The Role of Geomorphology in Remediestoration

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Some Lessons Learned

1. The more decisions you have to make, the more incrementally an outcome can shift from its original vision.

2. One’s tolerance for risk is negotiable.

Silver Bow Creek, 1997

DEQ and EPA (1998), Explanation of Significant Differences
Streamside Tailings Operable Unit

"This approach provides the most cost-effective way to comply with the ROD requirement that the reconstructed channel be designed as a geomorphically stable, naturally meandering alluvial system to the degree possible."

Arkansas River, 1997

Arkansas River OU11 ROD

The preferred remedy for Fluvial Mine Waste deposits is expected to result in the establishment of vegetation over the majority of waste deposits within three years. This will meet the primary objective of physically stabilizing the waste to minimize erosion into the Arkansas River.

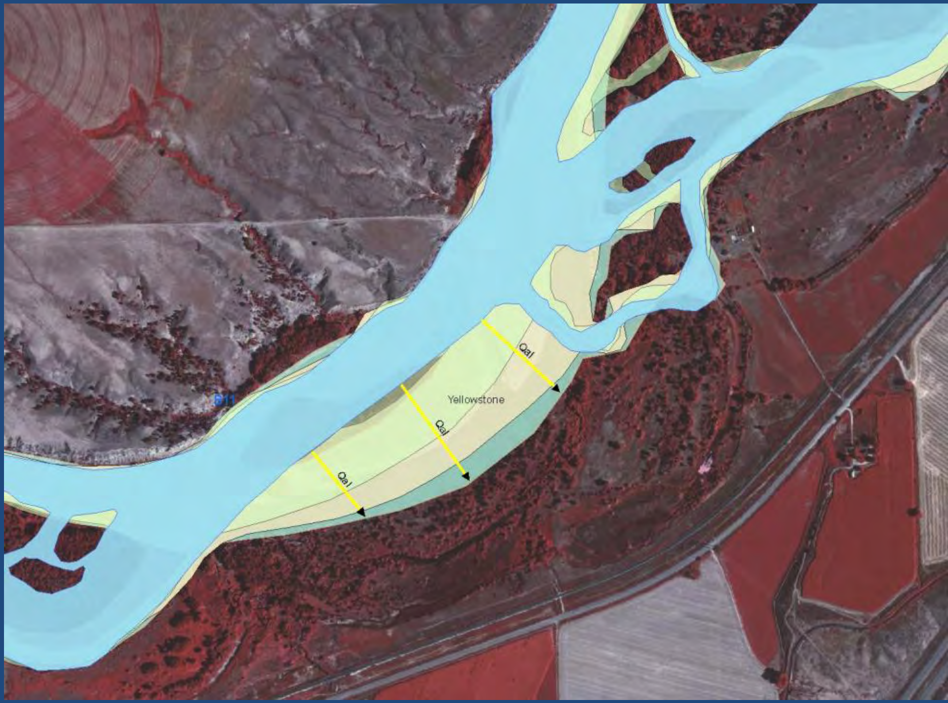
Ongoing Discussions
What is “Stability”?

Dynamic

Engineered

What is Meandering?

Meandering as Form



Meandering as Process

What is the "Illusion of Function"?

nd.com

Arkansas: What long-term floodplain turnover rates are acceptable? At what rate can the river access treated tailings?

Silver Bow: How soon can we "let it go?"

Silver Bow Creek Test Pits June 1997
What are we working with?

Silver Bow Creek Bank Toe 1997

Silver Bow Creek
Geomorphic Design Criteria

1. As-built conditions
   - Channel dimensions/layout
   - Substrate
   - Floodplain access
   - Bank stability

2. Post-construction
   - Deformability
   - Adjustment
   - Disturbance


What about risk? I'm stamping this, buddy!

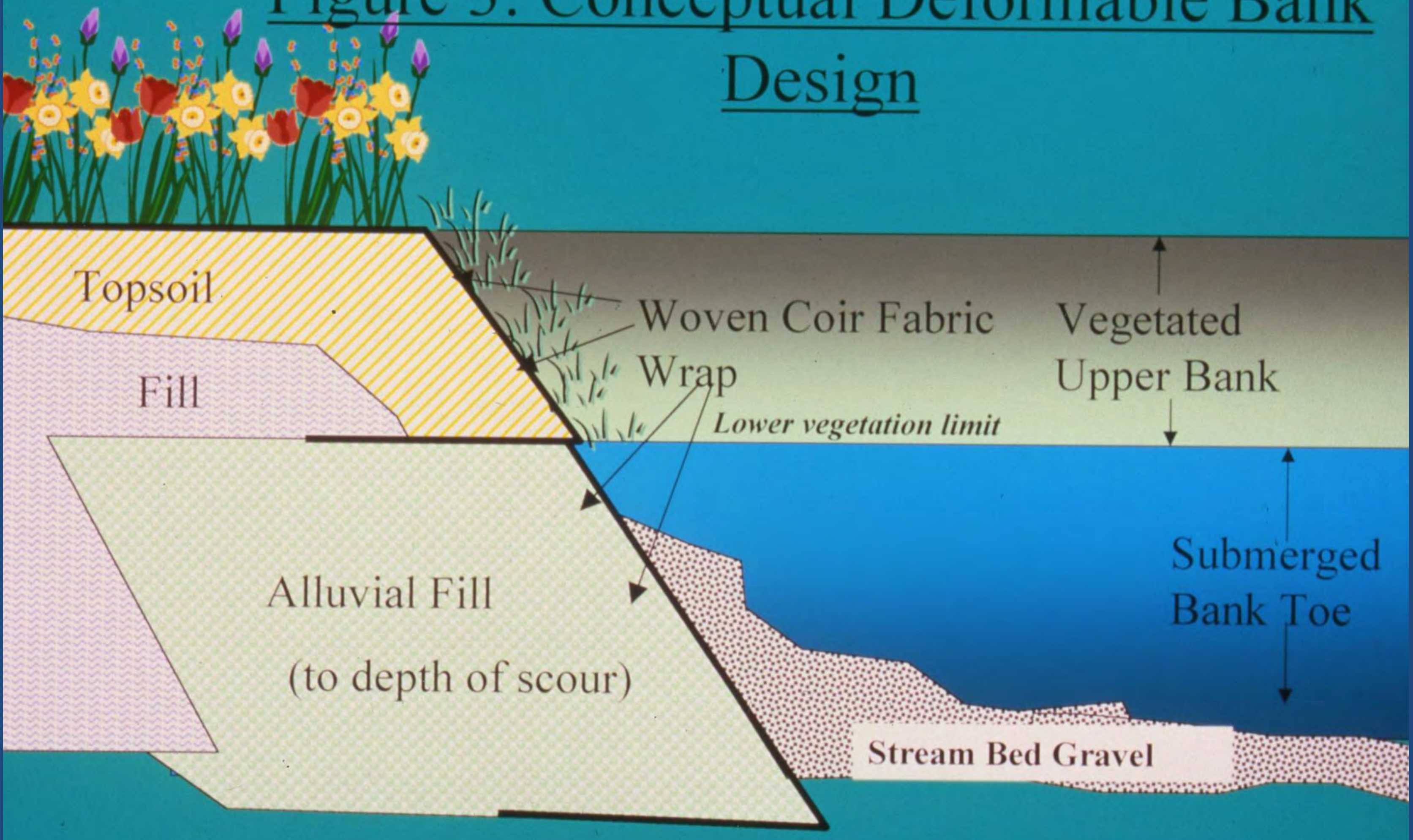
"Engineered Deformability"

(everybody wins!)

