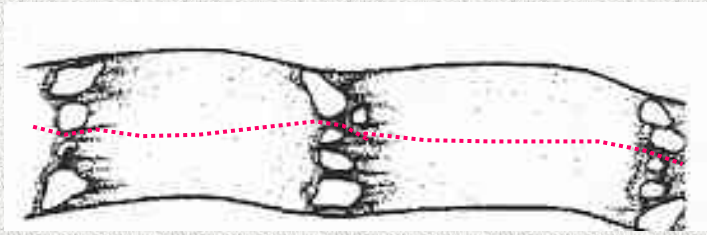
Plan View

Longitudinal Profile: Step-Pool Channel

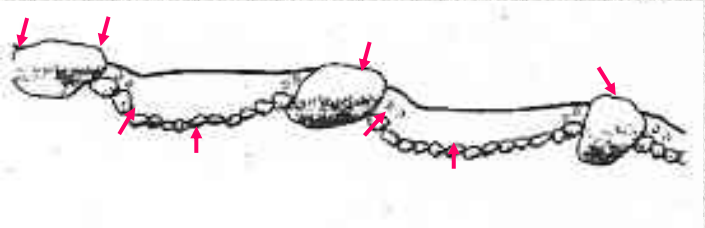
(Rosgen A, B, G)



Typical Measuring Points of a Longitudinal Profile for a Step-Pool Channel **(Rosgen A, B, G)**

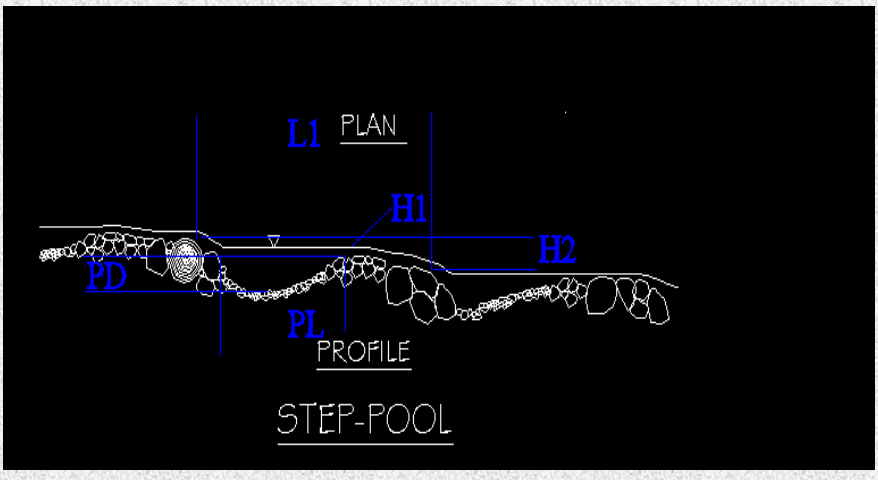


Plan View

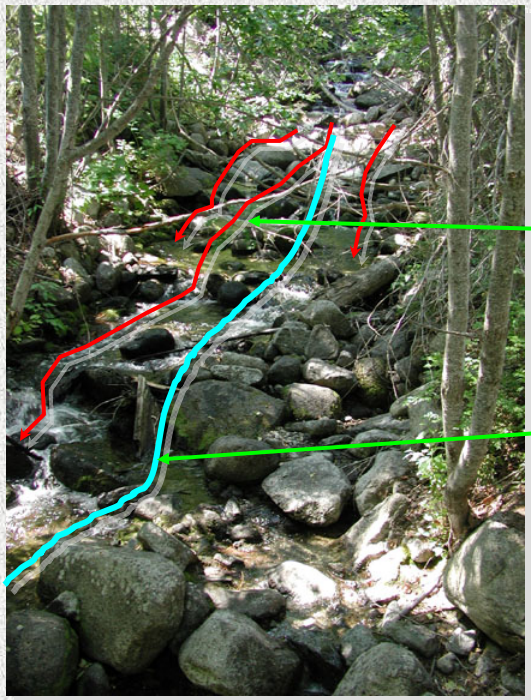


Profile View

Step Pool Measurements



L1 = length step to step crest, H1= height from crest to pool control, H2 = height from crest to crest, PD = residual pool depth, PL = pool length. Note that some configurations are step-step

