



Stream Simulation Design: Providing Unimpeded Aquatic Organism Passage at Road-Stream Crossings



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Region 9 Technical Services Team

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Forest Engineer
U.S. Forest Service WO-Engineering



Introduction

What is Stream Simulation?

Examples

Why This Works



- Natural and dynamic stream channel
- Passage of all aquatic organisms
- Low maintenance, flood-resilient road

Introduction

What is Stream Simulation?

Examples

Why This Works



White River N.F.,
Colorado

Introduction

What is Stream Simulation?

Examples

Why This Works



White River N.F.,
Colorado



Introduction

What is Stream Simulation?

Examples

Why This Works



Olympic N.F.,
Washington

Introduction

What is Stream Simulation?

Examples

Why This Works



Olympic N.F.,
Washington



Introduction

What is Stream Simulation?

Examples

Why This Works



Green Mountain N.F.

Introduction

What is Stream Simulation?

Examples

Why This Works



Green Mountain N.F.



Post Irene

Introduction

What is Stream Simulation?

Examples

Why This Works



Tongass N.F., Alaska

Introduction

What is Stream Simulation?

Examples

Why This Works

Tongass N.F., Alaska



What is Stream Simulation?



Examples

Why This Works

Collaboration

Multiple Benefits

Storm Tested



What is Stream Simulation?

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What is Stream Simulation?



Examples



Why This Works

Collaboration

Multiple Benefits

Storm Tested



Green Mountain National Forest



D. McKinley

What is Stream
Simulation?

Examples

Why This Works

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Multiple Benefits

Storm Tested

Post Irene, September 2011

Green Mountain National Forest

What is Stream Simulation?

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Why This Works

Collaboration

Multiple Benefits

Storm Tested



Post Irene, September 2011

NFS System:

- 380,000 miles of road
- 200,000 miles of stream
- 25,000 aquatic passage structures
- 20,000 some level of barrier



Ecological Context:

- 470 fish
- 346 crayfish
- 124 T&E aquatic species
- Replacing 250 structures/year



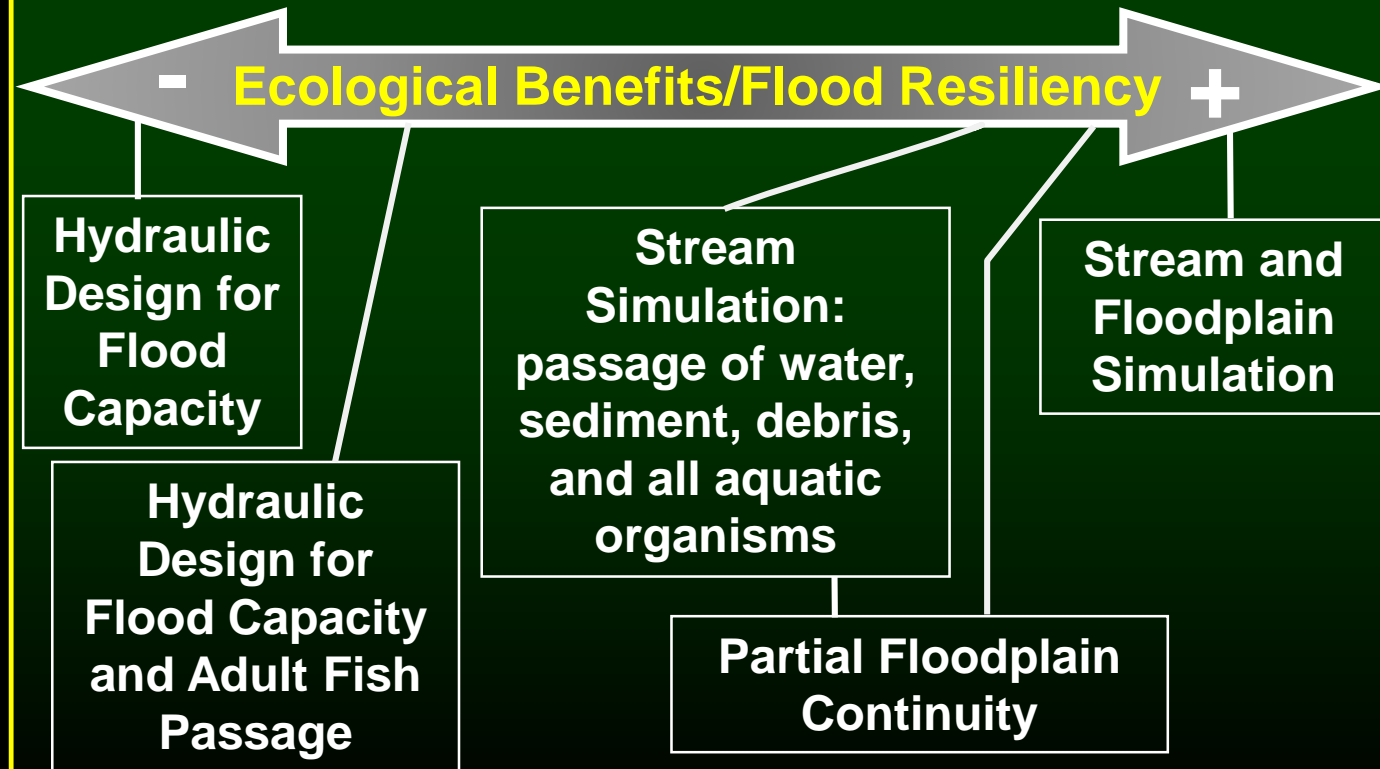
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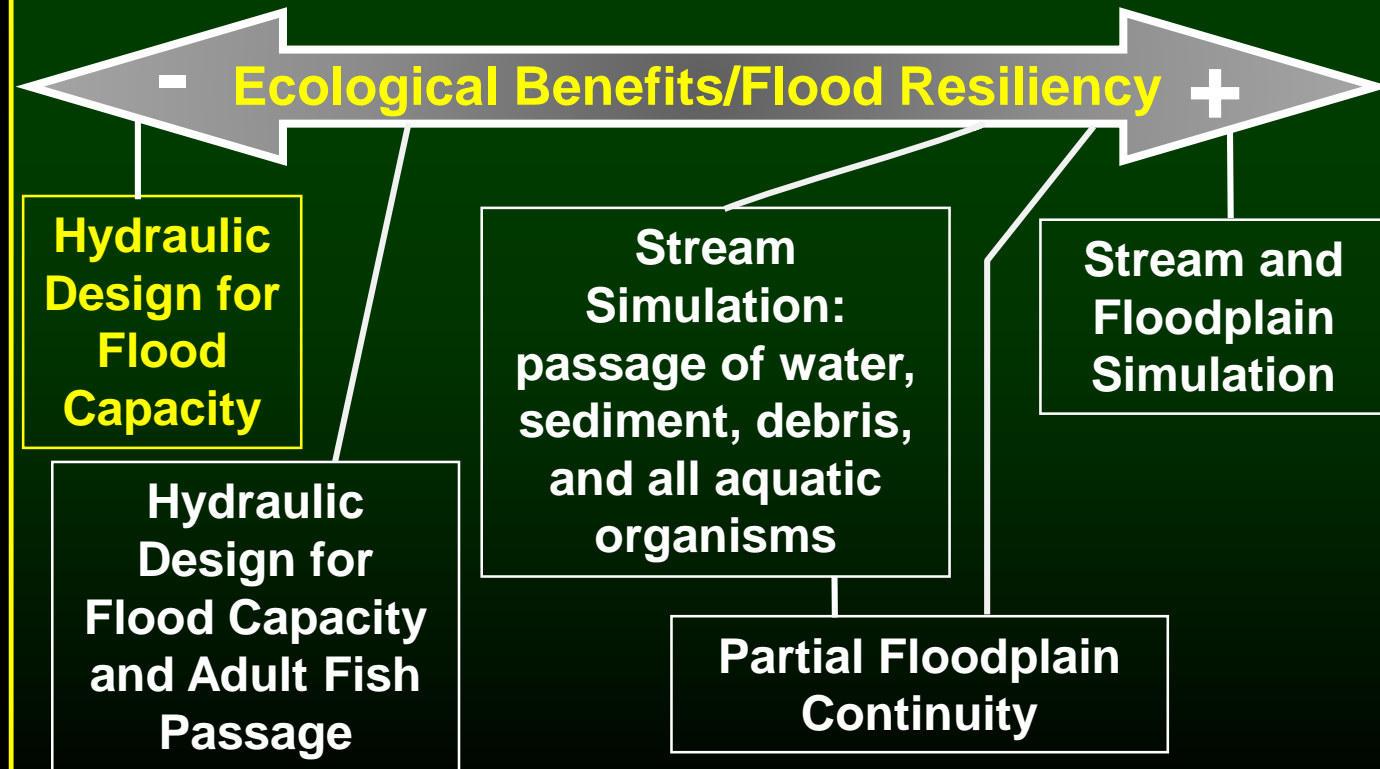
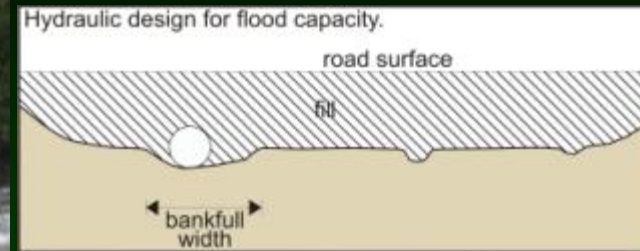


This is a Solvable Problem !

Ecological
Connectivity
+
Flood Resiliency
(Dependable
Transportation
System)



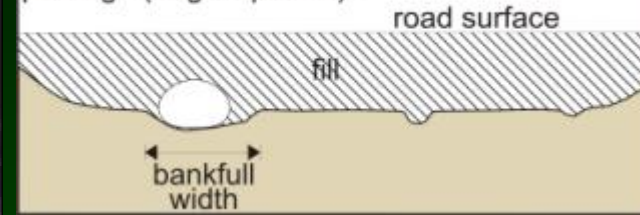
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Ecological
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B. Hydraulic design for flood capacity and fish passage (target species).



Hydraulic
Design for
Flood
Capacity

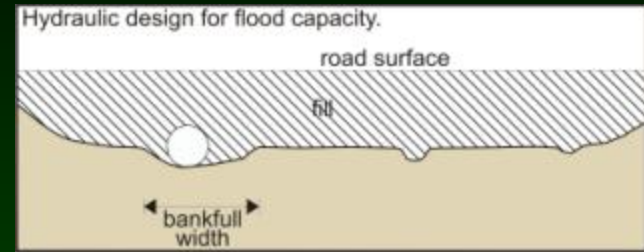
**Hydraulic
Design for
Flood Capacity
and Adult Fish
Passage**

Stream
Simulation:
passage of water,
sediment, debris,
and all aquatic
organisms

Partial Floodplain
Continuity

Stream and
Floodplain
Simulation

Ecological
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**Hydraulic
Design for
Flood
Capacity**

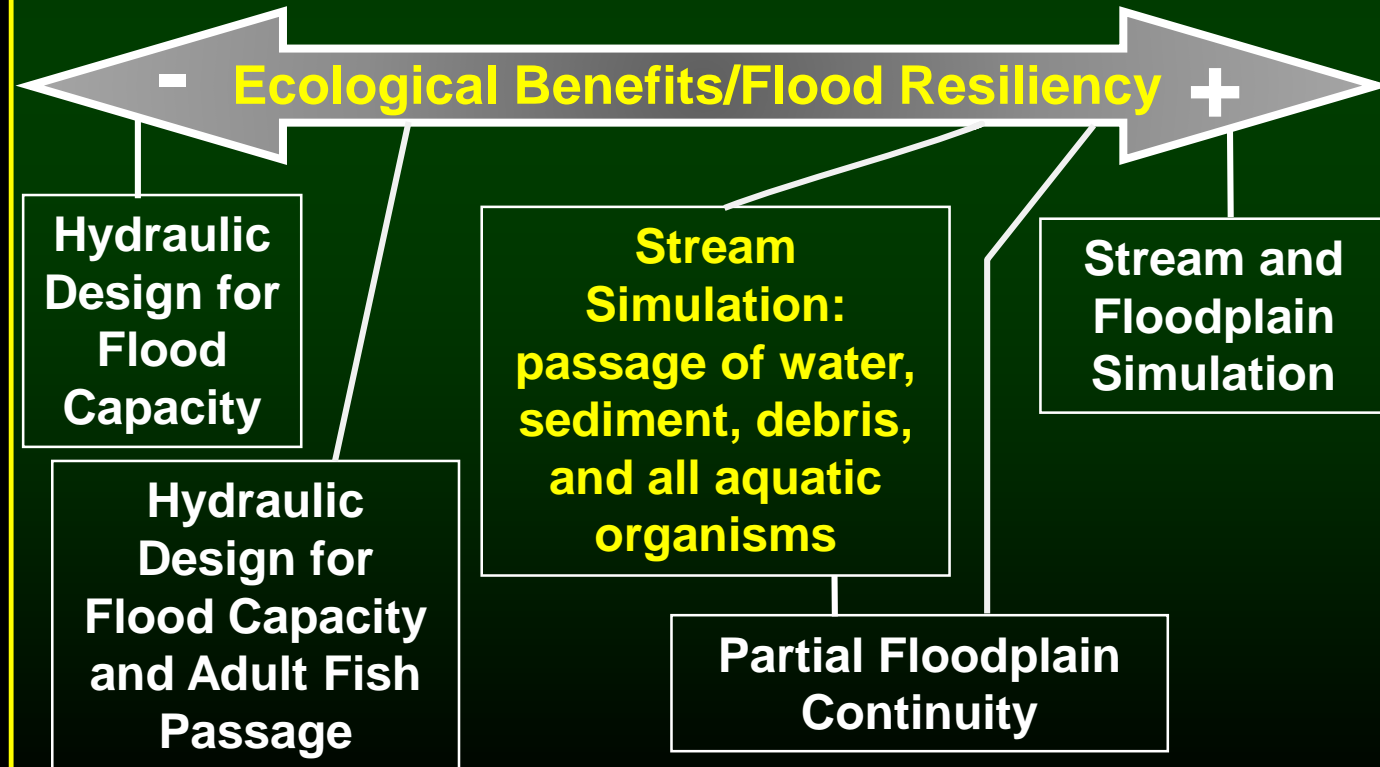
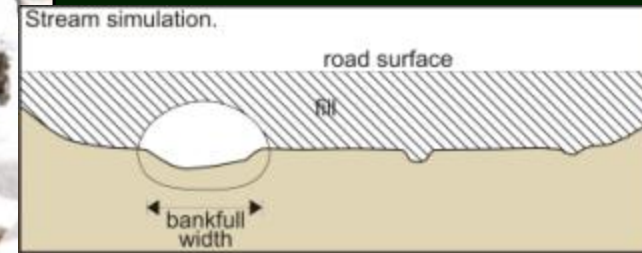
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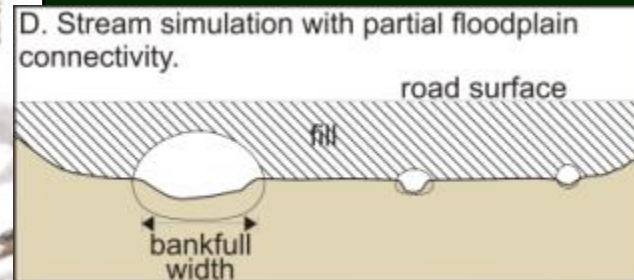
**Partial Floodplain
Continuity**

**Stream and
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Ecological
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Ecological Connectivity
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Flood Resiliency
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Hydraulic Design for Flood Capacity

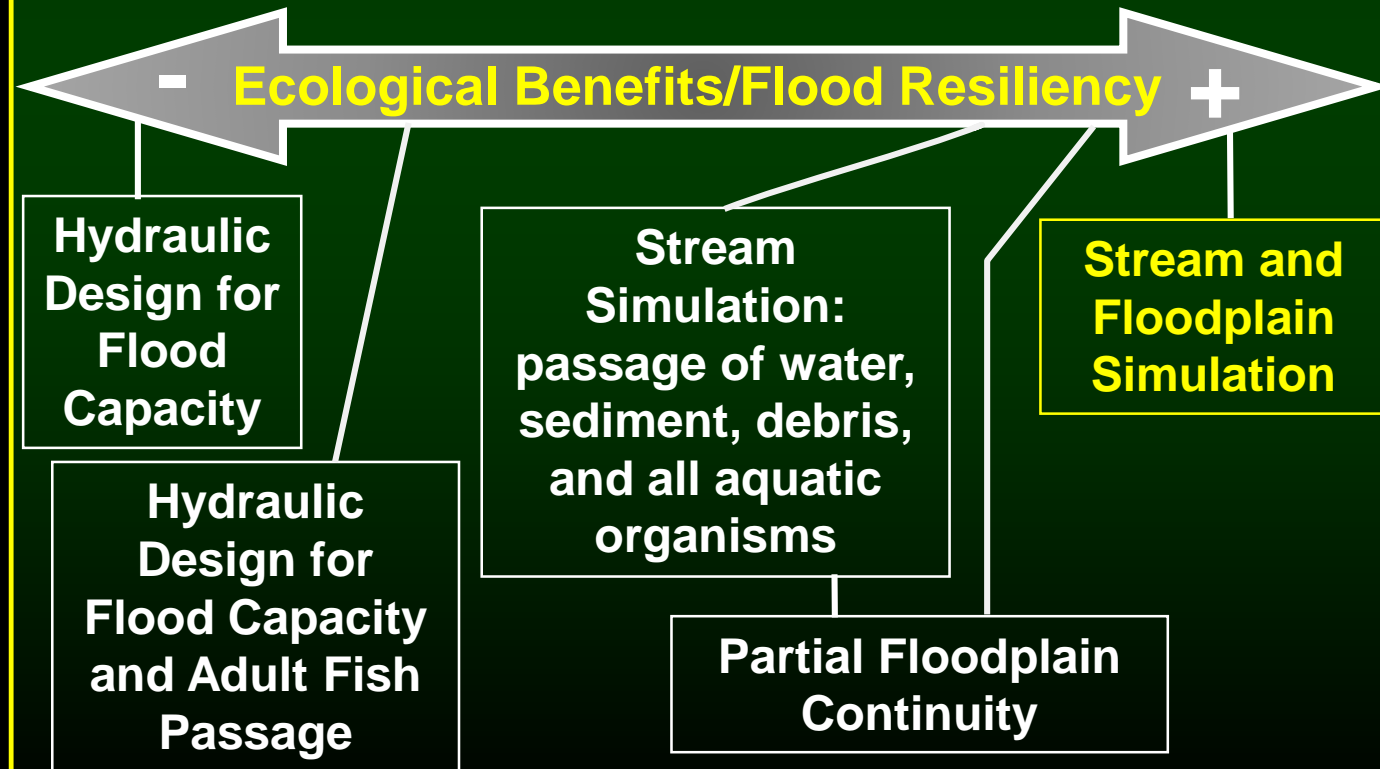
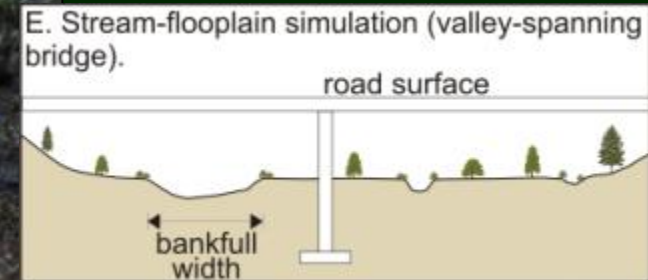
Hydraulic Design for Flood Capacity and Adult Fish Passage

Stream Simulation:
passage of water, sediment, debris, and all aquatic organisms

Partial Floodplain Continuity

Stream and Floodplain Simulation

Ecological
Connectivity
+
Flood Resiliency
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Regulatory Guidance:

National Forest Management Act (NFMA)

- **NFMA Implementing Regulations (36 CFR 219.19)**
 - “Fish and wildlife **habitat shall be managed to maintain viable populations** of existing native and desired non-native vertebrate species in the planning area.”
 - “No management practices causing ... **blockages of water courses**, or deposits of sediment shall be permitted ...”
 - “... preserve and enhance the **diversity of plant and animal communities** ... so that it is at least as great as that which would be expected in a natural forest.”

