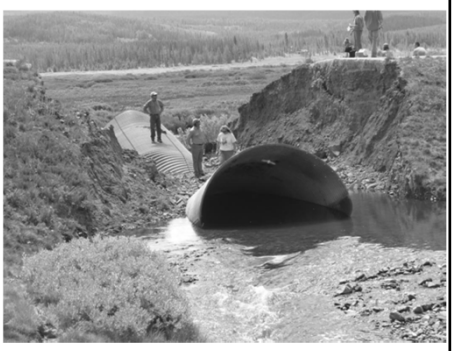
Historical Perspective

Rout N.F Colorado



Historical Perspective | Stream Simulation

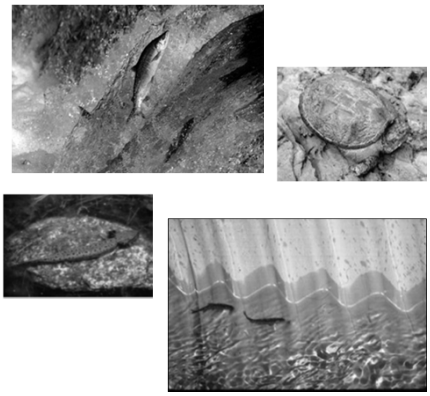
NFS System:

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

Historical Perspective | Stream Simulation

Ecological Impacts:

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



This is a Solvable Problem !

Historical Perspective | Stream Simulation

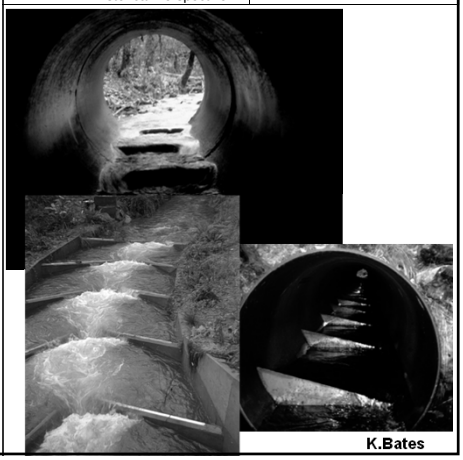
HISTORICAL FIXES:

Hydraulic Designs

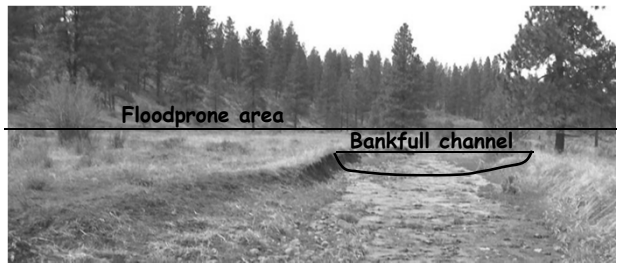
Baffles

Weirs

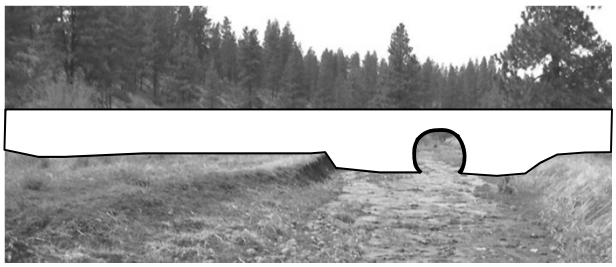
Fishways



K.Bates

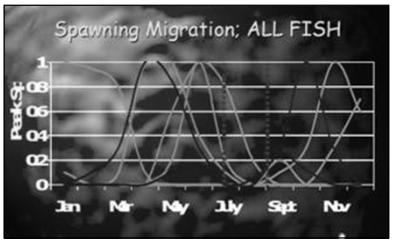


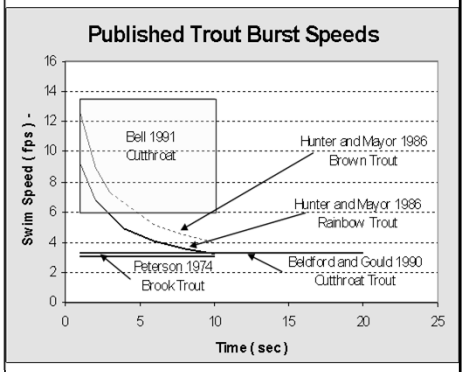
Natural channel with
- Bankfull channel
- Flood plain
- Ecological processes



