5B. Stream Simulation Design

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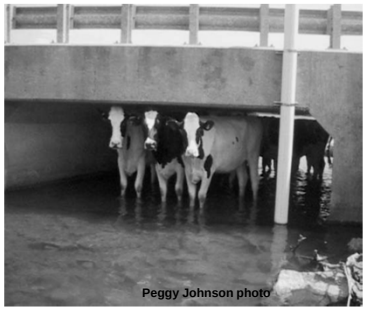
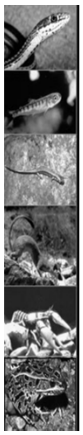




Phase 1
Initial Assessment

Phase 2
Site Assessment

Phase 3
Stream Simulation Design

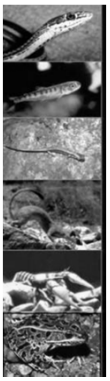
Phase 4
Final Design & Contract Preparation

Phase 5
Construction

Phase 6
Maintenance & Monitoring

Stream simulation project phases

Stream Simulation Design Process



Assessment
Stream simulation feasibility

Project alignment and profile

- **Scour or incision, scale of the problem**
- **Geomorphic connectivity**
- **Channel restoration needed**
- **Headcut issues**

Verify reference reach

Bed shape and material

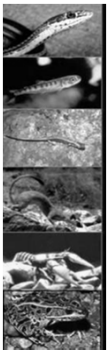
Structure width, elevation, details

Mobility / stability

Finalize design profile control

This applies to any in-stream design!

Outline



Horizontal Alignment (plan view)
- Integral with long profile

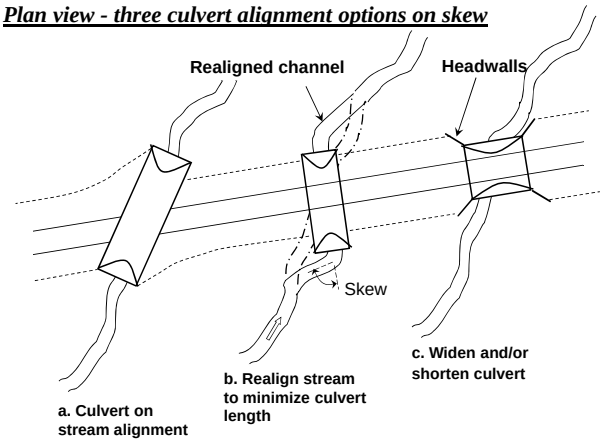
Inlet and Outlet Transitions

Vertical Alignment (longitudinal profile)
- Step-wise design process
- Profile control options and channel restoration
- Grade control suitability

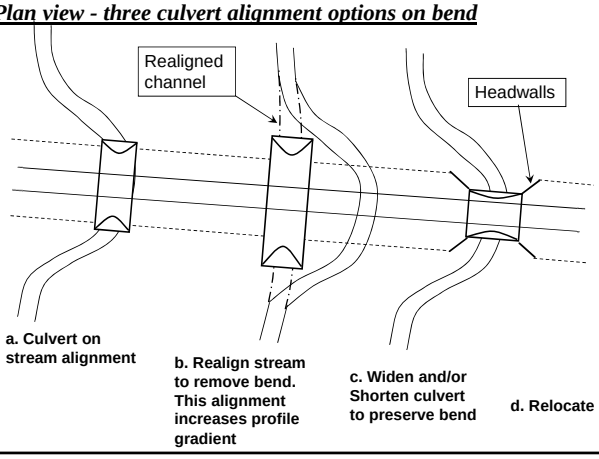
Alignment

- **Concurrent with profile design. *Any changes in horizontal alignment changes the stationing and elevations of the vertical alignment profile***
- **Important factor for debris blockage, sediment transport, and failure**
- **Consider existing and future stream channel.**

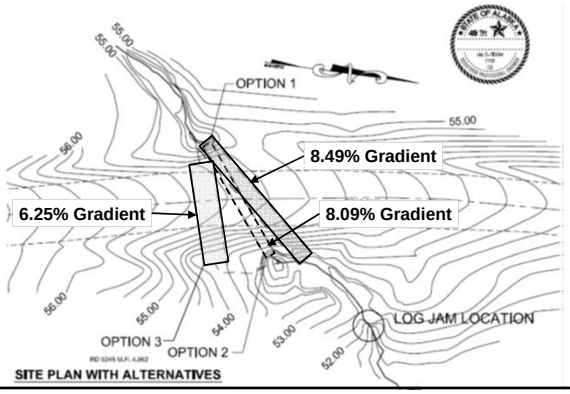
Plan view - three culvert alignment options on skew