Regulatory Guidance:

National Forest
Management Act
(NFMA)

Clean Water Act
(CWA)

- **NFMA Implementing Regulations (36 CFR 219.19)**
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- **CWA Silviculture road exemption (40 CFR 232.3)**
 - “The design, construction and maintenance of the **road crossing shall not disrupt the migration or other movement** of those species of aquatic life inhabiting the water body.”

Program Pieces:

National Inventory Protocol

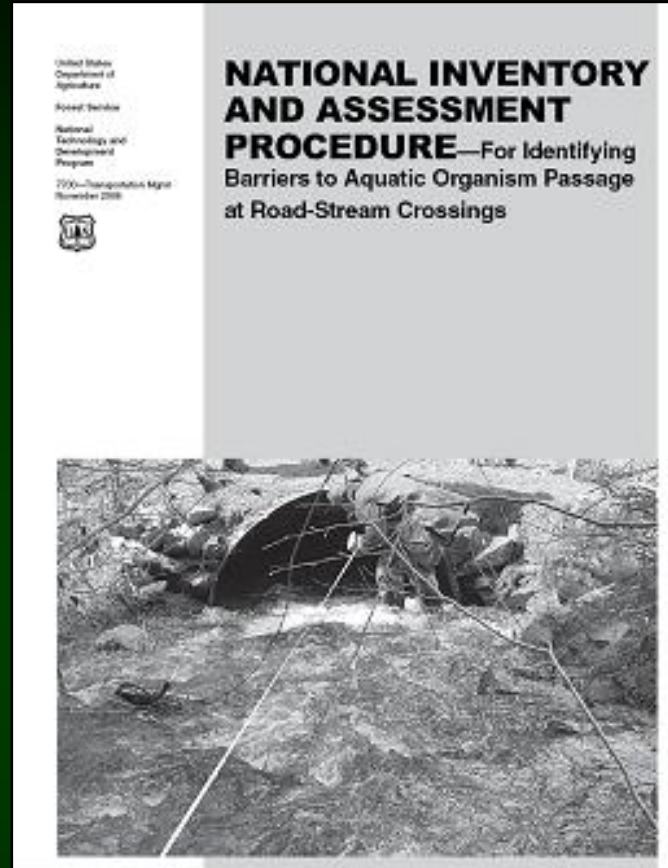
Technical Document

Training Workshops

E-learning Tool

Monitoring Protocols

Key Players



FishXing v3 beta

Created by:

Susan Firor

Michael Love

Michael Furniss

Antonio Llanos

Kathleen Moynan

Jeff Guntle

Bob Gubernick



[click to enlarge](#)

Program Pieces:

National Inventory
Protocol

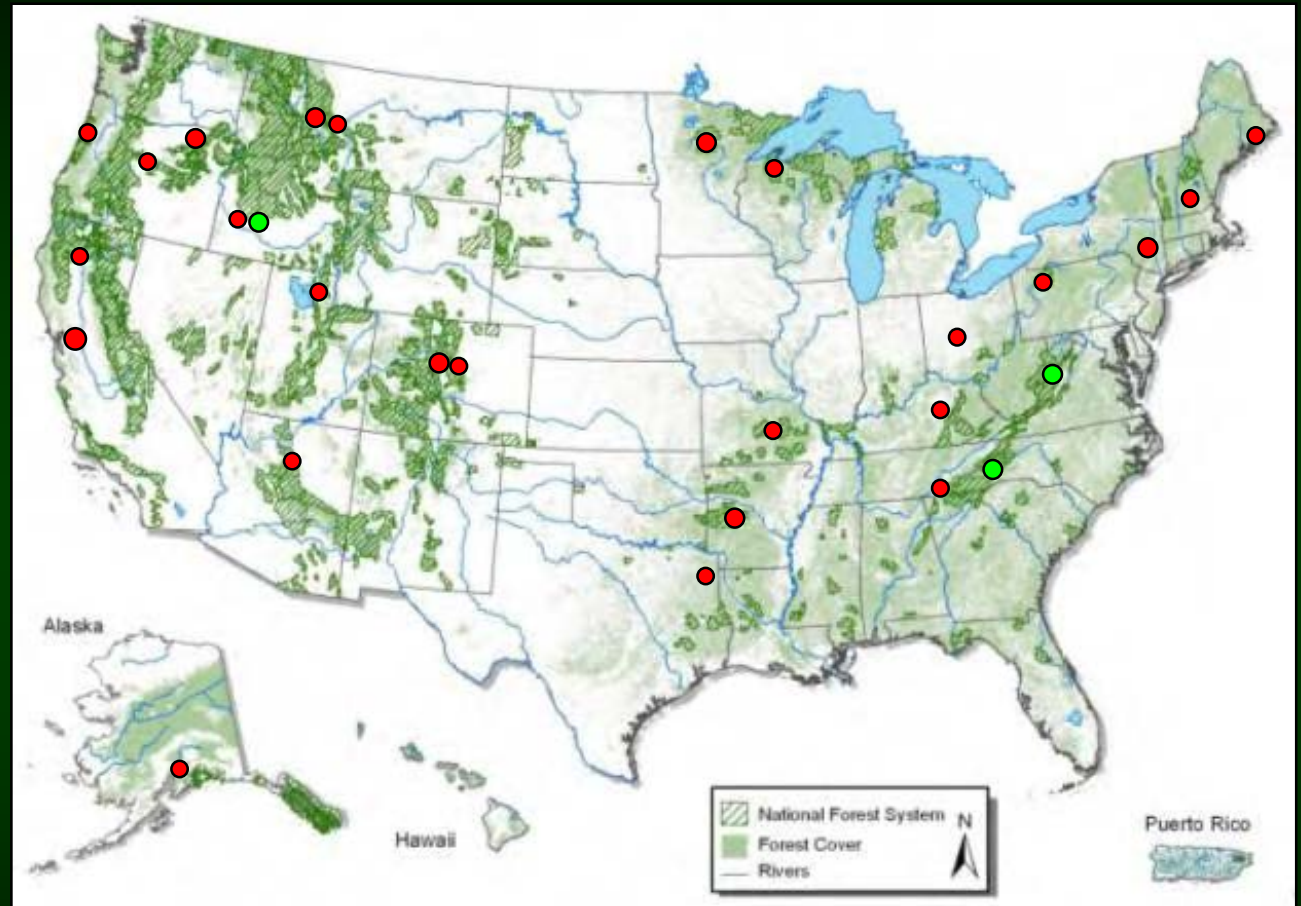
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28 Courses through Fiscal Year 2013

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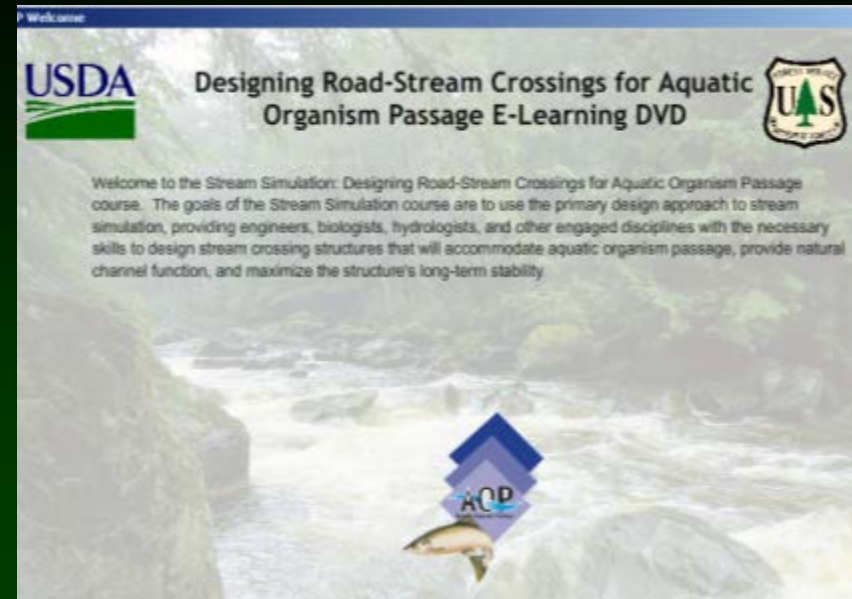
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e-Learning Design Tool



Monitoring



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National Inventory
Protocol

National Training Cadre

Dan Cenderelli; USFS, WO-Stream Team

Mark Weinhold; USFS, R2-White River NF

Bob Gubernick; USFS, Region 9

Technical Document

Training Workshops

Policy Advocates

Paul Anderson; USFS, WO-Engineering

Emilee Blount; USFS, WO-Engineering

E-learning Tool

Amy Unthank; USFS, WO-Watershed, Fish, Wildlife

Nat Gillespie; USFS, WO-Watershed, Fish, Wildlife

Monitoring Protocols

San Dimas TDC Project Leaders

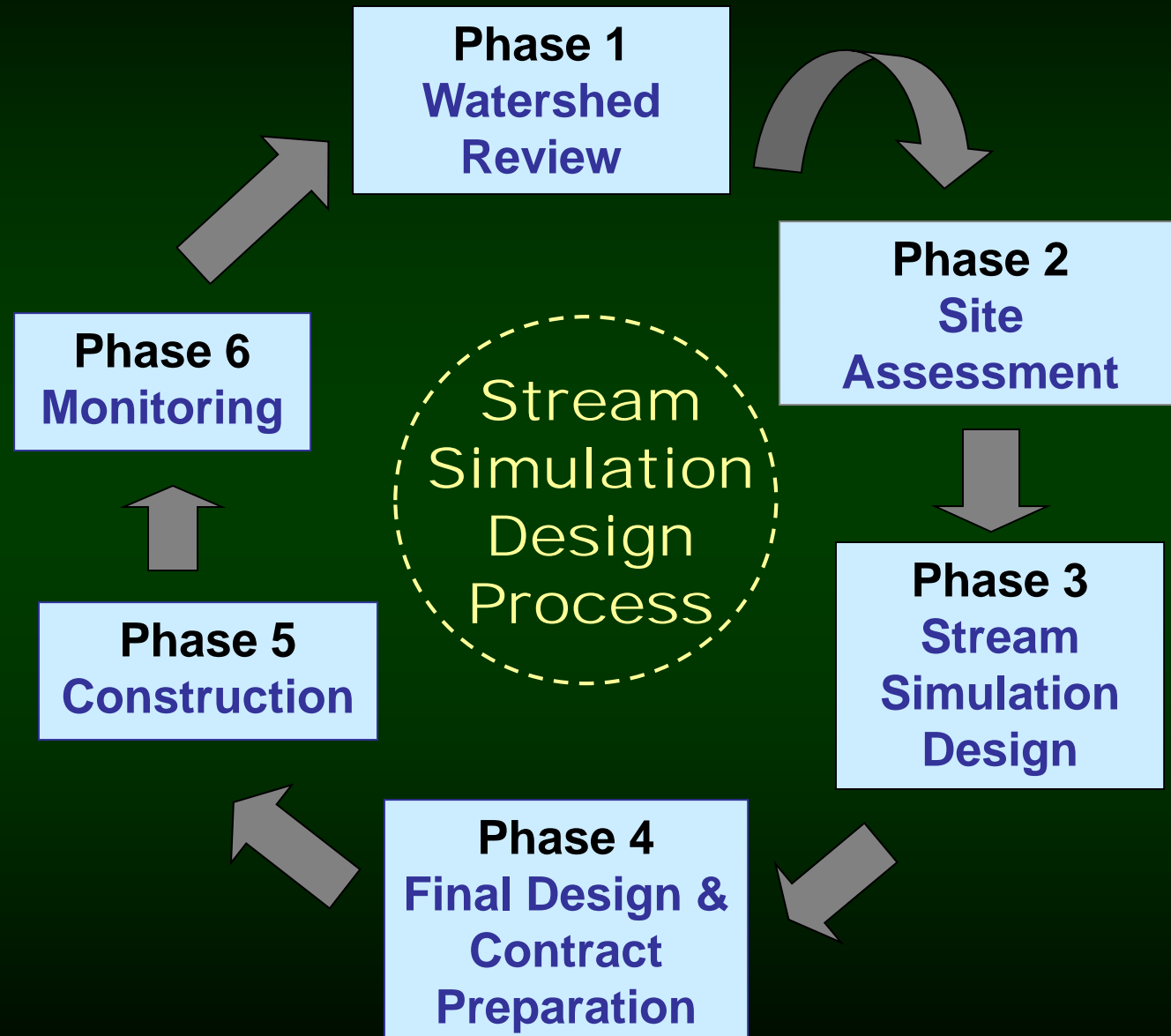
Greg Napper; USFS, SDTDC - Project Leader

Kim Clarkin; USFS, SDTDC - Project Leader (retired)

Alan Yamada; USFS, SDTDC - Program Manager (retired)

John Fehr; USFS, SDTDC - Program Manager

Key Players



Watershed Review:

Road Context

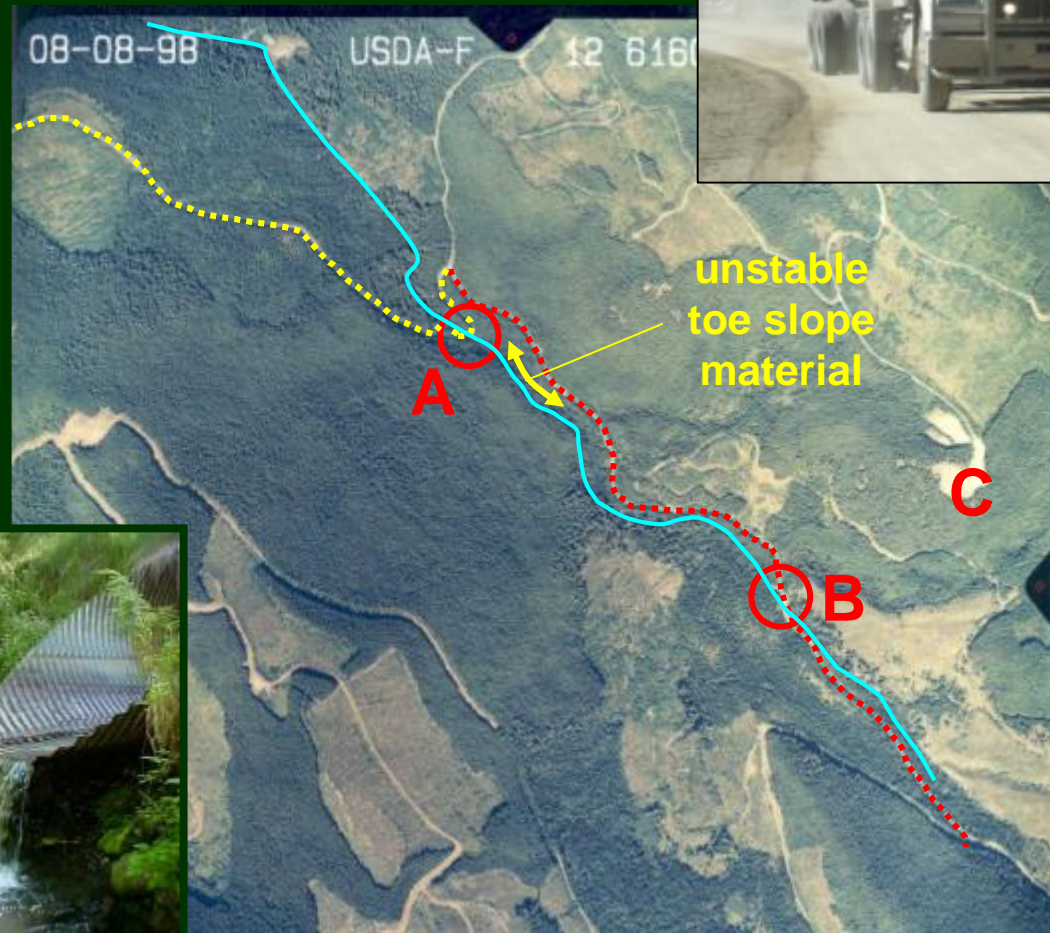
- Maintenance history
- Right of way concerns
- Type of vehicle use



Resource Values

Watershed-Scale Risk Factors

Site Risk Factors



Watershed Review:

Road Context

Resource Values

Watershed-Scale Risk Factors

Site Risk Factors

- Aquatic organisms present
- T&E species
- Extent/quality of habitat



Watershed Review:

- Geologic/watershed processes
- Management activities

Road Context

Resource Values

Watershed-Scale Risk Factors

Site Risk Factors



Watershed Review:

Road Context

Resource Values

Watershed-Scale
Risk Factors

Site Risk Factors

- **Channel stability**
- **Vertical adjustment potential**
- **Headcut potential**
- **Lateral adjustment potential**
- **Floodplain conveyance/connectivity**

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Photo courtesy of Bill Dickson)