What about risk? I'm stamping this, buddy!

Miller, D.E. and P.B. Skidmore. 1998. Application of deformable stream bank concepts to natural channel design. ASCE Bank Stabilization Mini-Symposium of the International Water Resources Engineering Conference, Memphis, TN.

Figure 3: Conceptual Deformable Bank Design



(Skidmore and Miller, 1998)

Pilot Test September 1997

CONSTRUCTED CHANNEL

- **TYPE A -** Fabric Encapsulated Stone Toe
- **TYPE B -** Stone Filled Fabric Columns
- **TYPE C -** Coir Bio-logs over Fabric Wrapped Straw Bales
- **TYPE D -** Fabric Wrapped Large Straw Bales
- **TYPE E -** Woody Debris over Fabric Wrapped Straw Bales
- **UPPER BANK TREATMENT -** Fabric Encapsulated Soil
- **PLUGS**


STOP

Table 1: Geomorphically-based design criteria, Silver Bow Creek

Design Element	Criteria	Description
Gradient	Iterate with geometry to maintain sediment continuity	Determined from sediment continuity analysis
Bankfull Discharge	230 cfs	Intermediate between 2-yr Q and estimates from relatively stable reaches
Channel Geometry	Convey Qbf; W/D ratio 10-15; iterate with gradient to maintain sediment continuity	Determined from sediment continuity analysis
Sinuosity	Valley gradient/ channel gradient	Product of design grade
Planform	Rc/W<4; 50' buffer to areas of concern	Minimize cutoff; entrainment potential
Bed Material	Replicate existing riffle gradations	Designed to allow pool/riffle sorting
Bank Toe	50-yr protection for 3-5 yrs; 2-50 yr mobilization after	Natural deformability after 3-5 yrs
Upper Bank	50-yr Q protection for 3-5 yrs	Natural deformability after 3-5 yrs

→ Deformable, but optimistically so

Silver Bow Creek Design Criteria
Banks

Mobile stone toe with coir lift

Deformable, but slow

Silver Bow Creek Design Criteria
Capacity

Bankfull: 230 cfs

Deformable, but conservatively so

Silver Bow Creek Design Criteria Planform

Planform: Rc/W<4, 50 ft buffer to areas of concern

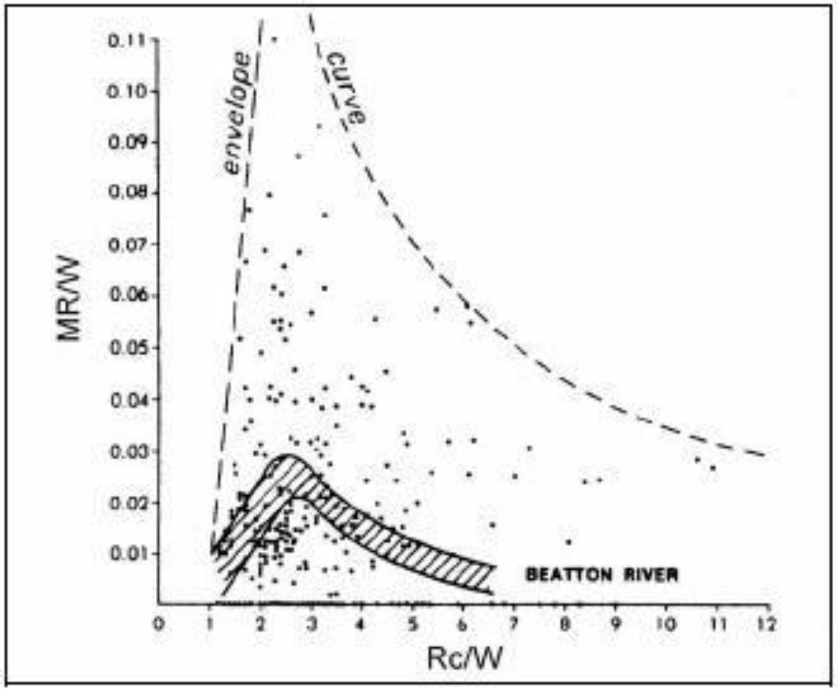


Figure 15. Migration Rate (MR/W) versus Radius of Curvature/Width *(91)* (see also Figure 7).

Deformable, but conservatively so

Primary Source

Boulder Batholith

Silver Bow Creek Design Criteria
Substrate

Bed material: Replicate existing riffle gradations

Deformable, but conservatively so

How Deformable is Silver Bow Creek?

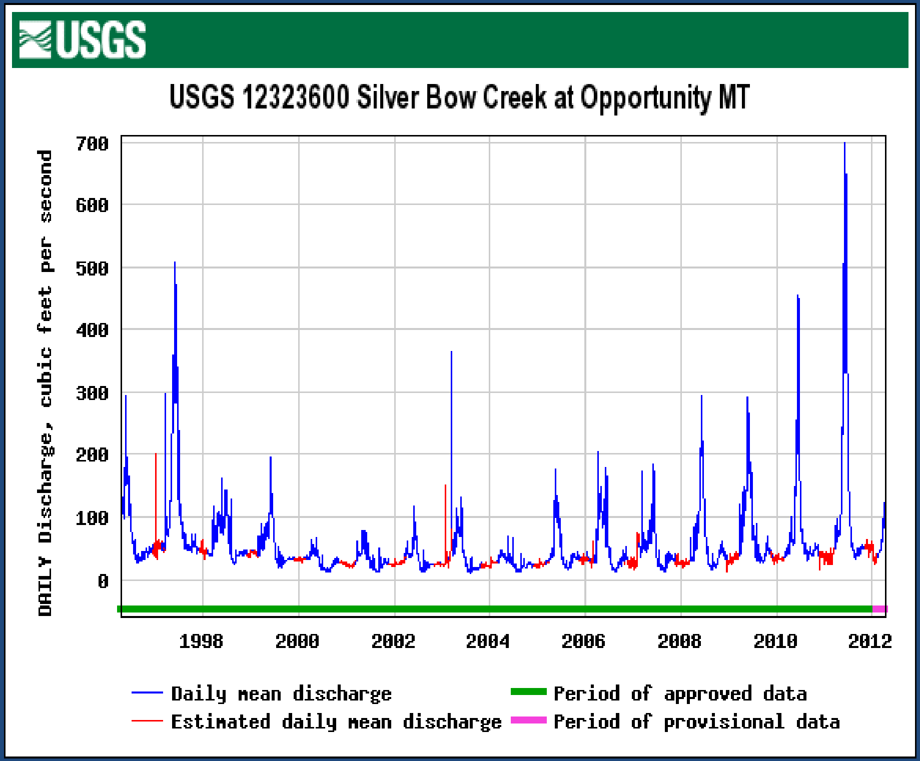
- Large cross section
- Big meanders
- Coarse substrate
- Slowly decaying fabric

The survey results for SS-10A are encouraging, as they indicate the channel is transitioning toward a relatively narrow and deep cross section suitable for fish habitat and sediment transport.