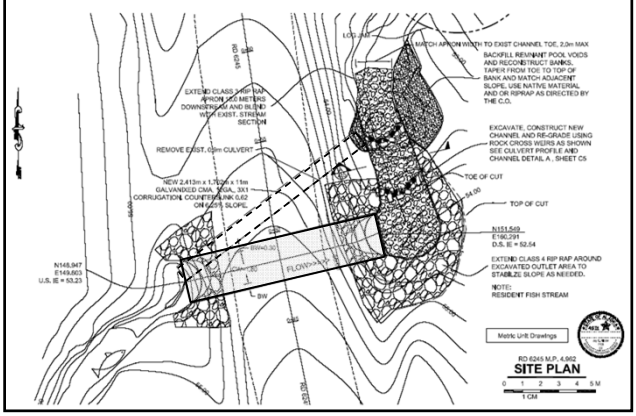
Plan view - three culvert alignment options on bend



Alignment Decisions Affect Project Profile Gradient and Structure Performance



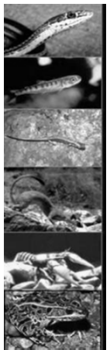
Horizontal Alignment Plan View Example



Structure Alignment and Project Profile

- **When alignment changes, profiles change especially in high gradient channels. In low gradient channels these changes are usually minor.**
- **Balance both if possible - good hydraulic alignment with the channel and a sustainable profile grade.**
- **Not all sites can be optimized, the design decision then becomes risk based. Which will be the most controlling factor, poor alignment or steeper profiles?**

Outline

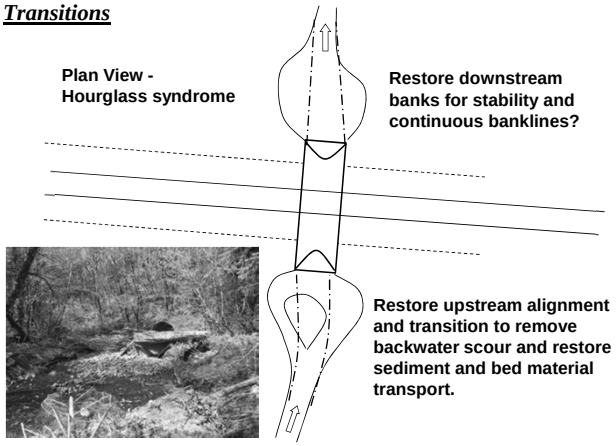


Horizontal Alignment (plan view)
- Integral with long profile

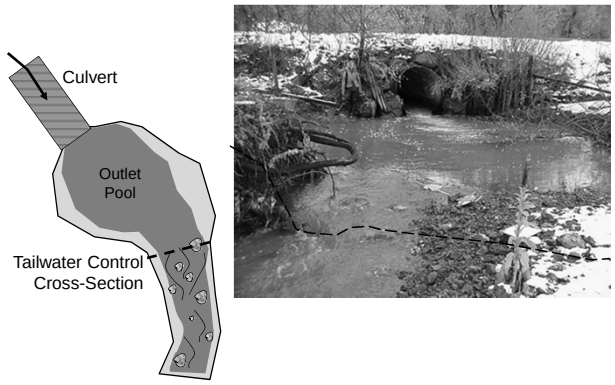
→Inlet and Outlet Transitions

Vertical Alignment (longitudinal profile)
- Step-wise design process
- Profile control options and channel restoration
- Grade control suitability