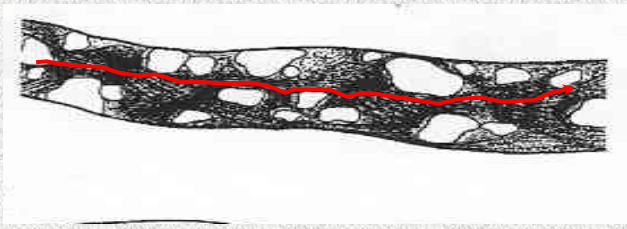


Longitudinal Profile: Cascade Channel
(Rosgen Aa)

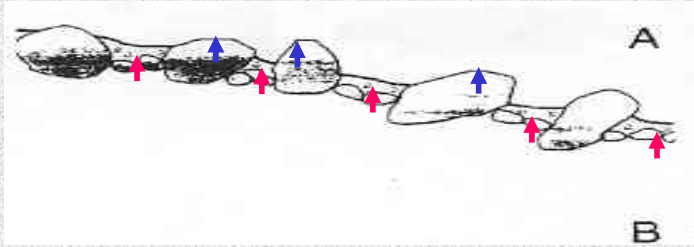
Water Paths (red)

Survey Centerline profile (Cyan)

Typical Measuring Points of a Longitudinal Profile for a Cascade Channel **(Rosgen Aa)**



Plan View



Profile View

What should be the length of the longitudinal profile survey?

- **Extend well upstream and downstream from the influence of the undersized culvert.**
- **Of sufficient length to identify repeating sequences of channel units. Typically a length of 20-30 times the bankfull width is adequate.**
- **When two or more stable, bedrock or boulder grade-control features are identified and surveyed. Make sure you have enough channel segments to determine spacing and dimensions of the grade controls!**

Grade Control Bedforms Control Points in Order of Stability

- **Bedrock falls, knickpoints, and ledges**
- **Boulder steps**
- **Log forced steps**
- **Cobble steps**
- **Beaver dams**
- **Pool tail crests and gravel bars**

Think about the life span of the feature compared to the service life of the structure when determining stability

Physical Factors Influencing Bedform and Large Woody Debris Stability

- **Size, strength, and durability of rocks.**
- **Type, length, diameter, and condition of wood.**
- **Orientation of particles and wood pieces.**
- **Relationship to other bedform structures.**