---Bighorn Environmental, Confluence Consulting, MTFWP, and PBS&J: 2009 Monitoring Report

There’s work to be done!

- Flow
- Sediment
- Coir Decay



Lessons Learned

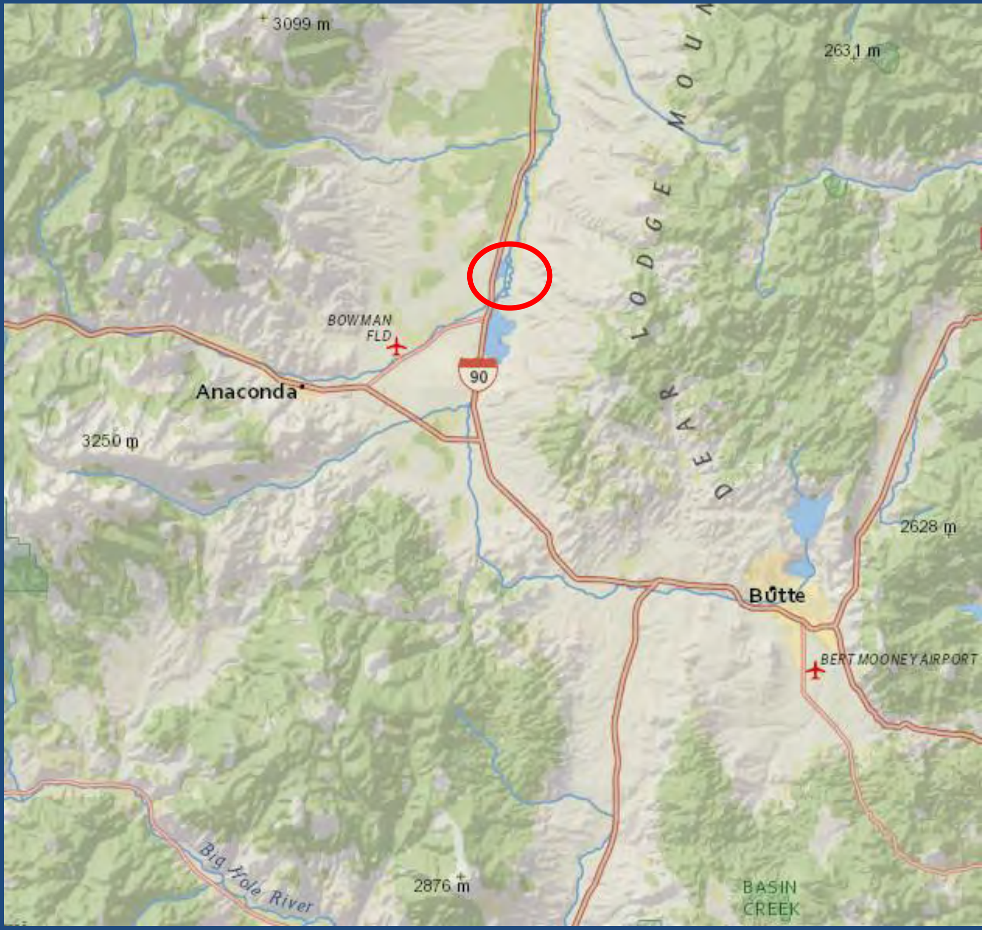
1. Design decisions are incremental

2. An aversion to increased risk tends to move us to more conservative outcomes

3. In deformable settings, that’s probably just fine in the long run

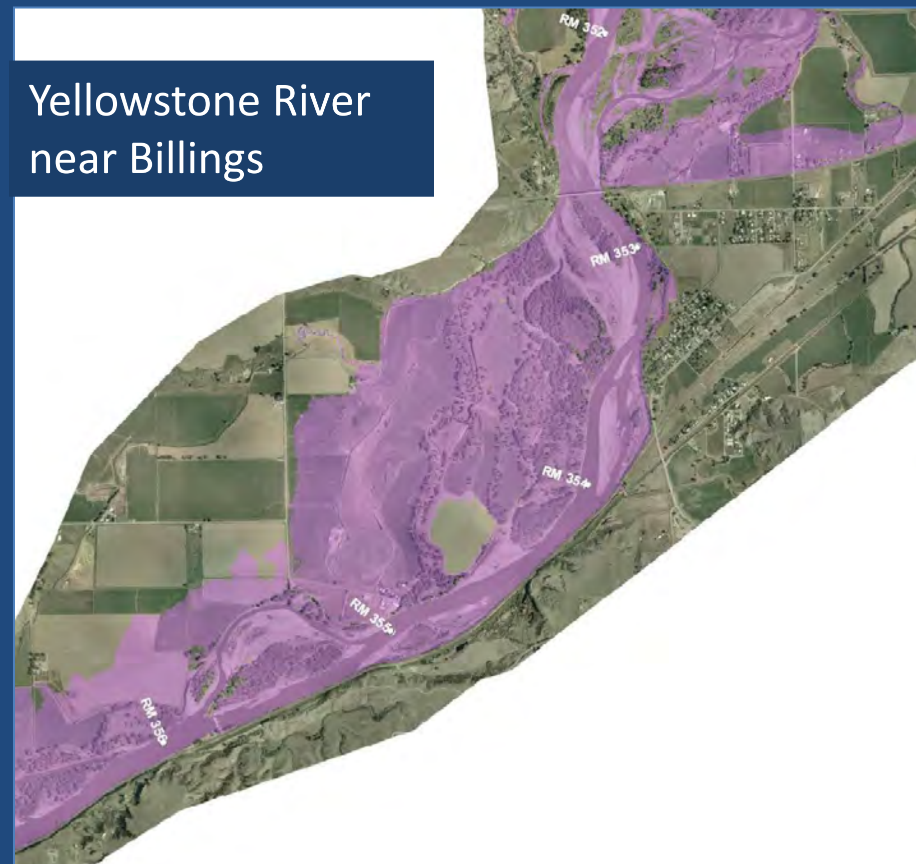
Upper Clark Fork River Geomorphic Design Approach

- Preserve Existing Channel
- Increase Floodplain Access
- Minimize Avulsion Risk



Floodplain Access
10-Year Inundation Examples

Clark Fork River
Reach A Phase 1



Yellowstone River
near Billings

Geomorphic Approach
Floodplain Access

- Remedy calls for development of a stable vegetated floodplain
- Current floodplain vegetation is on a decay trajectory
- Reconnecting the river to the floodplain surface will sustain the riparian community and improve system resilience.

Geomorphic Approach

Improve Floodplain Access to Provide Long-Term Stability (Riparian Recovery)

Can Commonly Identify Historic Floodplain Surface

Geomorphic Approach

Managing Short-Term Floodplain Exposure

- Floodplain Reinforcement at Potential Cutoff Areas
- Secondary Channel Design Components

Monitoring

Goal:

Minimize geomorphic adjustment during period of vegetation re-establishment (15 years) and allow for long-term dynamic equilibrium.