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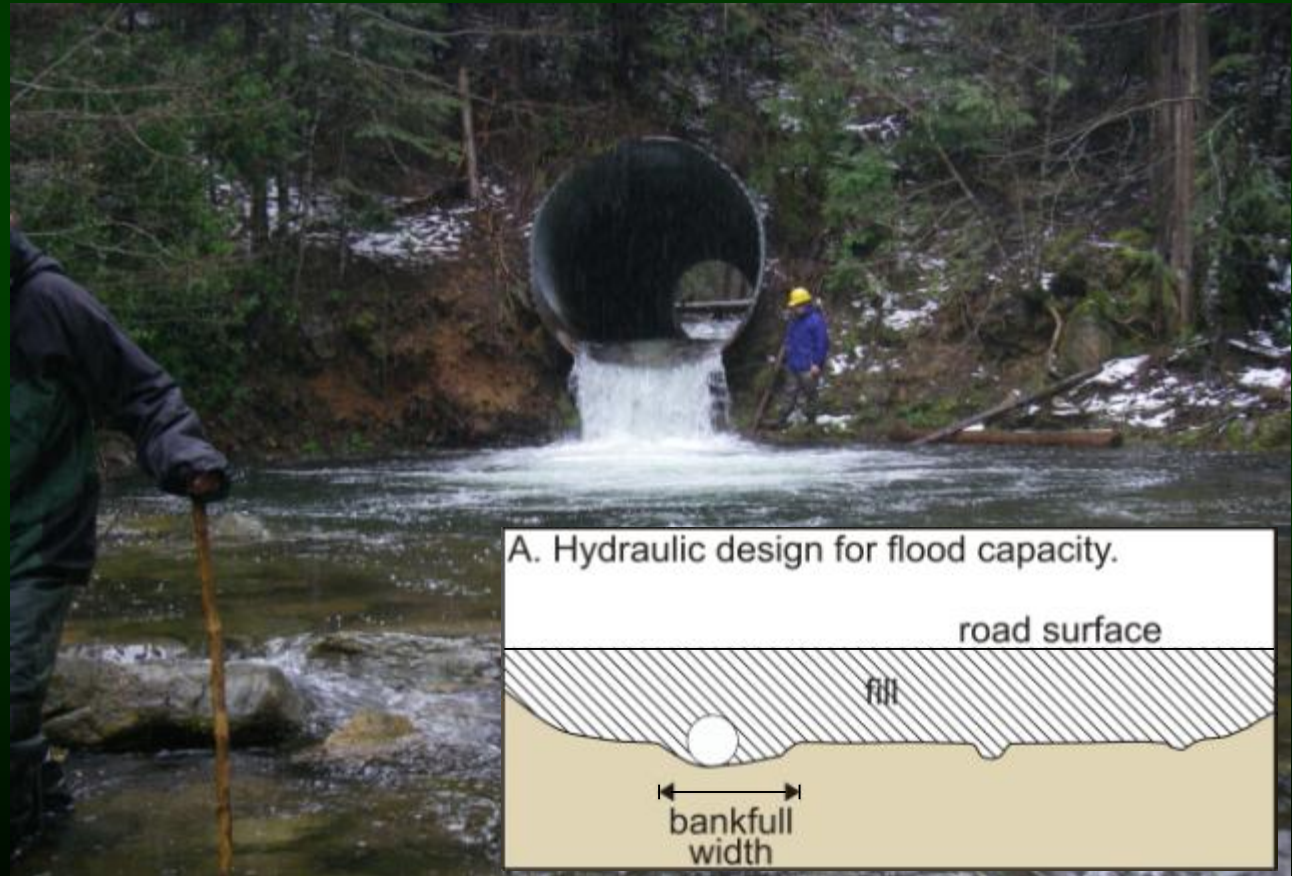
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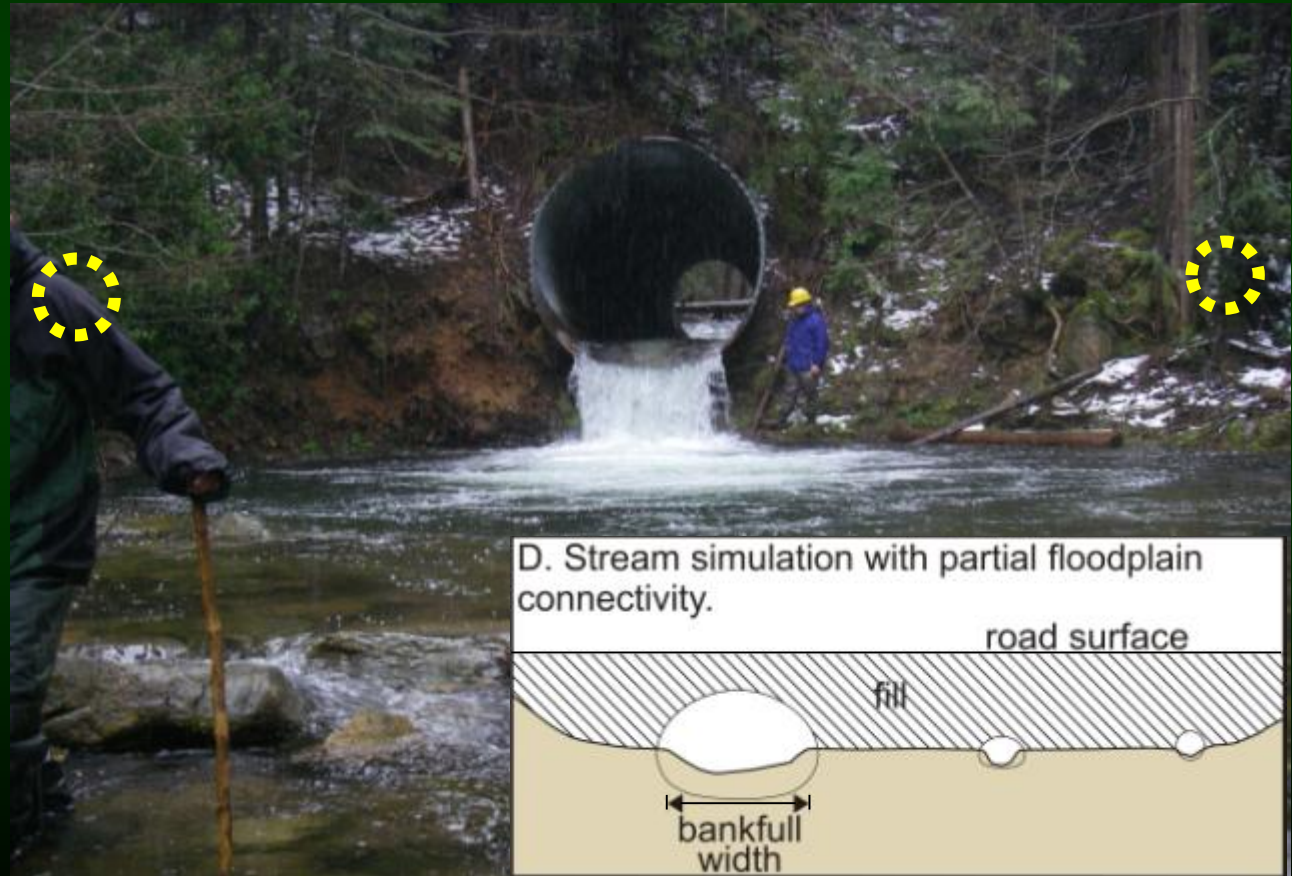
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Watershed Review

Site Assessment

Stream Simulation Design

Final Design/Contract Preparation

Construction

Monitoring

Site Assessment:

Planform
Characteristics

Longitudinal Profile

Cross Sections

Bed/Bank Sediments
and Characteristics

Geotechnical
Investigation

Site Risk Assessment



Site Assessment:

Planform Characteristics

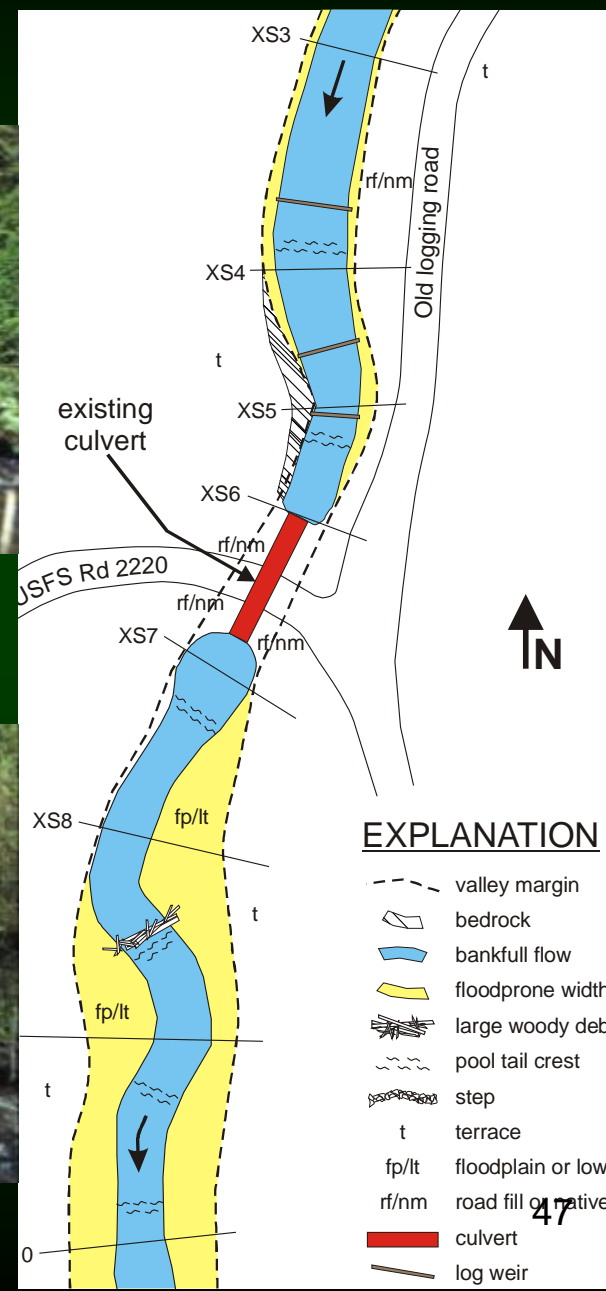
Longitudinal Profile

Cross Sections

Bed/Bank Sediments and Characteristics

Geotechnical Investigation

Site Risk Assessment



EXPLANATION

- - - valley margin
- ▭ bedrock
- ▭ bankfull flow
- ▭ floodprone width
- ▭ large woody debris
- ▭ pool tail crest
- ▭ step
- t terrace
- fp/lt floodplain or low terrace
- rf/nm road fill or relative
- ▭ culvert
- ▭ log weir

Site Assessment:

Planform Characteristics

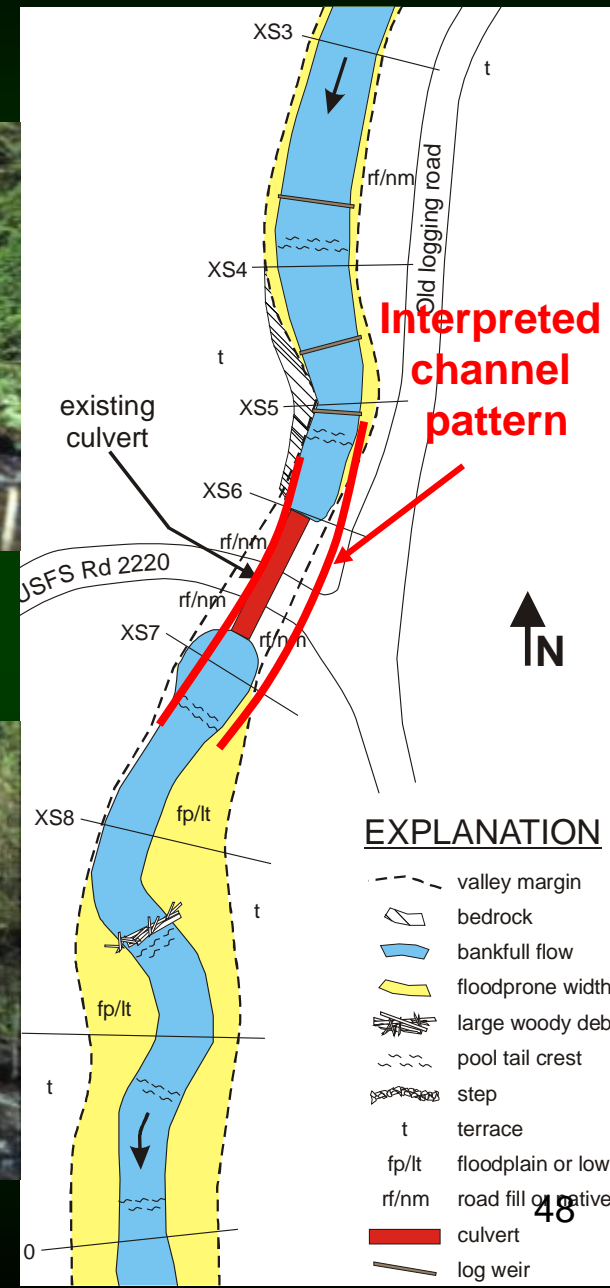
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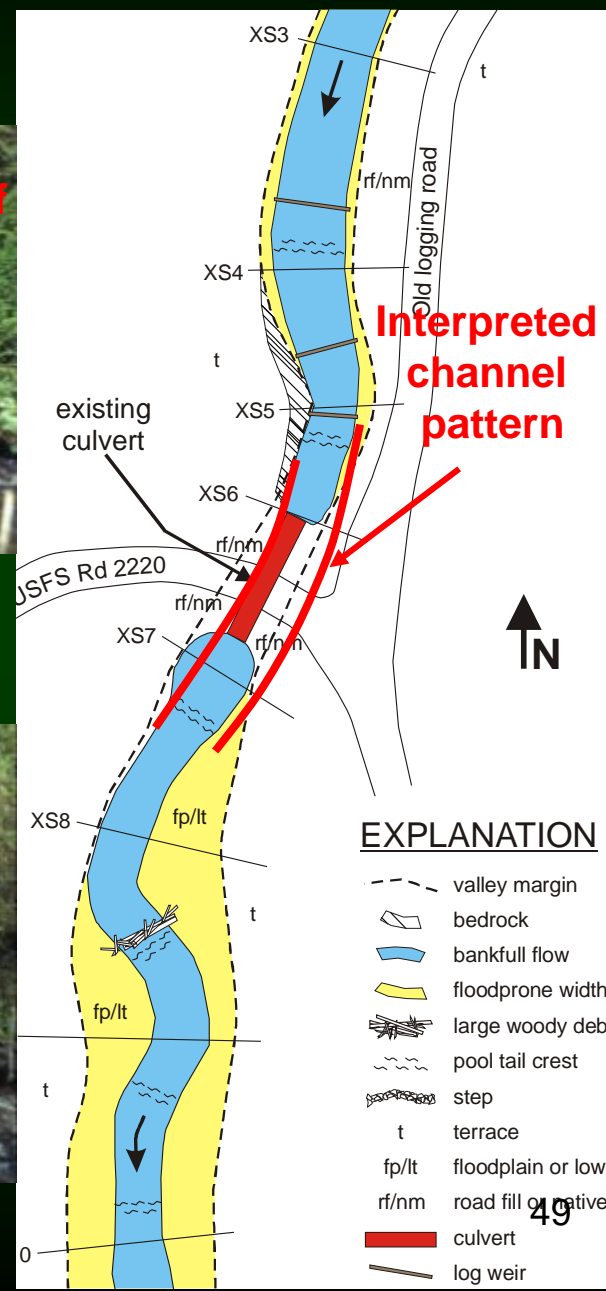
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Site Assessment:

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- Site Risk Assessment: Lateral Adjustment Potential



Site Assessment:

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Characteristics

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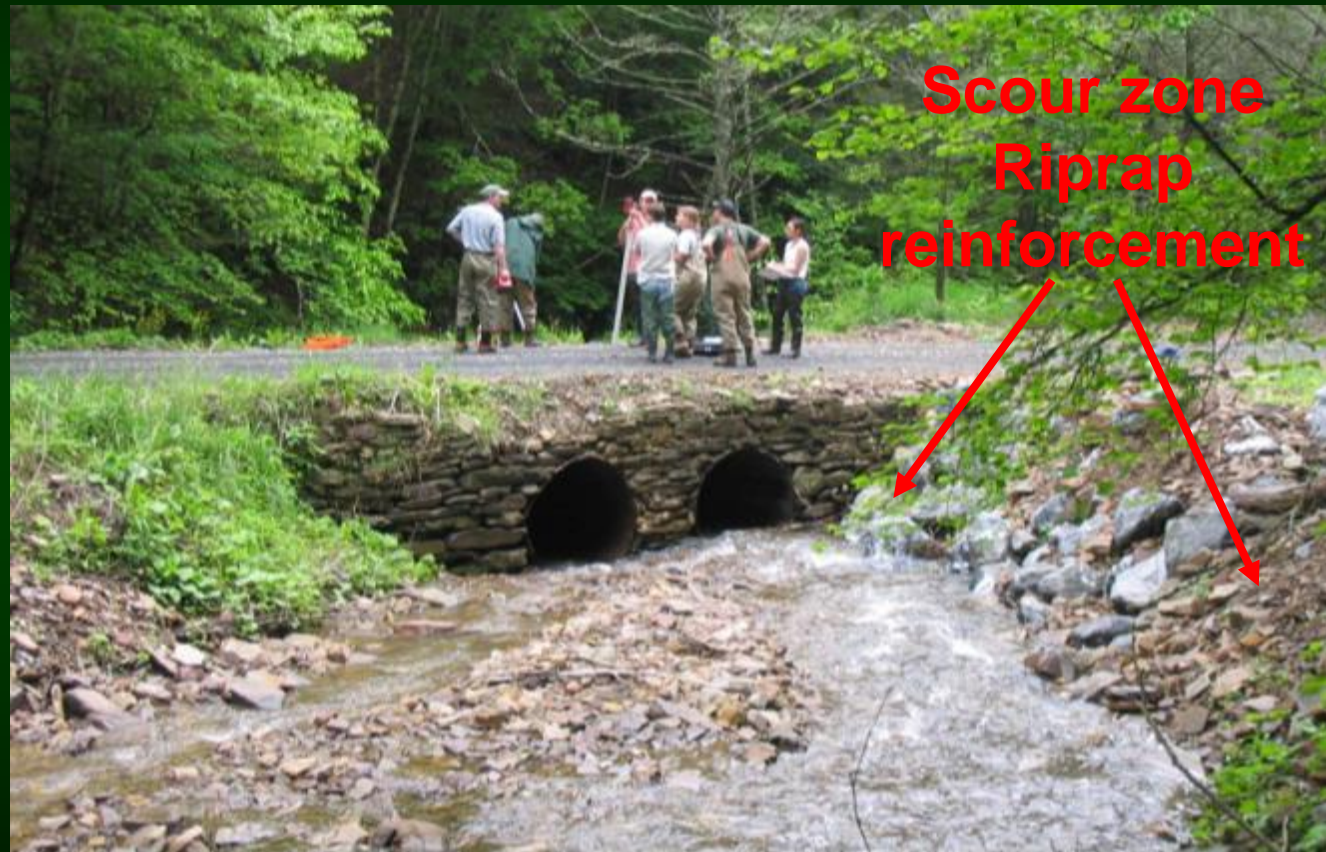
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Site Assessment:

Planform
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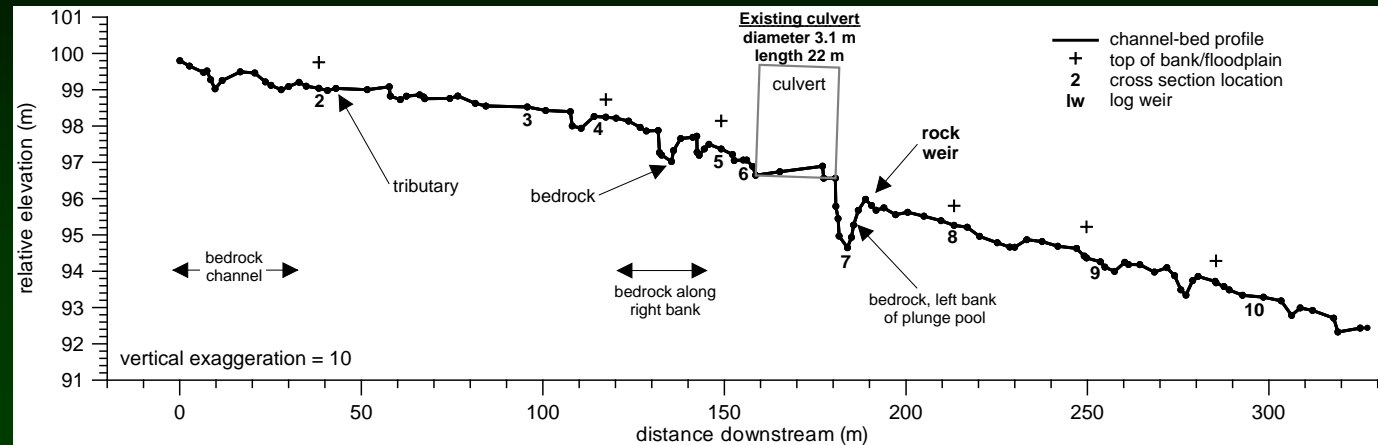
Longitudinal Profile