- Ecological solutions at Road Crossings +

Hydraulic Design - Objectives
- Pass flood flows
- Pass target species at certain flows

	Historical Perspective	Stream Simulation
Hydraulic Design Parameters Biological - Species, Timing - Ability Hydrology - Low Passage Q - High Passage Q Hydraulics - Roughness - Velocity, Depth - Turbulence	 	

	Historical Perspective	Stream Simulation
Hydraulic Design Parameters Biological - Species, Timing - Ability Hydrology - Low Passage Q - High Passage Q Hydraulics - Roughness - Velocity, Depth - Turbulence		

Hydraulic Design Parameters

Biological
- Species, Timing
- Ability

Hydrology
- Low Passage Q
- High Passage Q

Hydraulics
- Roughness
- Velocity, Depth
- Turbulence

Historical Perspective | Stream Simulation

California	Alaska	Washington	NMFS
High Hydraulic Design Flow			
• 100-year flood	• 50% 100-year flood	• 100-year flood	• 100-year flood
High Fish Design Flow			
• 10% exceedance discharge for migratory period, or • 5% annual exceedance discharge	• Q_1D_2 $Q_2D_2 = 0.4 \times Q_2$	• 10% exceedance discharge for migratory period	• 1% exceedance for migratory period (adults), 10% annual exceedance (juveniles), or • 50% of 2-year flood • Discharge of the cross sectional area of active channel
Low Fish Design Flow			
• 50% annual exceedance discharge	• None Required • Match existing stream conditions	• 2-year, 7-day low flow	• 50% annual exceedance (adults) • 95% annual exceedance (juveniles)

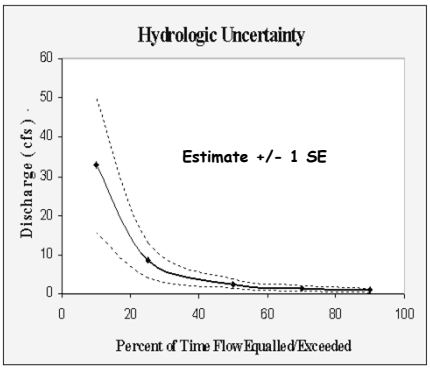
Hydraulic Design Parameters

Biological
- Species, Timing
- Ability

Hydrology
- Low Passage Q
- High Passage Q

Hydraulics
- Roughness
- Velocity, Depth
- Turbulence

Historical Perspective | Stream Simulation



Hydraulic Design Parameters

Biological
- Species, Timing
- Ability

Hydrology
- Low Passage Q
- High Passage Q

Hydraulics
- Roughness
- Velocity, Depth
- Turbulence

Historical Perspective | Stream Simulation

- Hyraulically model flow conditions (1-D)
- Roughness: Culvert, bed material
- Balancing Act
  - Minimize velocity
  - Maximize depth
  - Can accidentally create a turbulence barrier

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

Hydraulic Design Parameters

Biological
- Species, Timing
- Ability

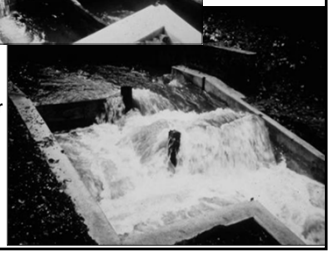
Hydrology
- Low Passage Q
- High Passage Q

Hydraulics
- Roughness
- Velocity, Depth
- Turbulence

Historical Perspective | Stream Simulation

Hydraulic designs heavily depend of increased roughness

Roughness can convert a velocity barrier into a turbulence barrier.



Historical Perspective | Stream Simulation

Hydraulic Designs

Bare Culverts

Baffles and Weirs

Roughened Channels

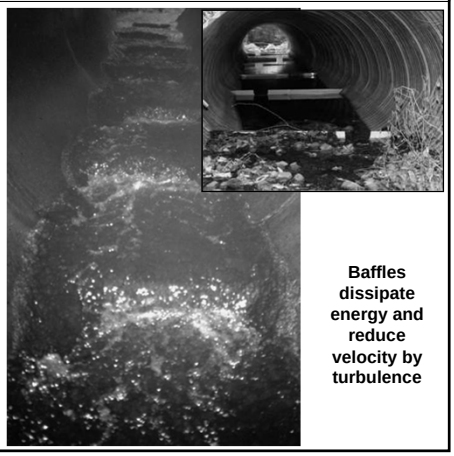
Historical Perspective | Stream Simulation