Short-Term Objectives:

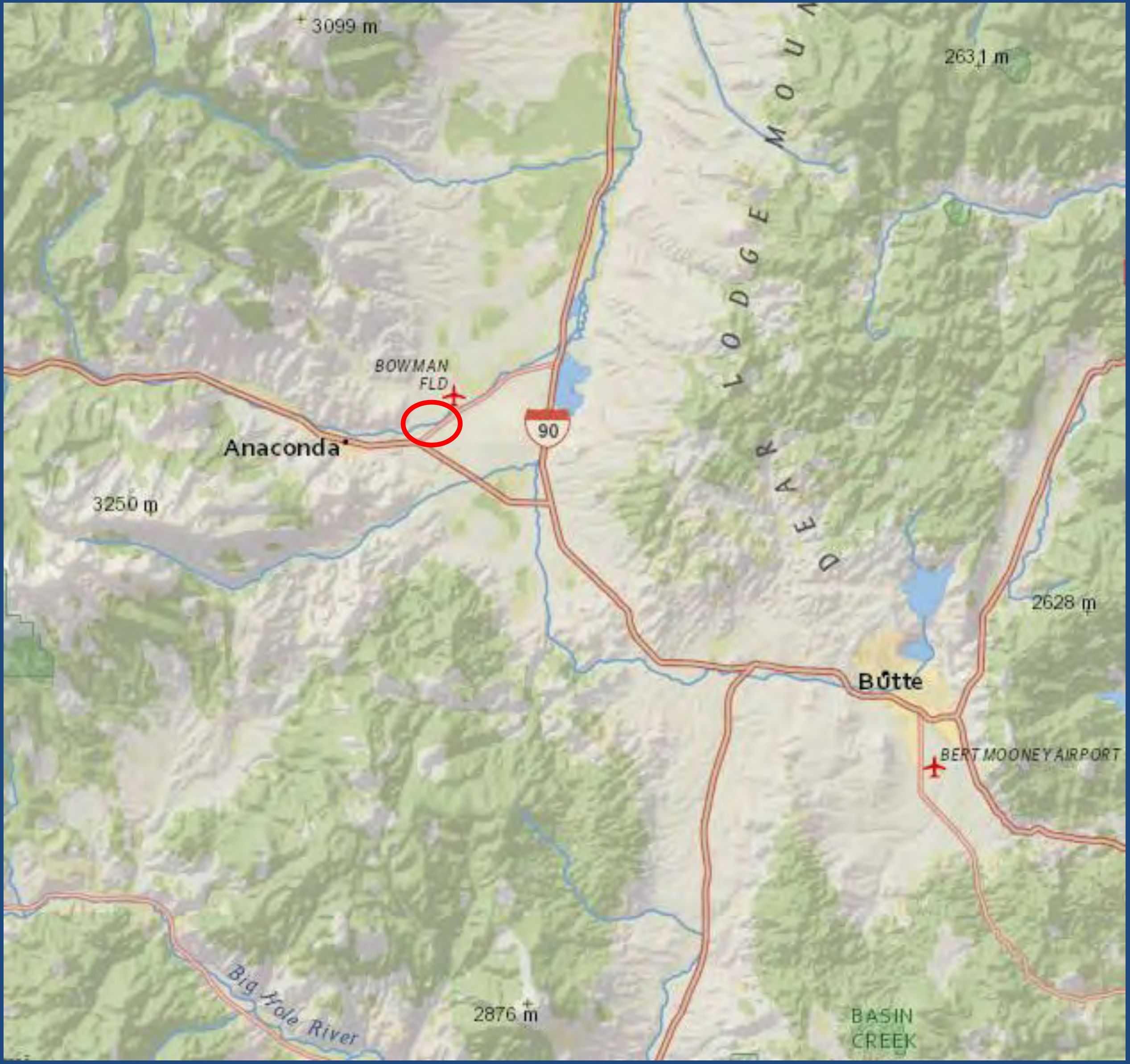
Channel planform and slope adjustments maintain floodplain connectivity at the 2-year flow.

The floodplain will convey flows without destabilizing or capturing the main channel.

Long-Term Objectives (15+ years):

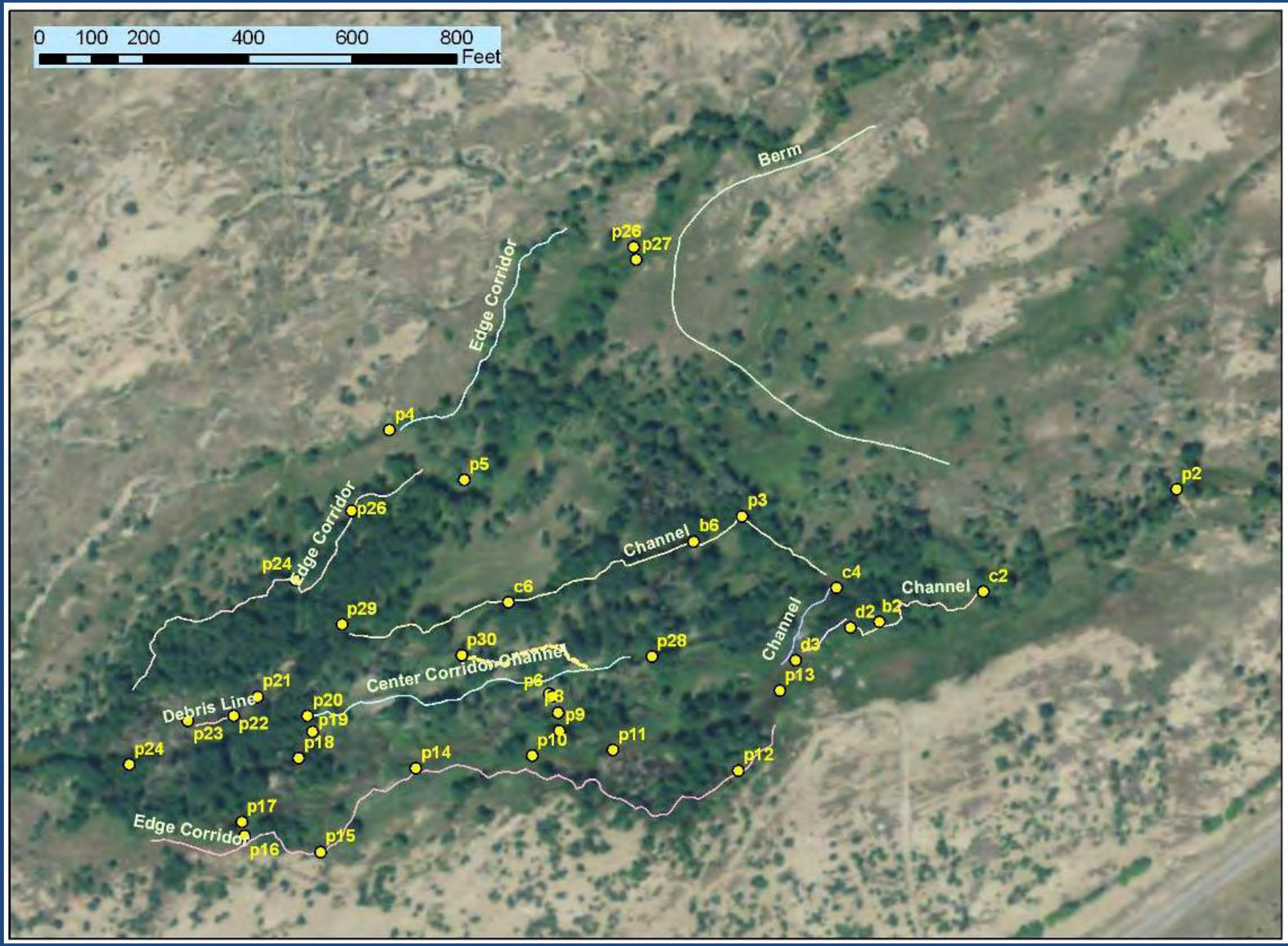
Erosion of floodplain channels is variable and may create continuous threads that are active at all flows.

