$$d = \frac{\tau}{\gamma S}$$

How:

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$$d = \frac{\tau}{\gamma S}$$

Standards for ecologically successful river restoration

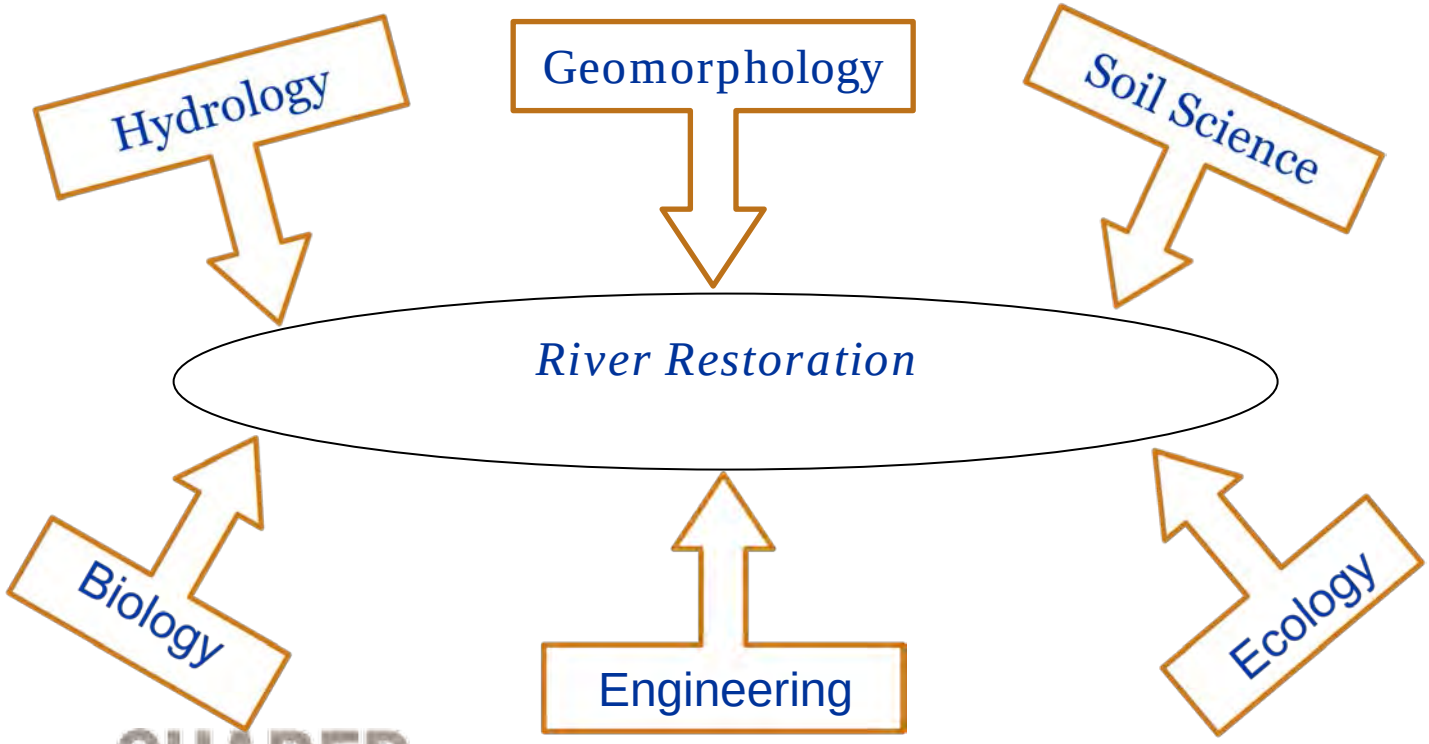
Palmer et al., Journal of Applied Ecology, 2005, 42, 208–217

1. design of an ecological river restoration project should be based on a specified guiding image of a more dynamic, healthy river
2. river's ecological condition must be measurably improved
3. river system must be more self-sustaining and resilient to external perturbations so that only minimal follow-up maintenance is needed
4. during the construction phase, no lasting harm should be inflicted on the ecosystem
5. pre- and post-assessment must be completed and data made publicly available

$$d = \frac{\tau}{\gamma S}$$

Stream Restoration is a Systematic Process

1. Planning & Assessment
2. Engineering
3. Construction
4. Monitoring, Maintenance, Adjustments



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$$d = \frac{\tau}{\gamma S}$$

Channel Morphology & Floodplain Connection

1. Dimension (Bankfull & Flood Flow)
2. Pattern (Meander)
3. Profile (Bed Profile)
4. Floodplain Connection

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$$d = \frac{\tau}{\gamma S}$$

$$d = \frac{\tau}{\gamma s}$$

$$d = \frac{\tau}{\gamma S}$$

Stream Design Approaches

1. Threshold Channel
2.

Threshold	Alluvial
Bed & banks immobile	Active transport
Easier to model & design Bed & banks must only be strong enough	Harder to design Requires a balance between transport capacity & sediment supply

d. Analytical Models

3. Combination of Methods

$$d = \frac{\tau}{\gamma S}$$

Stream Design Approaches

United States
Department of
Agriculture

Natural
Resources
Conservation
Service

Part 654 Stream Restoration Design
National Engineering Handbook

Chapter 8 Threshold Channel Design

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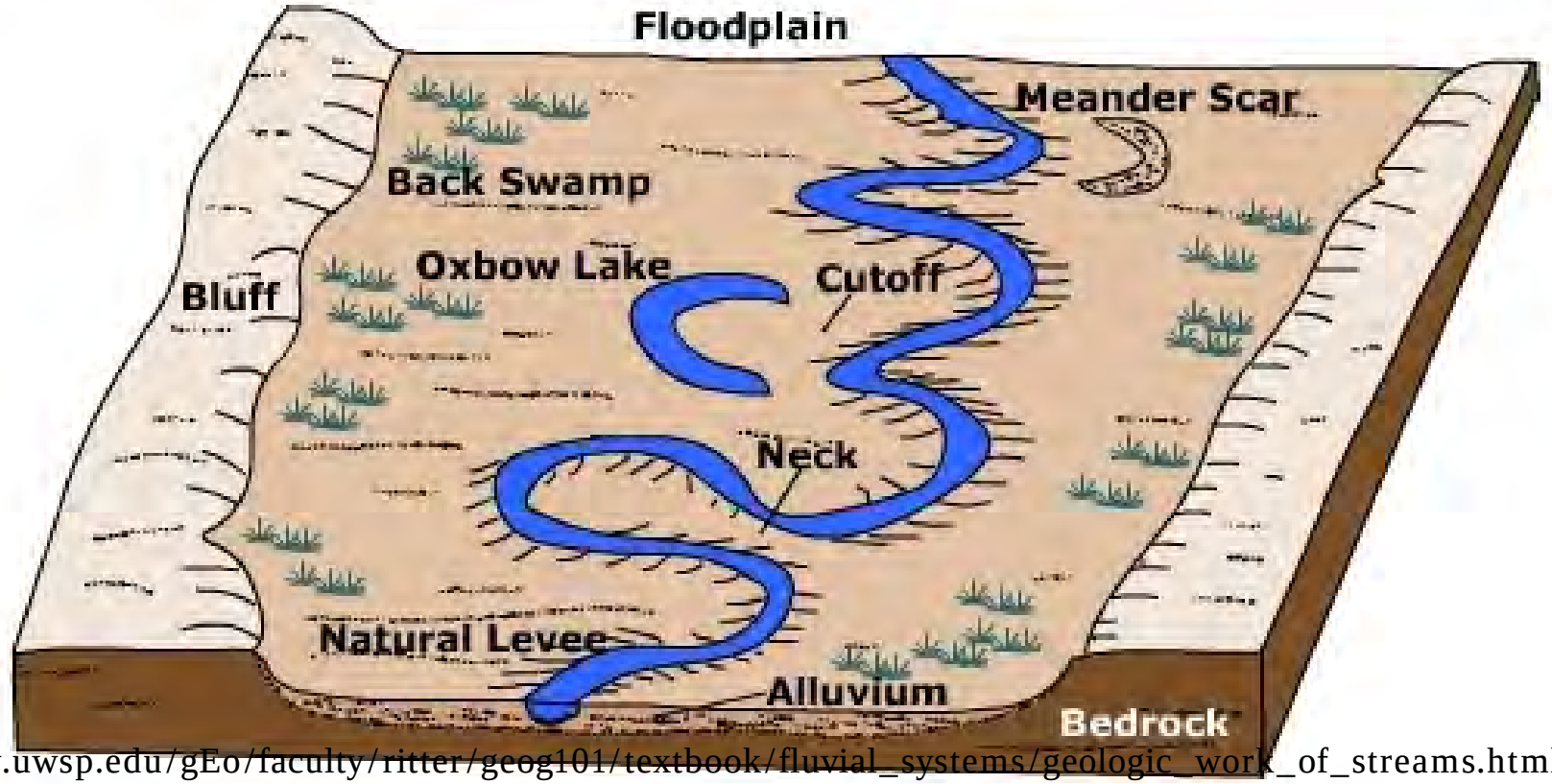
Alluvial River Processes

Rivers that have reached base level develop broad valleys by erosion caused by meandering channels. The stream channel cuts through and redistributes its sediment or **alluvium** that lines the area bordering the stream.



http://www.uwsp.edu/gEo/faculty/ritter/geog101/textbook/fluvial_systems/geologic_work_of_streams.html

Alluvial Channels *(not threshold)*

1. Movable boundary systems (“natural” streams)
2. *Complex design approach*: assess sediment continuity and channel performance for a range of flows
3. *Dependent variables:* Width, Depth, Slope, Planform
4. *Independent variables:* Sediment inflow, Water inflow, Bank composition
5. <u>Empirical</u> & <u>Analytical</u> approaches should be used concurrently

$$d = \frac{\tau}{\gamma S}$$

Stream Design Approaches

United States
Department of
Agriculture

**Natural
Resources
Conservation
Service**

**Part 654 Stream Restoration Design
National Engineering Handbook**

Chapter 11

Rosgen Geomorphic Channel Design

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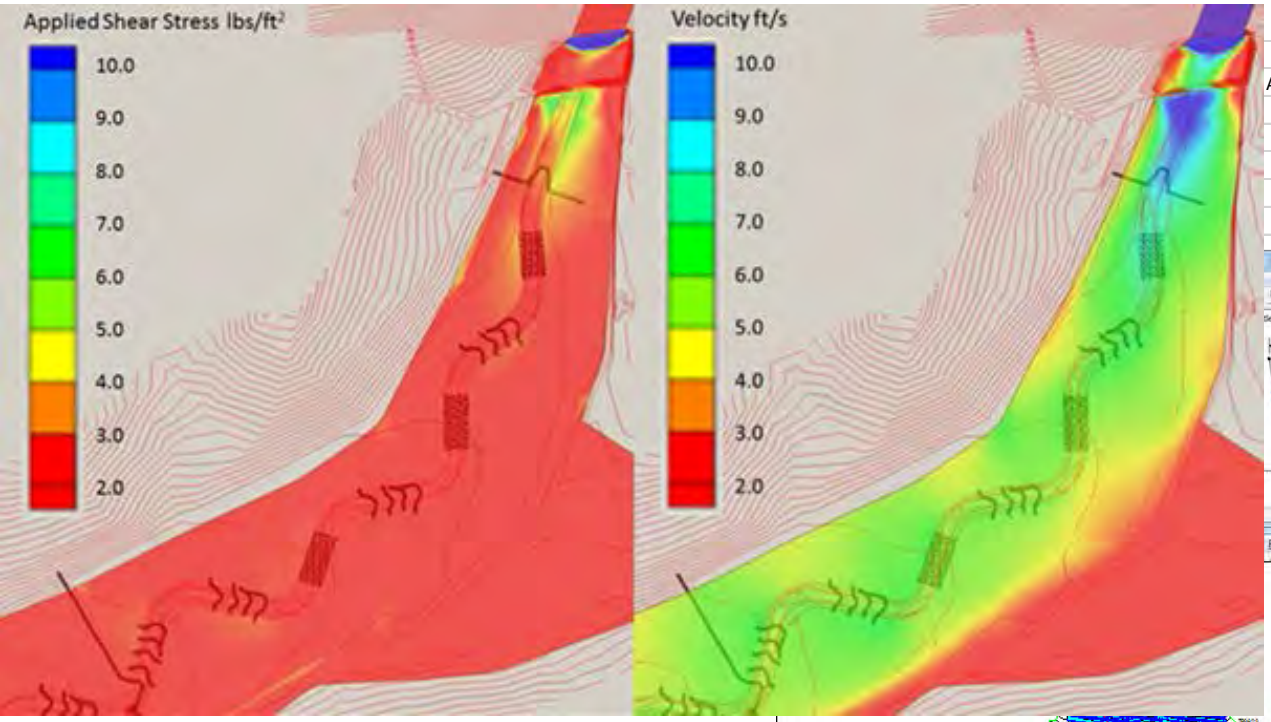
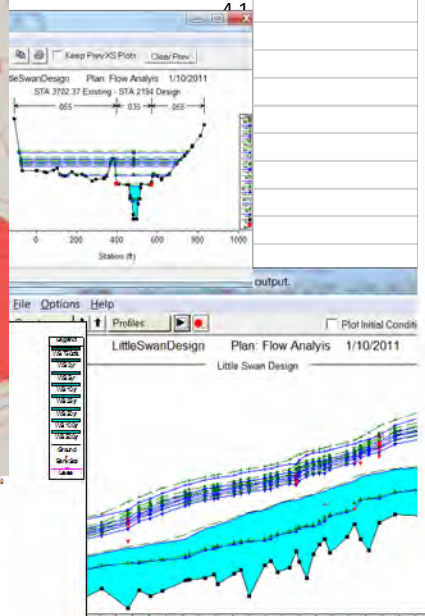
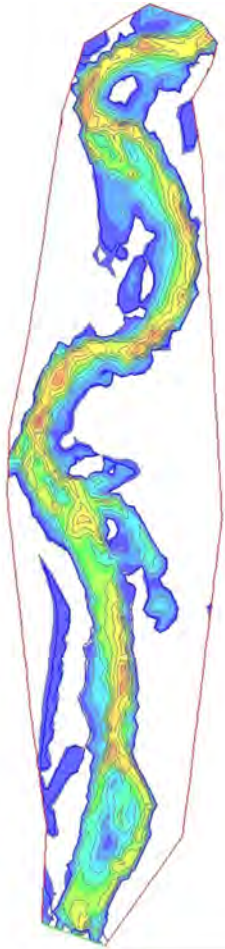
Hydraulic Modeling

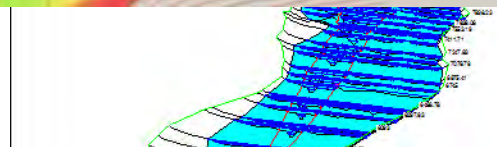
Hydraulic and Geomorphic modeling varies by design **Phase** and Objectives