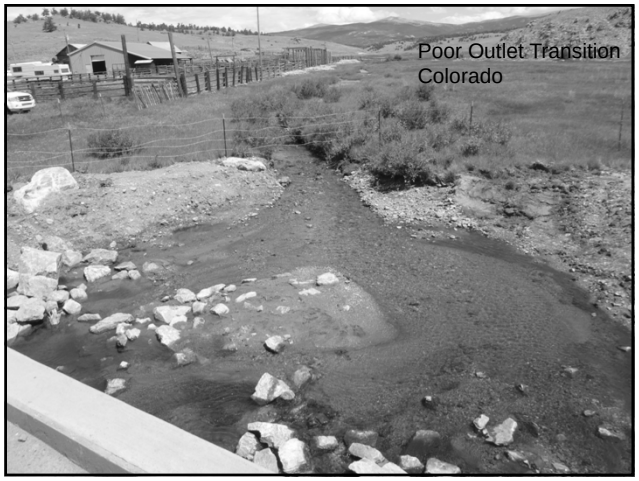
Transitions

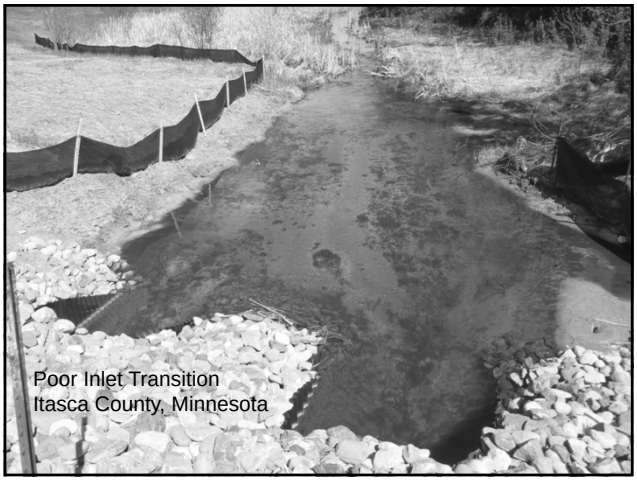


Transitions

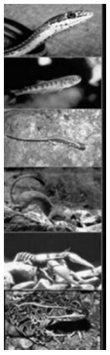


Poor Outlet Transition
Itasca County, Minnesota


Poor Outlet Transition
Colorado


Poor Inlet Transition
Itasca County, Minnesota

Outline



Horizontal Alignment (plan view)
- Integral with long profile

Inlet and Outlet Transitions

Vertical Alignment (longitudinal profile)
- Step-wise design process
- Profile control options and channel restoration
- Grade control suitability

Design Project Profile - General

- **Project profile is what is actually constructed**
- **Start with initial vertical adjustment potential from site assessment to determine limiting design project profile options.**
- **Consider profile and alignment issues concurrently. Can stream to structure alignment be improved?**
- **Changes in alignment and location of the structure have direct effect on the configuration of a suitable design project profile.**
- **Design project profiles should tie into stable grade control points at upstream and downstream ends of the profile.**
- **A forced profile might be necessary in some cases (limited ROW or utility conflicts).**
- **When a forced profile is used it is sometimes necessary to construct a stable grade control point in the re-grade section.**

Stream Simulation Channel Design Process

1. Identify one downstream design elevation control point and two upstream design elevation control points to connect the upstream and downstream channel through the road-stream crossing.

2. A) Delineate design channel profile(s).
   B) Calculate the design gradients.
   C) Calculate the percent difference in gradients between the design profiles and the channel slope segments.

3. A) Select your preliminary design gradient profile.
   B) Select a preliminary reference reach.

4. Using the selected reference reach and conditions at the crossing, adjust (if necessary) the upper and lower vertical adjustment potential lines through the crossing.

Stream Simulation Channel Design Process

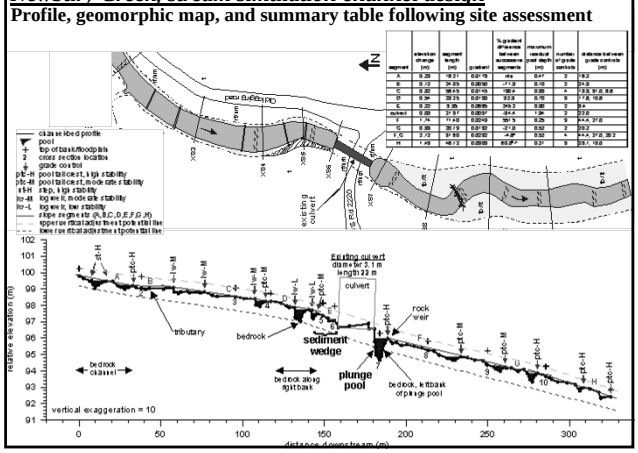
5. A) Using the reference reach identify the type of bedforms to construct in the design channel.
   B) Determine the number of existing, stable grade controls in the design profile.
   C) Identify the location of any controls on pool due to structure to stream geometry.
   D) Delineate the number and spacing of bedforms to be constructed in the design channel.
   E) Explore another design profile (return to step 3)?

6. A) Delineate the depth of sediment to fill plunge pool.
   B) Delineate base of structure or footing (embedment depth).

7. Delineate the long-term channel-bed surface through the crossing following channel adjustments (headcutting, erosion, etc.).