Warm Springs Creek



2006

2006


0 100 200 400 600 800
Feet
Berm
Edge Corridor
Edge Corridor
Edge Corridor
Channel
Channel
Channel
Center Corridor Channel
Debris Line
p2
p3
p4
p5
p6
p8
p9
p10
p11
p12
p13
p14
p15
p16
p17
p18
p19
p20
p21
p22
p23
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p27
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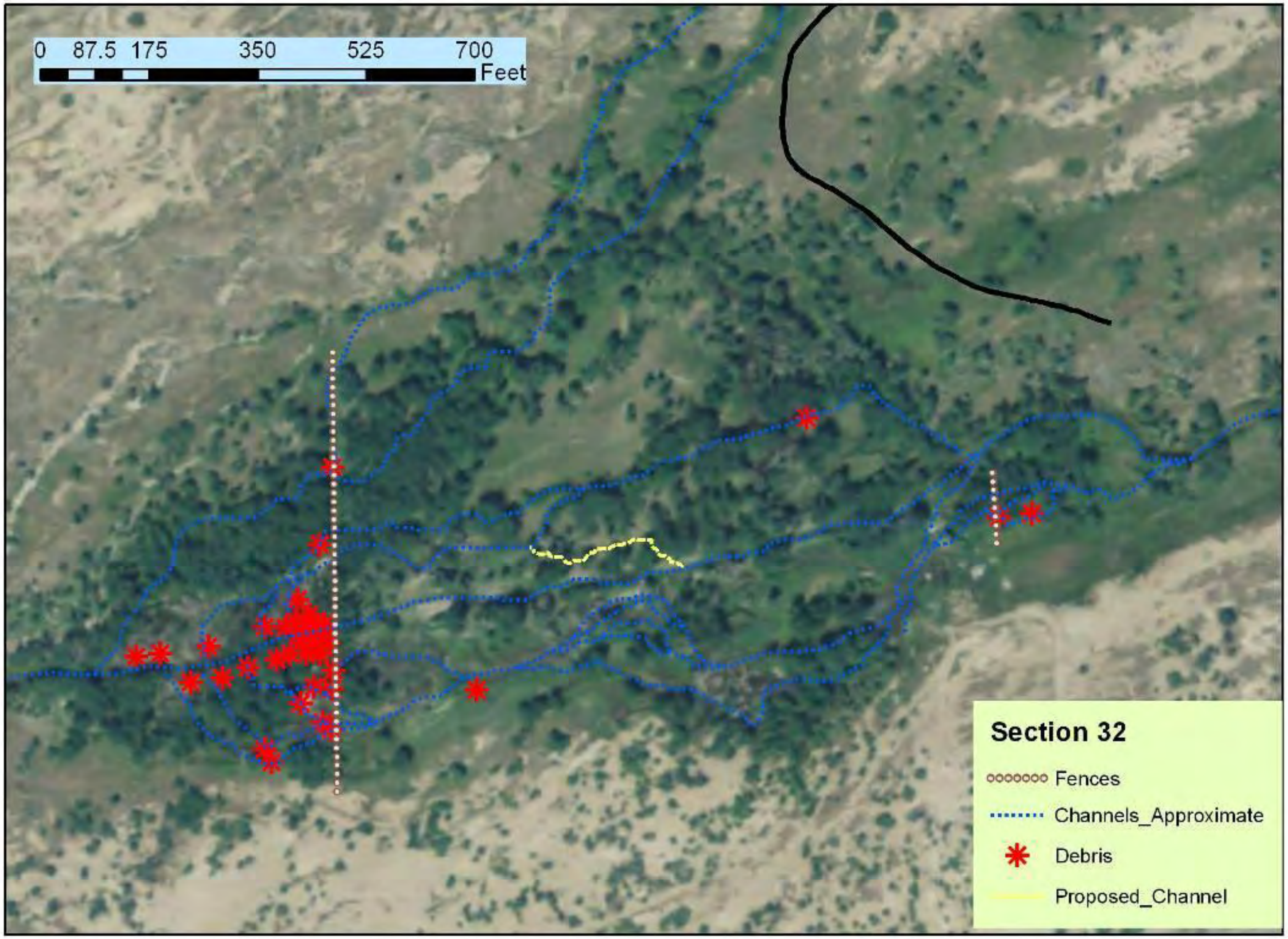
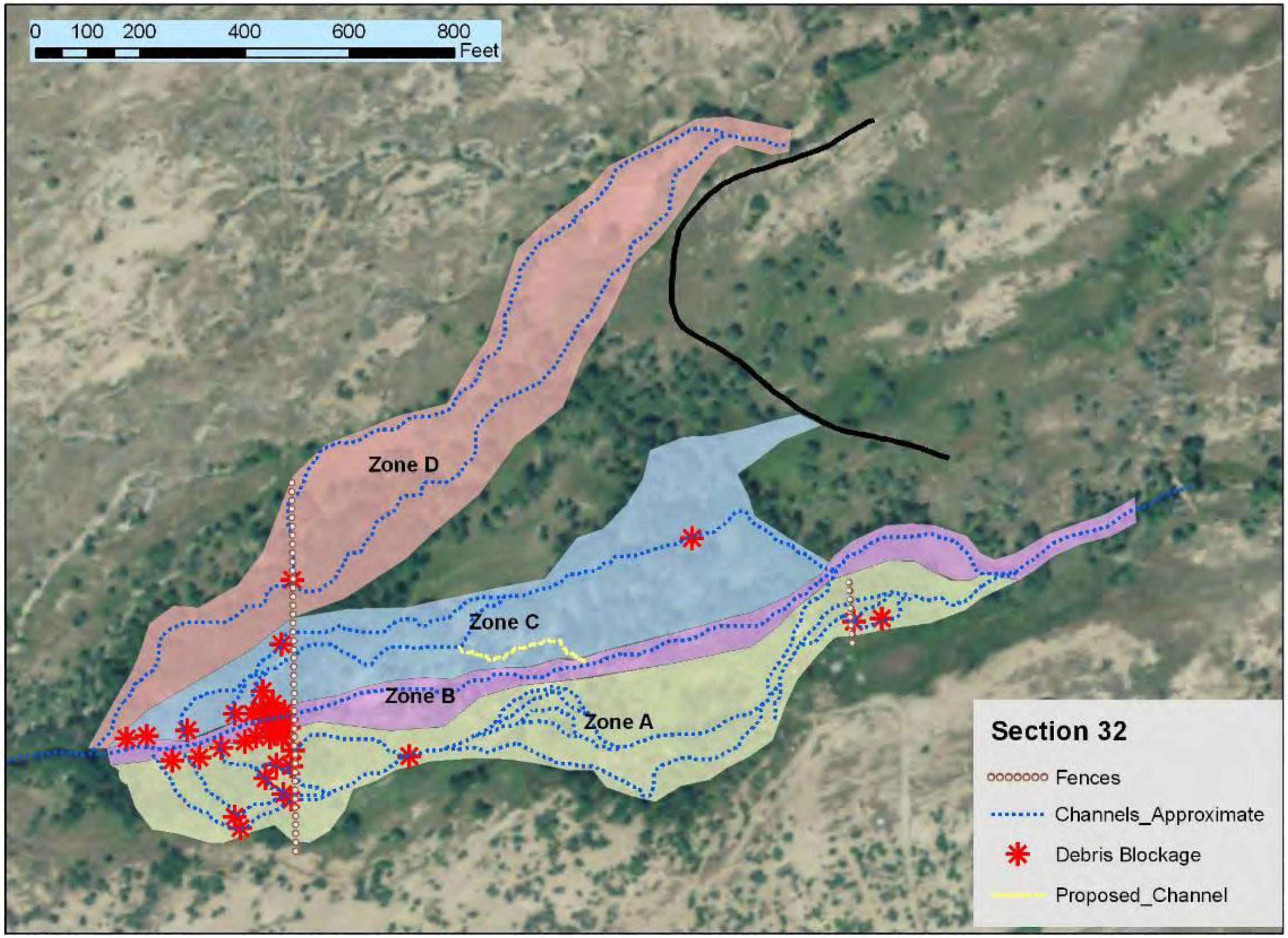
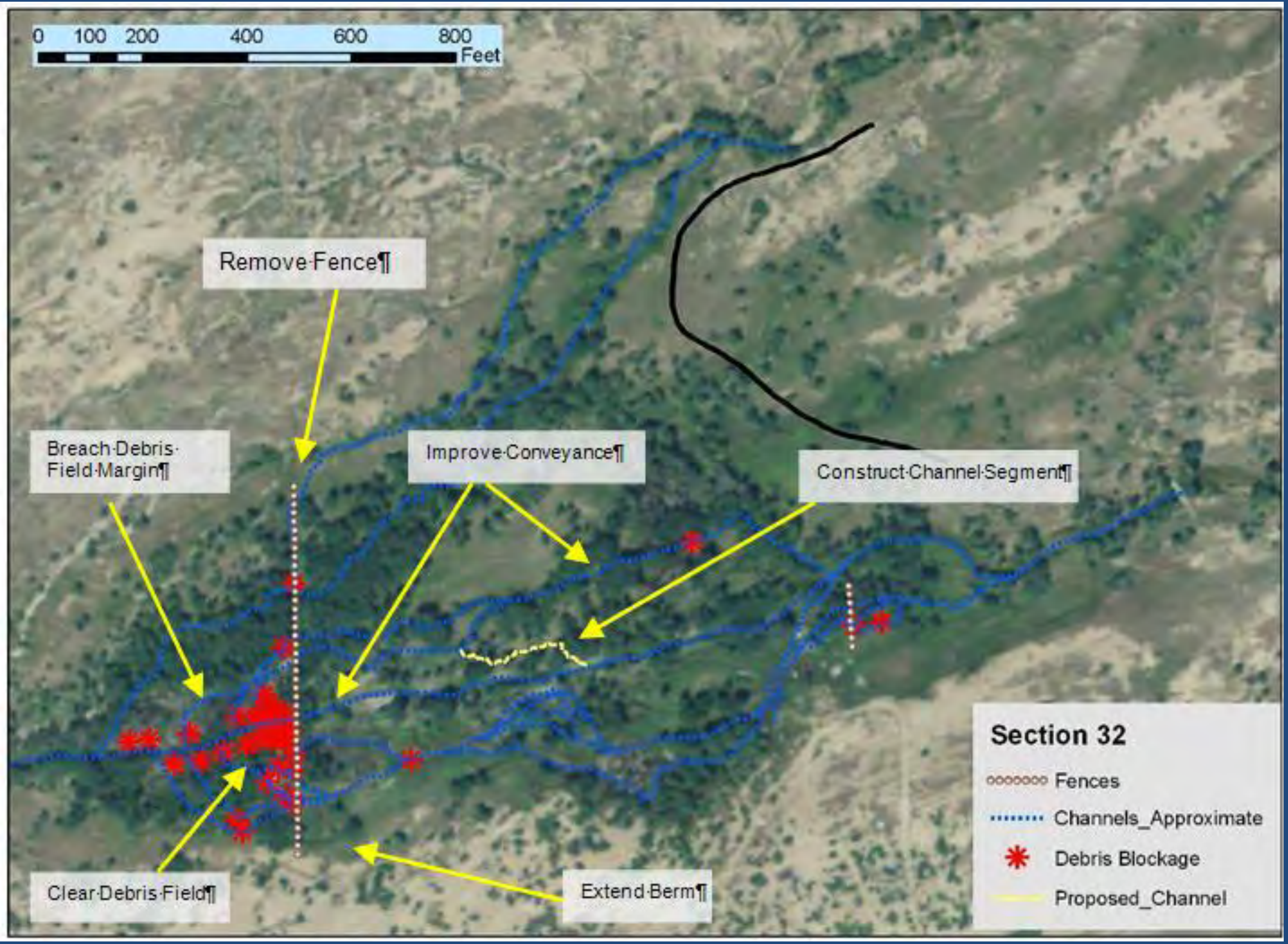
p30
b2
b6
c2
c4
c6
d2
d3