Average Floodplain Velocity	Approximate Desig
4.4	
4.4	
4.0	
4.1	
4.0	



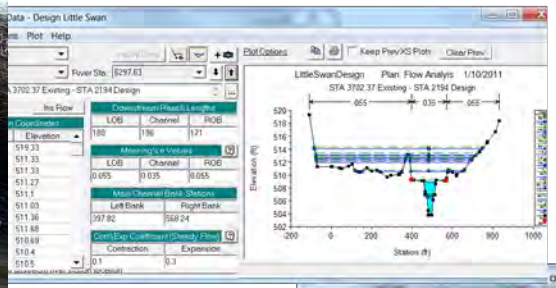


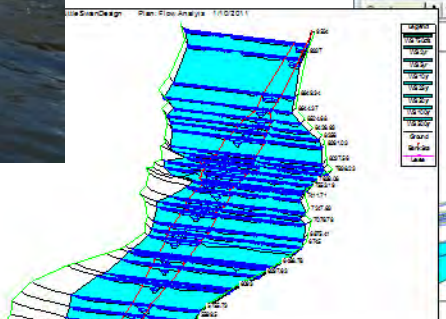


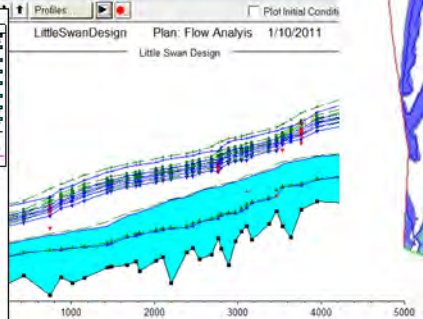
Definition Design

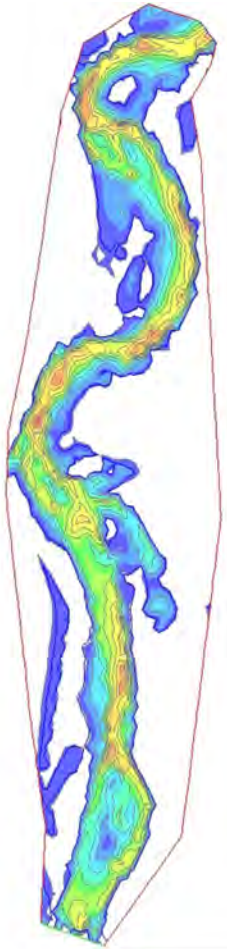
Hydraulic Modeling

Hydraulic and Geomorphic modeling varies by design Phase and **Objectives**









$$d = \frac{\tau}{\gamma S}$$

Hydrologic & Hydraulic Analysis

- Develop Regional Curves
- Gage Analysis
- Calculations – Regime Equations
- Field Calibration
  - Bar Sample
  - Riffle Pebble Count
  - Geomorphic Survey Data

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	Encampment River	Location:	XS3 Existing
Date: 10/20/2016	Stream Type: C3/4	Valley Type:	
Observers:	CB,JS,KO,MJG	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	231.66	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	3.04	d_{bkf} (ft)
Bankfull Riffle WIDTH	76.12	W_{bkf} (ft)	Wetted PERIMETER ~ $(2 * d_{bkf}) + W_{bkf}$	77.30	W_p (ft)
D_{84} at Riffle	168.69	Dia. (mm)	D_{84} (mm) / 304.8	0.55	D_{84} (ft)
Bankfull SLOPE	0.0040	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	3.00	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	5.43	R / D_{84}
Drainage Area	205.0	DA (m^2)	Shear Velocity $u^* = (gRS)^{1/2}$	0.622	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [2.83 + 5.66 * Log\{R / D_{84}\}] u^*$	4.34	ft / sec	1004.91	cfs
2. Roughness Coefficient: a) Manning's n from Friction Factor / Relativ Roughness (Figs. 2-18, 2-19) $u = 1.49*R^{2/3}*S^{1/2}/n$ $n =$ 0.044	4.44	ft / sec	1028.80	cfs
2. Roughness Coefficient: b) Manning's n from Stream Type (Fig. 2-20) $u = 1.49*R^{2/3}*S^{1/2}/n$ $n =$ 0.0395	4.96	ft / sec	1149.61	cfs
2. Roughness Coefficient: c) Manning's n from Jarrett (USGS): $u = 1.49*R^{2/3}*S^{1/2}/n$ $n = 0.39*S^{0.38}*R^{-0.16}$ Note: This equation is applicable to steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3 $n =$ 0.040	4.87	ft / sec	1128.88	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Darcy-Weisbach (Leopold, Wolman and Miller)	4.43	ft / sec	1025.89	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Chezy C	4.11	ft / sec	990.05	cfs
4. Continuity Equations: a) Regional Curves $u = Q / A$ Return Period for Bankfull Discharg Q = 0.0 year	n/a	ft / sec	n/a	cfs
4. Continuity Equations: b) USGS Gage Data $u = Q / A$	n/a	ft / sec	n/a	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure **"protrusion heights"** proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

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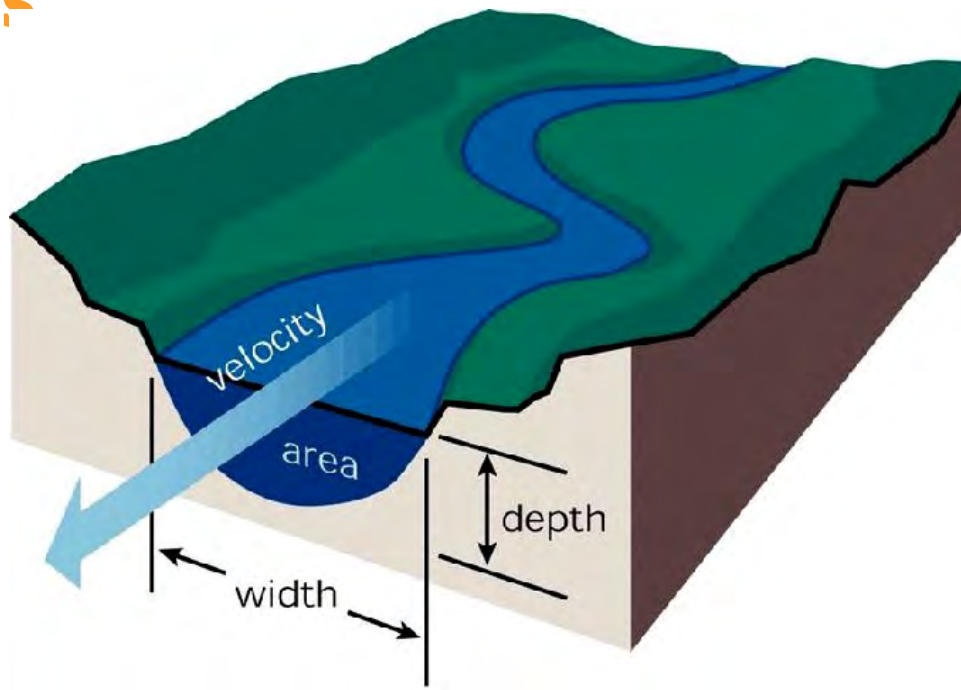
$$d = \frac{\tau}{\gamma s}$$

Hydrologic & Hydraulic Analysis

Velocity & Discharge



$Q = VA$ = Discharge (cfs)

V = Velocity (ft/s)

A = Cross-Section Area (ft^2)

V related to slope, channel shape, and channel roughness

Manning Formula

$$V = \frac{k}{n} R_h^{\frac{2}{3}} \cdot S^{\frac{1}{2}}$$

where:

V is the cross-sectional average velocity (ft/s, m/s)
k is a conversion constant equal to 1.486 for U.S. customary units or 1.0 for SI units
n is the Gauckler-Manning coefficient (independent of units)
R_h is the hydraulic radius (ft, m)
S is the slope of the water surface or the linear hydraulic head loss (ft/ft, m/m) ($S = h_f / L$)

$$R_h = \frac{A}{P}$$

where:

R_h is the hydraulic radius (m)
A is the cross sectional area of flow (m^2)
P is wetted perimeter (m)

$$d = \frac{\tau}{\gamma S}$$

Hydrologic & Hydraulic Analysis

Manning's n for Channels (Chow, 1959).

Type of Channel and Description	Minimum	Normal	Maximum
Natural streams - minor streams (top width at floodstage < 100 ft)			
1. Main Channels			
a. clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
[illegible]			
[illegible]			
[illegible]		

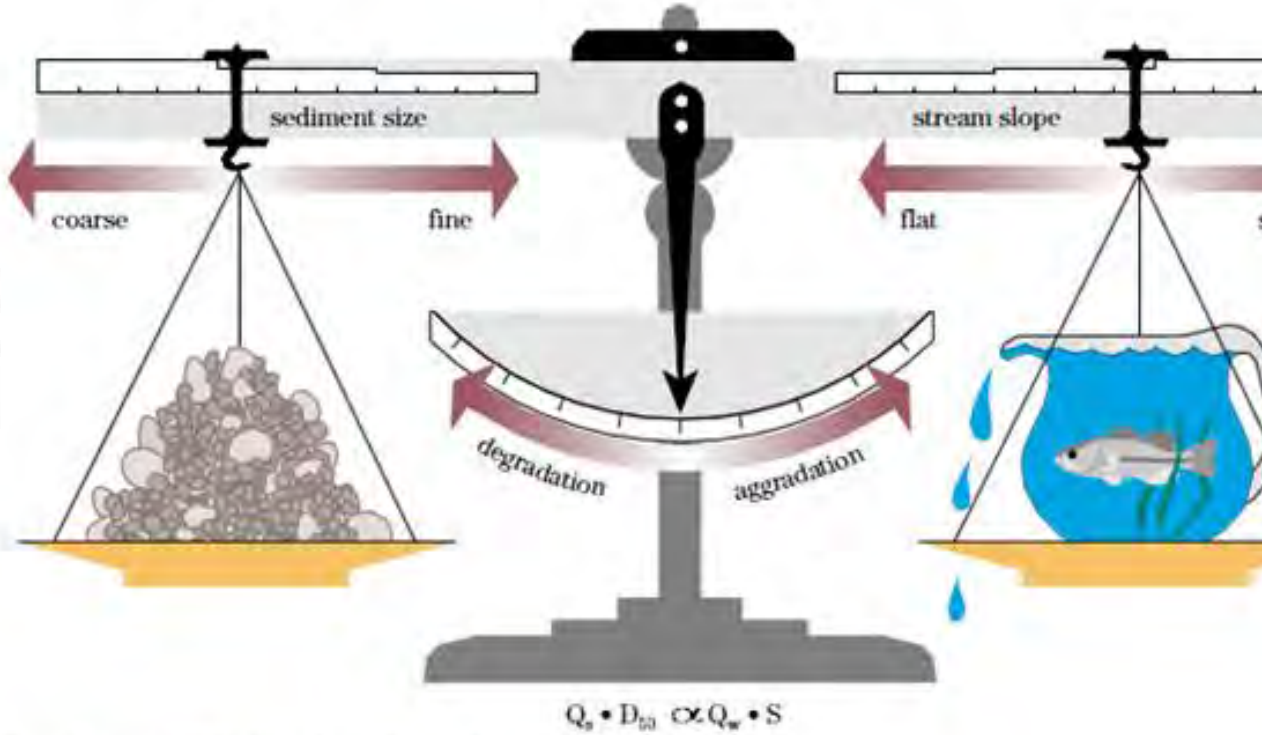
$$d = \frac{\tau}{\gamma S}$$

Sediment Transport in Alluvial Streams

Channels are Formed, Maintained and Altered by Two Things:

1) Flow
2) Sediment Loads

$$Q_s \cdot D_{50} \propto Q_w \cdot S$$



From Rosgen (1996), from Lane, Proceedings, 1955.
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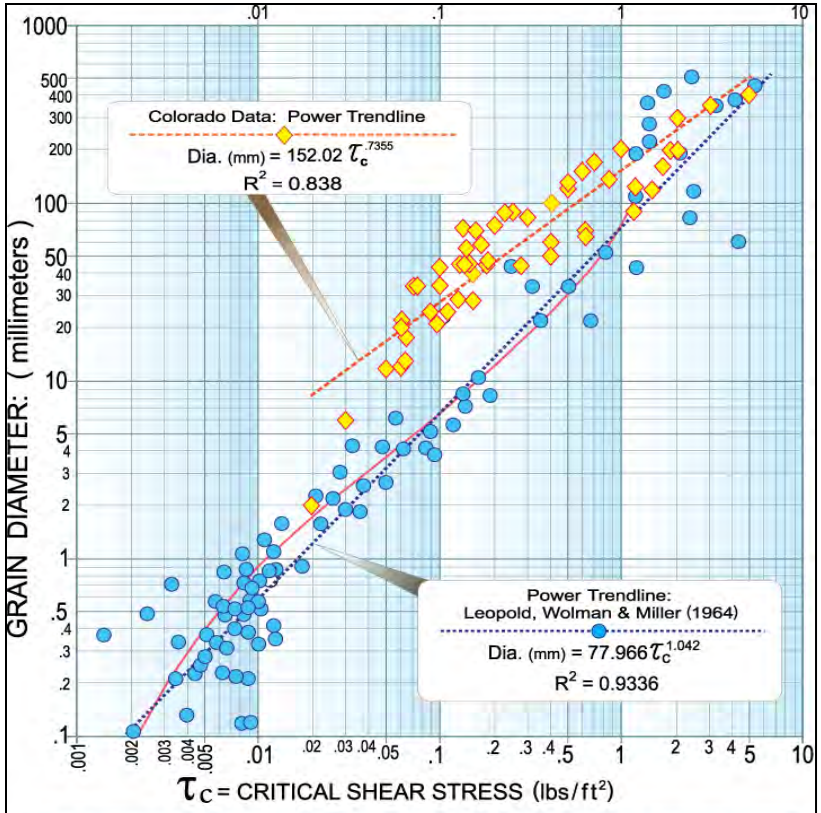
$$d = \frac{\tau}{\gamma S}$$

Sediment Transport in Alluvial Streams

Stream Load includes: dissolved + suspended + bedload

Capacity: max load that can be transported (associated with stream power)

Competence: largest size that can be transported (associated with shear stress)



Laboratory and field data on critical shear stress required to initiate movement of grains (Leopold, Wolman, & Miller, 1964). The solid line is the Shields curve of *the threshold of motion*; transposed from the Θ versus R_g form into the present form, in which critical shear stress is plotted as a function of grain diameter.