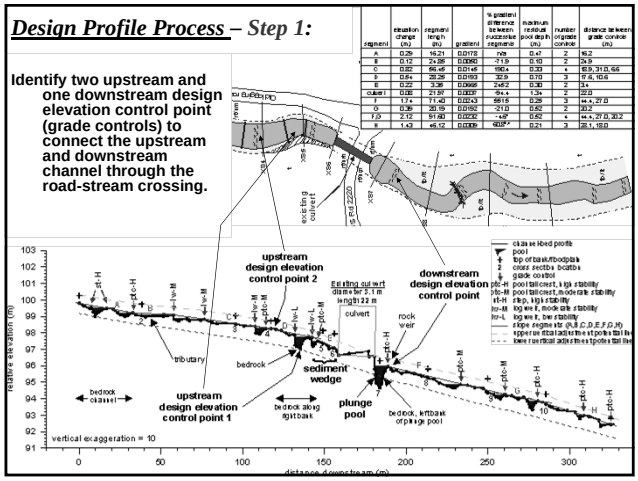
Newbury Creek, stream simulation channel design

Profile, geomorphic map, and summary table following site assessment



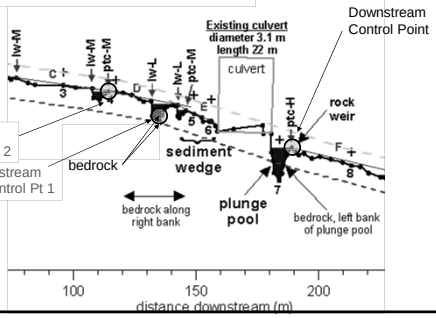
Design Profile Process *– Step 1:*

Identify two upstream and one downstream design elevation control point (grade controls) to connect the upstream and downstream channel through the road-stream crossing.



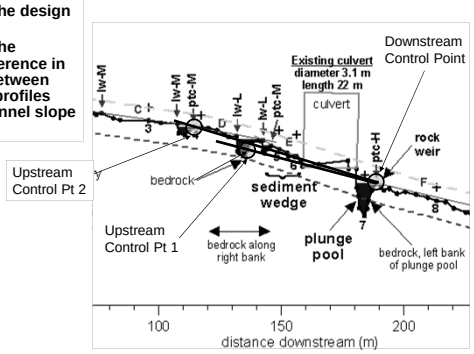
***Design Profile Process** – Step 1 (zoom in):*

Identify one downstream and two upstream and design elevation control point (grade controls) to connect the upstream and downstream channel through the road-stream crossing.



***Design Profile Process** – Step 2:*

A) Delineate design channel profile(s).
B) Calculate the design gradients
C) Calculate the percent difference in gradients between the design profiles and the channel slope segments.



***Design Profile Process** – Step 2 (cont):*

A) Delineate design channel profile(s)

B) Calculate the design gradients

C) Calculate the percent difference in gradients between the design profiles and the channel slope segments.

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)	design 1 (S=0.0257), percent slope difference	design 2 (S=0.0305), percent slope difference
A	0.29	16.21	0.0178	n/a	0.47	3	10.1, 16.2	-44.88	-71.62
B	0.12	24.85	0.0050	-71.9	0.10	2	24.9	-415.98	-511.22
C	0.82	56.45	0.0145	190.4	0.33	4	18.9, 31.0, 6.6	-77.68	-110.48
D	0.54	28.25	0.0193	32.9	0.70	3	17.6, 10.6	-33.72	-58.40
E	0.22	3.35	0.0665	245.2	0.30	2	3.4	61.26	54.11
culvert	0.08	21.97	0.0037	-94.4	1.34	2	22.0	-589.96	-717.31
F	1.74	71.40	0.0243	551.5	0.25	3	44.4, 27.0	-5.91	-25.45
G	0.39	20.19	0.0192	-21.0	0.52	2	20.2	-34.00	-58.73
F,G	2.12	91.60	0.0232	-4.6[a]	0.52	4	44.4, 27.0, 20.2	-11.04	-31.53
H	1.43	46.12	0.0309	60.8[b,c]	0.21	3	28.1, 18.0	16.67	1.29

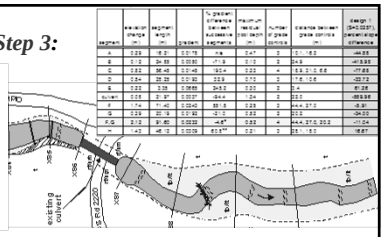
a. Percent gradient difference when compared to slope segment F.
b. Percent gradient difference when compared to slope segment G.
c. When compared to combined slope segments of F and G, the percent gradient difference is 33.3%