0 87.5 175 350 525 700
Feet
Section 32
Fences
Channels_Approximate
Debris
Proposed_Channel


0 100 200 400 600 800
Feet
Zone D
Zone C
Zone B
Zone A
Section 32
Fences
Channels_Approximate
Debris Blockage
Proposed_Channel

2010



0 100 200 400 600 800
Feet
Remove·Fence¶
Breach·Debris·
Field·Margin¶
Improve·Conveyance¶
Construct·Channel·Segment¶
Clear·Debris·Field¶
Extend·Berm¶
Section 32
Fences
Channels_Approximate
Debris Blockage
Proposed_Channel

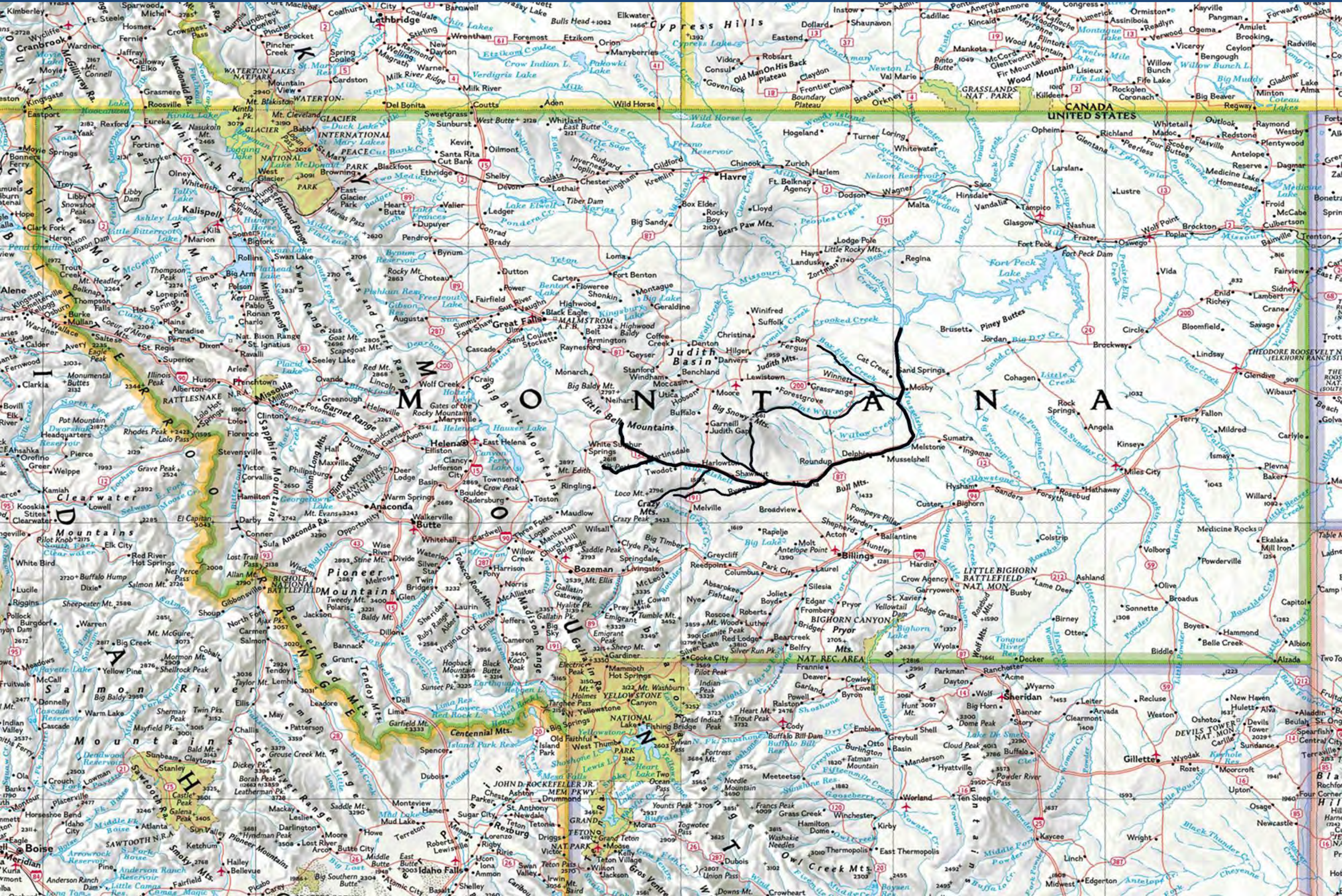
2011

0 125 250 500 750 1,000
Feet
New·Overflow·Path¶
2011·Debris·Jam¶
Main·Debris·Field¶