Leopold, Wolman & Miller (1964)
Colorado Data (Wildland Hydrology)

$$d = \frac{\tau}{\gamma S}$$

Shear Stress: *fluid force per unit area acting on the channel bed*

$\tau_{av} = \gamma\gamma\ R\ S$ = Average Shear Stress (lb/ft^2)

$\gamma\gamma$ = Unit Weight of Water = 62.4 lb/ft^3

R = Hydraulic Radius (ft) = A_{bkf} / P

S = Average Water Surface Slope (ft/ft)

A_{bkf} = Riffle Cross-Section Area (ft^2)

P = Wetted Perimeter (ft) = $W_{bkf} + 2*d_{bkf}$ (approx)

Unit Stream Power: *rate of energy loss to the channel bed per unit area*

$\omega_{av} = V\ \tau_{av}$ = Average Unit Stream Power (lb/ft/s)

V = Average Velocity (ft/s)

$$d = \frac{\tau}{\gamma S}$$

Calibrate Sediment Models
Measured Bed-load and Suspended

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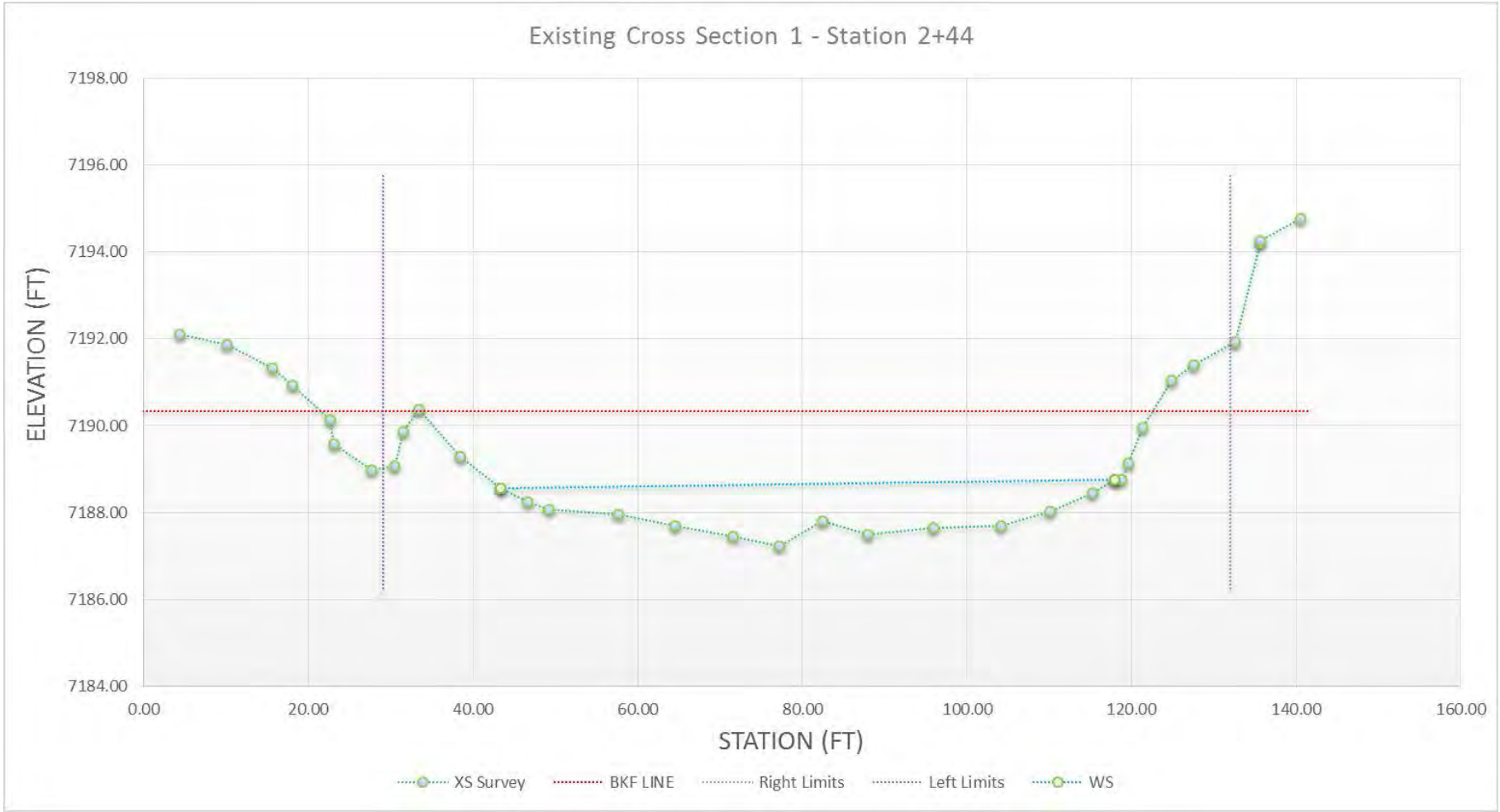
$$\mathbf{d} = \frac{\tau}{\gamma \mathbf{S}}$$

$$d = \frac{\tau}{\gamma S}$$

Case Study – Encampment River Oddfellows



WS ft	Depth Y ft	XS Area ft2	Top Width ft	V ft/s	Hydraulic Depth ft	Hydraulic Radius ft	Shear	Stream Power	Slope ft/ft	Q cfs
7190.66	2.33	190.33	104.18	4.63	1.83	1.79	0.73	3.38	0.0064	986.00

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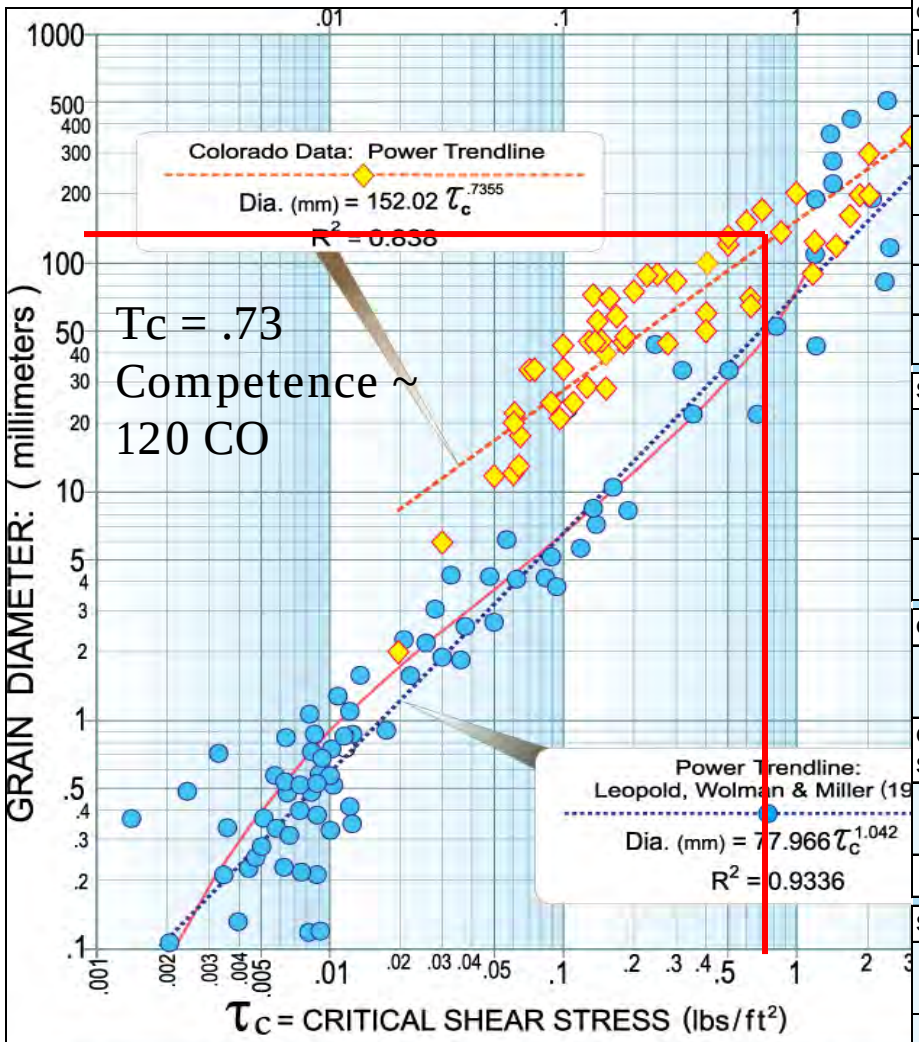
$$d = \frac{\tau}{\gamma S}$$

Case Study – Encampment River C



Laboratory and field data on critical shear stress required to init movement of grains (Leopold, Wolman, & Miller, 1964). The solid lin Shields curve of *the threshold of motion*; transposed from the Θ v form into the present form, in which critical shear stress is plott function of grain diameter.

Stream:	Encampment River		Stream Type:		
Location:	XS 1 - Existing		Valley Type:		
Observers:			Date:		

Enter Required Information for Existing Condition

79.3	D_{50}	Median particle size of riffle bed material (mm)			
51.2	$D_{50}^{\wedge}$	Median particle size of bar or sub-pavement sample (mm)			
0.591	D_{max}	Largest particle from bar sample (ft)	180	(mm)	304.8 mm/ft
0.00640	S	Existing bankfull water surface slope (ft/ft)			
1.83	d	Existing bankfull mean depth (ft)			
1.65	γ_s-γ/γ	Immersed specific gravity of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

1.55	$D_{50}/D_{50}^{\wedge}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/D_{50}^{\wedge})^{-0.872}$
2.27	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
0.019	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	2

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

2.83	d	Required bankfull mean depth (ft)	$d = \frac{\tau^*(\gamma_s - 1)D_{max}}{S}$ (use D_{max} in ft)

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.00988	S	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^*(\gamma_s - 1)D_{max}}{d}$ (use D_{max} in ft)

Check: ☐ Stable ☑ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

0.731		Bankfull shear stress $\tau = \gamma d S$ (lbs/ft²) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
Shields 56.23	CO 120.7	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
Shields 2.232	CO 1.258	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
Shields 5.59	CO 3.15	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
Shields 0.0195	CO 0.0110	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth

Check: ☐ Stable ☑ Aggrading ☐ Degrading

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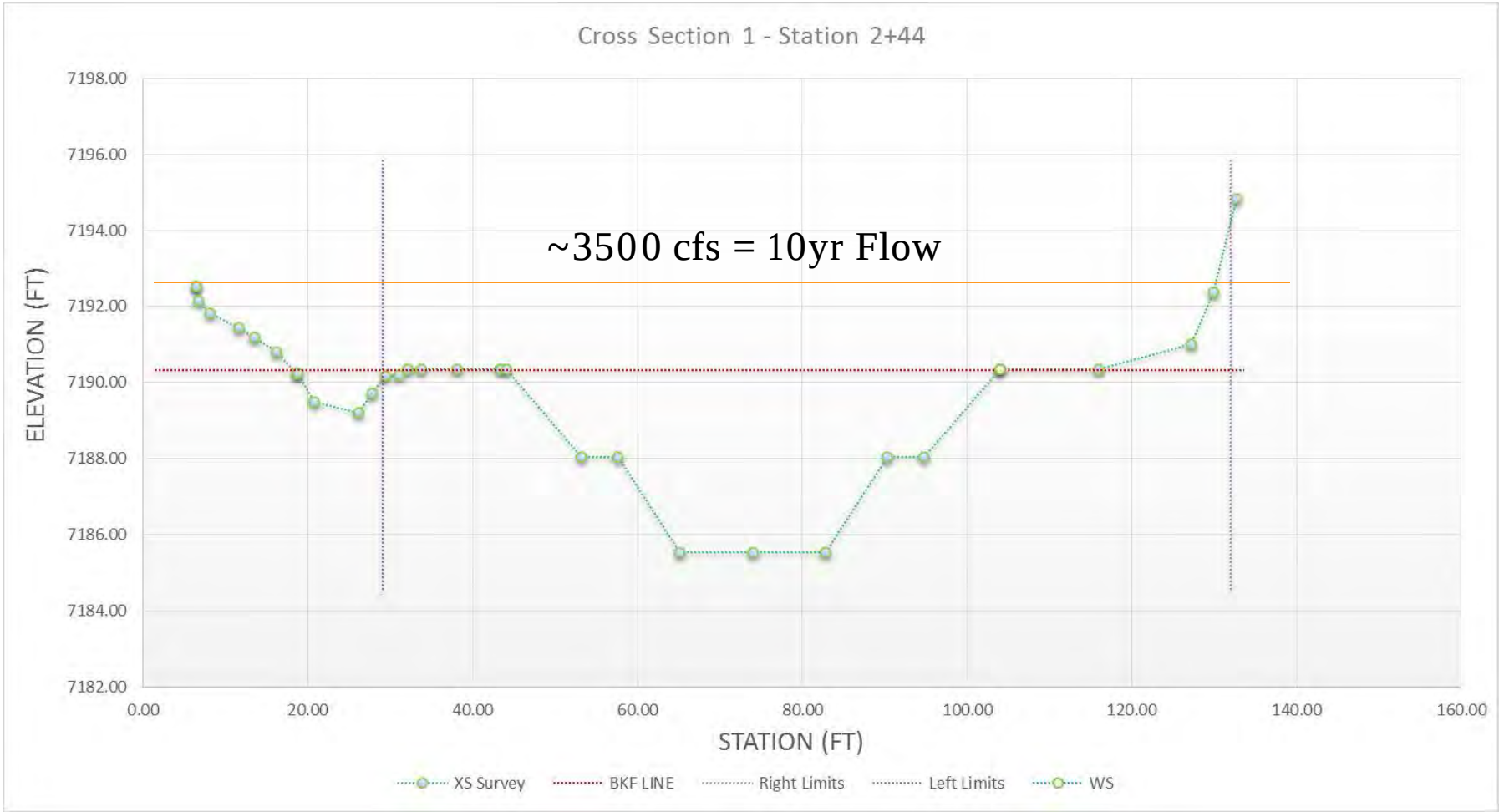
$$d = \frac{\tau}{\gamma S}$$

Case Study – Encampment River Oddfellows



WS ft	Depth Y ft	XS Area ft2	Top Width ft	V ft/s	Hydraulic Depth ft	Hydraulic Radius ft	Shear	Stream Power	Slope ft/ft	Q cfs
7190.34	4.80	195.00	63.05	4.99	3.00	3.10	1.19	5.94	0.0064	969.78