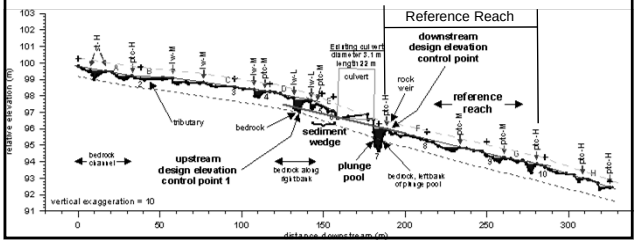
***Design Profile Process** – Step 3:*

A) Select preliminary design profile

B) Select a preliminary reference reach

NOTE: Design 1 selected





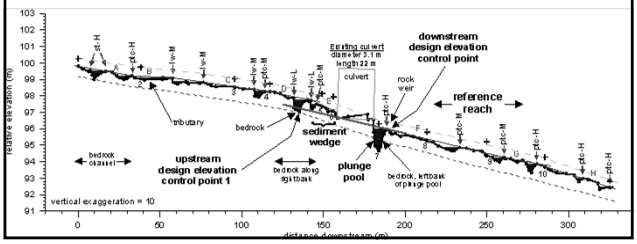
Selection of Reference Reach

- **Serves as template for Project reach**
- **Primarily selected by project profile gradient**
- **Consider length and confinement of project reach**
- **Nearby, adjacent, upstream?**
  Provides "input" to stream simulation so must be "connected" to crossing reach. If downstream ref. reach is used the upstream must have required sediment size available.
- **Out of the influence of existing crossing**
- **Try to avoid very complex channels**

Design Profile Process – Step 4:

Adjust the VAP lines - Using the selected reference reach and conditions at the crossing, adjust (if necessary) the upper and lower vertical adjustment potential lines through the crossing.

NOTE: Design 1 selected, not necessary to adjust VAP lines due to proximity of bedrock (channel won't go lower than the bedrock surface)



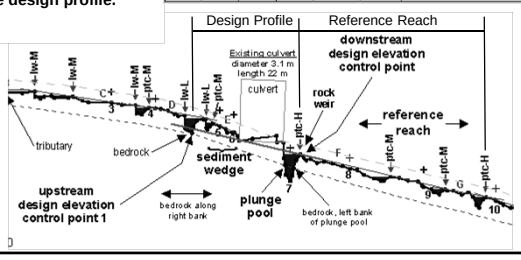
Profile Design Process – Step 5:

Locate key features -

A) Using the reference reach identify the type of bedforms to construct in the design channel.

B) Determine the number of existing, stable grade controls in the design profile.

segment	segment elevation change (m)	total segment length (m)	gradient	number of grade controls	distance between grade controls (m)	comments
F,G	2.12	91.60	0.0232	1	0.0	pto-riffle, boulder-cobble, high stability
				2	44.4	pto-riffle, cobble-gravel, moderate stability
				3	27.0	pto-riffle, cobble-gravel, moderate stability
				4	20.2	pto-riffle, boulder-cobble, high stability
Design 1	1.36	52.90	0.0257	1	0.0	pool exit slope, bedrock, high stability
				2	6.4	log weir, low stability
				3	3.4	pto-riffle, cobble-gravel, moderate stability
				4	43.1	pto-riffle, boulder-cobble, high stability



Profile Design Process Step 5 (cont):

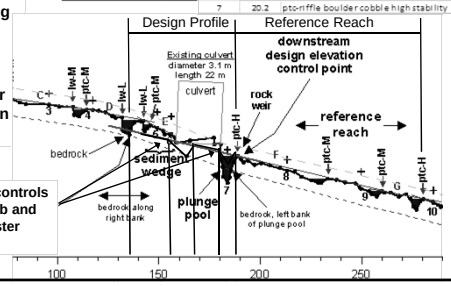
Locate key features -

C) Identify the location of any controls on pools due to structure to stream geometry or other pool forming mechanisms

D) Delineate the number and spacing of bedforms to be constructed in the design channel.

E) To explore another design profile return to Step 3.

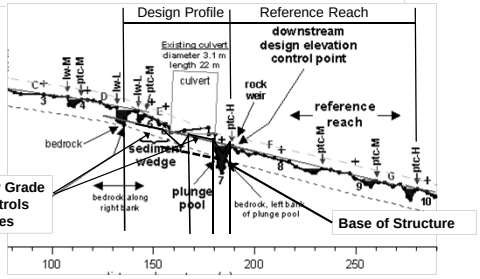
segment	segment elevation change (m)	total segment length (m)	gradient	number of grade controls	distance between grade controls (m)	comments
F,G	2.12	91.60	0.0232	1	0.0	pto-riffle, boulder-cobble, high stability
				2	44.4	pto-riffle, cobble-gravel, moderate stability
				3	27.0	pto-riffle, cobble-gravel, moderate stability
				4	20.2	pto-riffle, boulder-cobble, high stability
Design 1	1.362	52.90	0.0257	1	0.0	pool exit slope, bedrock, high stability)
				2	6.4	log weir, low stability
				3	3.4	pto-riffle, cobble-gravel, moderate stability
				4	8.2	Rib & boulder cluster
				5	21	pto-riffle boulder cobble high stability
				6	12.7	Rib & boulder cluster
				7	20.2	pto-riffle boulder cobble high stability