Bedrock control

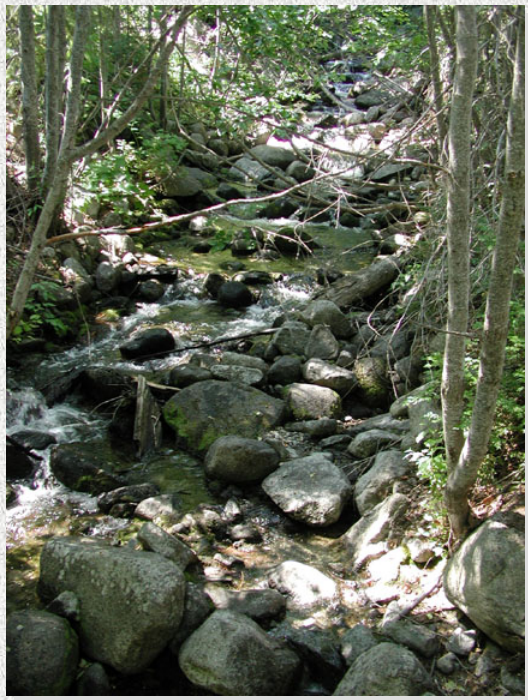
High Stability

MIXED CONTROL

High to Moderate Stability

Boulder/cobble steps

High to Moderate Stability

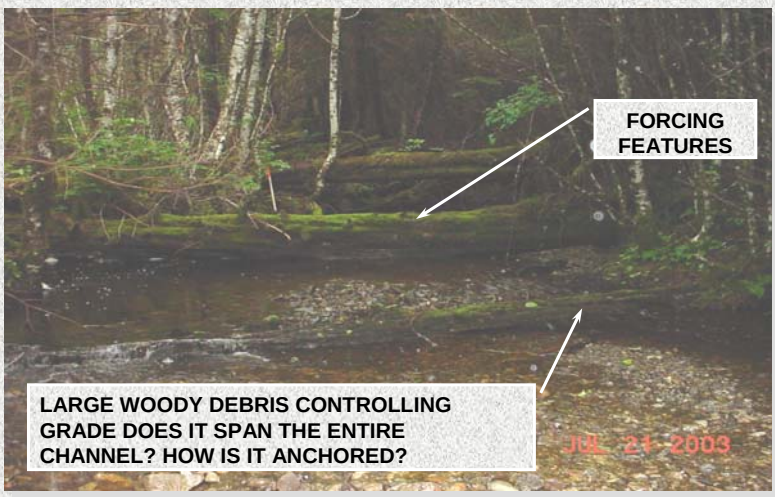


Isolated boulders, boulder clusters

High to Low Stability depending on size of material and clusters.

LWD CONTROL

High to Low Stability



Pool Tail Crests or Head of Riffles

High to Low Stability (depends on size and arrangement of particles, pool/riffle hydraulics)

Riprap Riffle

Beaver Dams

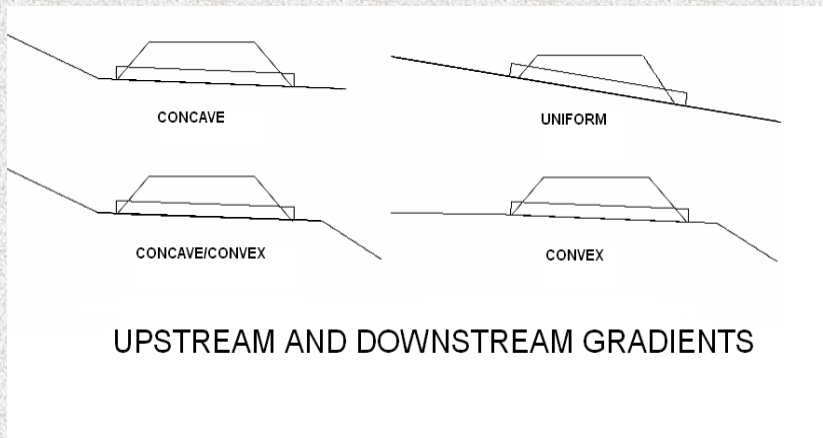
Moderate to Low Stability

Beaver Dams can be persistent but design should consider loss of water surface control

How long will this grade control last?

Decaying Log and bedrock step pool

Interpreting Longitudinal Profiles at Crossings

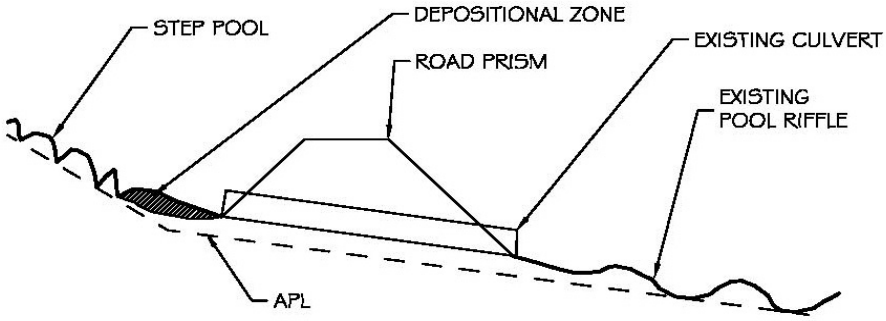


Gubernick, Furniss, and Clarkin, *2003*

Interpreting Longitudinal Profiles at Crossings:

Channel Slope Transitions and Effects on Geomorphic Processes

Concave Example

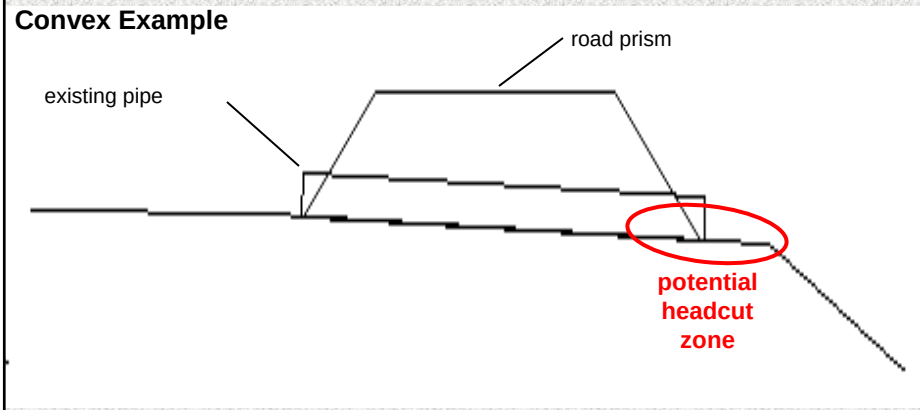


Gubernick, Clarkin and Furniss, *2003*

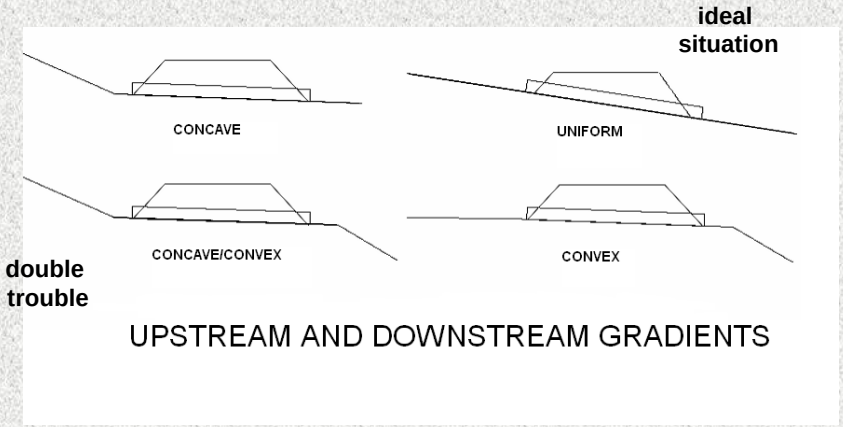
Interpreting Longitudinal Profiles at Crossings:

Channel Slope Transitions and Effects on Geomorphic Processes

Convex Example



Interpreting Longitudinal Profiles at Crossings

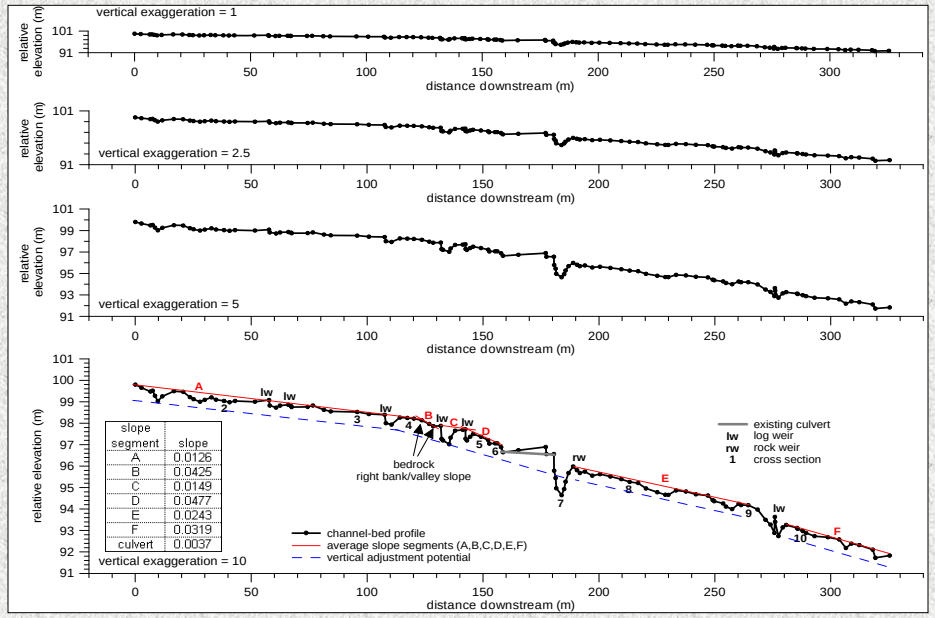


Gubernick, Furniss, and Clarkin, *2003*

Newbury Creek, Olympic National Forest

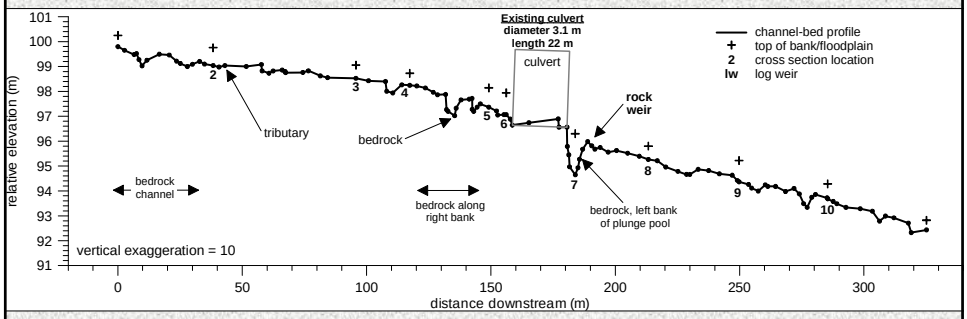
Longitudinal Profile Differences in Vertical Exaggeration

Newbury Creek, WA, Olympic National Forest



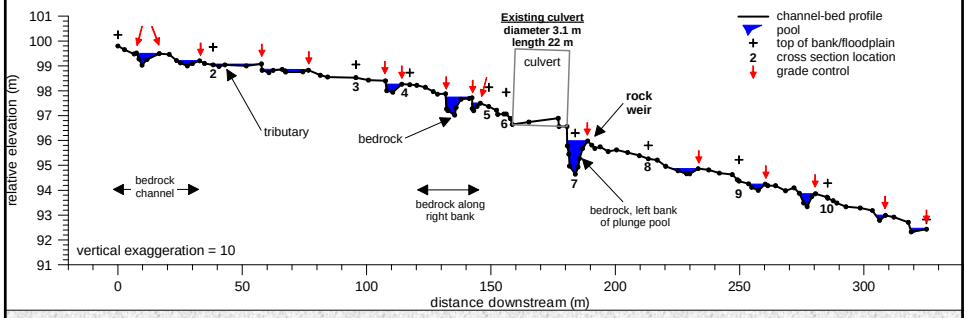
Newbury Creek Longitudinal Profile

Example Assessment



Newbury Creek, Longitudinal Profile Assessment (Steps 1)