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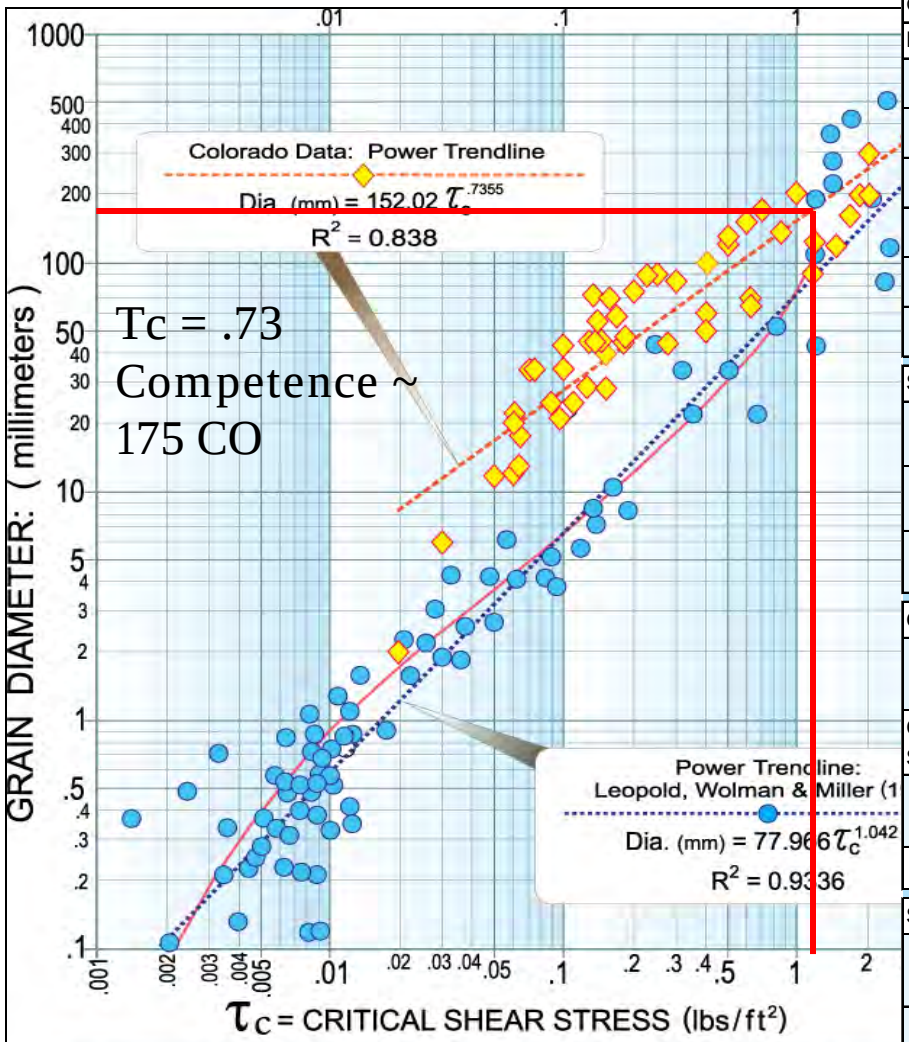
$$d = \frac{\tau}{\gamma S}$$

Case Study – Encampment River



Laboratory and field data on critical shear stress required to ini movement of grains (Leopold, Wolman, & Miller, 1964). The solid li Shields curve of *the threshold of motion*; transposed from the Θ form into the present form, in which critical shear stress is plott function of grain diameter.

Stream:	**Encampment River**		Stream Type:		
Location:	**XS 1 - Design**		Valley Type:		
Observers:			Date:		

Enter Required Information for Existing Condition

79.3	D_{50}	Median particle size of riffle bed material (mm)			
51.2	$D^{\wedge}_{50}$	Median particle size of bar or sub-pavement sample (mm)			
0.591	D_{max}	Largest particle from bar sample (ft)	180	(mm)	304.8 mm/ft
0.00640	S	Existing bankfull water surface slope (ft/ft)			
3.00	d	Existing bankfull mean depth (ft)			
1.65	$\gamma_s - \gamma / \gamma$	Immersed specific gravity of sediment			

Select the Appropriate Equation and Calculate Critical Dimensionless Shear Stress

1.55	$D_{50}/D^{\wedge}_{50}$	Range: 3 – 7	Use EQUATION 1:	$\tau^* = 0.0834\,(D_{50}/D^{\wedge}_{50})^{-0.872}$
2.27	D_{max}/D_{50}	Range: 1.3 – 3.0	Use EQUATION 2:	$\tau^* = 0.0384\,(D_{max}/D_{50})^{-0.887}$
0.019	τ^*	Bankfull Dimensionless Shear Stress	EQUATION USED:	2

Calculate Bankfull Mean Depth Required for Entrainment of Largest Particle in Bar Sample

2.83	d	Required bankfull mean depth (ft)	$d = \frac{\tau^*(\gamma_s - 1)D_{max}}{S}$ (use D_{max} in ft)

Calculate Bankfull Water Surface Slope Required for Entrainment of Largest Particle in Bar Sample

0.00603	S	Required bankfull water surface slope (ft/ft)	$S = \frac{\tau^*(\gamma_s - 1)D_{max}}{d}$ (use D_{max} in ft)

Check: ☑ Stable ☐ Aggrading ☐ Degrading

Sediment Competence Using Dimensional Shear Stress

1.198		Bankfull shear stress $\tau = \gamma d S$ (lbs/ft²) (substitute hydraulic radius, R, with mean depth, d) γ = 62.4, d = existing depth, S = existing slope
Shields 94.12	CO 173.6	Predicted largest moveable particle size (mm) at bankfull shear stress τ **(Figure 3-11)**
Shields 2.232	CO 1.258	Predicted shear stress required to initiate movement of measured D_{max} (mm) **(Figure 3-11)**
Shields 5.59	CO 3.15	Predicted mean depth required to initiate movement of measured D_{max} (mm) $d = \frac{\tau}{\gamma S}$ τ = predicted shear stress, γ = 62.4, S = existing slope
Shields 0.0119	CO 0.0067	Predicted slope required to initiate movement of measured D_{max} (mm) $S = \frac{\tau}{\gamma d}$ τ = predicted shear stress, γ = 62.4, d = existing depth

Check: ☑ Stable ☐ Aggrading ☐ Degrading

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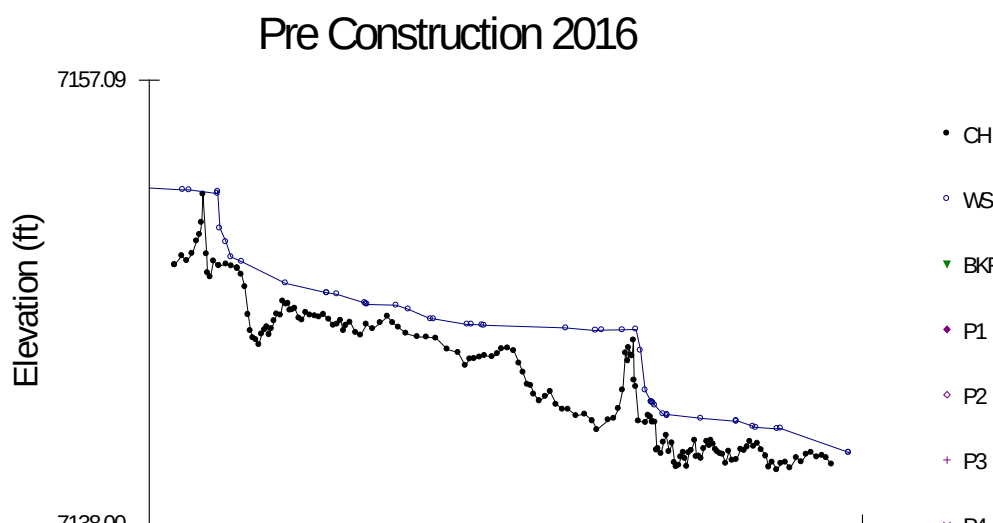
$$d = \frac{\tau}{\gamma S}$$

$$d = \frac{\tau}{\gamma S}$$

Concept Design Process and Iterations

1. Incorporate the objectives, assessment and physical and ecological criteria
2. Use Existing Geomorphic Data to Aid in Design
3. Define Constraints
4. Evaluate Design Alternatives
5. Build MCDA Model
6. Meet with Stakeholders at Concept, 30%, 60% and 90%
7. Project Feasibility and Cost-Benefit Analysis



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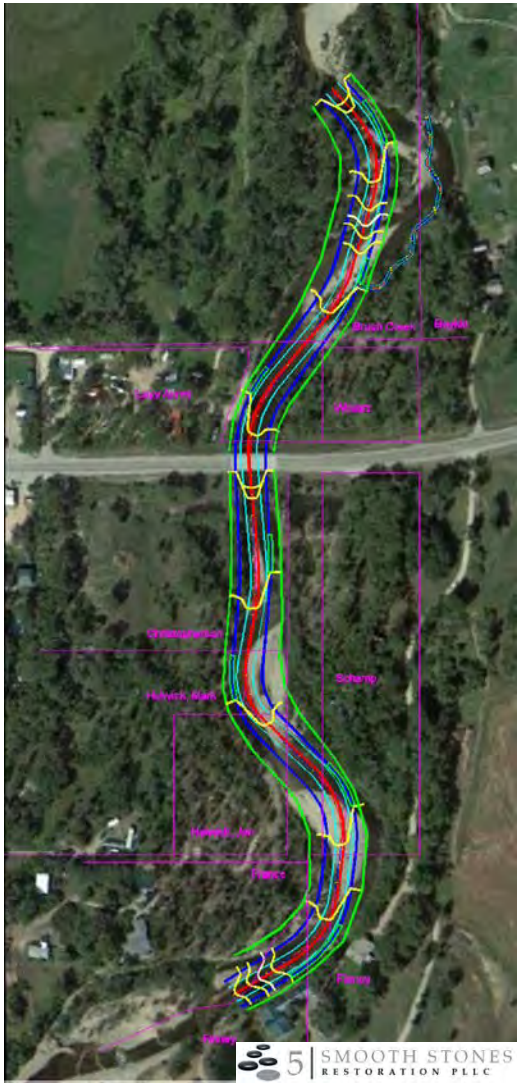
Land Owner and Stakeholder Meeting

Encampment River Restoration and Enhancement
Wyoming Game and Fish Department
Wyoming Trout Unlimited
SER Conservation District
06-10-16



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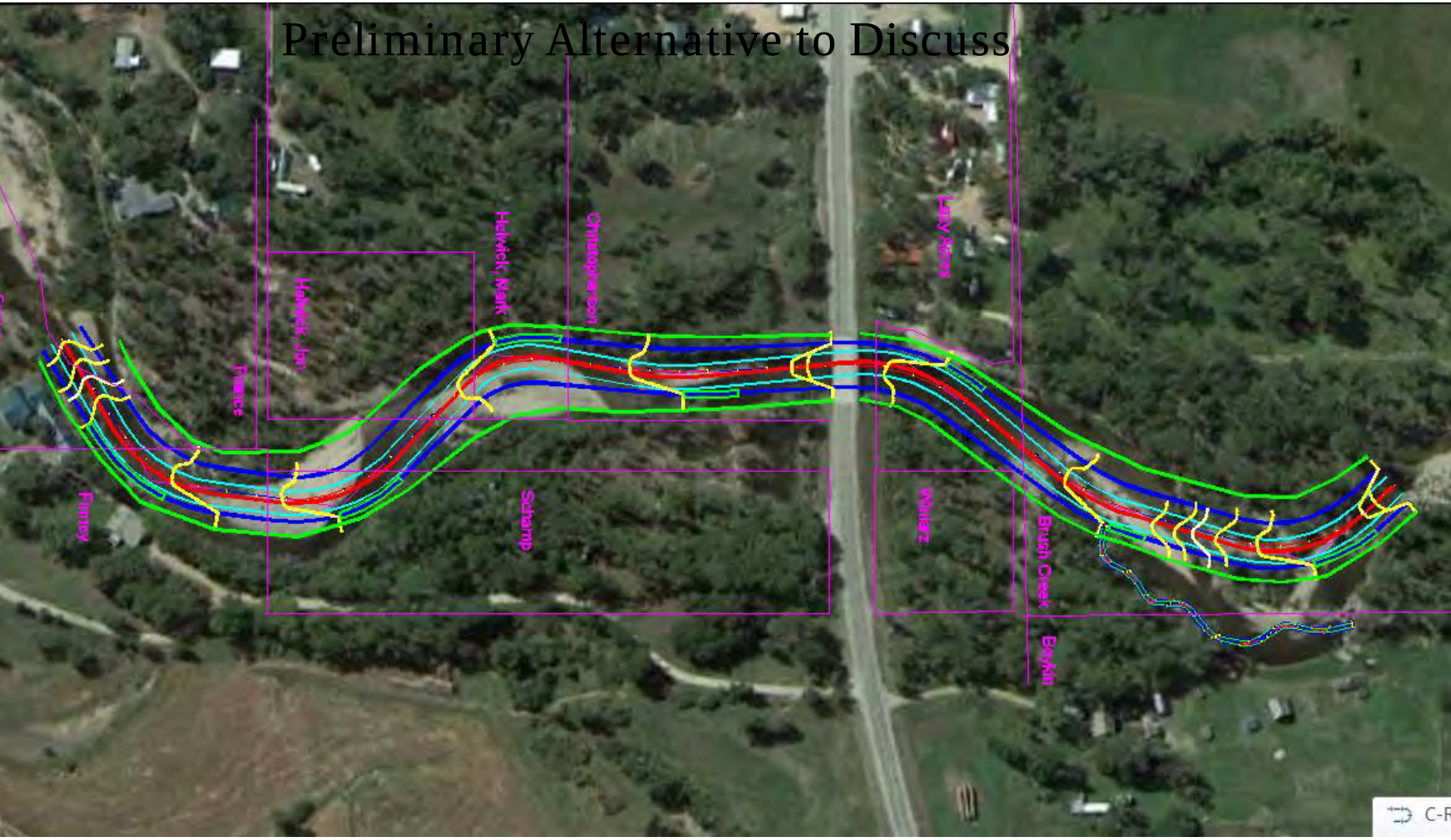
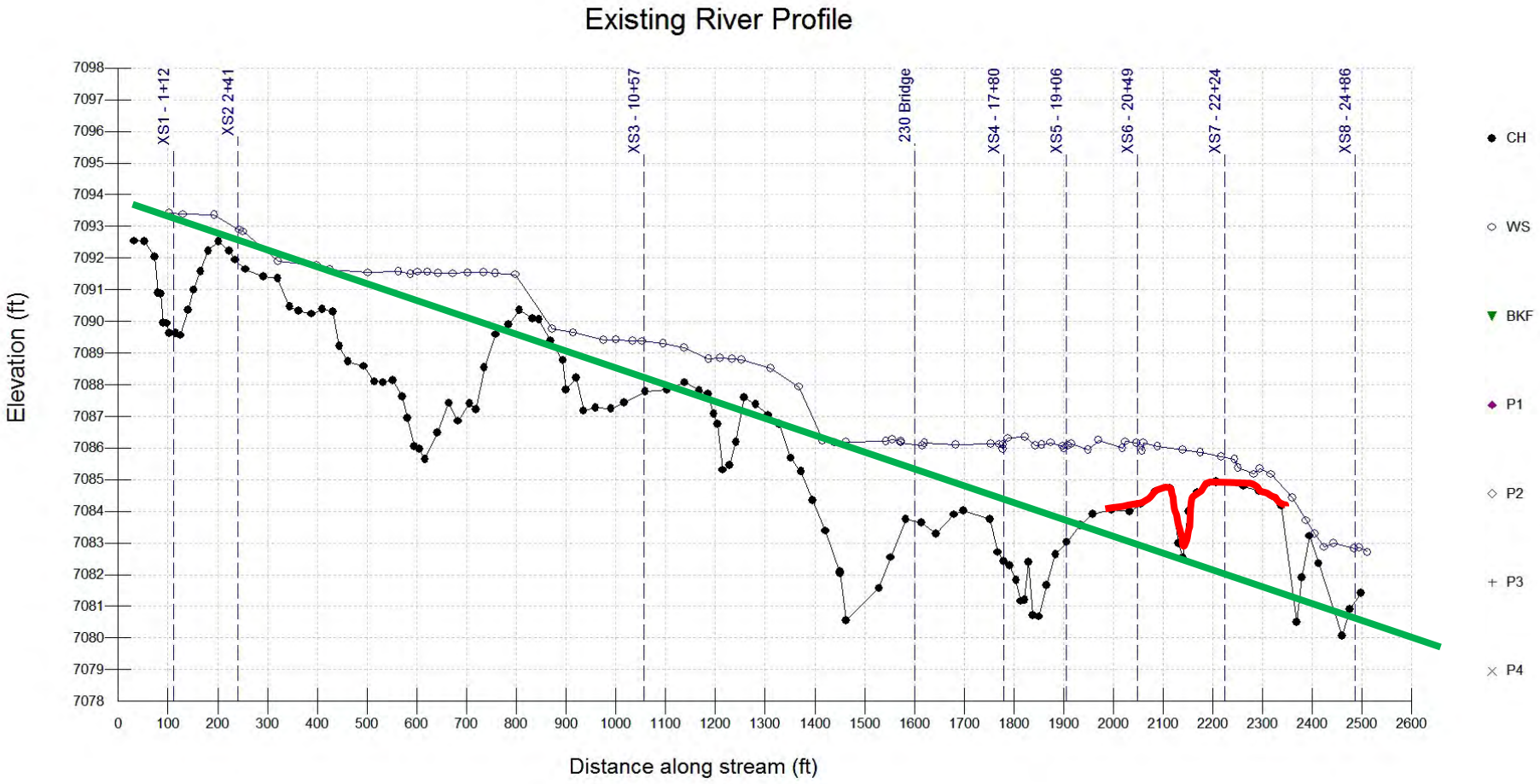
5 | SMOOTH STONES RESTORATION PLLC