Profile Design Process* – *Step 6:

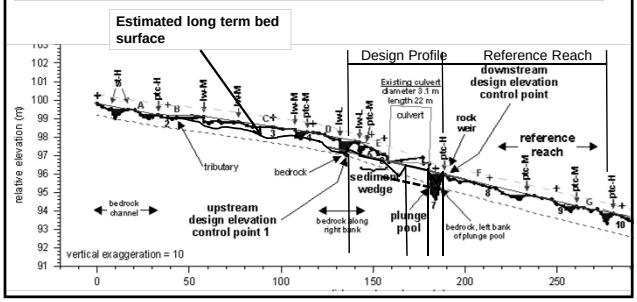
A) Determine the depth of sediment to fill plunge pool.

B) Delineate the base of structure or footing (embedment depth).

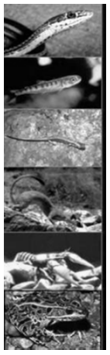


Profile Design Process* – *Step 7:

Delineate the long-term channel-bed surface through the crossing following channel adjustments (headcutting, erosion, etc.).



Outline



Horizontal Alignment (plan view)
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Inlet and Outlet Transitions

Vertical Alignment (longitudinal profile)
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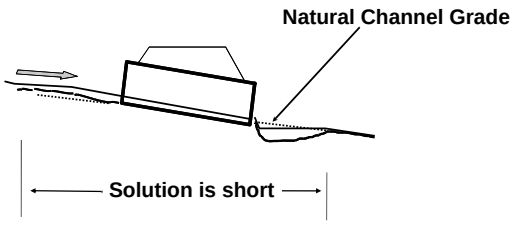
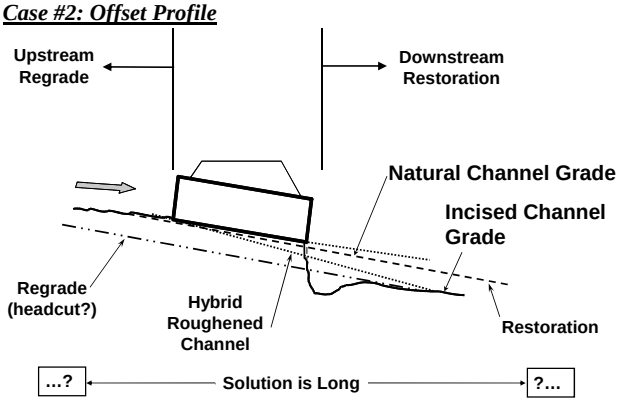
Case #1: Continuous Profile

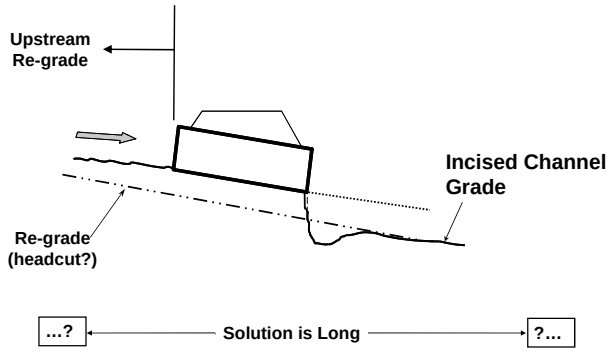


Can occur at any grade but more common in high gradient and well armored channels

Case #2: Offset Profile



Case #2a: Re-grade Upstream



Upstream Channel Re-grade Considerations

- **Extent of regrade expected**
- **Adjacent channel**
  - **Upstream banks – stability, riparian, impounded wetlands?**
  - **Is there value of culvert as nick point? Habitat, infrastructure**
- **Bed material**
  - **Backwater sediment wedge?**
  - **Potential bedrock exposure?**
  - **Protect existing armored bed**
- **Culvert and channel capacity with sediment slug**
- **Potential passage barriers created upstream**
- **Construction access to build regrade**
- **Opportunities for downstream habitat restoration**

Headcut Tolerable?

Headcut Tolerable?