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Site Risk Assessment



- Bedform Type and Spacing
- Slope Segments and Gradient Variability
- Channel Bed Elevation Variability (Scour Depths and Aggradation)

Site Assessment:

Planform
Characteristics

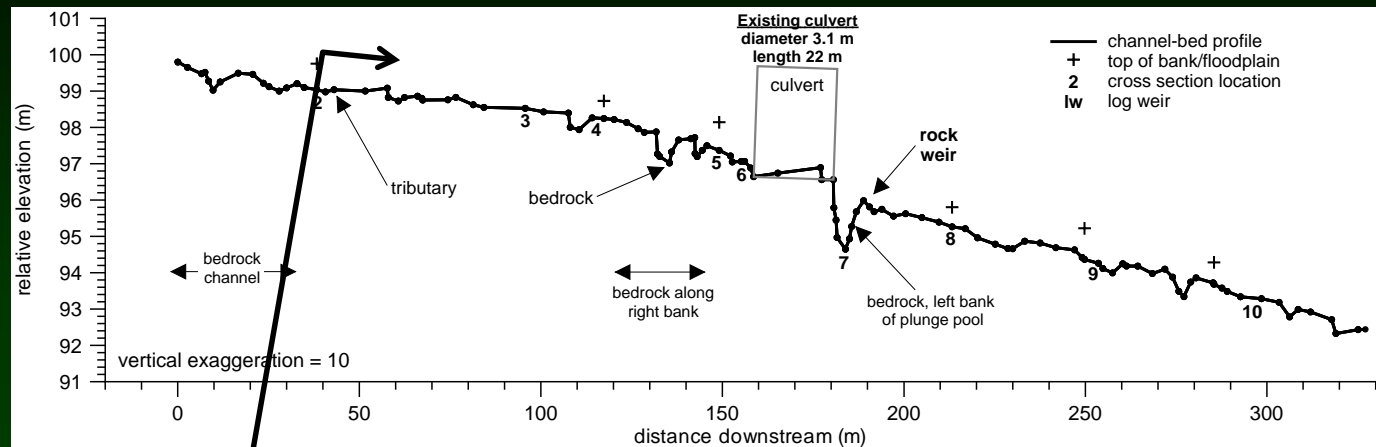
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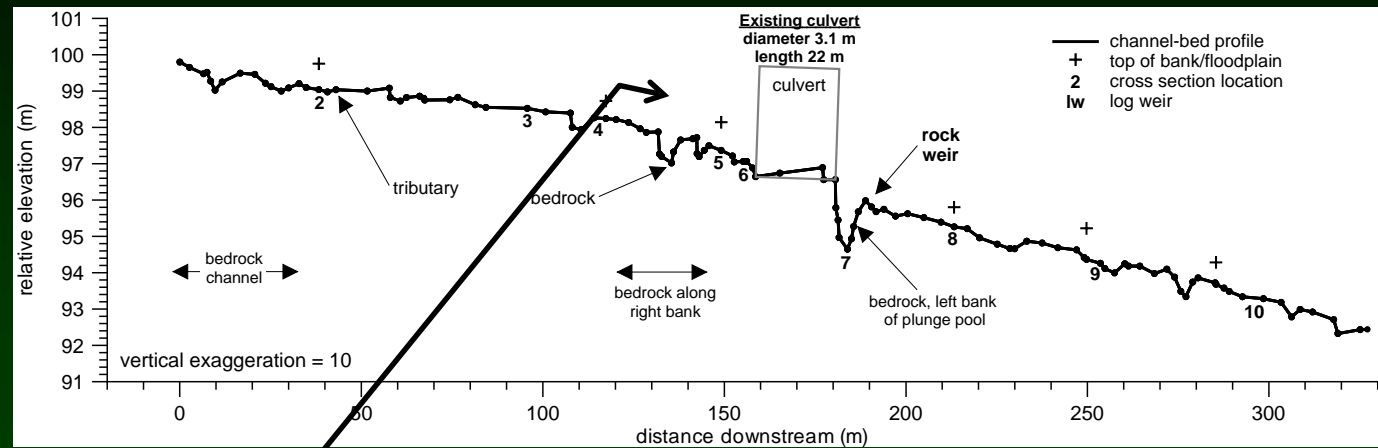
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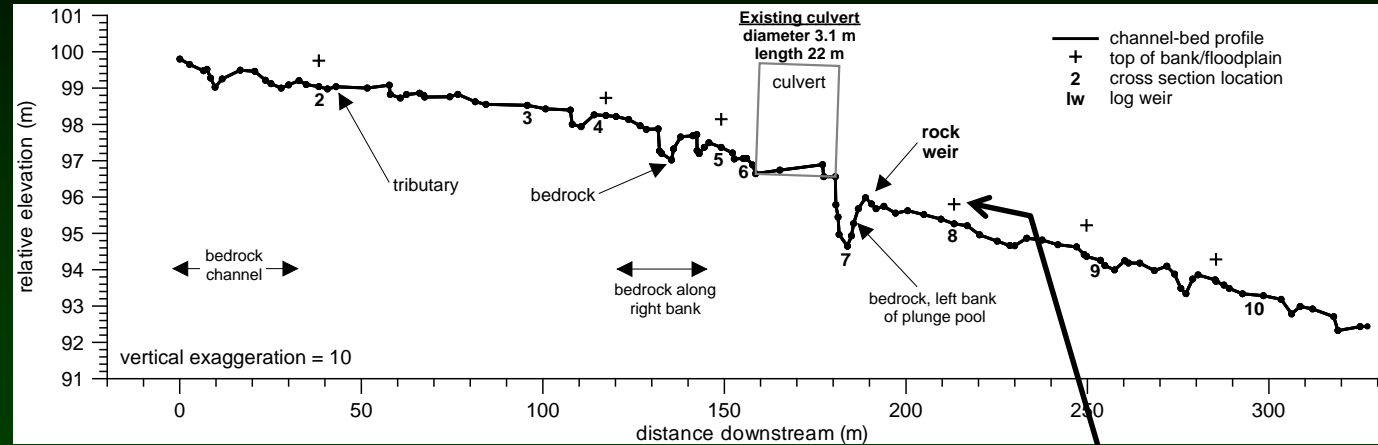
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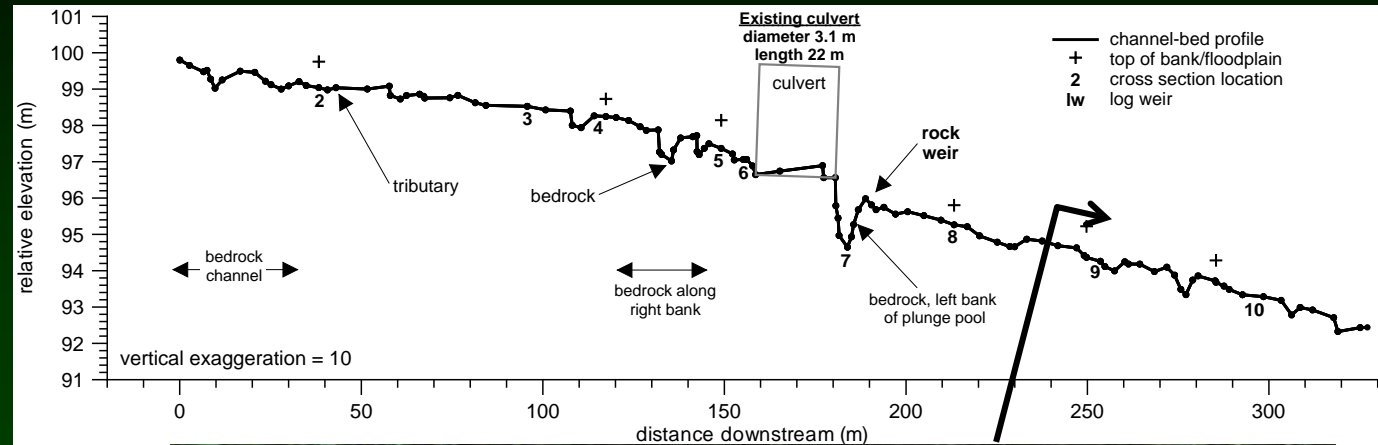
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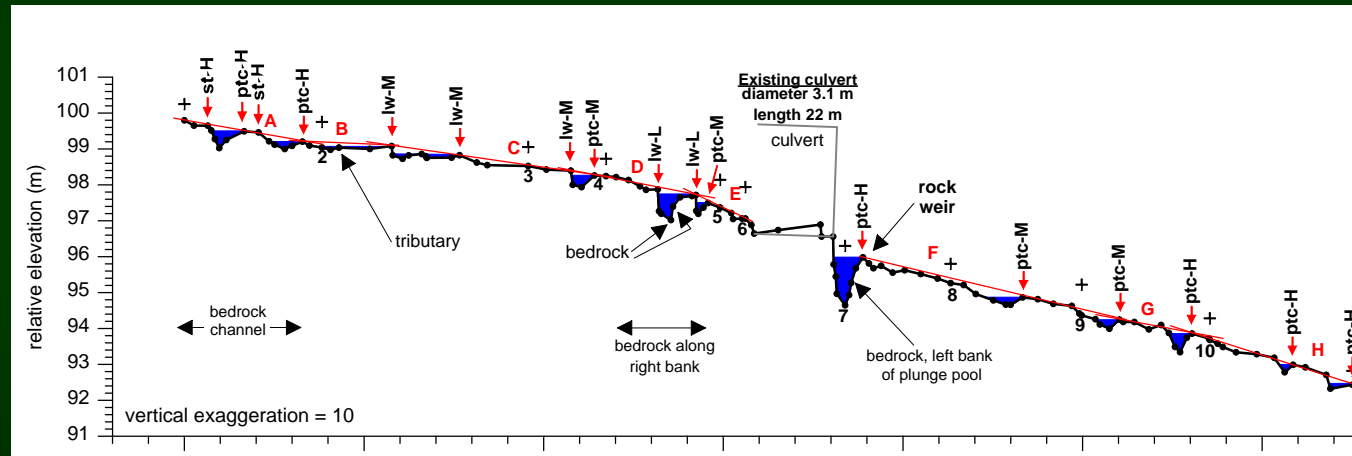
Cross Sections

Bed/Bank Sediments
and Characteristics

Geotechnical
Investigation

Site Risk Assessment

- Bedforms
- Grade Controls
- Grade Control Stability



—	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)

Site Assessment:

Planform
Characteristics

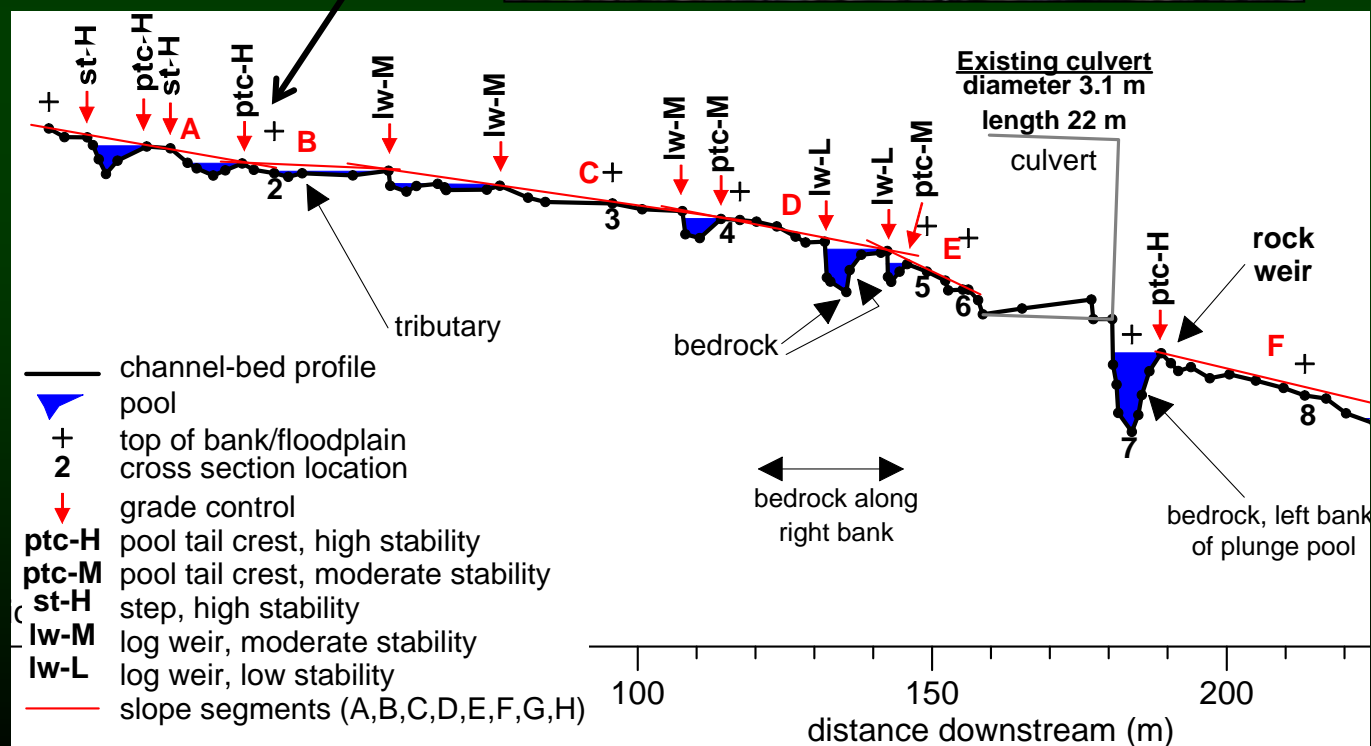
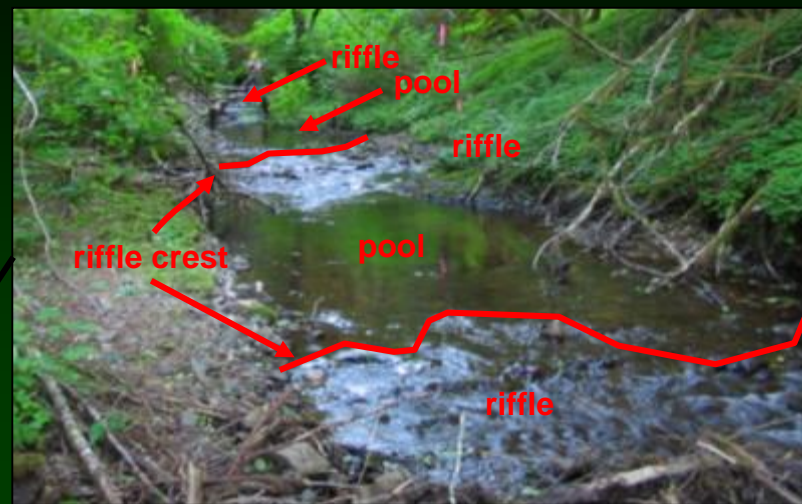
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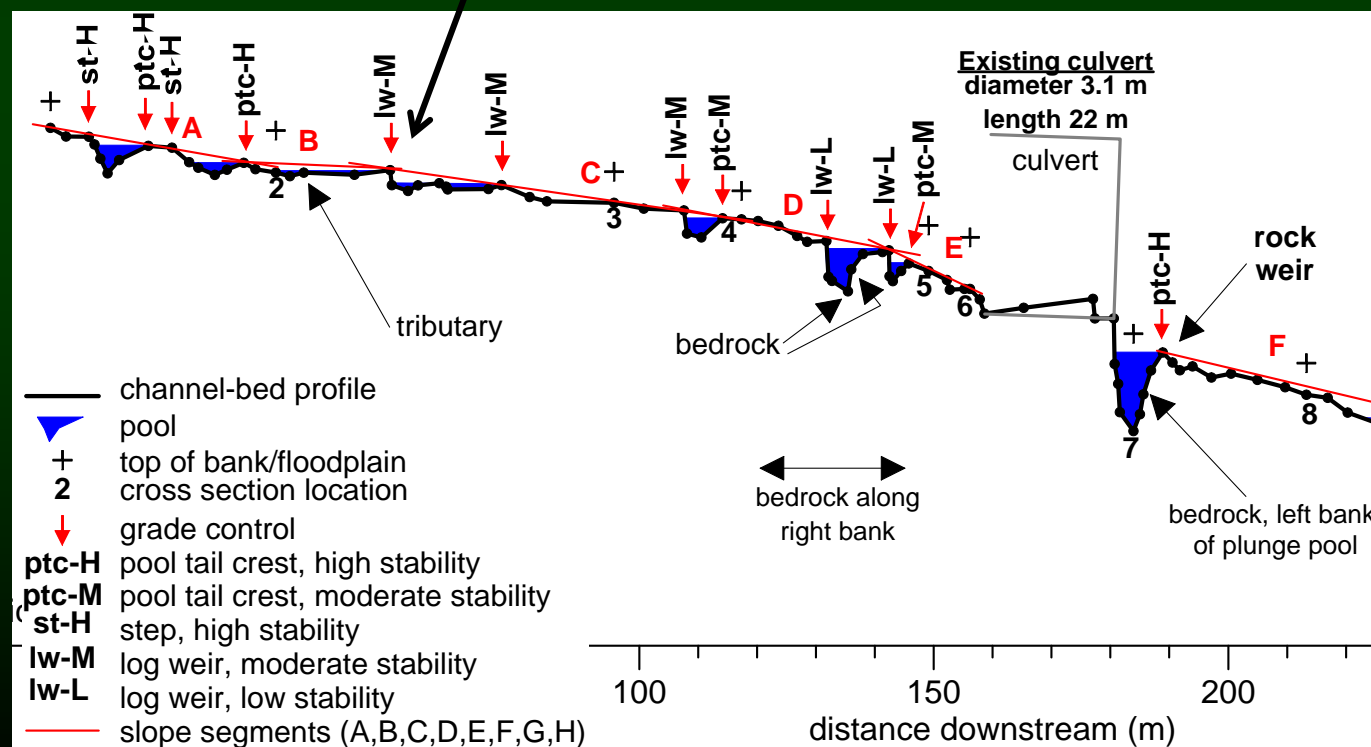
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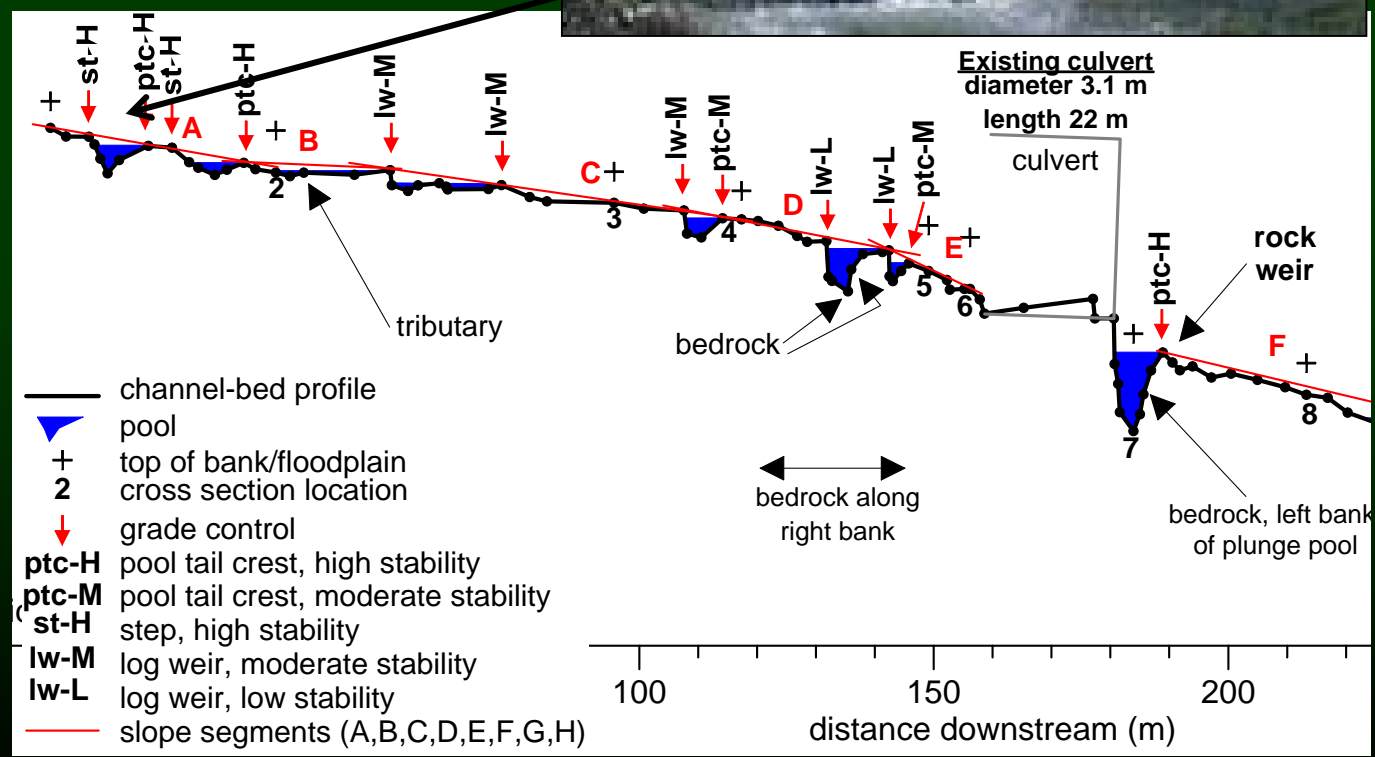
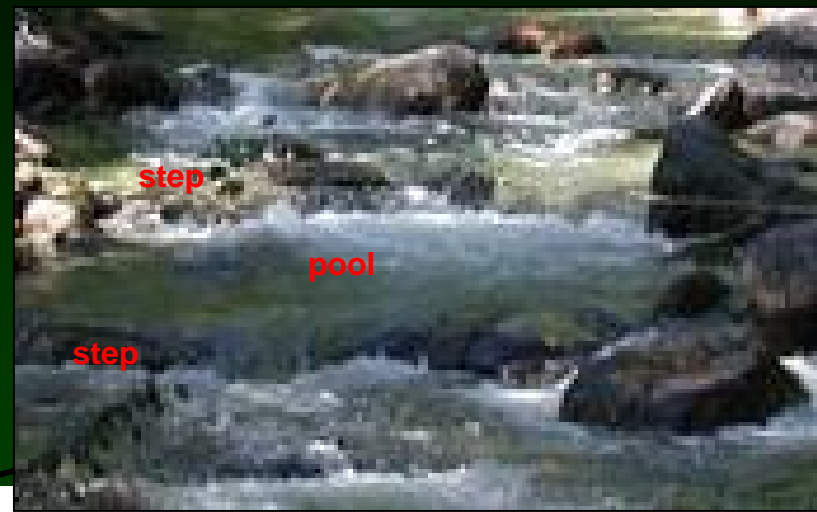
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Site Assessment:

- Planform Characteristics
- Longitudinal Profile
- Cross Sections
- Bed/Bank Sediments and Characteristics
- Geotechnical Investigation
- Site Risk Assessment

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Site Assessment:

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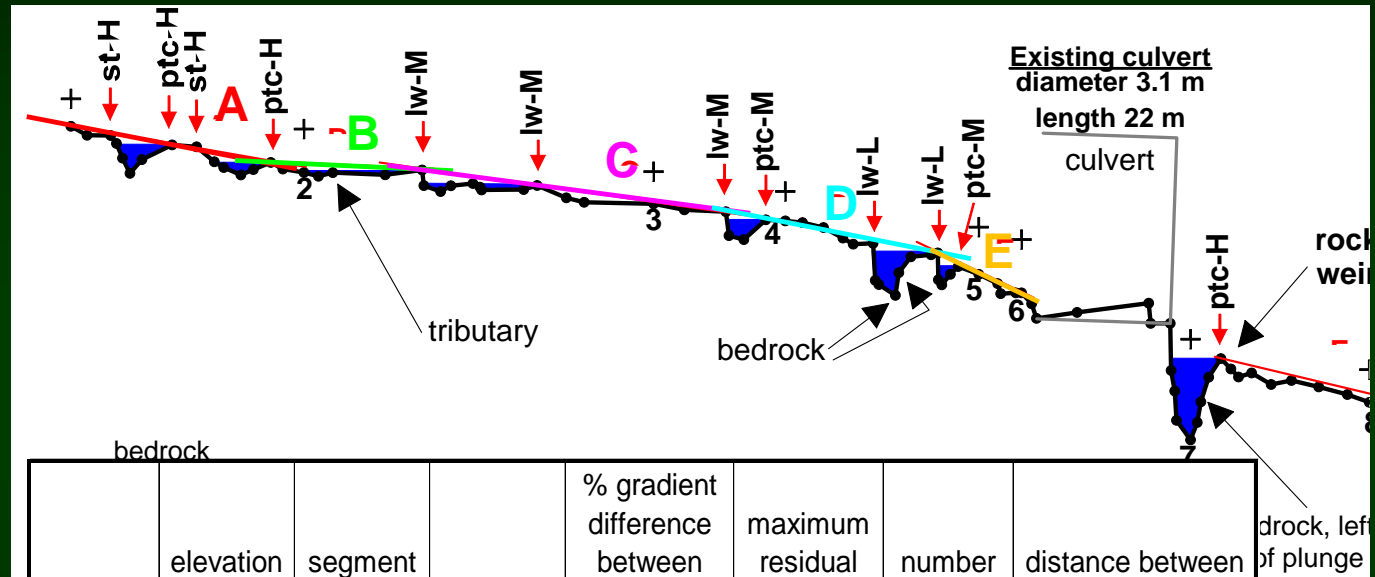
Cross Sections

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Site Risk Assessment

- Slope Segments
- Gradient Variability



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	3	10.1, 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

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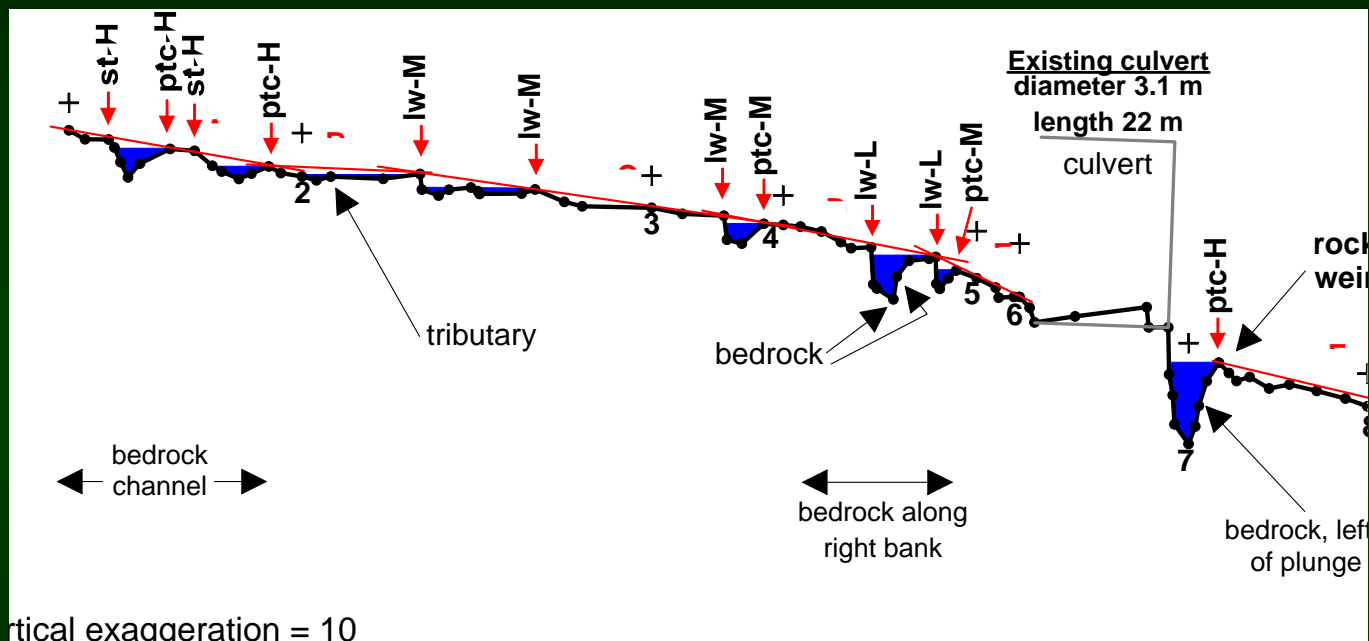
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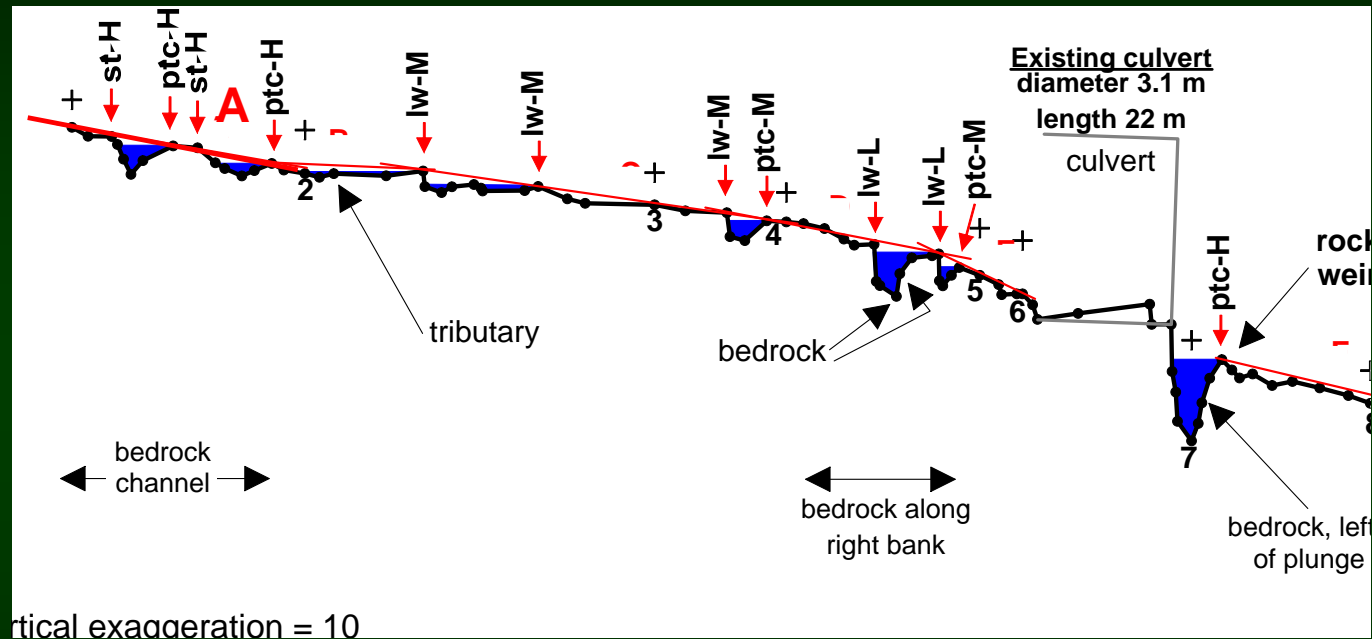
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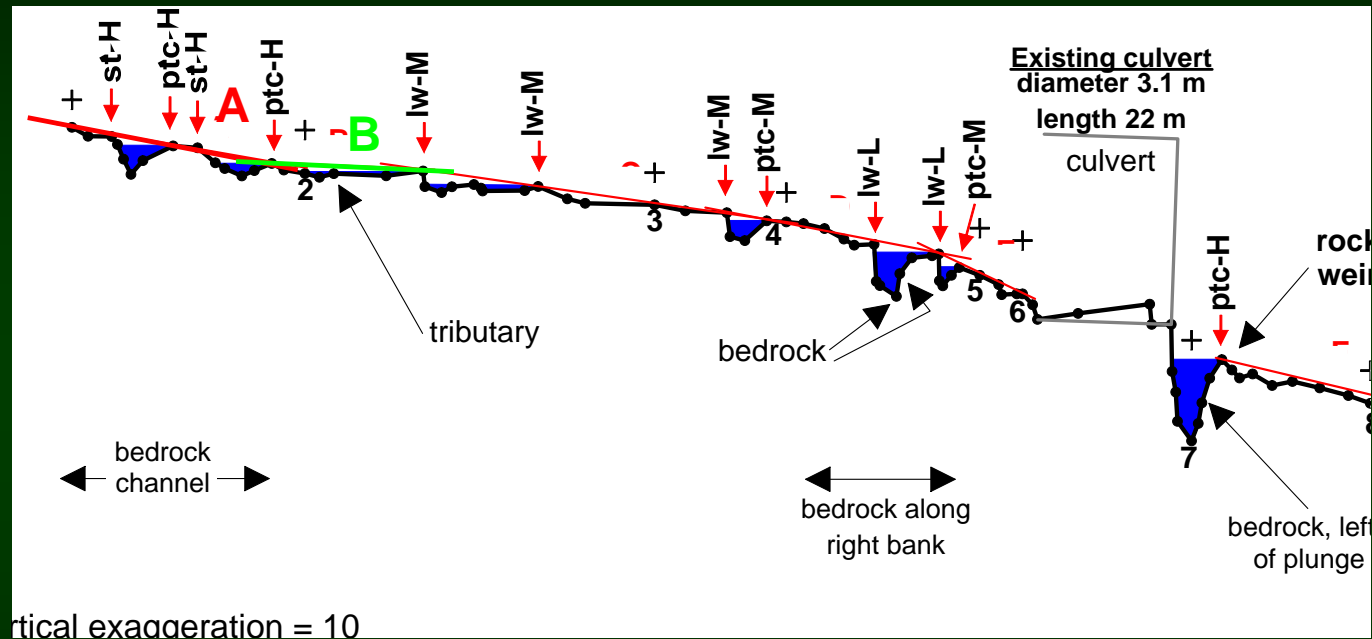
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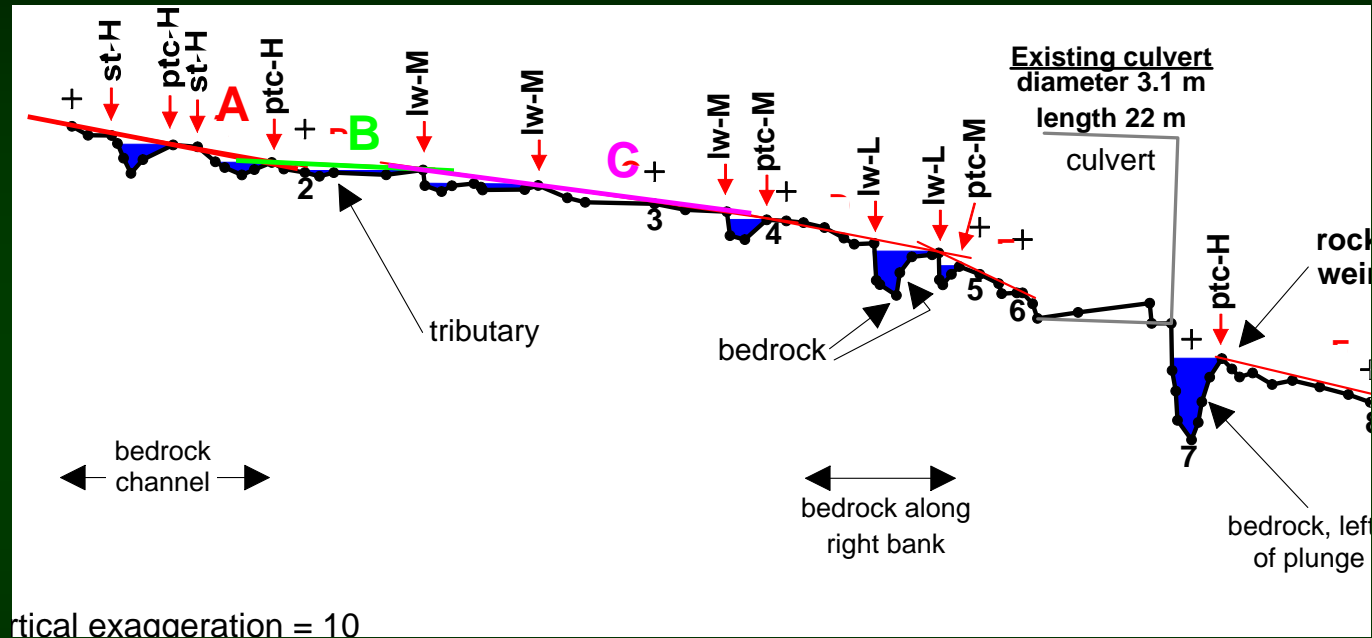
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vertical exaggeration = 10