Encampment River Restoration and Stabilization Project Goals

1.) Property Protection
    - Re-Alignment of the River
    - Change in Channel Dimension
2.) Water Rights Protection/Enhancement
    - Change in Point of Diversion
3.) Fisheries Improvement
    - Access on Vane Arms
    - Better Habitat
4.) River Stability
    - Limit build up of Gravels downstream of the bridge
5.) Flood Reduction at the 230 Bridge
6.) Fish Habitat Improvements
    - Deeper Pools
    - More Productive Riffles
7.) Boat Passage
8.) Riparian Restoration

Preliminary Alternative to Discuss

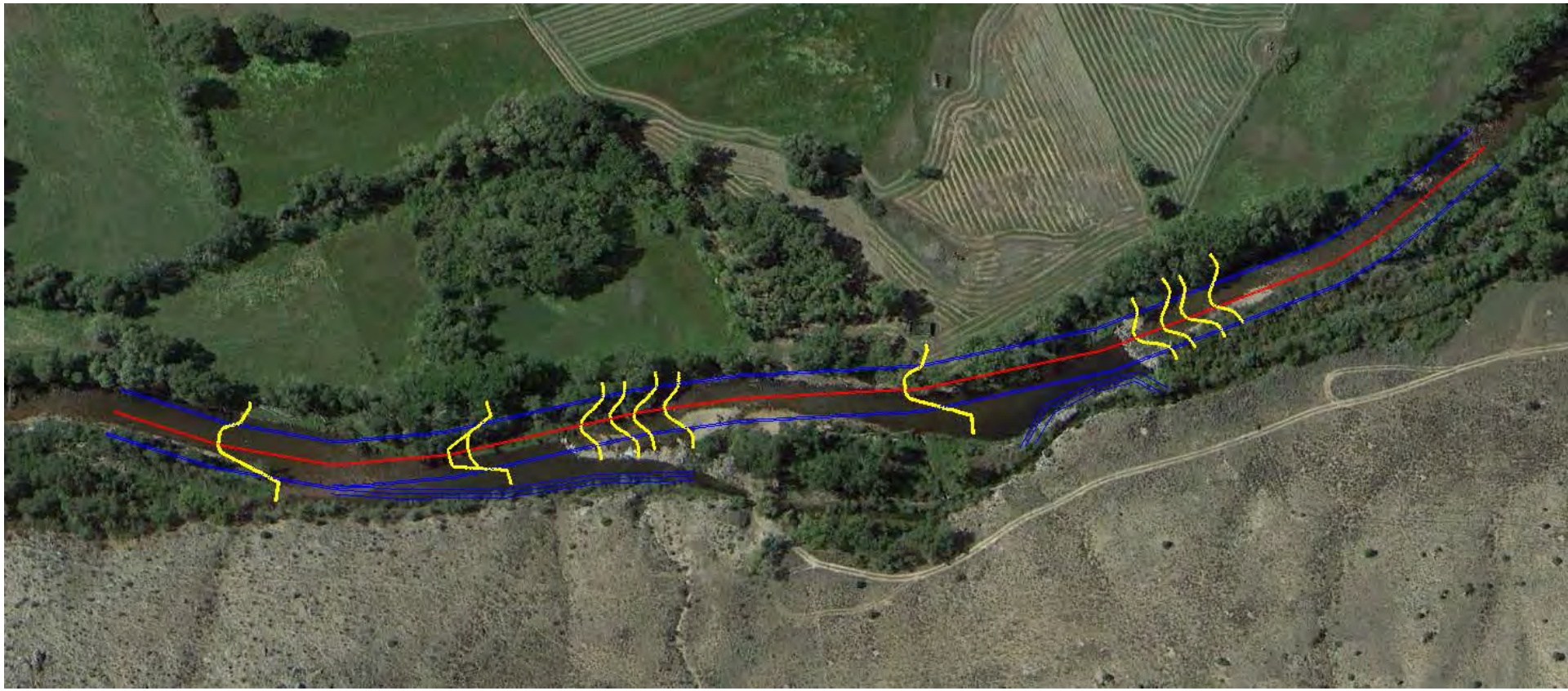


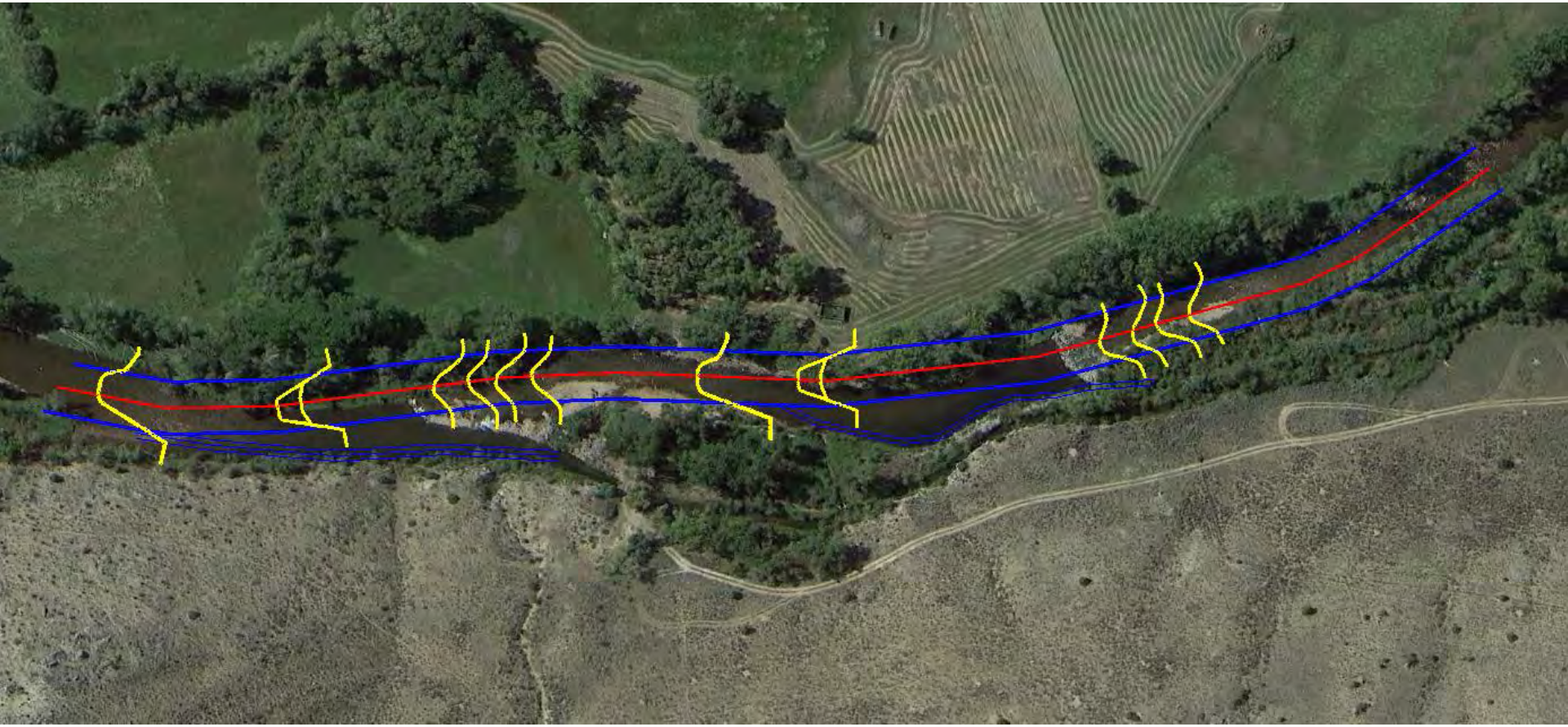

Existing River Profile
Elevation (ft)
Distance along stream (ft)
XS1 - 1+12
XS2 2+41
XS3 - 10+57
230 Bridge
XS4 - 17+80
XS5 - 19+06
XS6 - 20+49
XS7 - 22+24
XS8 - 24+86
CH
WS
BKF
P1
P2
P3
P4