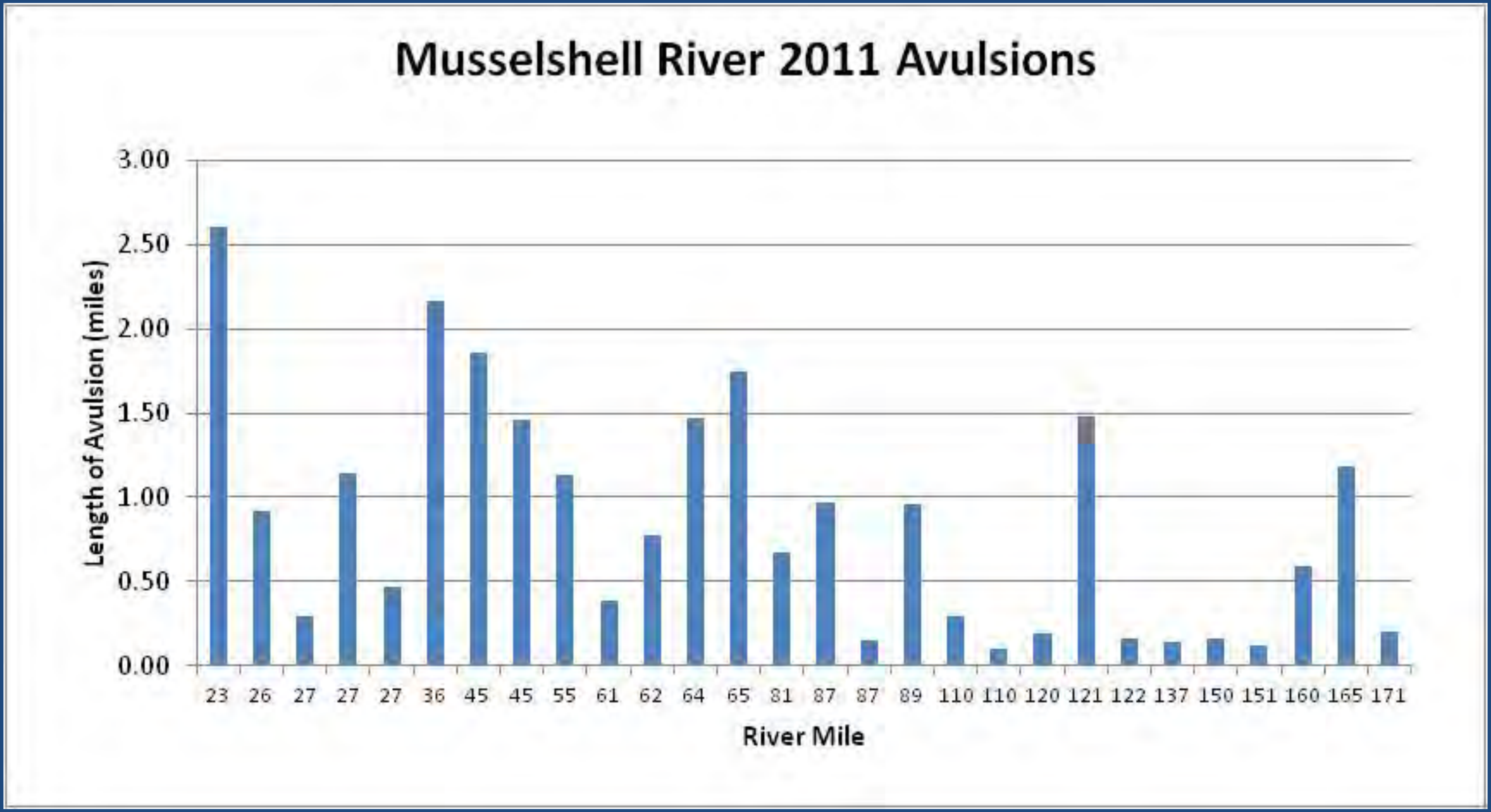
2011

Letting Go

Musselshell River 2011



Reality Check: The Musselshell



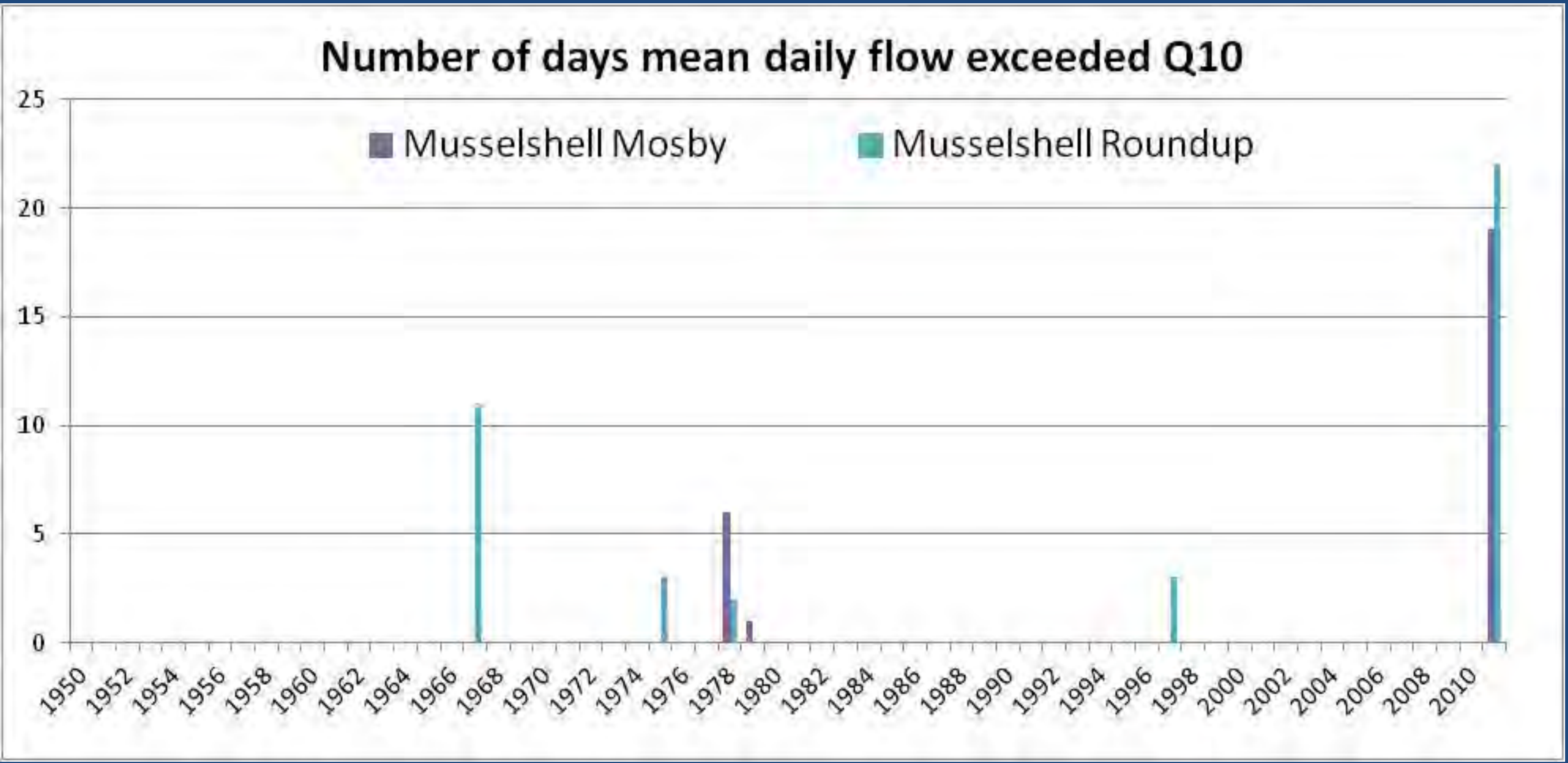
28 avulsions, 24 miles of shortening

June 16, 2011

June 16, 2011

July 28, 2011

Duration: Weeks of high flows



Q10 Roundup = 4,850 cfs

Q10 Mosby = 12,700 cfs


Chris Boyer, Kestrel Aerial Services, In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September 13, 2011

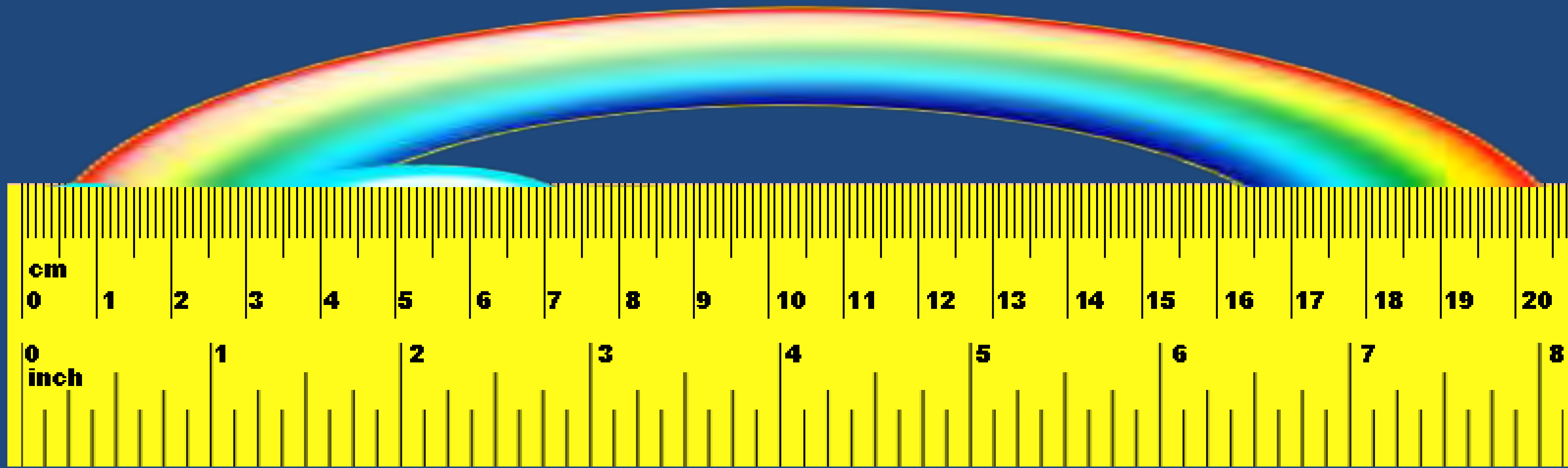
November 2, 2011

November 2, 2011

Disturbance Happens

Will “minimizing entrainment potential” succeed?

Geomorphology



Remedy

Restoration

Dale Miller
1955-2011

Founding Partner of Inter-Fluve, Inc.

Founder of Mainstream Restoration, Inc.

Thanks!

Arkansas River

Removal of the tailings was not feasible because of
(1) the potential to destabilize streambanks and cause massive changes in the river system,

(2) the potential for tailings to enter the river during field activities,

(3) the high cost of replacement topsoil, and

(4) the difficulty of locating an acceptable repository for contaminated soil.

---USEPA, 2011