1) Identify pools and grade controls

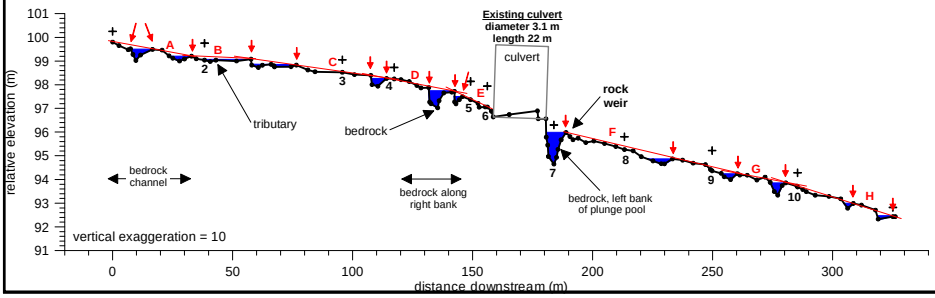


Newbury Creek, Longitudinal Profile Assessment (Step 2 & 3)

2) Delineate slope segments
3) Calculate the length, elevation change, and gradient for each slope segment

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

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

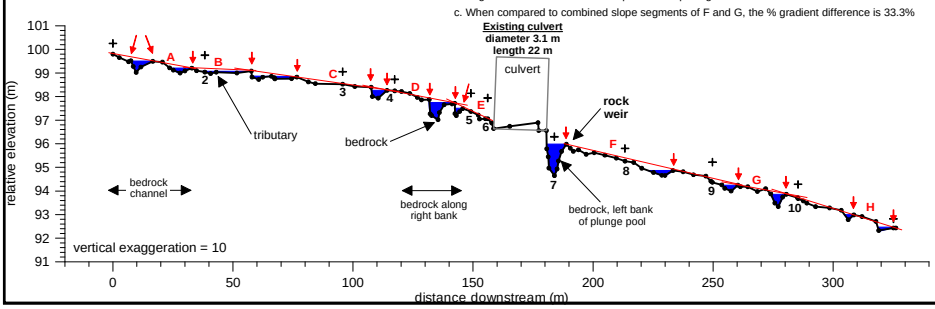


Newbury Creek, Longitudinal Profile Assessment (Step 4)

4) **Determine the maximum scour depth (residual pool depth) for each slope segment.**

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 [b,c]	0.21

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



Newbury Creek, Longitudinal Profile Assessment (Steps 5 & 6)

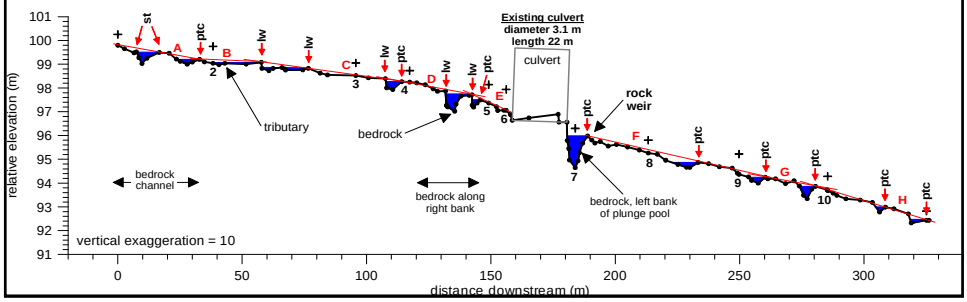
5) Determine the types of grade controls along the longitudinal profile.

6) Determine the number of and distance between grade controls for each slope segment.