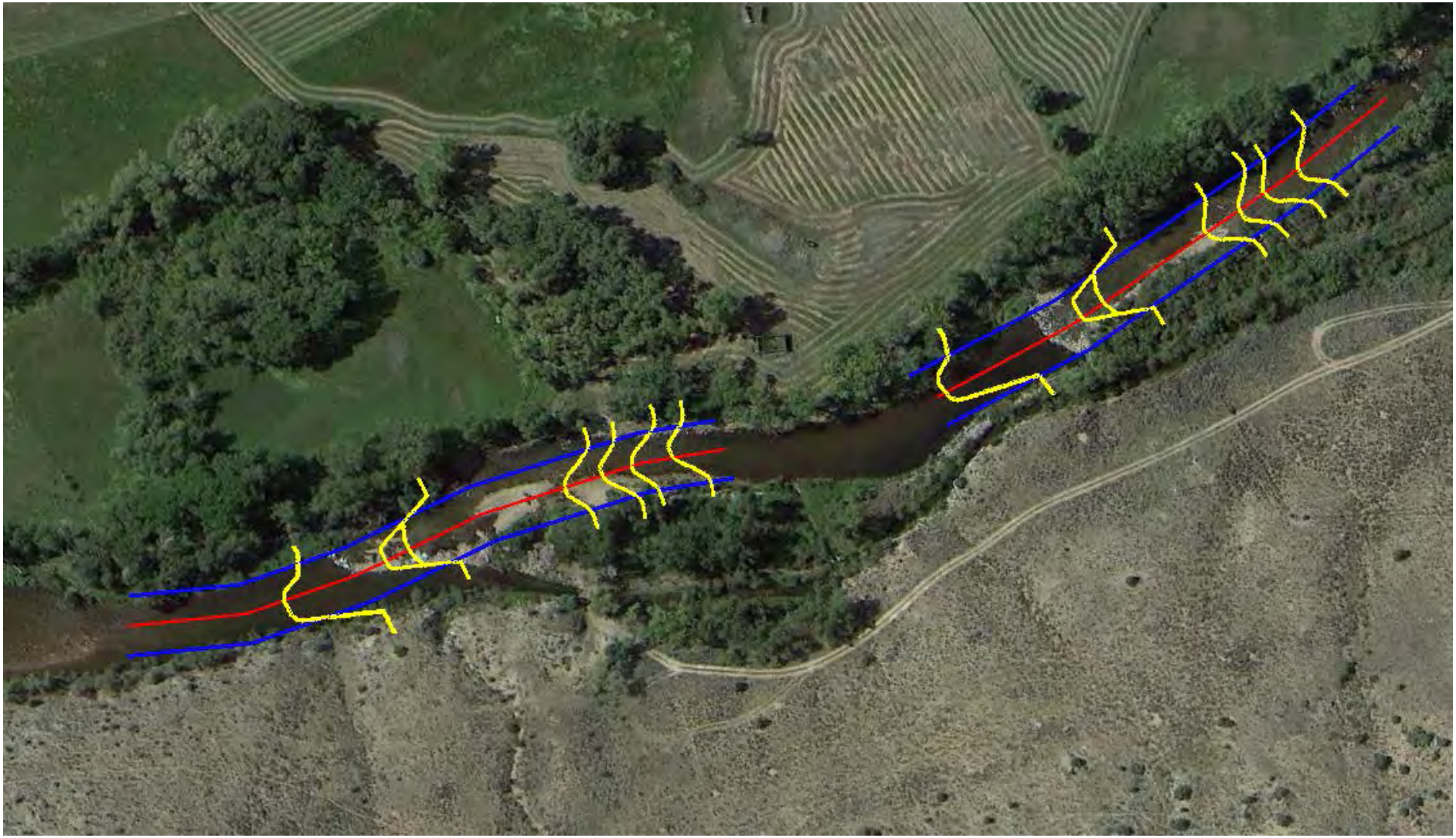
Christopherson
Helwick, Mark

Boulder Constructed Riffle

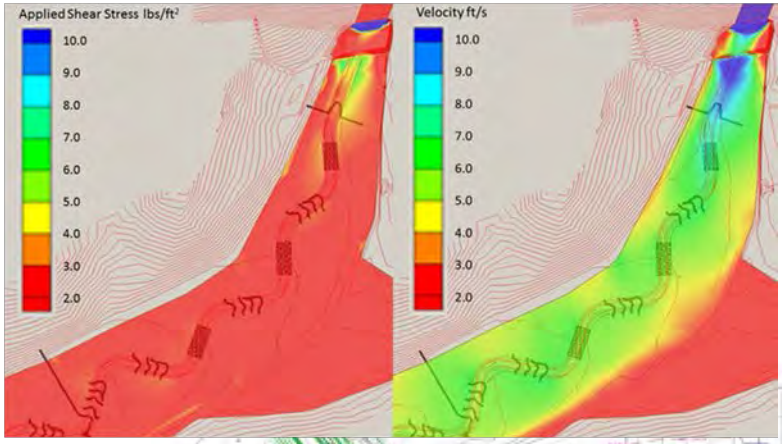
Boulder J-Hook

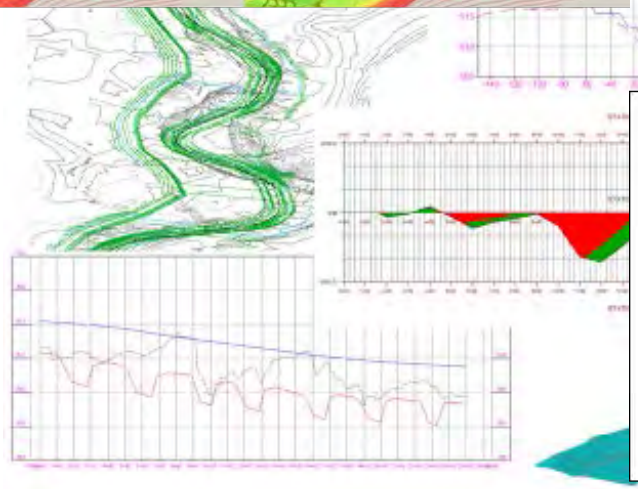


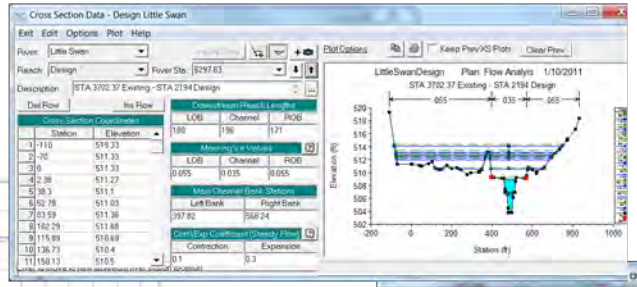


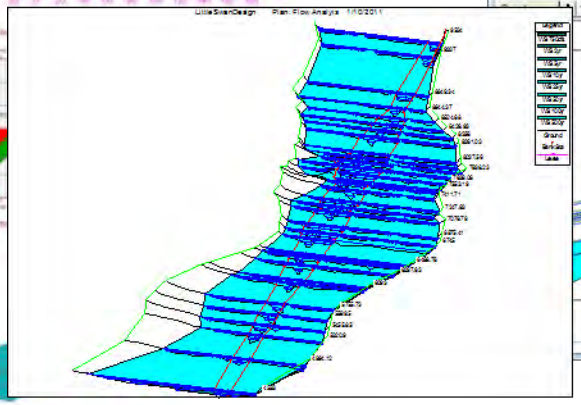


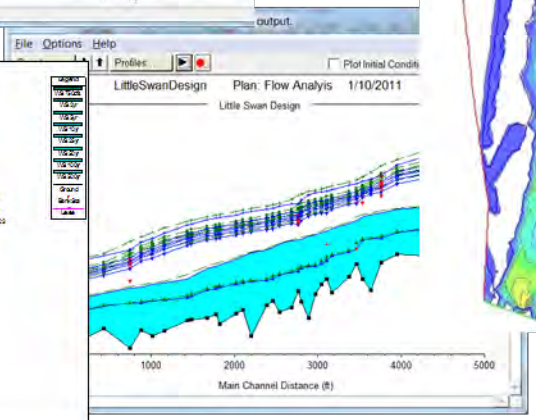
3-D Design Process

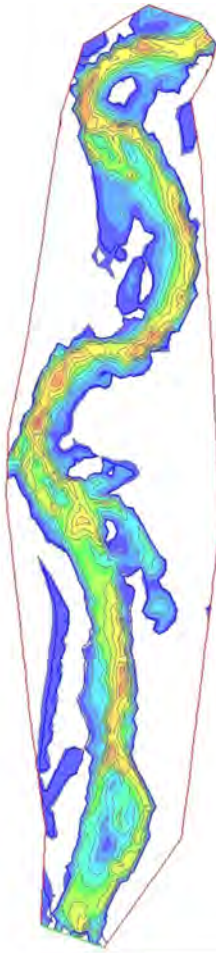




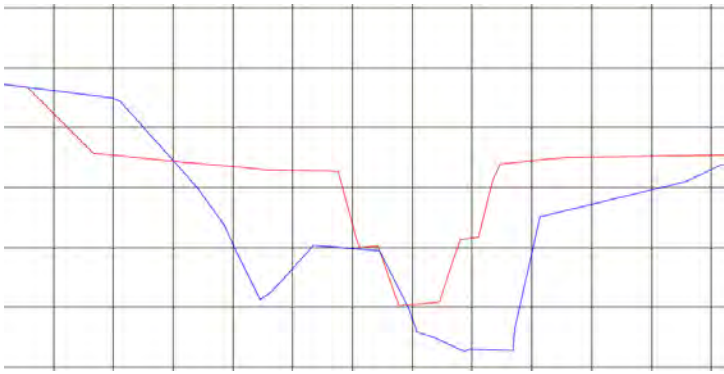




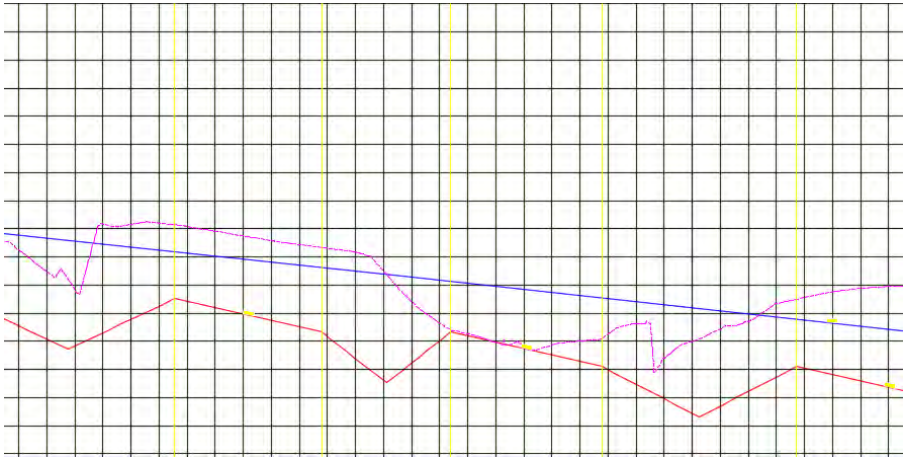


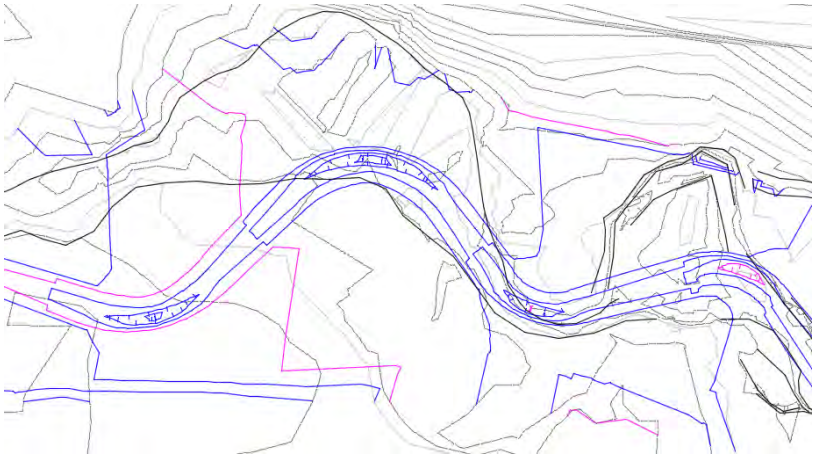


3-D Design Process



- Existing Base
- Create Alignment (1D)
- Apply Typical Cross-Sections (1D)
- Create Profile (2D)
- Create Surface from Breaklines (3D)
- Still Meeting Design Criteria





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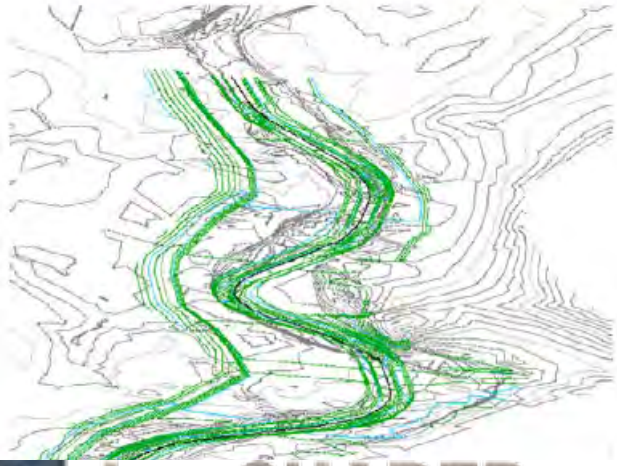
3-D Design

Optimization



- Hydraulic Modeling is Not Limited
- Grading is a Major Construction Cost
- Easier to Create Design Revisions and Iterations
- Assist in Construction Stakeout
- GPS Guided Construction Equipment
- Local Balanced based on equipment and site conditions

- Good Check for On-site Stupidity During Construction

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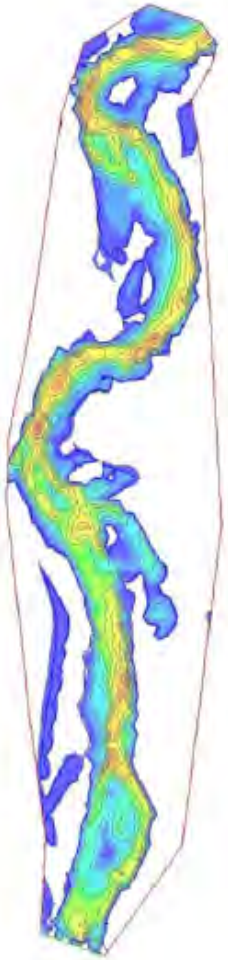
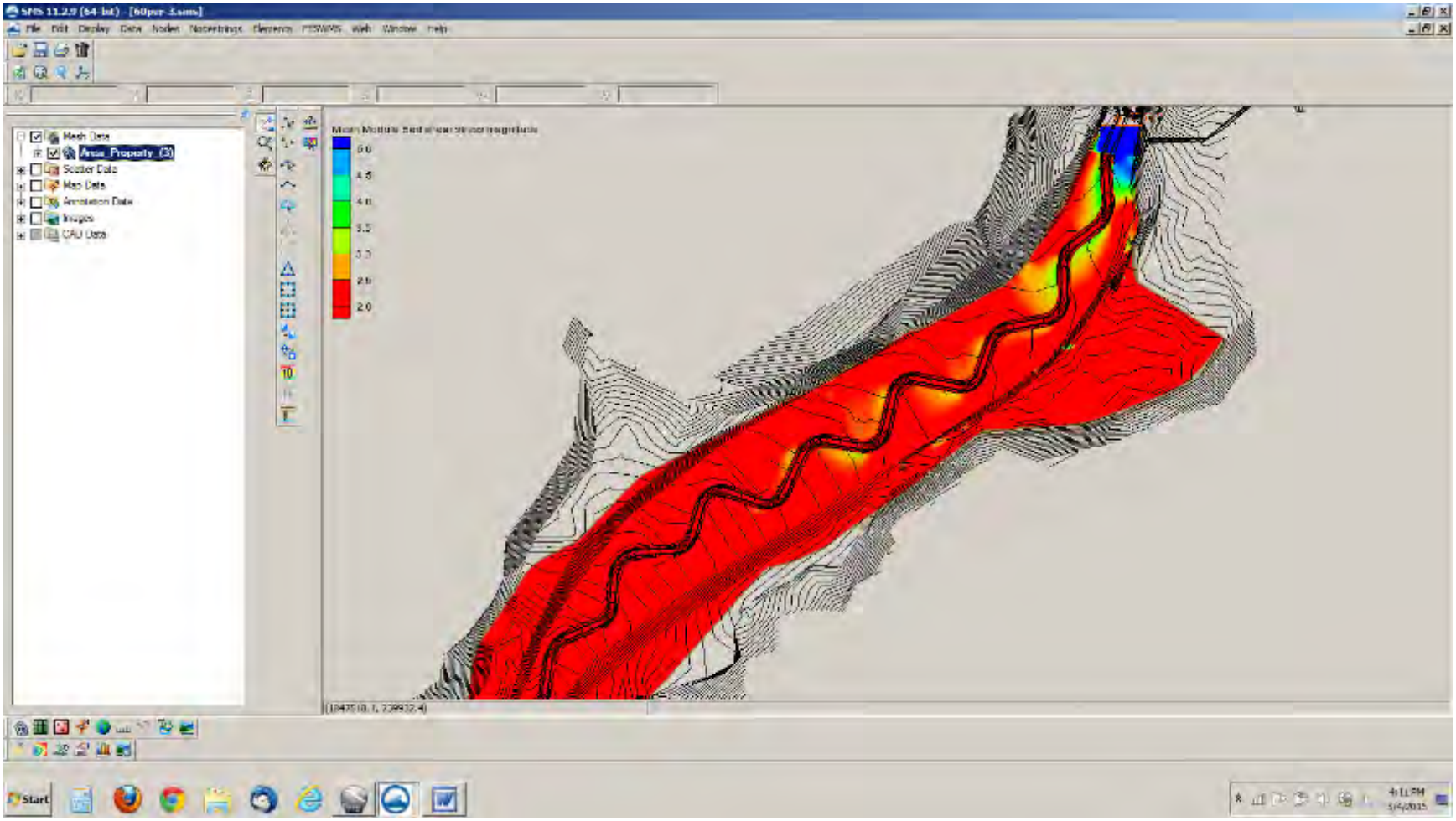
3-D Design

- Engineering to Check and Design
  - Sediment, Backwater, Velocity, & Shear Stress