Upstream impounded wetland

Culvert outlet and downstream channel

Headcut Expectations

Wynoochee trib - 1983

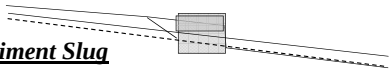
Culvert replaced

Headcut Expectations

Wynoochee trib – 2002

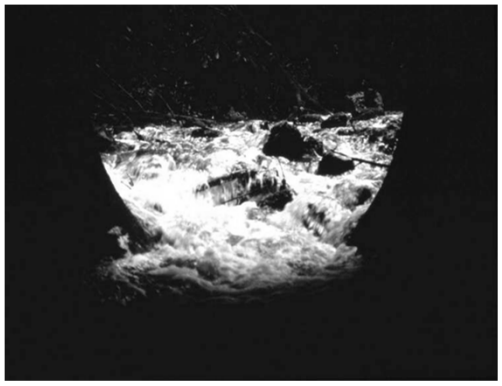
Channel regraded to bedrock

Headcut issues – Sediment Slug

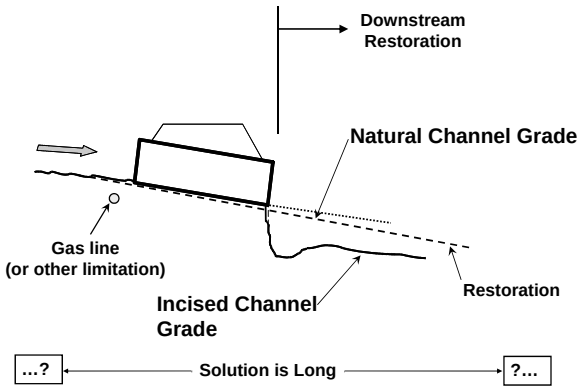


Downstream channel overwhelmed by sediment slug from headcut

Re-grade in High Gradient Channel



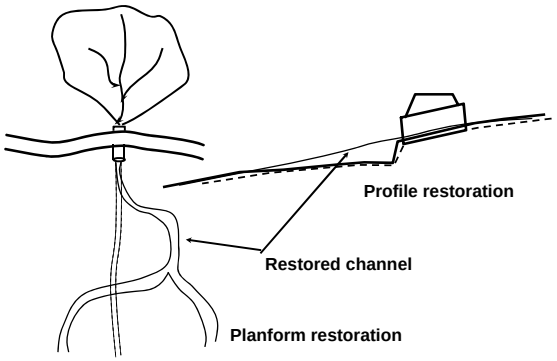
Case #2b: Downstream Restoration



Downstream Channel Restoration

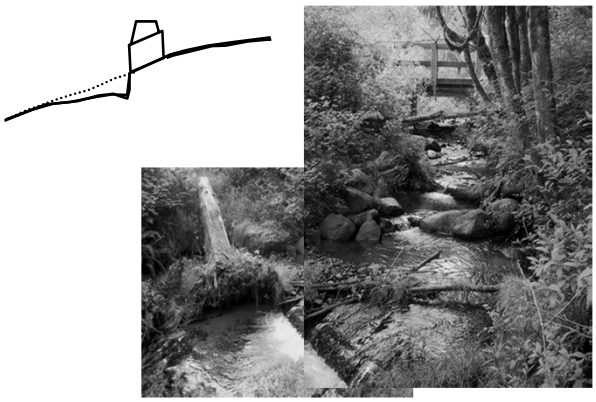
- **Objectives:**
  - **Steepen grade**
  - **Optimize passage**
  - **Restore habitat**
- **Design natural channel as full stream simulation project**
- **Higher cost with longer project length**
- **Max slope is function of channel width and passage objectives**

Downstream Channel Restoration with Realignment

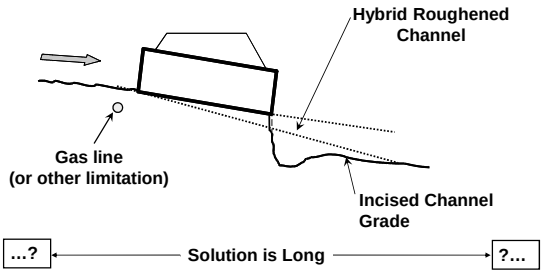


Downstream Channel Restoration - Outlet Creek

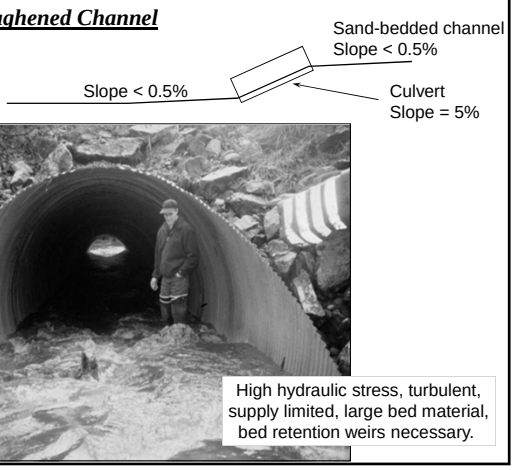
Downstream Channel Restoration – O'Grady Creek