Hydraulic Designs

Bare Culverts

Baffles and Weirs

Roughened Channels



Baffles dissipate energy and reduce velocity by turbulence

Historical Perspective | Stream Simulation

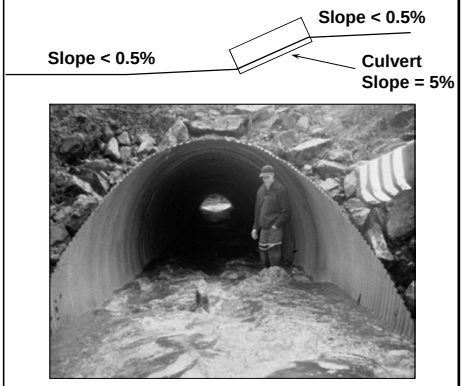
Hydraulic Designs

Bare Culverts

Baffles and Weirs

Roughened Channels

Sand-bedded channel



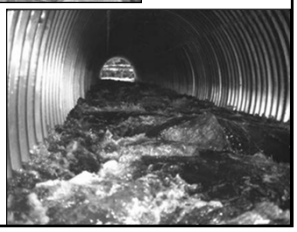
Historical Perspective | Stream Simulation

Hydraulic Designs

Bare Culverts

Baffles and Weirs

Roughened Channels



Historical Perspective | Stream Simulation

Hydraulic Designs

Bare Culverts

Baffles and Weirs

Roughened Channels

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October 2010

U.S. Department of Transportation
Federal Highway Administration

Hydraulic Engineering Circular No. 26, First Edition

CULVERT DESIGN FOR AQUATIC ORGANISM PASSAGE

Historical Perspective | Stream Simulation

Hydraulic Designs

Bare Culverts

Baffles and Weirs

Roughened Channels

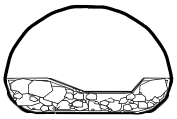
When the bird and the book disagree, always believe the bird.

- James Audubon

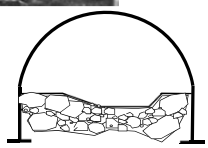
Historical Perspective | Stream Simulation

Stream Simulation

Driven by:
- Ecology
- Geomorphology
- Hydrology



Enclosed Pipe Arch



Bottomless Arch

Stream Simulation Design Elements

- Reference reach
  - Simulate natural channel
  - Bankfull cross section shape and dimensions
  - Channel slope
  - Channel structure
- Geomorphic design
  - Fits with and in equilibrium with adjacent reaches
  - Dynamically sustained over a broad range of flows
  - "Mobile bed in stable channel"

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Simple Stream Simulation Example

North Thompson Creek
White River National Forest, Colorado

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Introduction:

36 – inch culvert

30+ years old

Aggraded inlet

Here's How We Started…

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Introduction:

Bankfull width +

Natural streambed

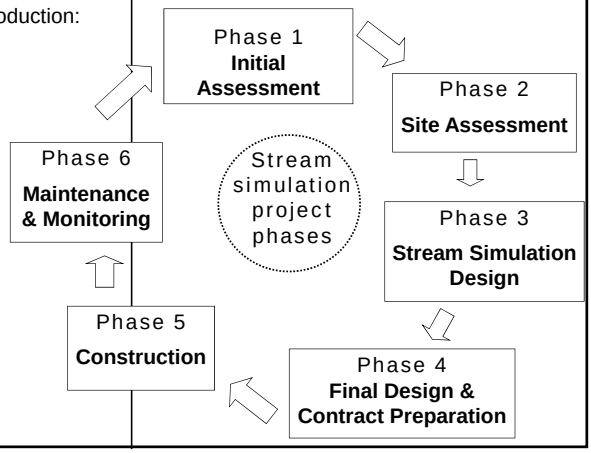
Continuous profile

Risk-free road

Here's How We Finished…

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Introduction:



Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 1 - Initial Assessment:

Road Context
- System Road
- Oil/Gas Traffic
- Timber Sales
- Heavy Rec Use

Resource Values

Watershed-Scale Risk Factors

Site-Scale Risk Factors

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

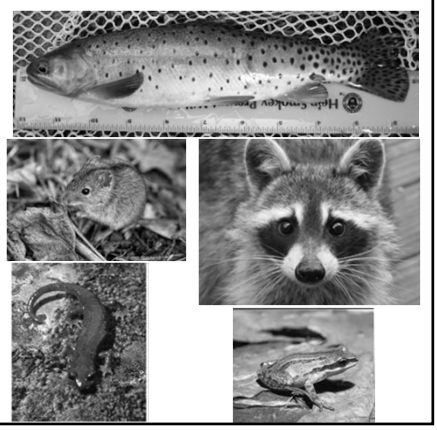
Phase 1 - Initial Assessment:

Road Context

Resource Values
- Brook Trout
- Cutthroat Trout
- Many Unknowns

Watershed-Scale Risk Factors

Site-Scale Risk Factors



Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 1 - Initial Assessment:

Road Context

Resource Values

Watershed-Scale Risk Factors
- Sandstone geology
- Basalt cap
- Beetle Kill

Site-Scale Risk Factors

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

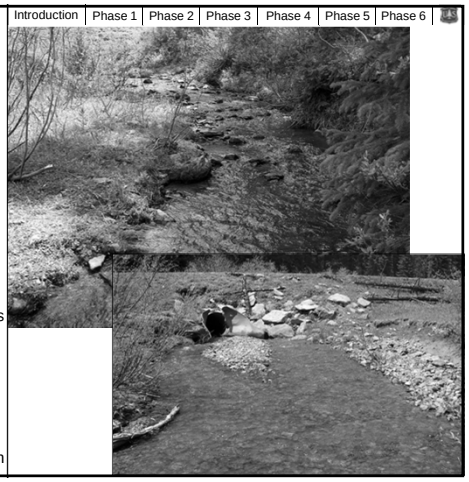
Phase 1 - Initial Assessment:

Road Context

Resource Values

Watershed-Scale Risk Factors

Site-Scale Risk Factors
- Channel stability
- Vertical adjustment
- Headcut potential
- Lateral adjustment
- Floodplain Inundation



Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 2 - Site Assessment:

Site Recon & Sketch

Collect Site Data

Preliminary Geotech Investigation

Upstream Channel

Accessible floodplain

Aggraded inlet. Sediment wedge upstream

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 2 - Site Assessment:

Site Recon & Sketch

Collect Site Data

Preliminary Geotech Investigation

Downstream Channel

Minor scour pool, no bedrock

Less sinuous but floodplain present

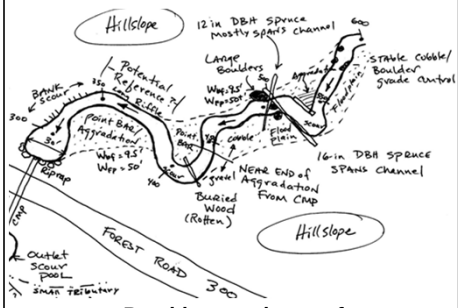
Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 2 - Site Assessment:

Site Recon & Sketch

Collect Site Data

Preliminary Geotech Investigation



Provides good notes for Winter design sessions.

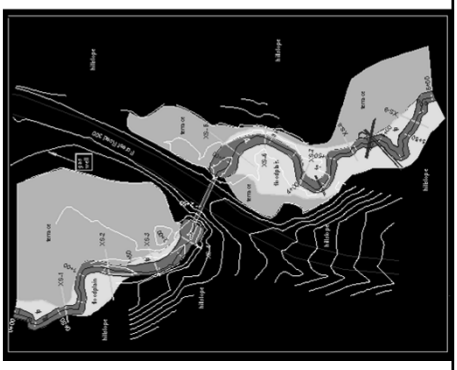
Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 2 - Site Assessment:

Site Recon & Sketch

Collect Site Data
- Site Topography
- Longitudinal Profile
- Cross Sections

Preliminary Geotech Investigation



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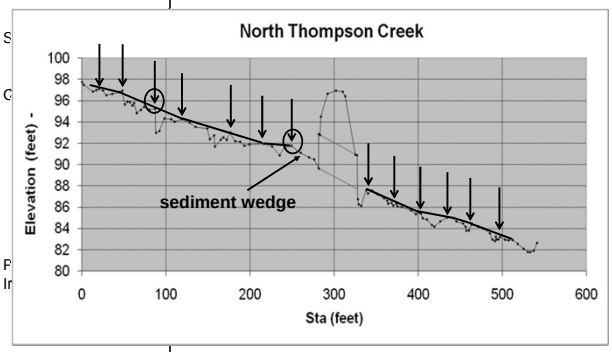
Phase 2 - Site Assessment:



Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

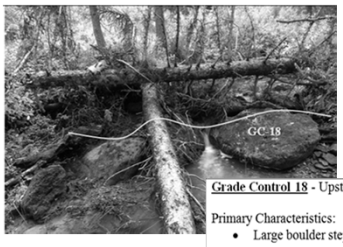
Phase 2 - Site Assessment:

Site Sketch

Collect Site Data
- Site Topography
- Longitudinal Profile
- Cross Sections

Preliminary Geotech Investigation

Grade Controls



Grade Control 18 - Upstream view

Primary Characteristics:
- Large boulder step
- Spans channel
- Particles large, interlocked and embedded into channel
- Particles much coarser than adjacent stream

Stability Rating - H

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

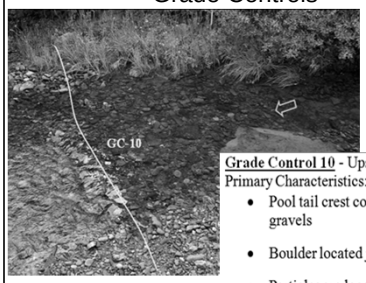
Phase 2 - Site Assessment:

Site Sketch

Collect Site Data
- Site Topography
- Longitudinal Profile
- Cross Sections

Preliminary Geotech Investigation

Grade Controls



Grade Control 10 - Upstream view

Primary Characteristics:
- Pool tail crest composed of gravels
- Boulder located just upstream
- Particles are loose and part of sediment wedge above culvert inlet
- Particles similar in size to adjacent stream

Stability Rating - L

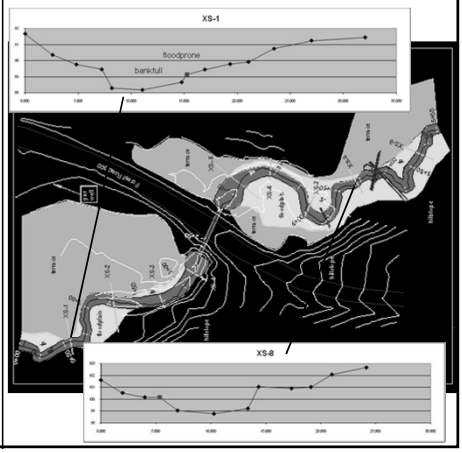
Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 2 - Site Assessment:

Site Recon & Sketch

Collect Site Data
- Site Topography
- Longitudinal Profile
- Cross Sections

Preliminary Geotech Investigation



Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 3 - Design:

Project Alignment

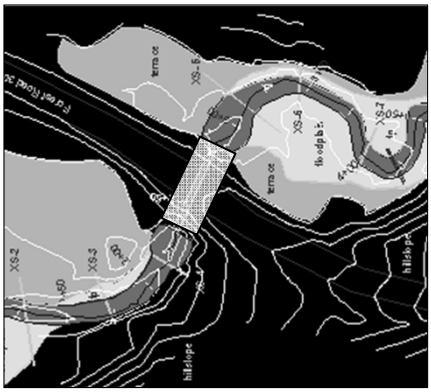
Project Profile

Reference Reach

Structure Width

Streambed Stability & Mobility

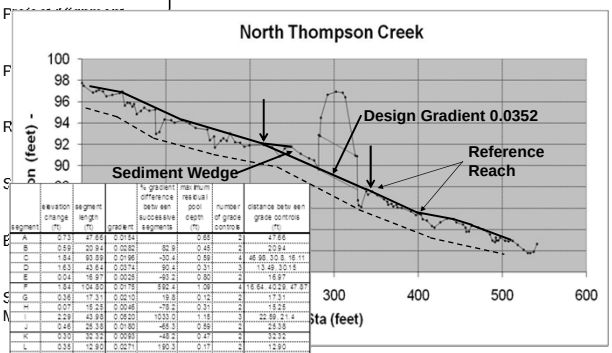
New Structure Alignment



Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 3 - Design:

Project Design Profile



segment	elevation change (ft)	segment length (ft)	gradient	% gradient difference between successive segments	maximum residual pool depth (ft)	number of grade controls	distance between grade controls (ft)
A	0.73	47.66	0.0154		0.66	2	47.66
B	0.59	20.94	0.0283	82.9	0.45	2	20.94
C	1.84	93.89	0.0196	-30.4	0.59	4	46.96, 30.8, 16.11
D	1.63	43.64	0.0374	90.4	0.31	3	13.49, 30.15
E	0.04	16.97	0.0025	-93.2	0.80	2	16.97
F	1.84	104.80	0.0176	592.4	1.06	4	16.64, 42.29, 47.87
G	0.36	17.31	0.0210	19.8	0.12	2	17.31
H	0.07	15.25	0.0046	-78.2	0.31	2	15.25
I	2.29	43.95	0.0520	1033.0	1.15	3	22.69, 21.4
J	0.46	26.38	0.0180	-65.3	0.59	2	26.38
K	0.00	32.32	0.0000	-48.2	0.47	2	32.32
L	0.35	12.90	0.0271	190.3	0.17	2	12.90
culvert	1.92	44.88	0.0428				