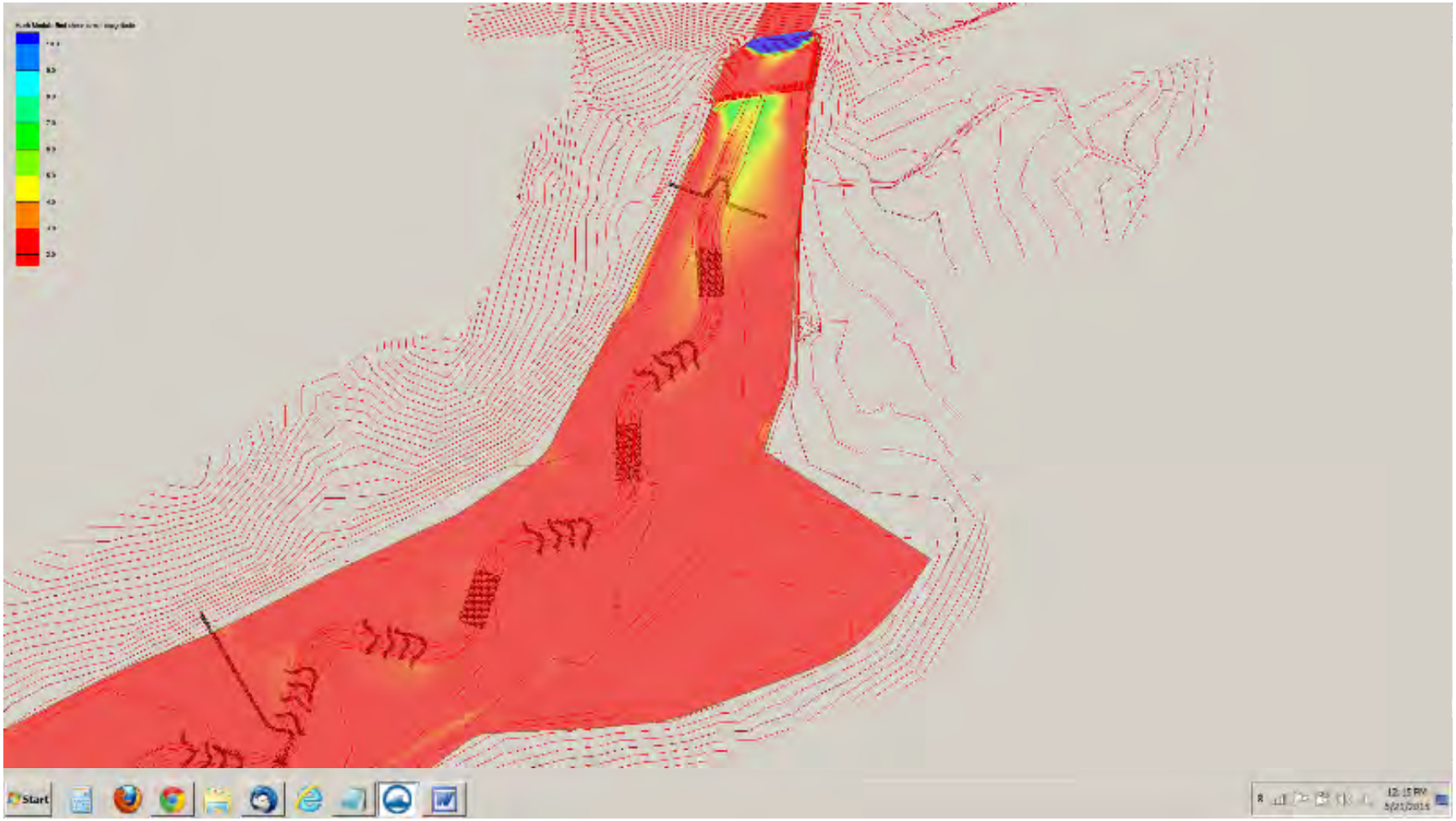
- HEC-RAS Limitations
  - 1-D only
    - cannot model actual flow around bends, in constrictions, or other 2-D, 3-D flows
    - cannot model channel-floodplain interactions

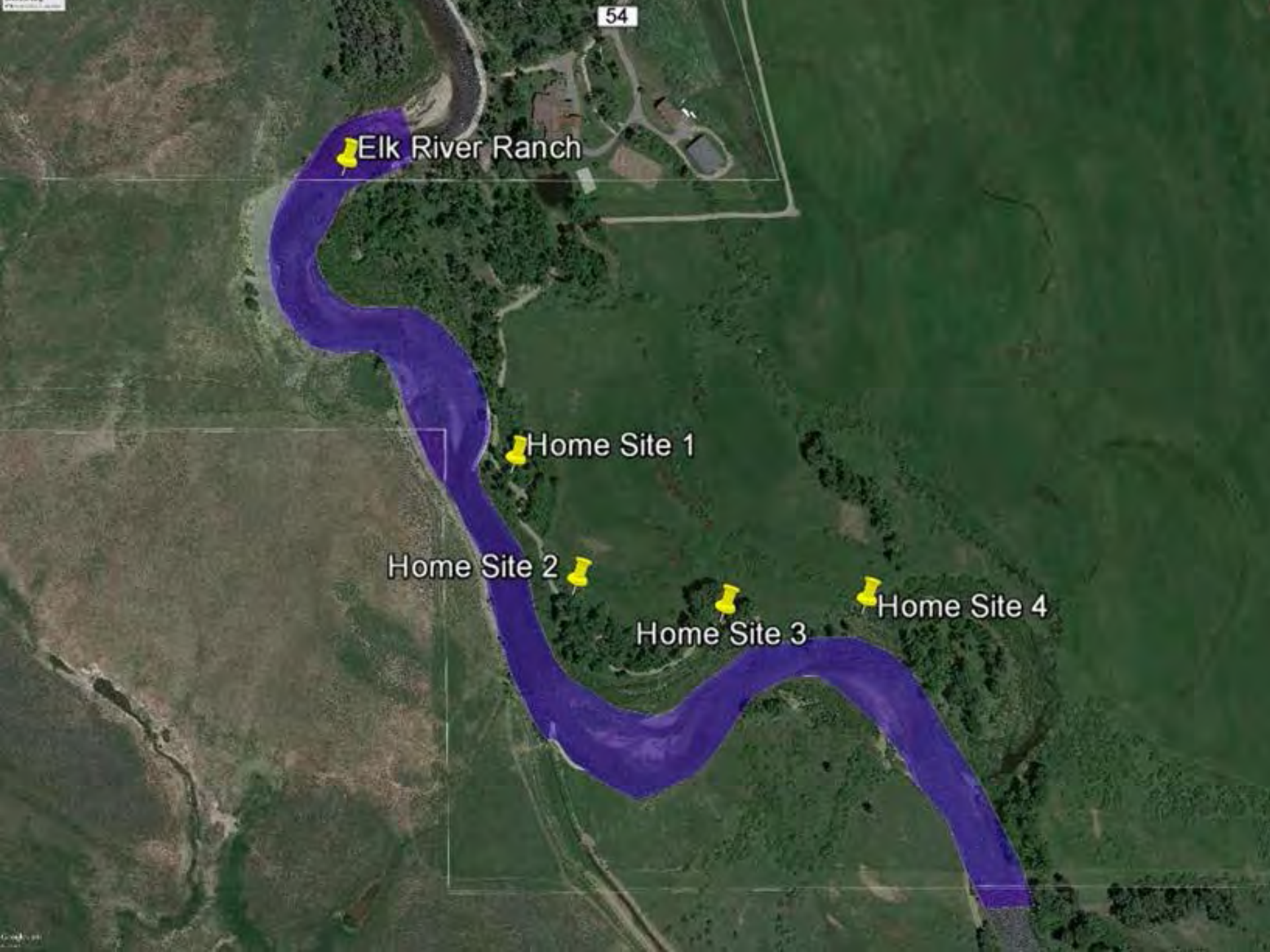


30% Design – 2D Modeling

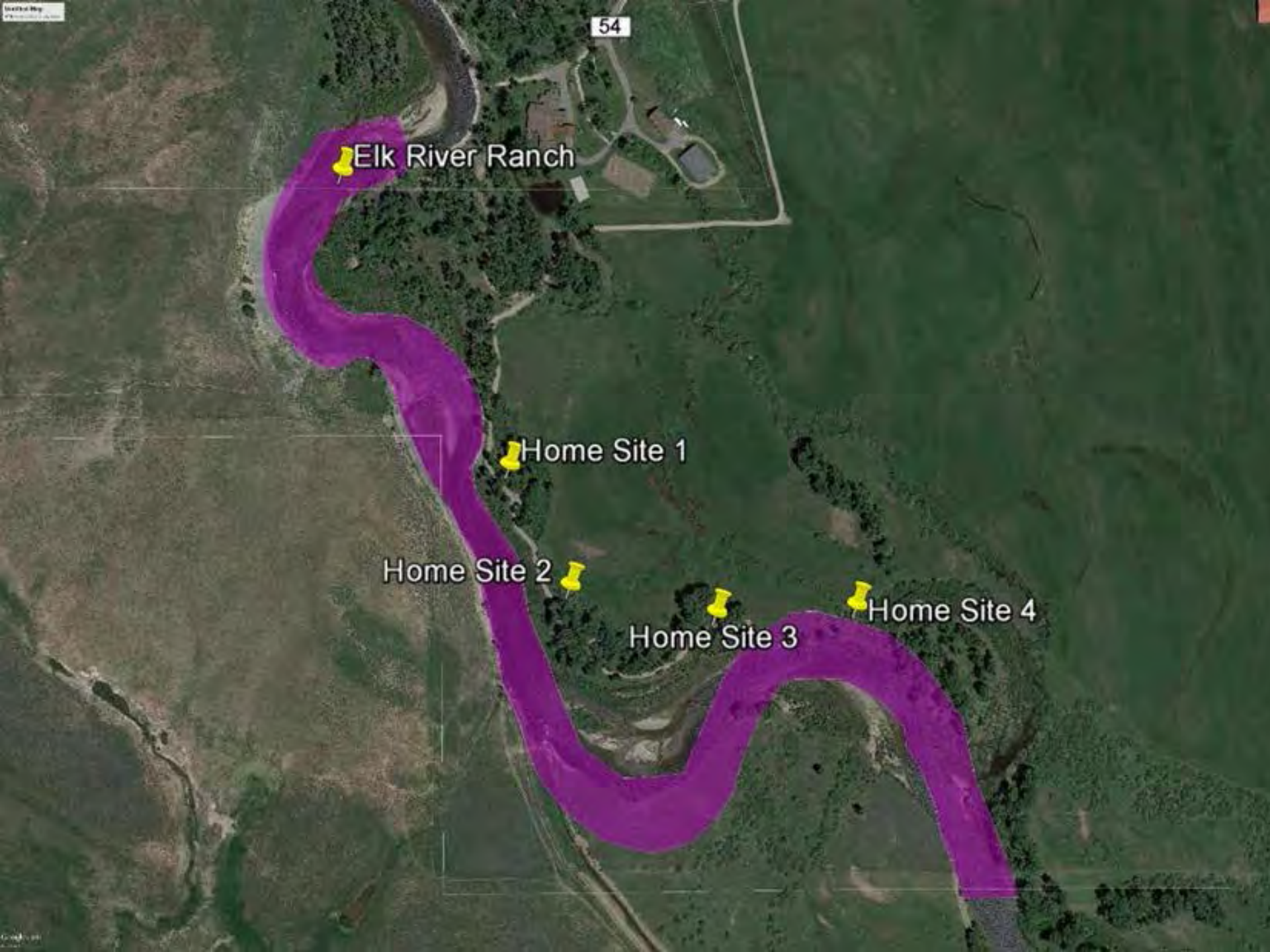


Design Iterations – 60% and 90%




54
Elk River Ranch
Home Site 1
Home Site 2
Home Site 3
Home Site 4

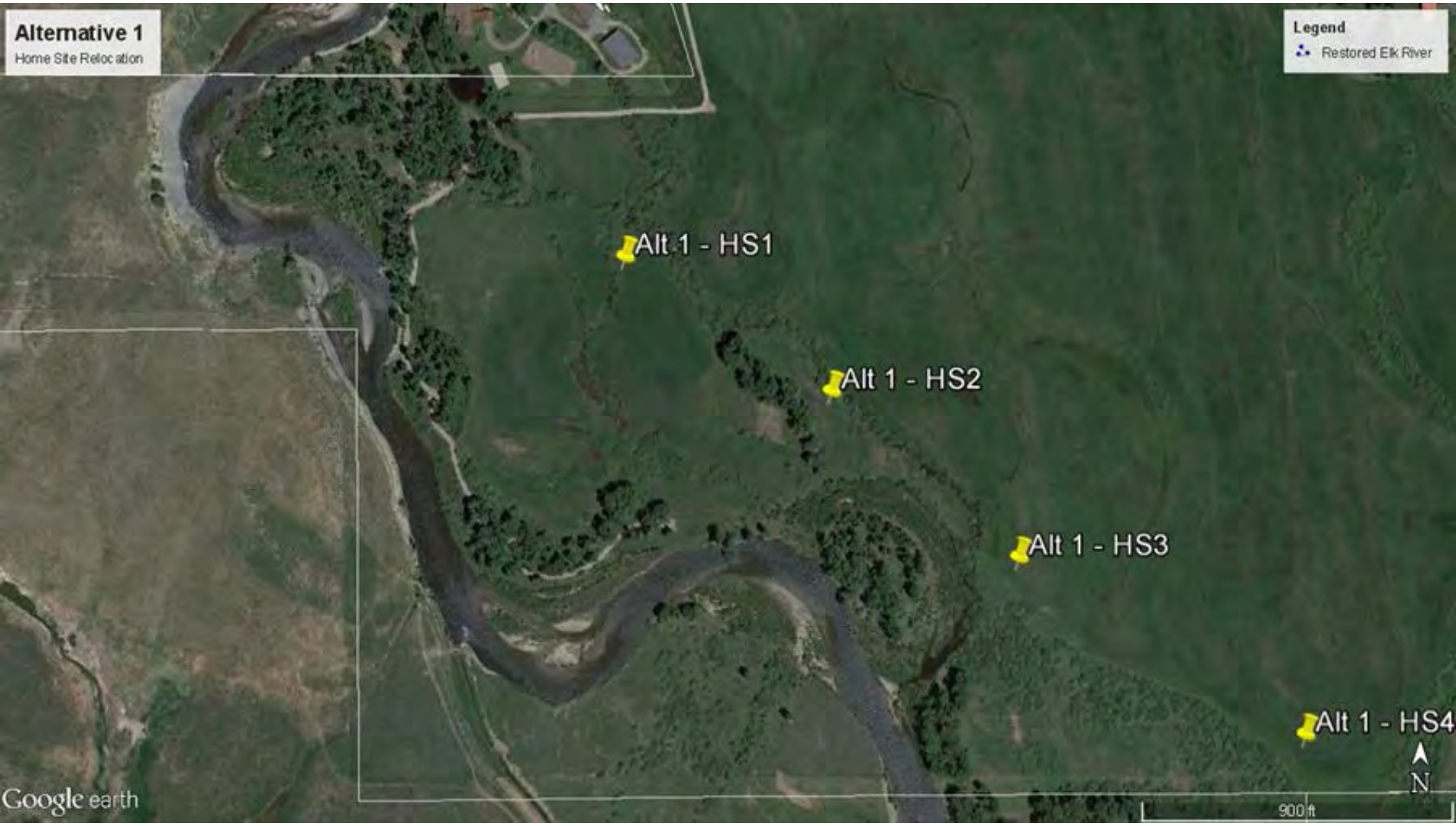
54
Elk River Ranch
Bank Erosion > 10ft/yr
Ref Bank Erosion < 0.25 ft/yr
Home Site 1
Home Site 2
Home Site 3
Home Site 4