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

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[a,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%



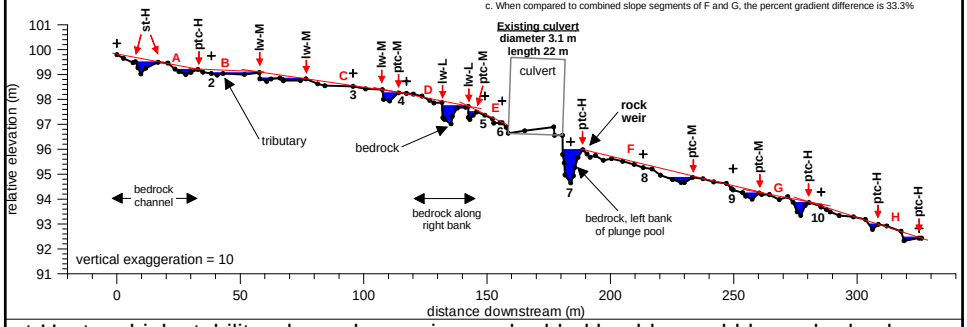
Newbury Creek, Longitudinal Profile Assessment (Step 7)

7) Assess the relative stability of each grade control.

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)

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[a,c]	0.21	3	28.1, 18.0

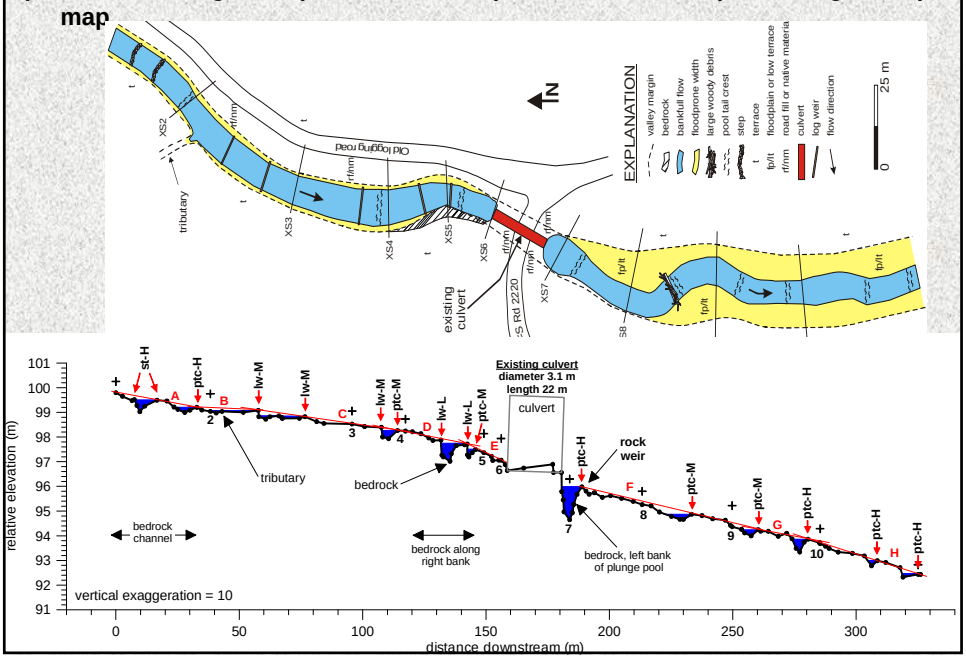
a. Percent gradient difference when compared to slope segment F.
b. Percent gradient difference when compared to slope segment G.
c. When compared to combined slope segments of F and G, the percent gradient difference is 33.3%



st-H: step, high stability, channel spanning, embedded boulders-cobbles or bedrock
ptc-H: pool tail crest, high stability, channel spanning, embedded boulders-cobbles
ptc-M: pool tail crest, moderate stability, channel spanning, embedded cobbles-gravels
lw-M: log weir, moderate stability, channel spanning, embedded in banks
lw-L: log weir, low stability, channel spanning, minimal bank embedment

Newbury Creek, Longitudinal Profile Assessment (Step 8)

8) What are the geomorphic controls on pool location? Compare with geomorphic map



Newbury Creek, Longitudinal Profile Assessment (Steps 9 & 10)