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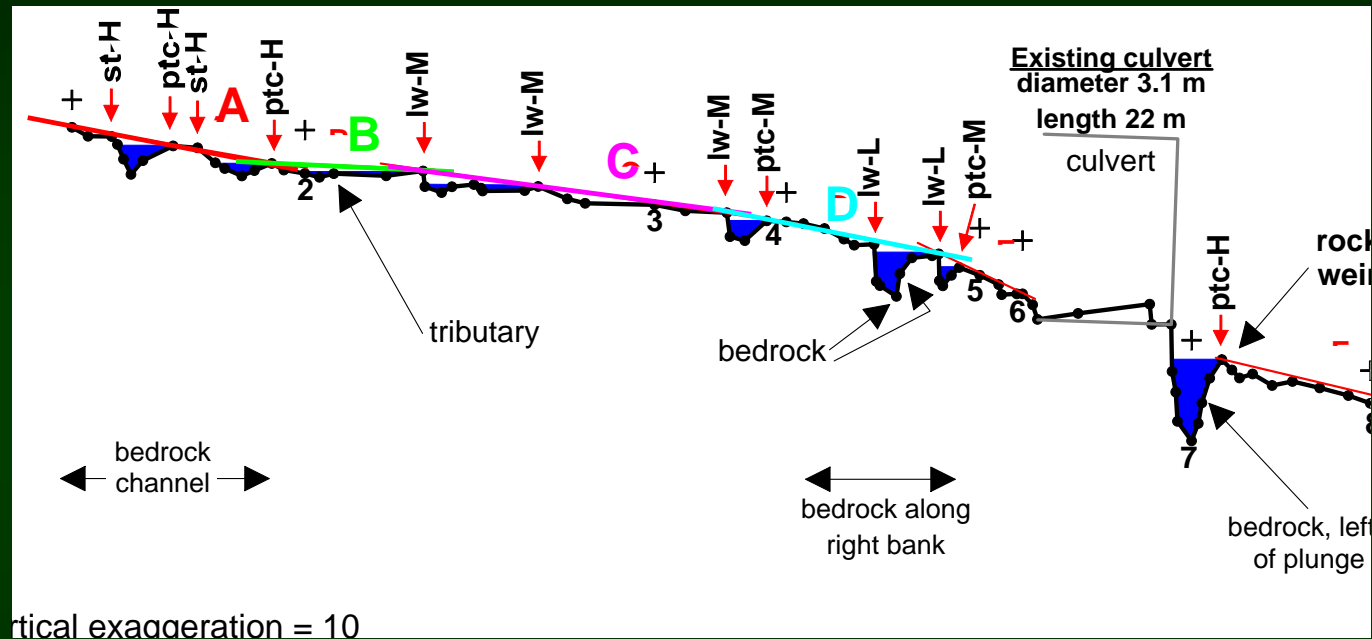
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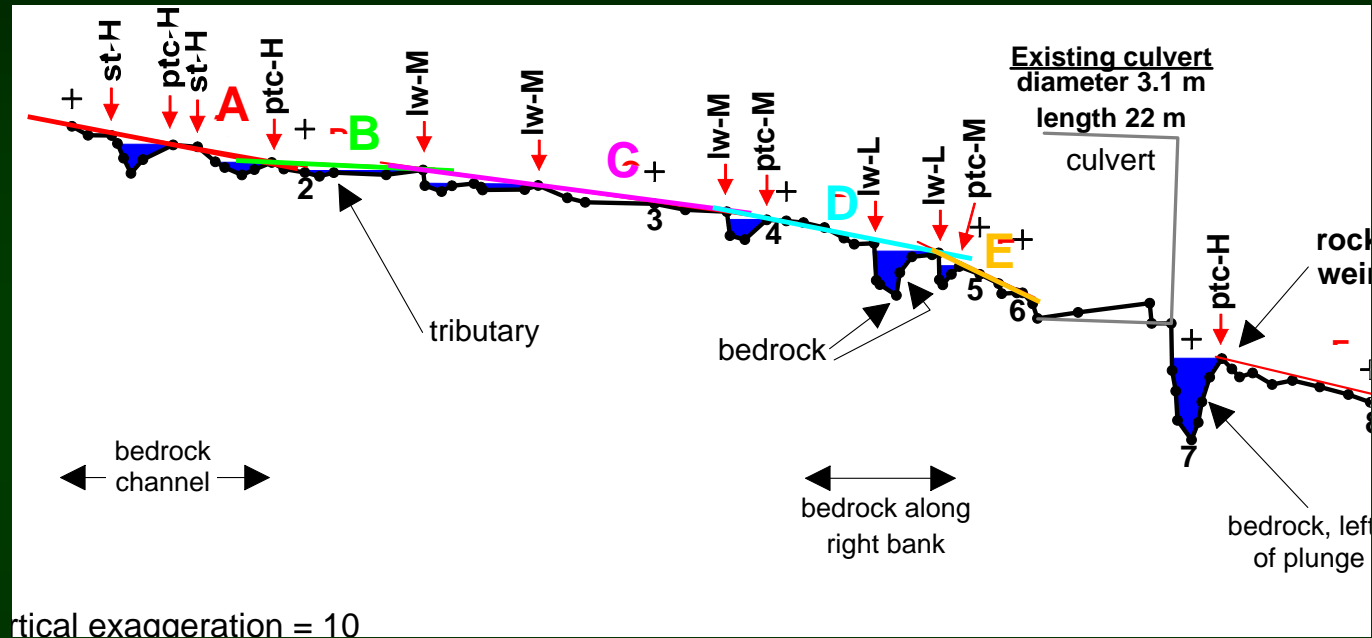
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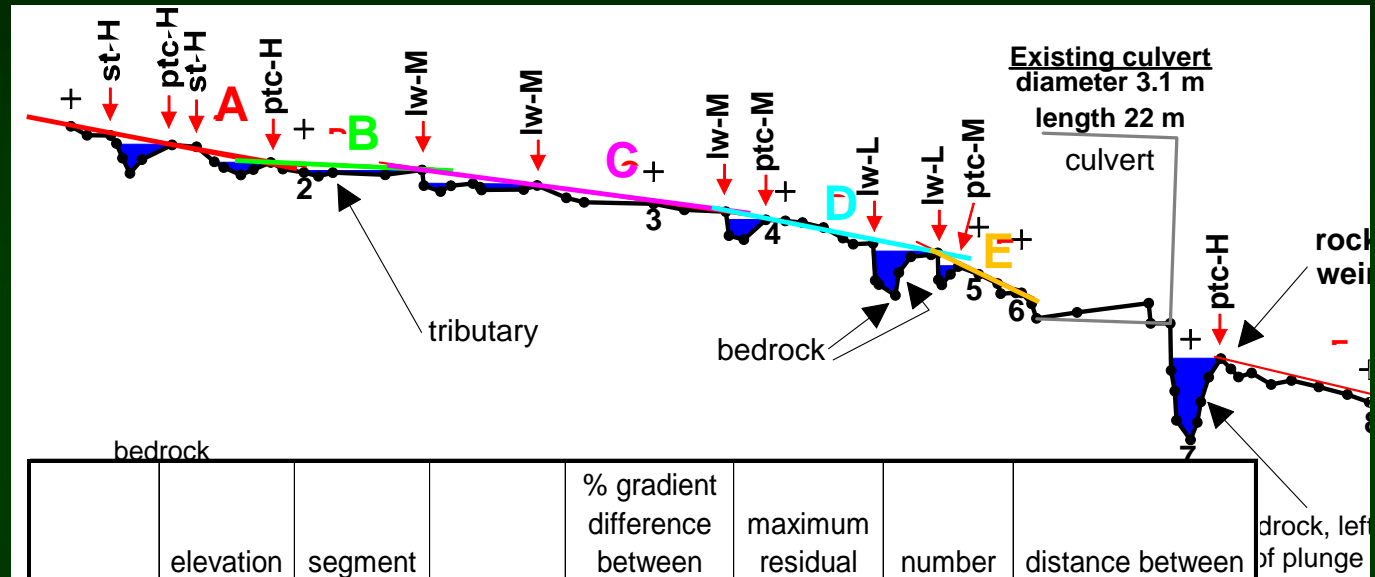
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segment	elevation change (m)	segment length (m)	gradient	% gradient difference between successive segments	maximum residual pool depth (m)	number of grade controls	distance between grade controls (m)
A	0.29	16.21	0.0178	n/a	0.47	3	10.1, 16.2
B	0.12	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

Site Assessment:

Planform
Characteristics

Longitudinal Profile

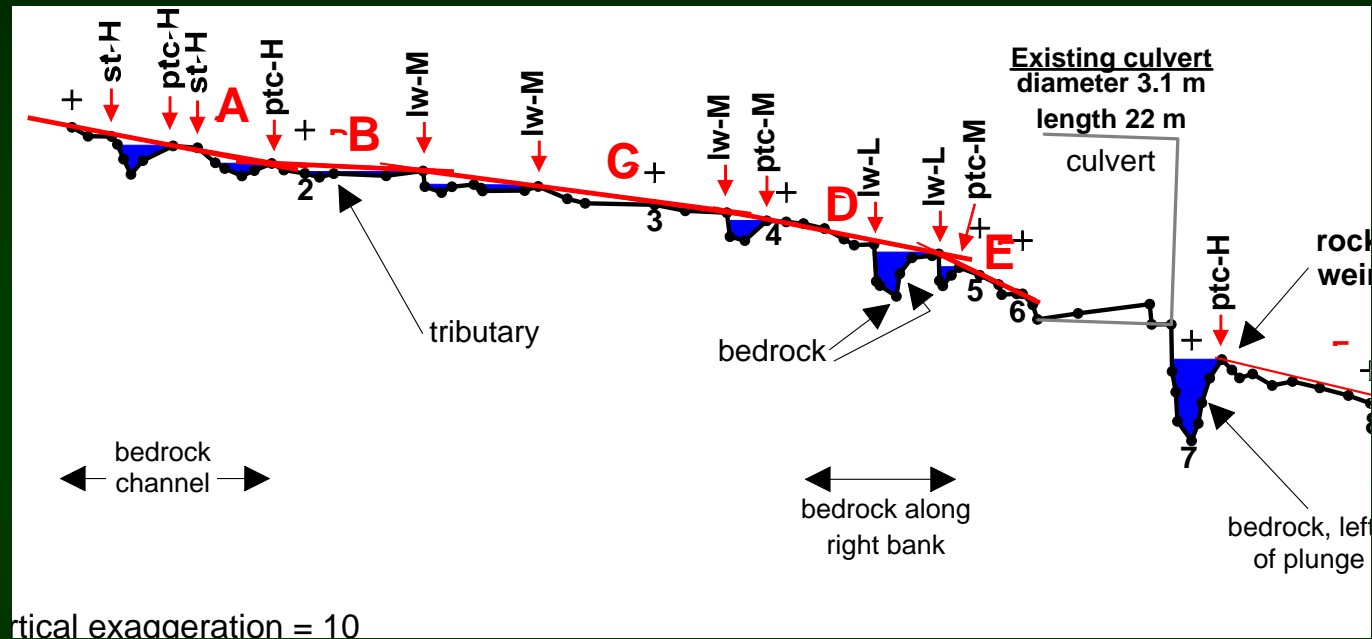
Cross Sections

Bed/Bank Sediments
and Characteristics

Geotechnical
Investigation

Site Risk Assessment

- Channel Bed Elevation Variability
(Vertical Adjustment Potential)



Site Assessment:

Planform
Characteristics

Longitudinal Profile

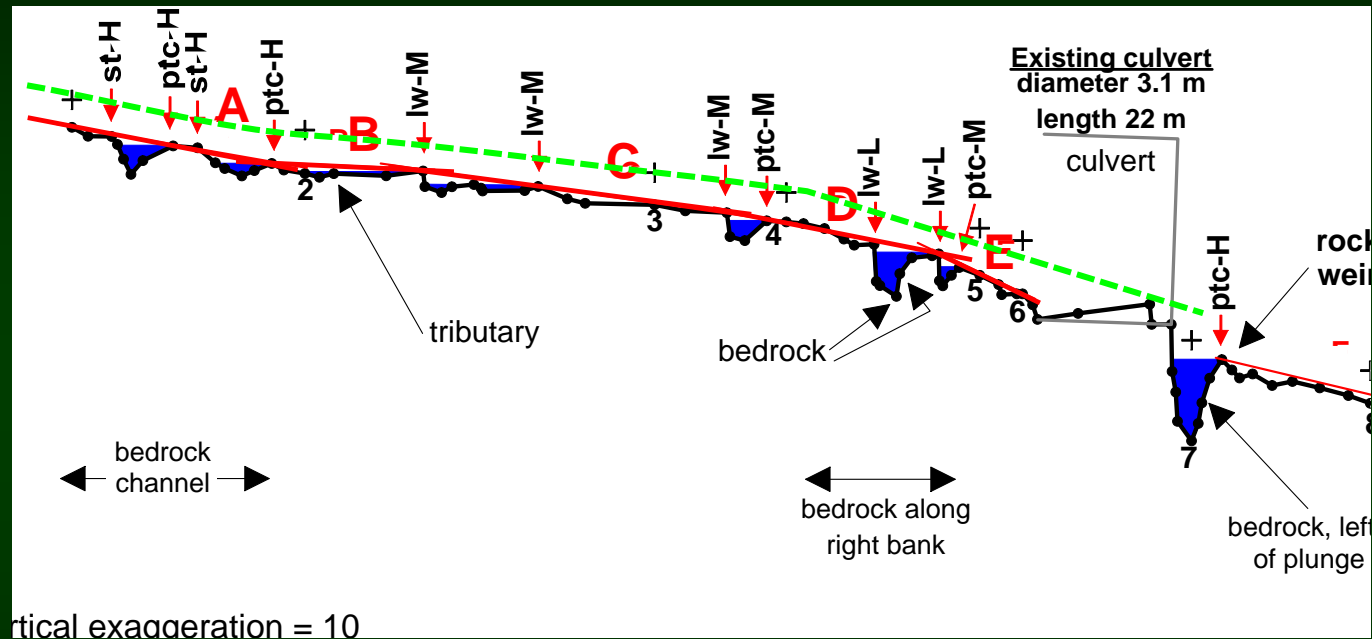
Cross Sections

Bed/Bank Sediments
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Investigation

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- Channel Bed Elevation Variability
(Vertical Adjustment Potential)



Site Assessment:

Planform
Characteristics

Longitudinal Profile

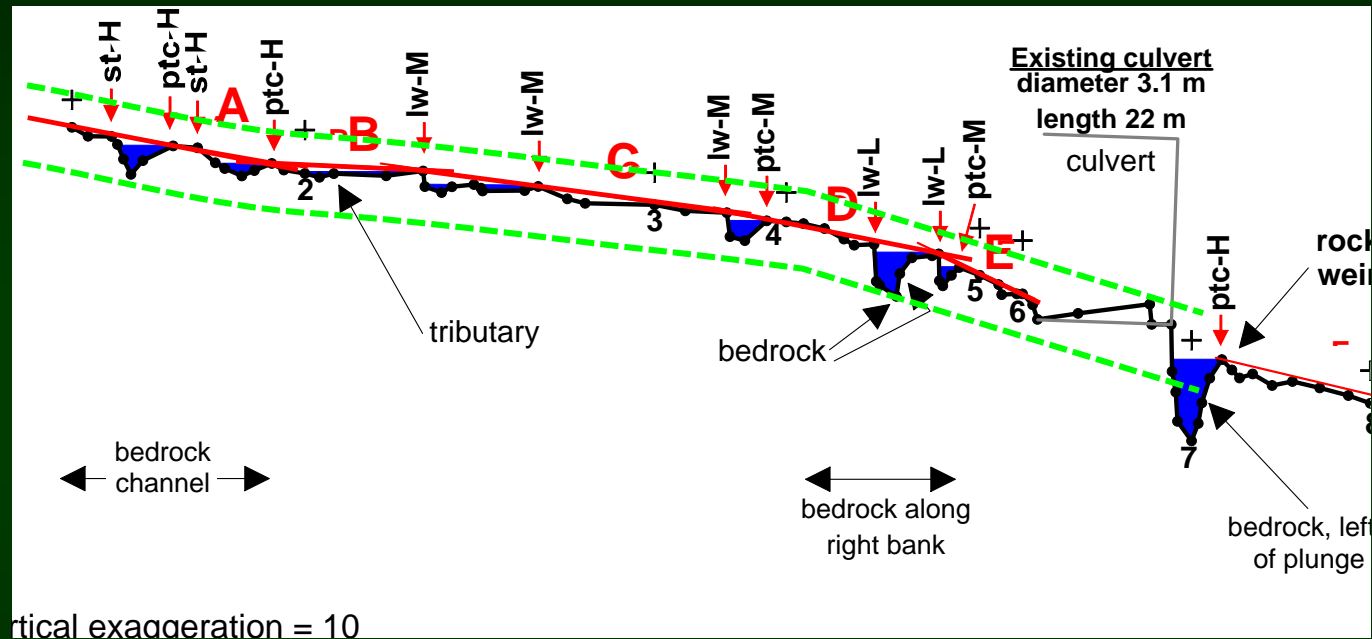
Cross Sections

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- Channel Bed Elevation Variability
(Vertical Adjustment Potential)



Site Assessment:

Planform
Characteristics

Longitudinal Profile

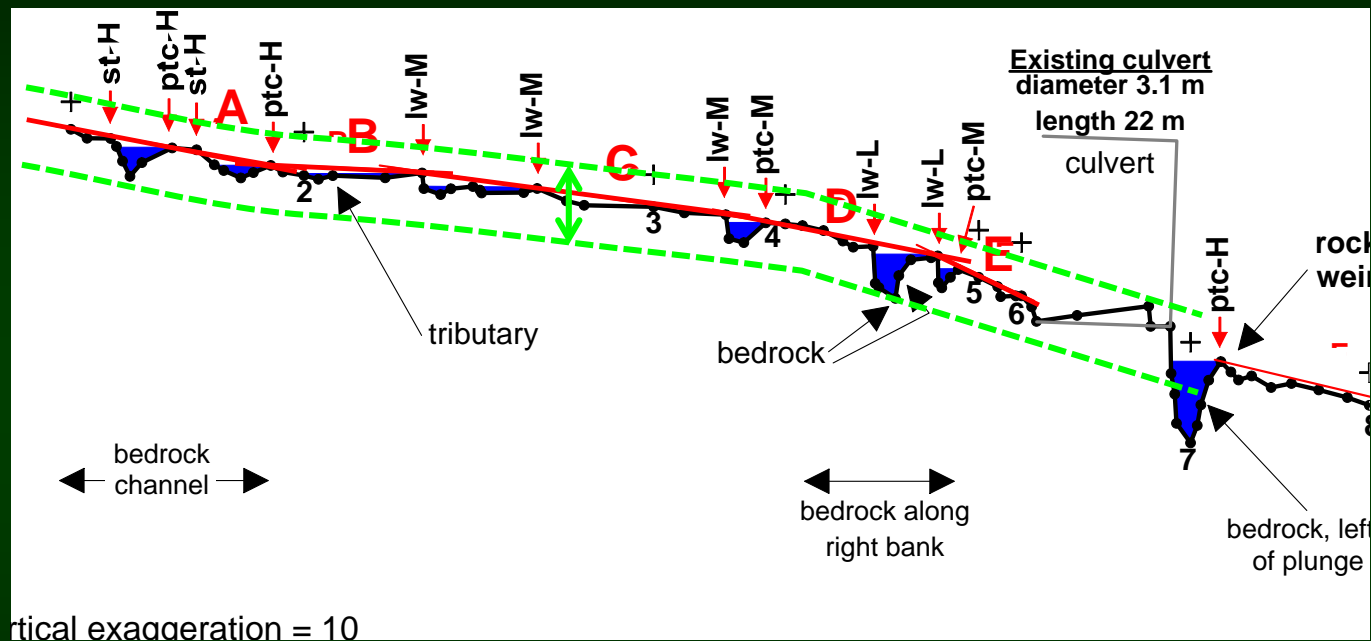
Cross Sections

Bed/Bank Sediments
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Investigation