54
Elk River Ranch
Home Site 1
Home Site 2
Home Site 3
Home Site 4

54
Elk River Ranch
Home Site 1
Home Site 2
Home Site 3
Home Site 4

	Approximate Distance from the Elk River	Predicted Bank Erosion Rate (ft/yr)	Years to Structure Scour at Predicted Bank Erosion Rate	Probability of Geomorphic Bank Erosion Occurrence	Cost of Occurrence	Geomorphic Risk from Bank Erosion	Years Before Major Channel Evolution or Chute Cut-off	Probability of Chute Cut-off Occurrence	Cost of Bridge Construction	Geomorphic Risk from Chute Cut-Off
Home Site 1	105	1.5	70	1.43%	$1,000,000.00	$ 14,285.71	50	2.0%	$ 350,000.00	$ 7,000.00
Home Site 2	125	Depositional			$1,000,000.00	$ -	50	2.0%	$ 350,000.00	$ 7,000.00
Home Site 3	1									
Home Site 4										

	Geomorphic Risk	Flooding Risk	Total Home Site Risk	Estimated Home Value	Annual Risk as a percent of Home Value
Home Site 1	$ 21,285.71	$40,000.00	$61,285.71	$ 1,000,000	6.1%
Home Site 2	$ 7,000.00	$40,000.00	$47,000.00	$ 1,000,000	4.7%
Home Site 3	$ 11,166.67	$40,000.00	$51,166.67	$ 1,000,000	5.1%
Home Site 4	$ 46,153.85	$40,000.00	$86,153.85	$ 1,000,000	8.6%



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	Approximate Distance from the Elk River	Predicted Bank Erosion Rate (ft/yr)	Years to Structure Scour at Predicted Bank Erosion Rate	Probability of Geomorphic Bank Erosion Occurrence	Cost of Occurrence	Geomorphic Risk from Bank Erosion	Years before Major Channel Evolution or Chute Cut-off	Probability of Chute Cut-off Occurrence	Cost of Bridge Construction	Geomorphic Risk from Chute Cut-Of
Home Site 1	500	1.5	333	0.30%	$ 1,000,000.00	$ 3,000.00	500	0.2%	$ 350,000.00	$ -
Home Site 2	500	1	500	0.20%	$ 1,000,000.00	$ 2,000.00	500	0.2%	$ 350,000.00	$ -
Home Site 3	500	0.5								
Home Site 4	500	3								

	Geomorphic Risk	Flooding Risk	Total Home Site Risk	Estimated Home Value	Annual Risk as a percent of Home Value	Cost of Alternative
Home Site 1	$ 3,000.00	$ 800.00	$ 3,800.00	$ 1,000,000.00	0.4%	$ -
Home Site 2	$ 2,000.00	$ 800.00	$ 2,800.00	$ 1,000,000.00	0.3%	$ -
Home Site 3	$ 1,000.00	$ 800.00	$ 1,800.00	$ 1,000,000.00	0.2%	$ -
Home Site 4	$ 6,000.00	$ 800.00	$ 6,800.00	$ 1,000,000.00	0.7%	$ -

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Types of Risk

	Existing Conditions and Layout			Alternative 1 Home Site Relocation			Alternative 2 Fill Pads and Rip Rap			Alternative 3 Channel Re-Alignment and Restoration		
	Existing Total Home Site Risk	Annual Risk as a percent of Home Value	Additional Cost	Alt 1 Total Home Site Annual Risk	Annual Risk as a percent of Home Value	Additional Cost	Alt 2 Total Home Site Annual Risk	Annual Risk as a percent of Home Value	Additional Cost	Alt 3 Total Home Site Annual Risk	Annual Risk as a percent of Home Value	Additional Cost
Home Site 1	$ 61,285.71	6.1%	$-	$ 3,800.00	0.4%	$-	$15,761.90	1.6%	$ 250,000.00	$ 3,250.00	0.3%	$ 575,000.00
Home Site 2	$ 47,000.00	4.7%	$-	$ 2,800.00	0.3%	$-	$11,000.00	1.1%	$ 100,000.00	$ 3,250.00	0.3%	$ 575,000.00
Home Site 3	$ 51,166.67	5.1%	$-	$ 1,800.00	0.2%	$-	$15,166.67	1.5%	$ 175,000.00	$ 3,250.00	0.3%	$ 575,000.00
Home Site 4	$ 86,153.85	8.6%	$-	$ 6,800.00	0.7%	$-	$11,692.31	1.2%	$ 700,000.00	$ 3,250.00	0.3%	$ 575,000.00
Project 1-4	$245,606.23	6.1%	$-	$15,200.00	0.4%	$-	$53,620.88	1.3%	$1,225,000.00	$13,000.00	0.3%	$2,300,000.00

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Engineers Opinion of Probably Cost

Item Description	Estimated Quantity	Unit	Unit Bid Price	Bid Amount
Construction Surveying	1	LS	$ 30,000.00	30,000.00
Mobilization	1	LS	$ 100,000.00	100,000.00
Temporary Construction Access Roads	1	LS	$ 50,000.00	50,000.00
Grading	21000	CU YD	$ 10.00	210,000.00
Clearing and Grubbing (As Directed)	9	Acres	$ 4,000.00	36,000.00
Log J-Hook with Rootwad	1	Each	$ 10,000.00	10,000.00
Constructed Boulder Riffle	16	Each	$ 30,000.00	480,000.00
Rock Cross-Vane	3	Each	$ 30,000.00	90,000.00
Rock J-Hook	1	Each	$ 25,000.00	25,000.00
Wood Toe	16	Each	$ 5,000.00	80,000.00
Log Drop Structures with Boulders (for trib)	13	Each	$ 3,650.00	47,450.00
Floodplain Rock Sill	90	Tons	$ 200.00	18,000.00
Floodplain Log Sill	1	Each	$ 1,500.00	1,500.00
Riprap channel	1	Each	$ 100,000.00	100,000.00
Bentomat Plug	2800	Sq. Yds.	$ 15.00	42,000.00
Temporary Construction Entrance	2	Each	$ 15,000.00	30,000.00
Temporary Silt Fence	2500	Ln. Ft.	$ 7.50	18,750.00
Erosion Control Matting (and stakes)	50337	Sq. Yds.	$ 10.00	503,368.12
Pump Around	5	Each	$ 5,000.00	25,000.00
Mulch straw	9	Acres	$ 500.00	4,500.00
Temporary Seeding	9	Acres	$ 350.00	3,150.00
Permanent Seeding	9	Acres	$ 1,500.00	13,500.00
Vegetation	9	Acres	$ 10,000.00	90,000.00
			Total Bid Estimate	2,008,218.12
			5% contingency	2,108,629.02

Construction Observation

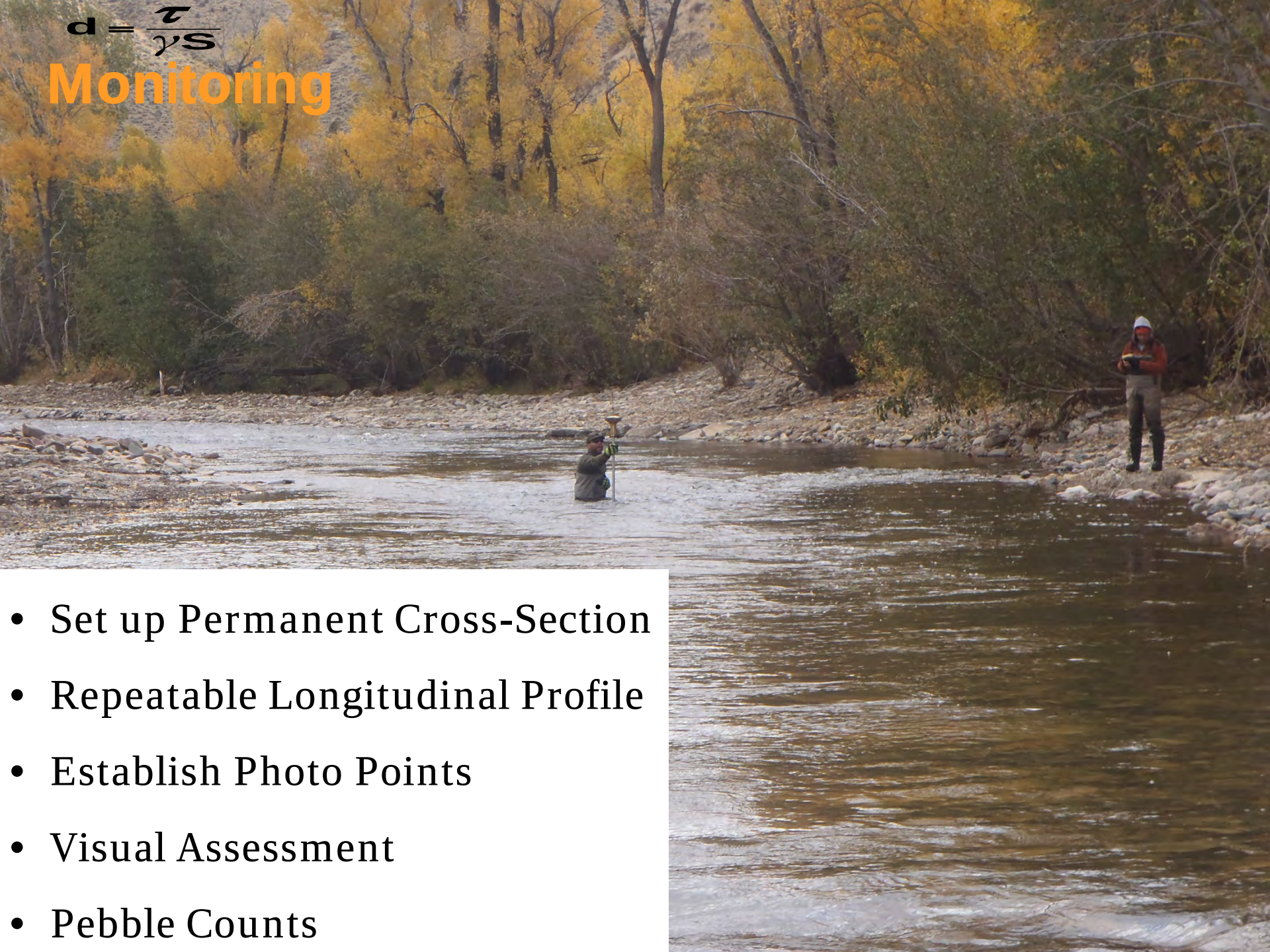
Construction Observation

250G
LC

KOMATSU
PC 220 LC
1470 KOMATSU

$$d = \frac{\tau}{\gamma S}$$

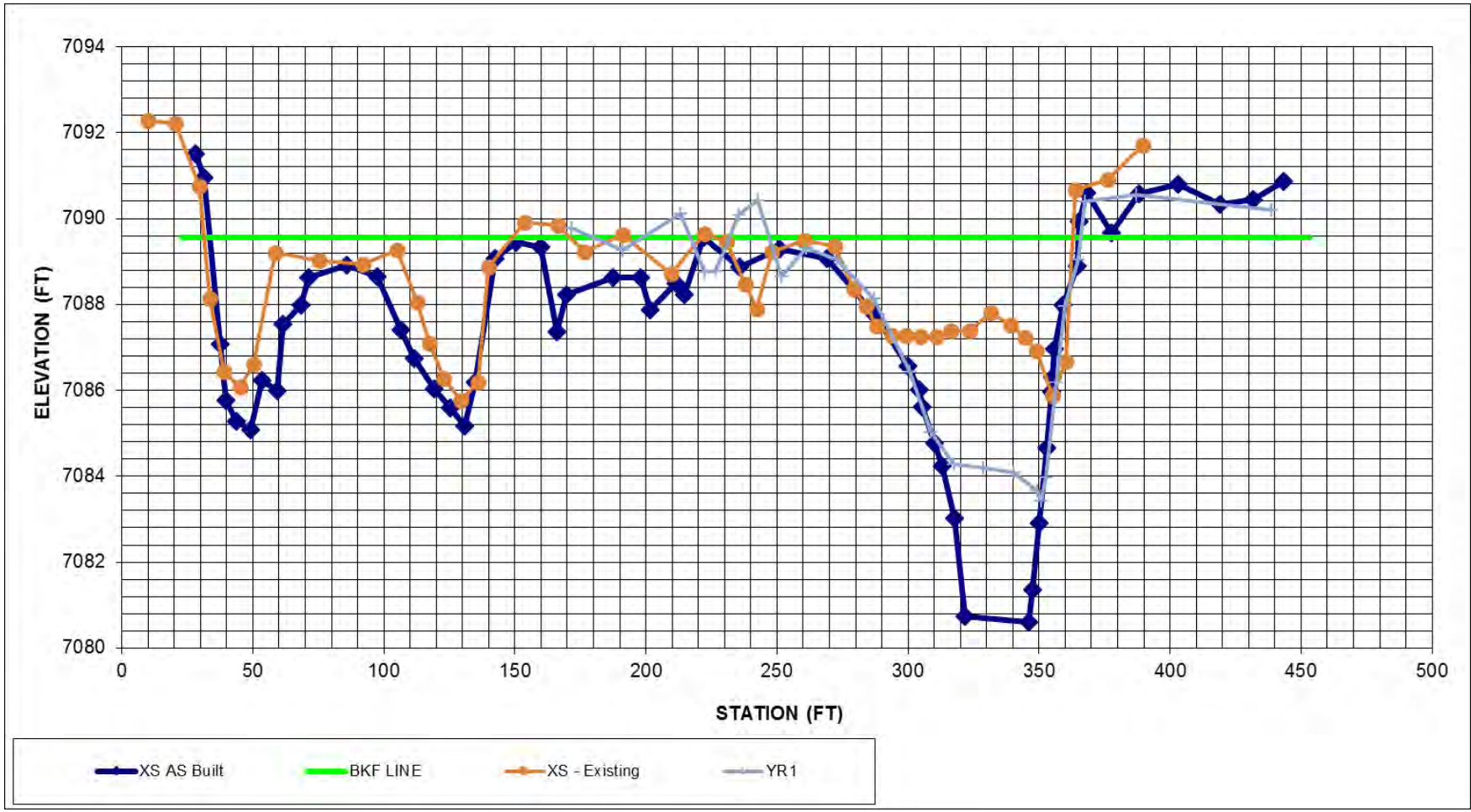
Monitoring



- Set up Permanent Cross-Section
- Repeatable Longitudinal Profile
- Establish Photo Points
- Visual Assessment
- Pebble Counts

$$d = \frac{\tau}{\gamma S}$$

Monitoring



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$$d = \frac{\tau}{\gamma S}$$

- **Questions?**