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 3 - Design:

Project Alignment

Project Profile

Reference Reach
- Grade Controls
- Sediment Sizes

Structure Width

Streambed Stability & Mobility

Reference Reach

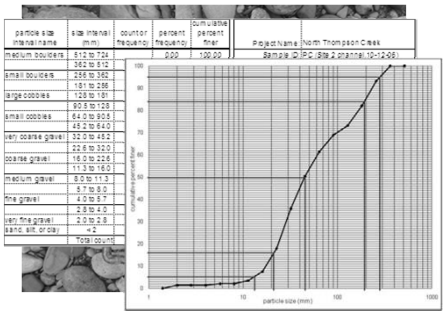
First Selection Criterion is Gradient Match

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 3 - Design:

- Project Alignment
- Project Profile
- Reference Reach
  - Grade Controls
  - Sediment Sizes
- Structure Width
- Streambed Stability & Mobility

Pebble Count



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			
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			

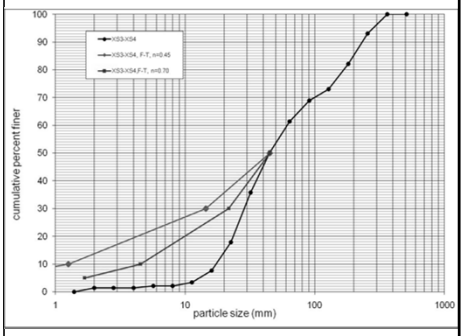
Project Name	North Thompson Creek
Sample ID	PC (Site 2 channel, 10-12-06)

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 3 - Design:

- Project Alignment
- Project Profile
- Reference Reach
  - Grade Controls
  - Sediment Sizes
- Structure Width
- Streambed Stability & Mobility

Sediment Design –
From Reference Reach Data



Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 3 - Design:

- Project Alignment
- Project Profile
- Reference Reach
  - Grade Controls
  - Sediment Sizes
- Structure Width
- Streambed Stability & Mobility

Key Pieces Too…

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 3 - Design:

- Project Alignment
- Project Profile
- Reference Reach
  - Grade Controls
  - Sediment Sizes
- Structure Width
- Streambed Stability & Mobility

Key Pieces Quantified

XS3-XS4 (Segment D Reference Reach). Summary of 10 largest particles for the key pieces.

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	400	340	230	315	1.18	blocky to tabular-shaped; subangular
2	740	410	170	372	1.80	tabular- to disc-shaped; subangular
3	420	330	185	278	1.21	blocky to tabular-shaped; subangular
4	500	340	300	371	1.47	tabular- to disc-shaped; subangular
5	500	350	110	268	1.43	tabular- to disc-shaped; subangular
6	360	250	180	243	1.44	tabular- to disc-shaped; subangular
7	750	430	230	420	1.74	tabular- to disc-shaped; subangular
8	350	244	50	200	1.37	blocky to tabular-shaped; subangular
9	370	270	130	235	1.37	blocky to tabular-shaped; subangular
10	490	380	240	355	1.29	blocky to tabular-shaped; subangular
average				306	1.43	

d95 percentile (mm)	746	421	273
d84 percentile (mm)	634	397	236
d50 percentile (mm)	445	340	165
d16 percentile (mm)	364	262	119

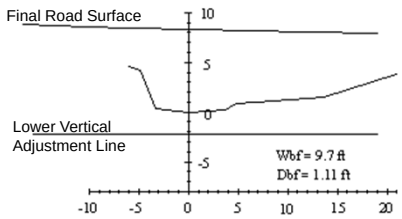
average cubic dimension of d95 percentile	441
average cubic dimension of d84 percentile	390
average cubic dimension of d50 percentile	292
average cubic dimension of d16 percentile	225

Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 3 - Design:

- Project Alignment
- Project Profile
- Reference Reach
- Structure Selection
  - Adequate Width
  - Embedment Depth
  - Minimum Cover
- Streambed Stability & Mobility