Site Risk Assessment

- Channel Bed Elevation Variability
(Vertical Adjustment Potential)



Site Assessment:

Planform
Characteristics

Longitudinal Profile

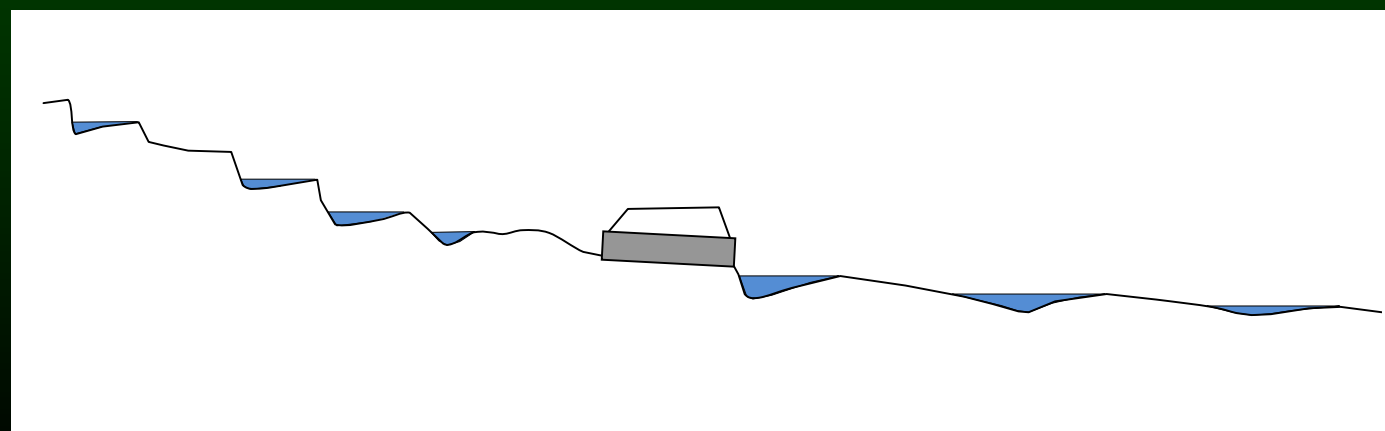
Cross Sections

Bed/Bank Sediments
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Site Risk Assessment

- Site Risk Assessment: Vertical Adjustment Potential



Site Assessment:

Planform
Characteristics

Longitudinal Profile

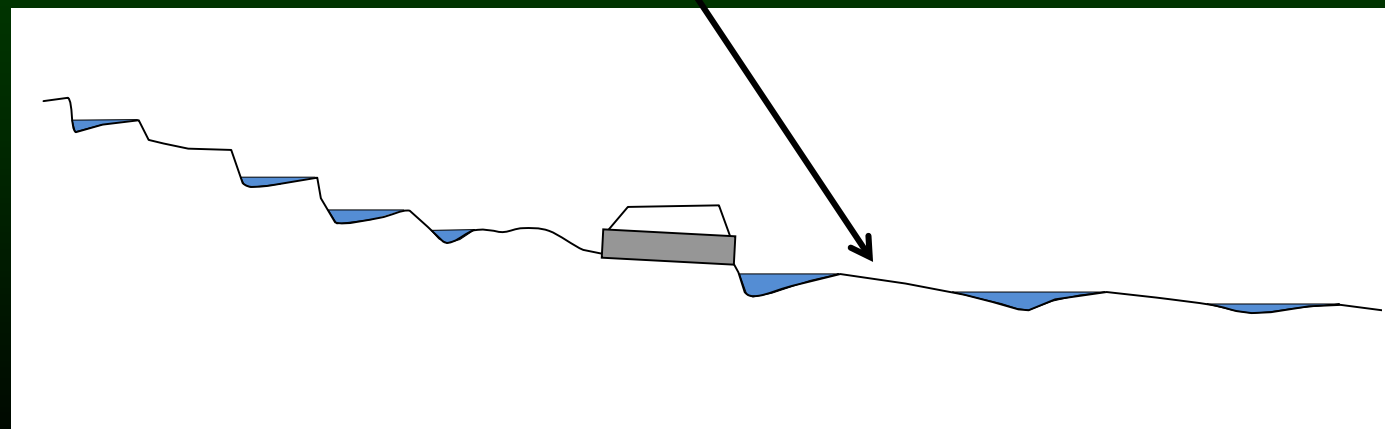
Cross Sections

Bed/Bank Sediments
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Site Risk Assessment

- Site Risk Assessment: Vertical Adjustment Potential



Site Assessment:

Planform
Characteristics

Longitudinal Profile

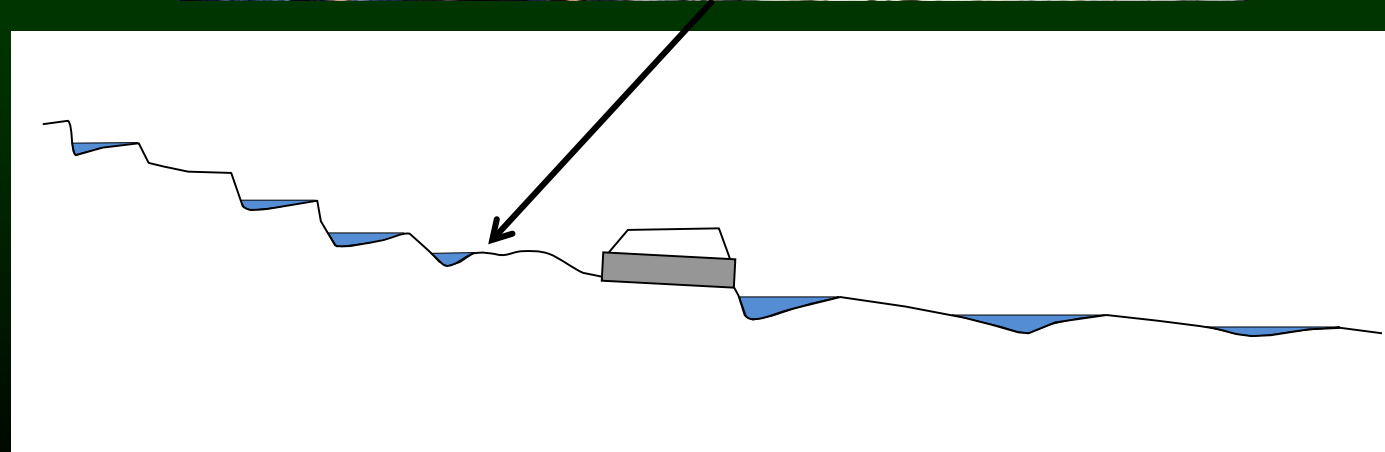
Cross Sections

Bed/Bank Sediments
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Site Risk Assessment

- Site Risk Assessment: Vertical Adjustment Potential



Site Assessment:

Planform
Characteristics

Longitudinal Profile

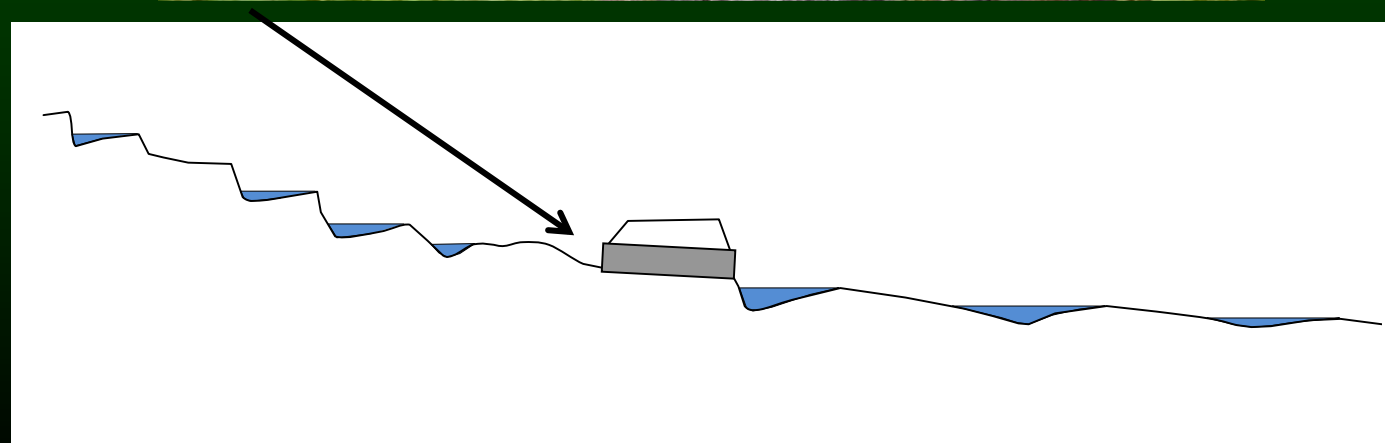
Cross Sections

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- Site Risk Assessment: Vertical Adjustment Potential



Site Assessment:

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Characteristics

Longitudinal Profile

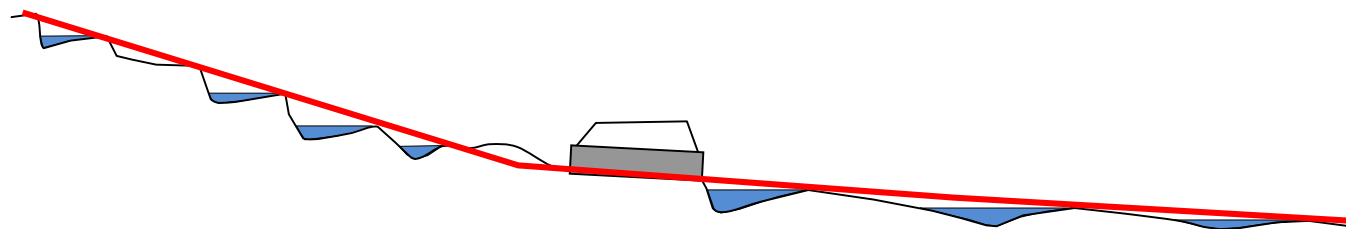
Cross Sections

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- Site Risk Assessment: Vertical Adjustment Potential



Site Assessment:

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Characteristics

Longitudinal Profile

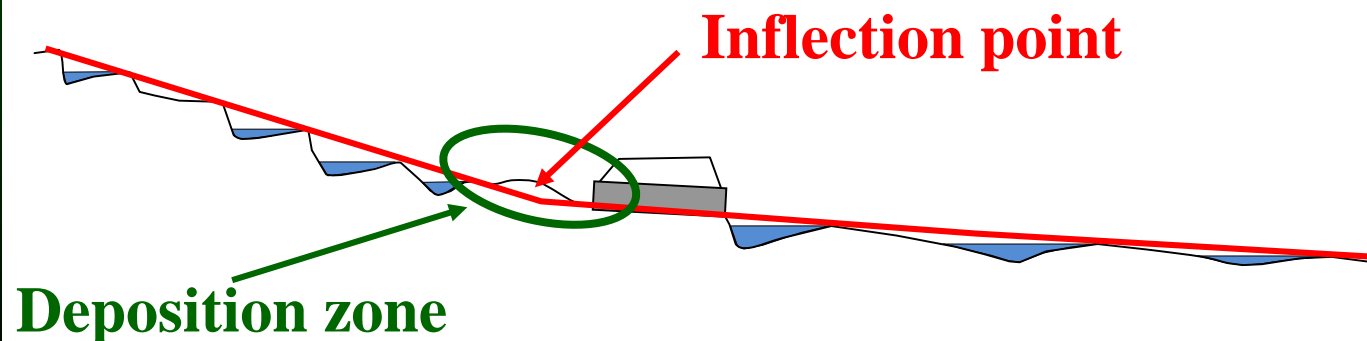
Cross Sections

Bed/Bank Sediments
and Characteristics

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Site Risk Assessment

- Site Risk Assessment: Vertical Adjustment Potential



Site Assessment:

Planform
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Longitudinal Profile

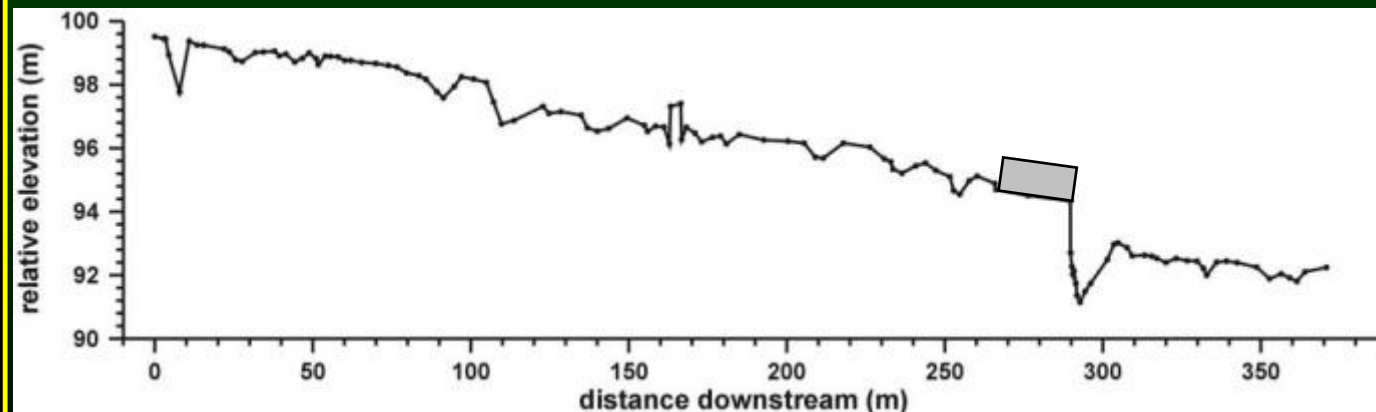
Cross Sections

Bed/Bank Sediments
and Characteristics

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Site Risk Assessment

- Site Risk Assessment:
Headcut Potential



Site Assessment:

Planform
Characteristics

Longitudinal Profile

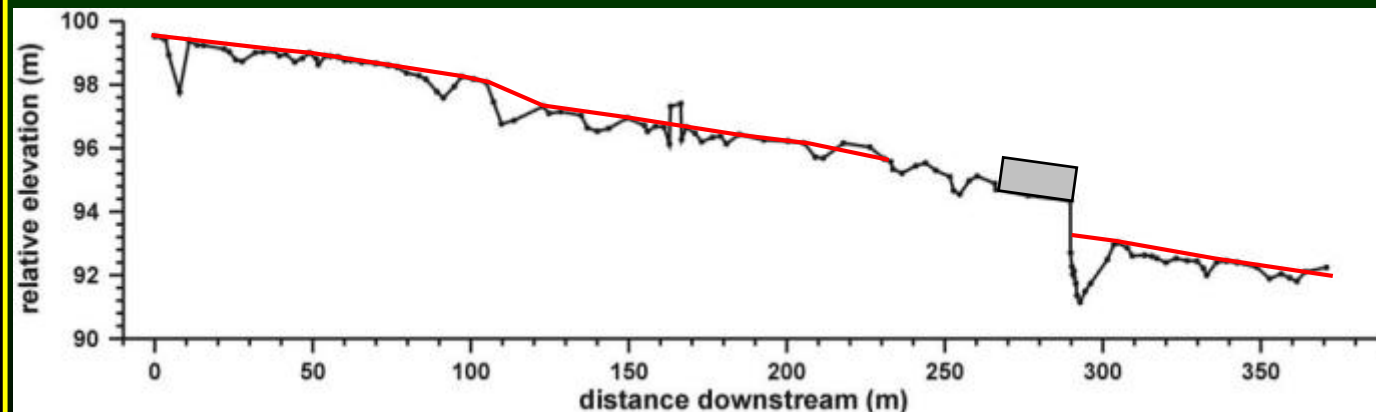
Cross Sections

Bed/Bank Sediments
and Characteristics

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Site Risk Assessment

- Site Risk Assessment:
Headcut Potential



Site Assessment:

Planform
Characteristics

Longitudinal Profile

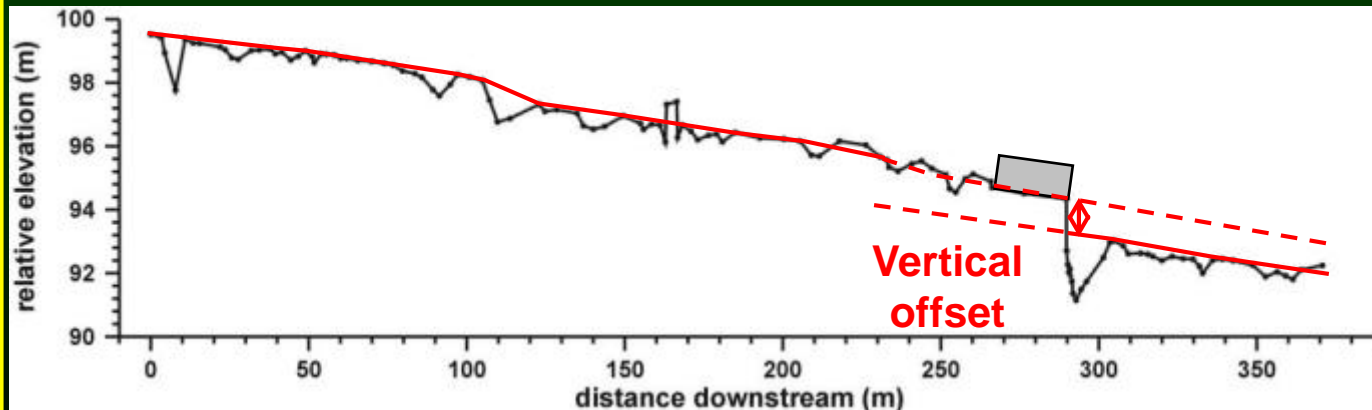
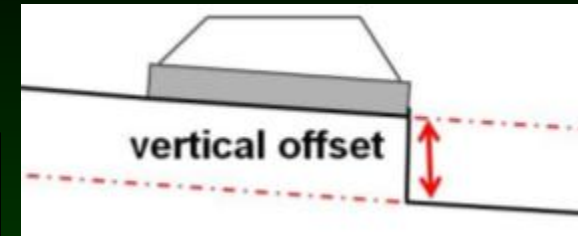
Cross Sections

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- Site Risk Assessment:
Headcut Potential



Site Assessment:

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Longitudinal Profile

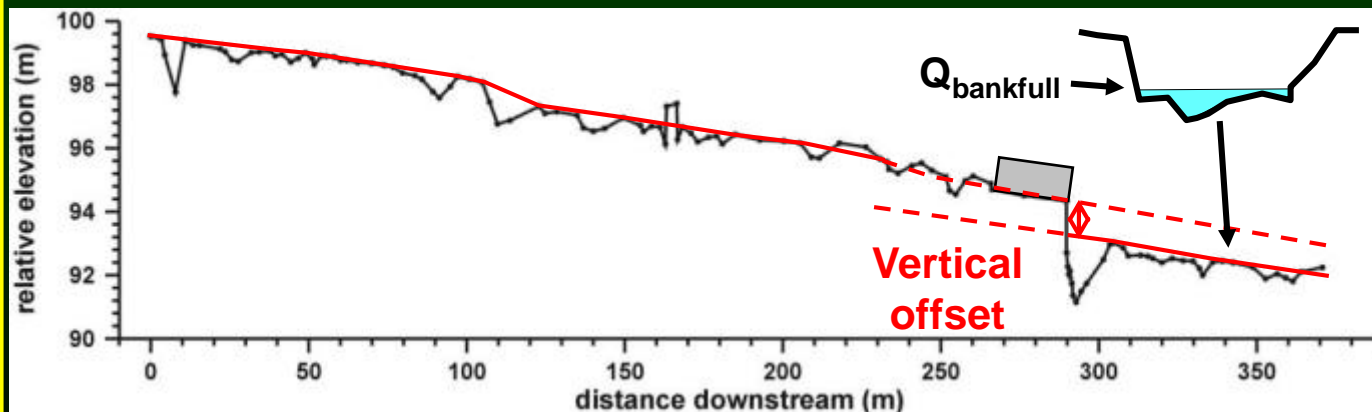
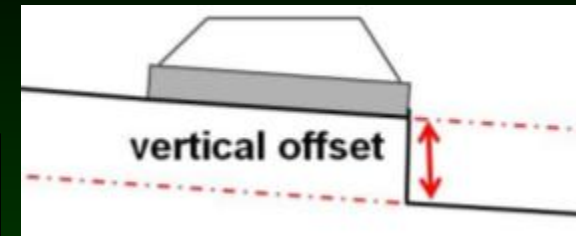
Cross Sections

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and Characteristics

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Site Risk Assessment

- Site Risk Assessment:
Headcut Potential



Site Assessment:

Planform
Characteristics

Longitudinal Profile

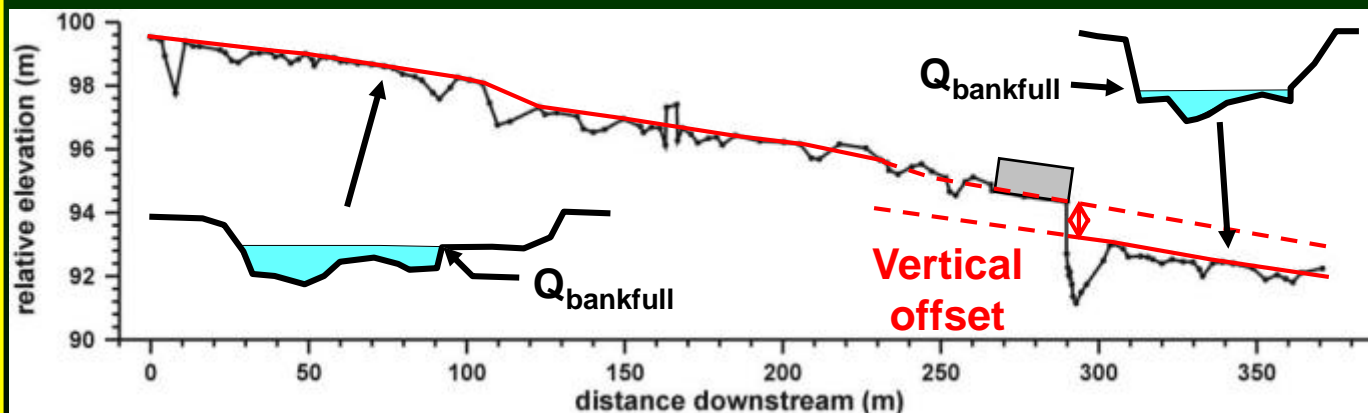
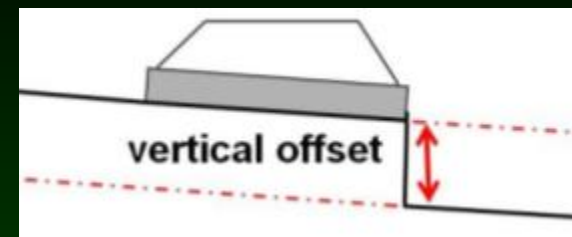
Cross Sections

Bed/Bank Sediments
and Characteristics

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Investigation

Site Risk Assessment

- Site Risk Assessment:
Headcut Potential



Watershed Review

Site Assessment

Stream Simulation Design

Final Design/Contract Preparation

Construction

Monitoring

Site Assessment:

Planform Characteristics

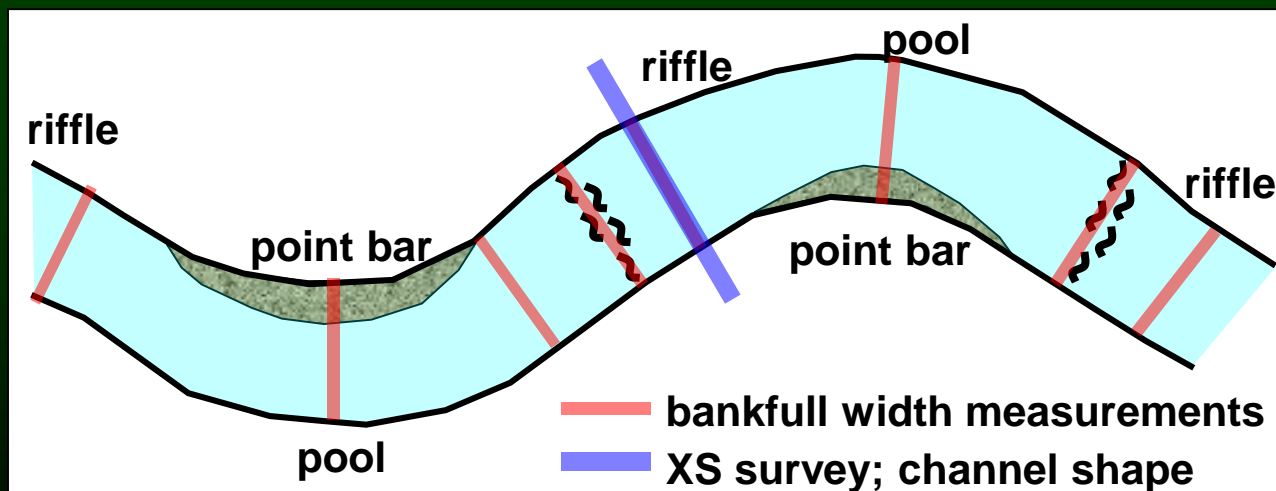
Longitudinal Profile

Cross Sections

Bed/Bank Sediments and Characteristics

Geotechnical Investigation

Site Risk Assessment



Site Assessment:

Planform
Characteristics

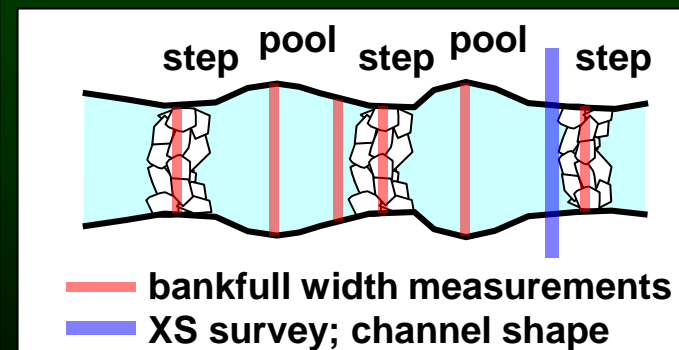
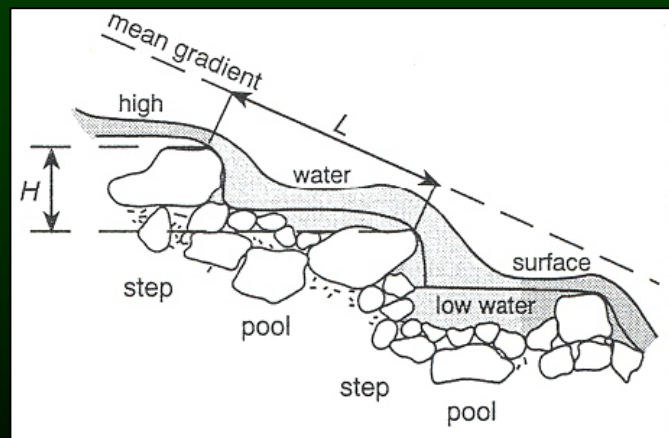
Longitudinal Profile

Cross Sections

Bed/Bank Sediments
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Investigation

Site Risk Assessment



Site Assessment:

Planform
Characteristics

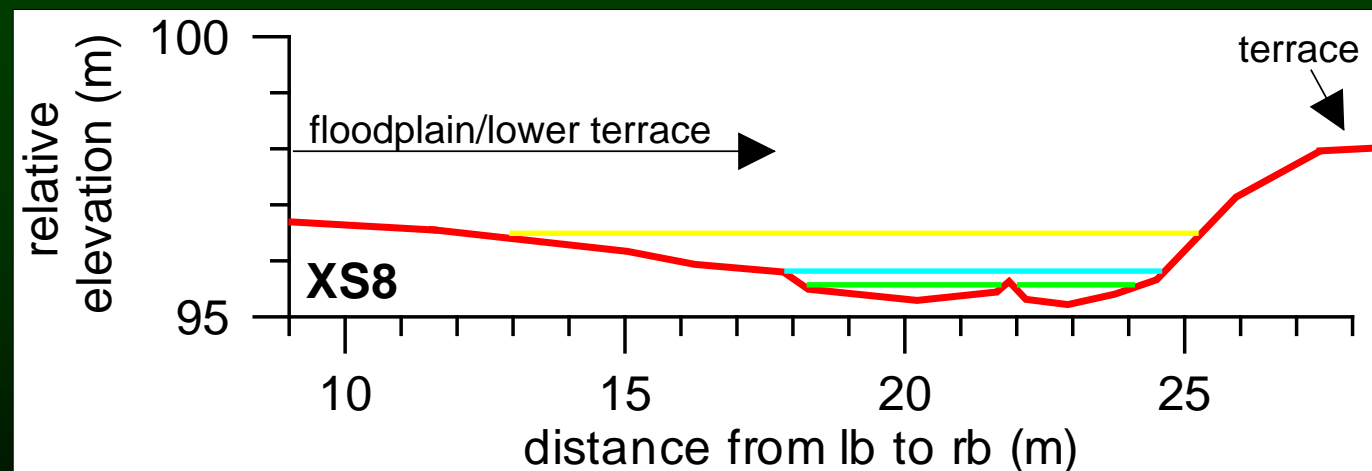
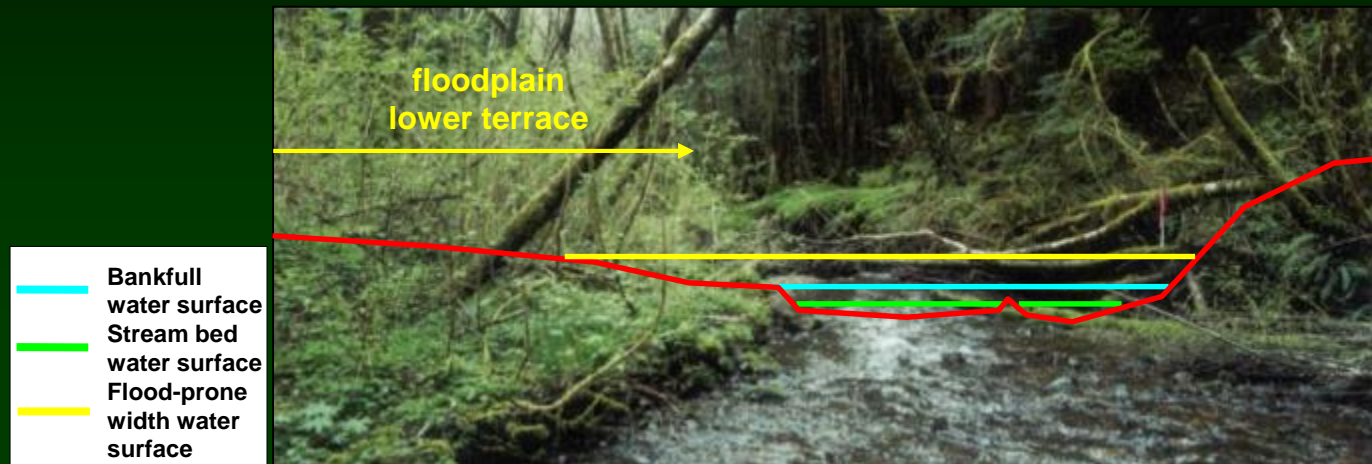
Longitudinal Profile

Cross Sections

Bed/Bank Sediments
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Geotechnical
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Site Risk Assessment



Site Assessment:

Planform
Characteristics

Longitudinal Profile

Cross Sections

Bed/Bank Sediments
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Site Risk Assessment

- Site Risk Assessment:
Floodplain Conveyance &
Connectivity



Site Assessment:

Planform
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Geotechnical
Investigation

Site Risk Assessment

- Site Risk Assessment:
Floodplain Conveyance &
Connectivity



Site Assessment:

Planform
Characteristics

Longitudinal Profile

Cross Sections

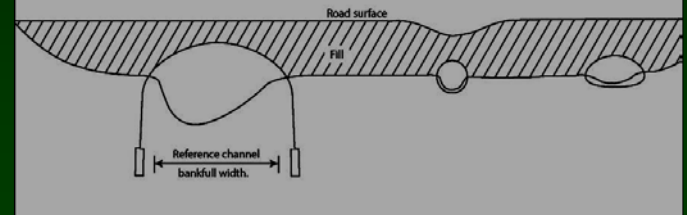
Bed/Bank Sediments
and Characteristics

Geotechnical
Investigation

Site Risk Assessment

- Site Risk Assessment:
Floodplain Conveyance &
Connectivity

- bankfull width sized culvert
- floodplain culverts



Site Assessment:

Planform
Characteristics

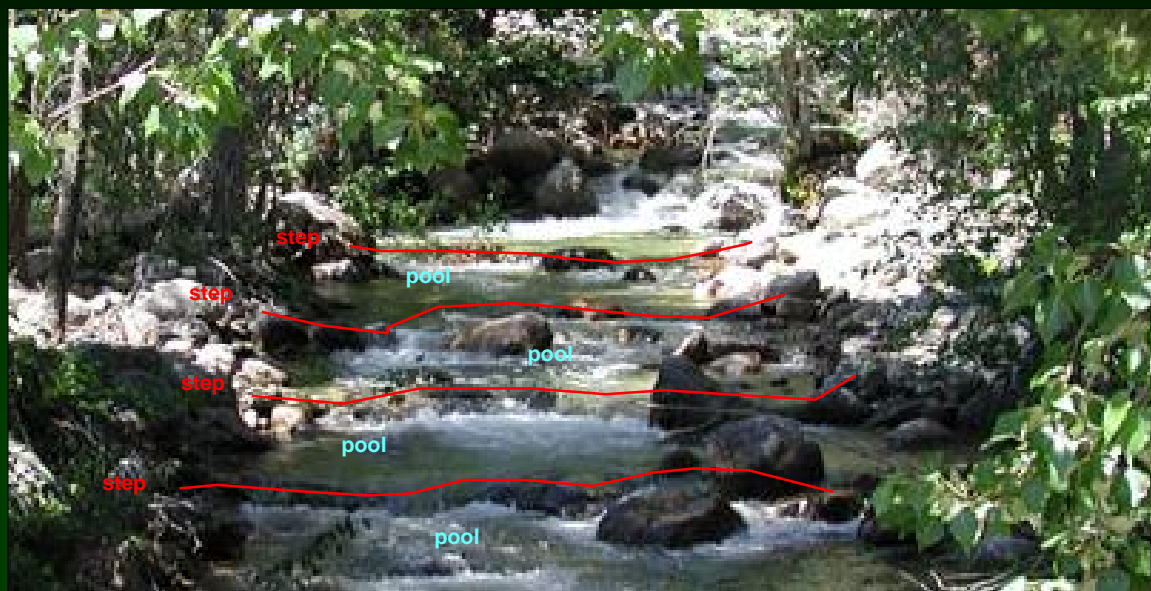
Longitudinal Profile

Cross Sections

Bed/Bank Sediments
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Site Assessment:

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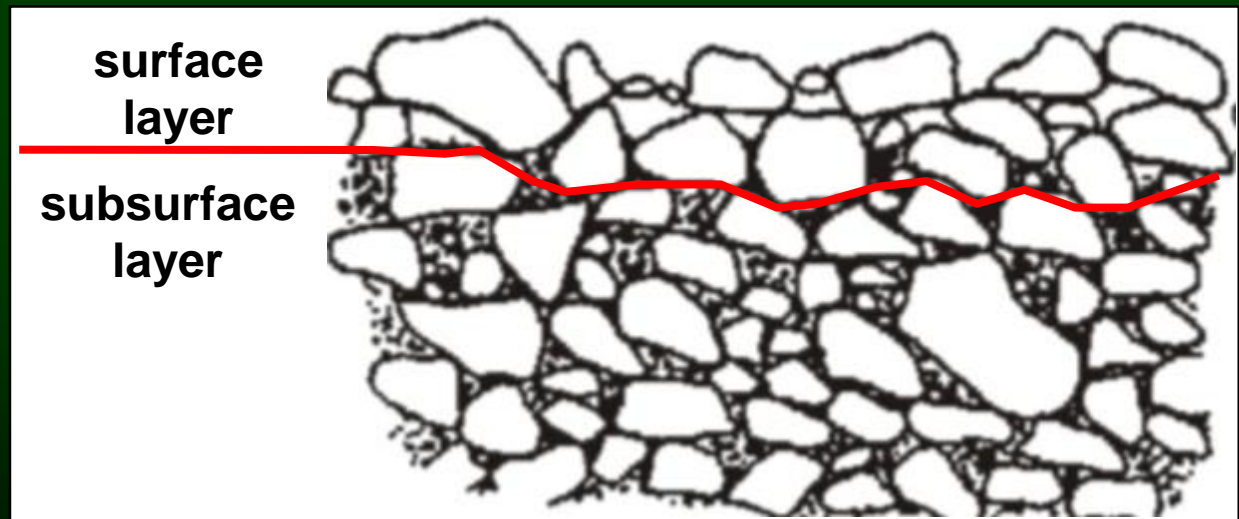
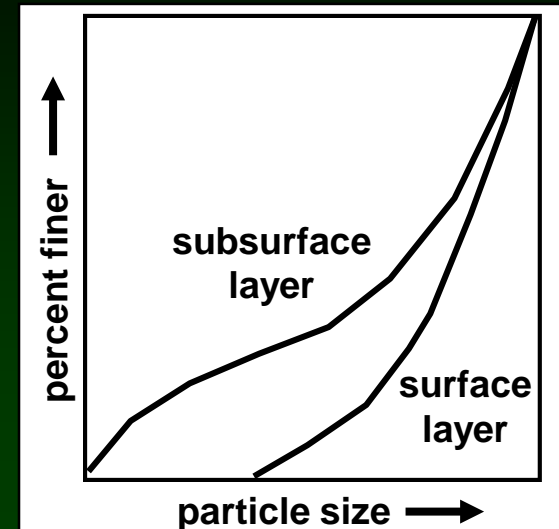
Longitudinal Profile

Cross Sections

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Channel bed sediments vary with depth; greater percentage of fines in the subsurface

Site Assessment:

Planform
Characteristics

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