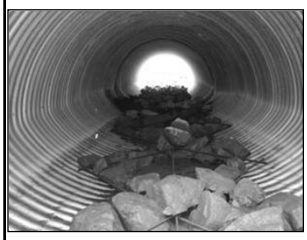
Case #2c: Hybrid Roughened Channel



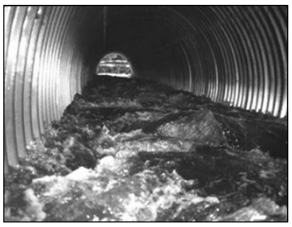
Hybrid Roughened Channel



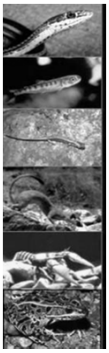
Hybrid Roughened Channel



- **Roughen channel with rock**
- **Use hydraulic culvert design**
- **Rigid structure**



Outline



Horizontal Alignment (plan view)
- Integral with long profile

Inlet and Outlet Transitions

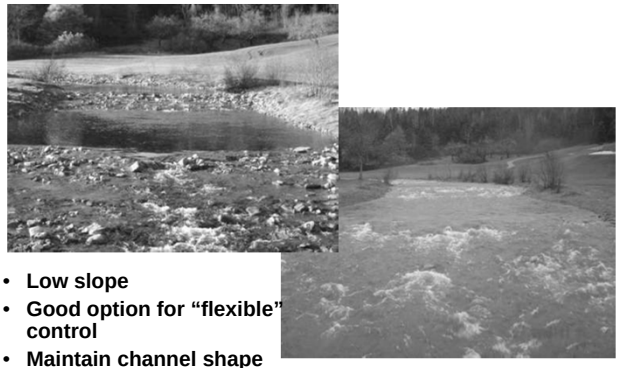
Vertical Alignment (longitudinal profile)
- Step-wise design process
- Profile control options and channel restoration
- Grade control suitability

Grade Control Suitability

Channel Type	Slope	Grade Control	Comments
Pool - Riffle	0 – 3 %	Riffle	May include wood
Transition (steep riffle) (plane bed)	2 – 4 %	Coarse Riffle w/ Ribs, Particle clusters	Ribs = micro-steps w/o pools, may include wood
Step Pool	3 – 10 %	Rock Steps w/ Pool	May include wood
Cascade	10 – 30 %	Steep Rock Steps	May include wood

Riffle as a Template

'Newberry' Riffle



- **Low slope**
- **Good option for "flexible" control**
- **Maintain channel shape**
- **Designs available**

Design: Robert Newberry
Jane Watts, Fundy NP

Riffle/Chute

Spring Prairie Cr

Cobble Riffle

Steep Riffle w/ Ribs

Riffle w/ Ribs (low flow)

Steep Riffle w/ Ribs (higher flow)

Steep Riffles – Particle Clusters

Rock/Boulder Steps

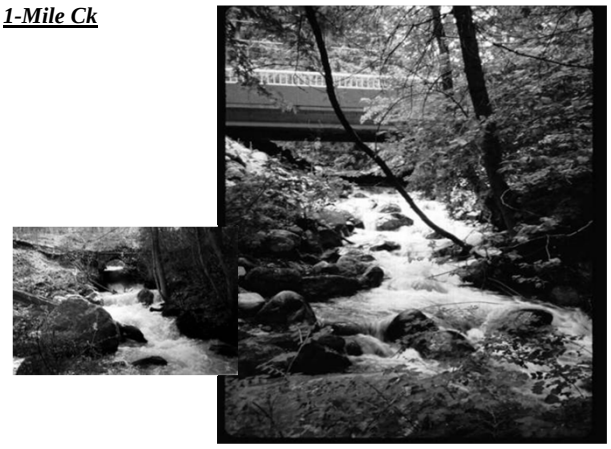
Rock/Boulder Steps

Downstream channel restoration Barnard - WDFW

Rock/Boulder Steps

channel restoration Sylte – Lolo NF

1-Mile Ck



Log Controls

Straight/Single Placements:

- **Objective: Steepen grade, optimize select passage, minimize cost and length, secure elevation control**
- **Can result in uniform channel**
- **Secure designs available**

Log Controls

V Log/Multiple Placements:

- **Objective: Steepen grade, deepen thalweg, narrow channel, provide select passage**
- **More diverse channel**
- **Can be made complex**
- **Durable**

Log Controls

Olympic NF

Let natural wood features guide material selection and placement

White River NF

Rigid Controls – NOT Stream Simulation

- **Fishways**
- **Roughened Channels**
- **Other rigid features**

Questionable Suitability

Questionable Suitability

Questionable Suitability

Questionable Suitability