Structure Selection –
Shape from Reference Reach XSECT

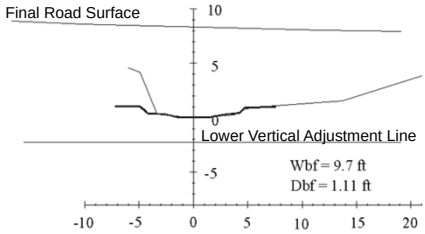


Introduction | Phase 1 | Phase 2 | Phase 3 | Phase 4 | Phase 5 | Phase 6

Phase 3 - Design:

- Project Alignment
- Project Profile
- Reference Reach
- Structure Selection
  - Adequate Width
  - Embedment Depth
  - Minimum Cover
- Streambed Stability & Mobility

Structure Selection –
Idealized (easy to build) XSECT



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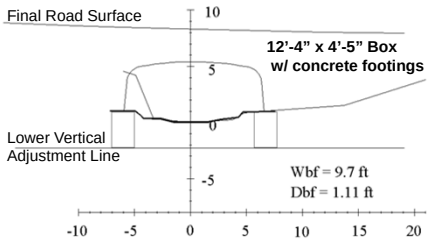
Phase 3 - Design:

- Project Alignment
- Project Profile
- Reference Reach
- Structure Selection
  - Adequate Width
  - Embedment Depth
  - Minimum Cover
- Streambed Stability & Mobility

Structure Selection –
Trial Structure Types



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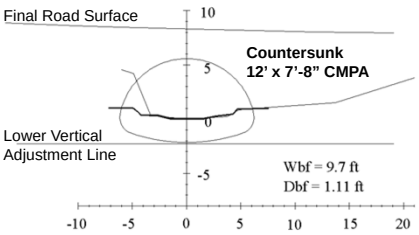

Final choice: Choose 12' x 7'-8" CMPA
- Economical shape, large opening, embedment depth
- No poured concrete, fast installation

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Phase 3 - Design:

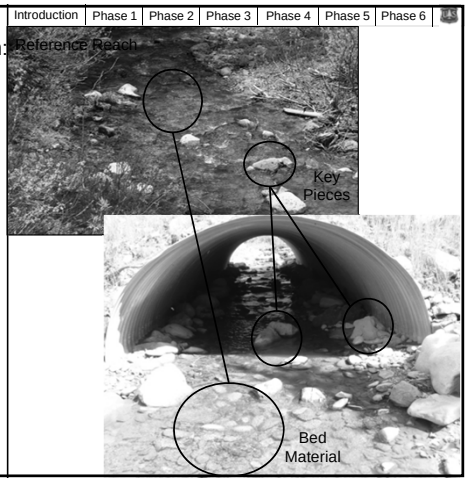
Project Alignment

Project Profile

Reference Reach

Structure Selection

Streambed Stability & Mobility



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Phase 4 – Final Design and Contract Prep:

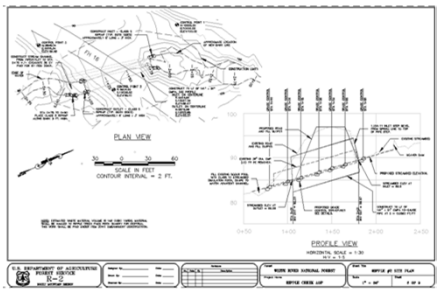
Plans and Specs

Quantities and Costs

Contract Documents

Bid Package

Plan & Profile Sheets



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Phase 4 – Final Design and Contract Prep:

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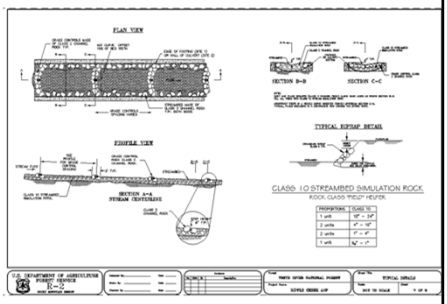
Typical Details



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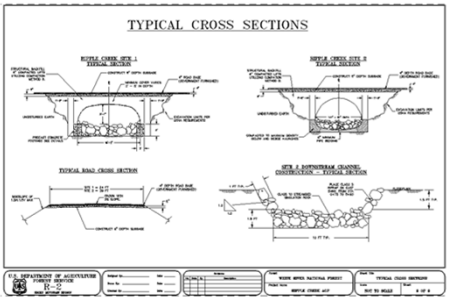