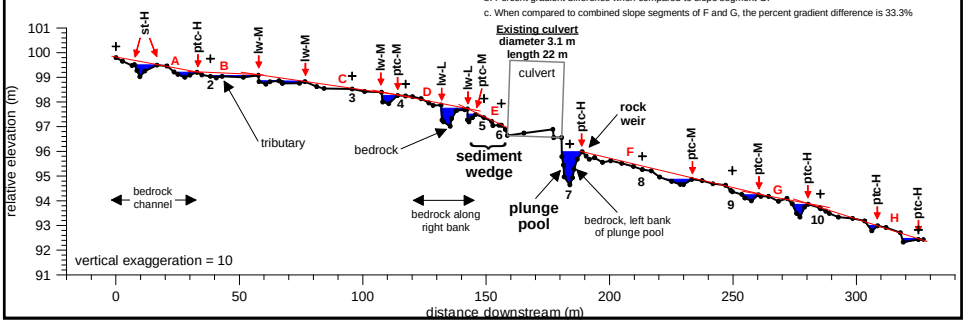
9) Identify and delineate extent of sediment aggradation (thickness and length) upstream from culvert inlet

10) Identify and determine maximum scour depth of culvert plunge pool

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)

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%



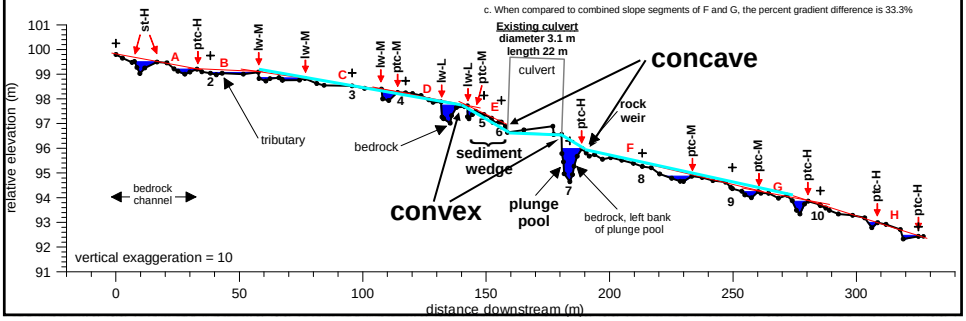
Newbury Creek, Longitudinal Profile Assessment (Step 11)

11) Identify the shape of the longitudinal profile (concave with inflection point downstream of crossing).

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)

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

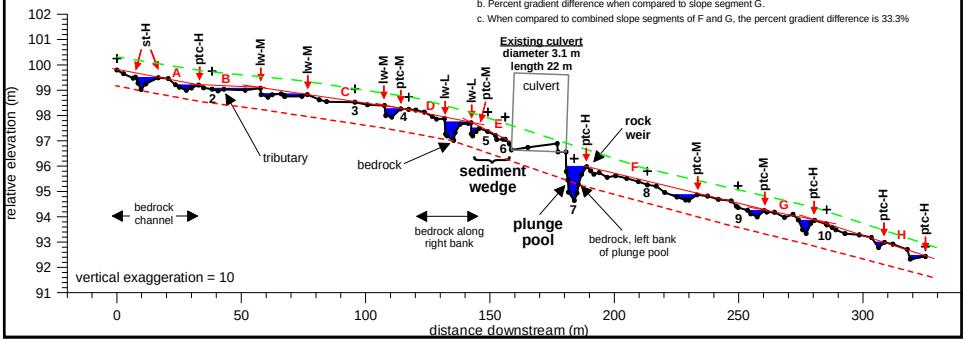
a. Percent gradient difference when compared to slope segment F.
b. Percent gradient difference when compared to slope segment G.
c. When compared to combined slope segments of F and G, the percent gradient difference is 33.3%



Newbury Creek, Longitudinal Profile Assessment (Steps 12 & 13)

12) Delineate the upper vertical adjustment potential line.
13) Delineate the lower vertical adjustment potential (scour) line

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)
upper vertical adjustment potential line
lower vertical adjustment potential line

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%