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Phase 5 – Construction:

Pre-Construction

Inspection

Documentation

- Dewatering
- Removal of critters and block net

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Phase 5 – Construction:

Pre-Construction

Inspection

Documentation

Verify Construction Staking

Schedule Road Closures (avoid bypass roads)

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Phase 5 – Construction:

Pre-Construction

Inspection

Documentation

Building the Bed

Moved Material with Bobcat

Positive Air Flow

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Phase 5 – Construction:

Pre-Construction

Inspection

Documentation

Bed Material & Grade Control

Reference Reach

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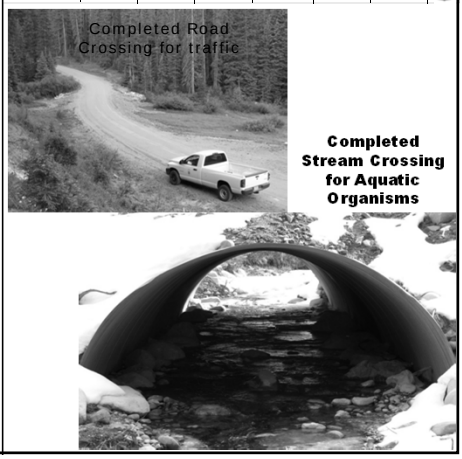
Phase 5 – Construction:

Pre-Construction

Inspection

Documentation



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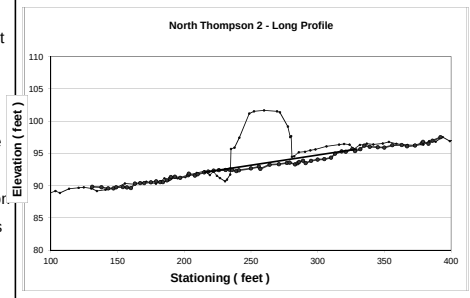
Phase 6 – Monitoring:

Implementation – built as designed?

Effectiveness

- Longitudinal Profile
- Bed Material
- Width/Cross Section
- Hydraulic Variables



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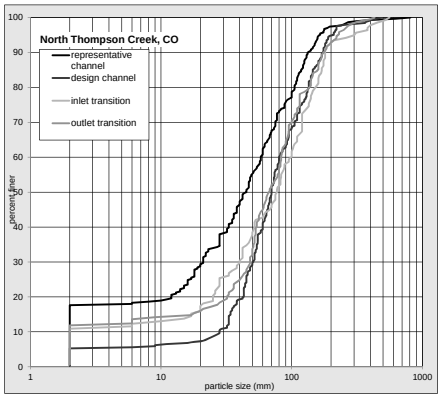

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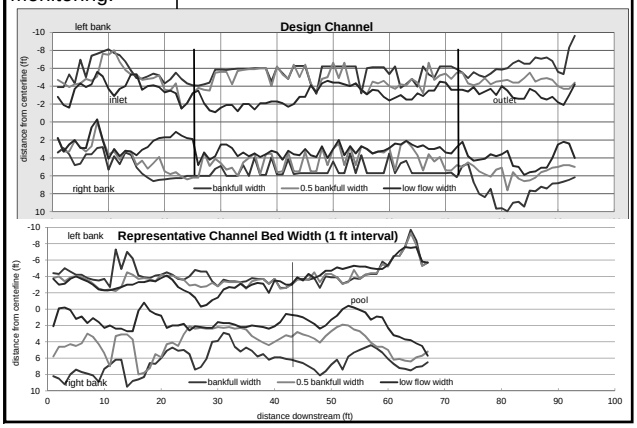
Phase 6 – Monitoring:



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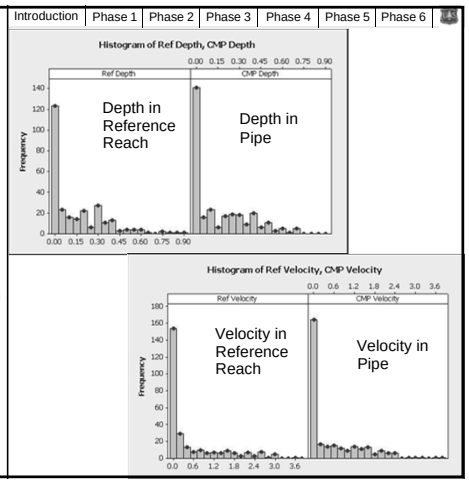
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