Dutch Creek Reconstruction, Coal Basin Mine, Redstone, CO - Geomorphic Design and Ongoing Geomorphic Development

Hal Pranger
Office of Surface Mining, Denver

“In theory, there is no difference between theory and practice. In practice, however, there is.”

A Plug for Monitoring

- **Synthesizing U.S. River Restoration Efforts, 29 APRIL 2005 VOL 308 SCIENCE**
  - 37,099 projects evaluated as of July 2004.
  - **at least** $14 to $15 billion spent on river restoration projects in the continental U S from 1990 to 2004 (average of >$1 billion a year).
  - in only 10% was there any assessment or monitoring (>20% in the Southwest and Central US)
  - “many opportunities to learn from successes and failures, and thus to improve future practice, are being lost.”
  - It's currently impossible to determine if the desired environmental benefits of river restoration are being achieved,"

OBJECTIVES:

- Prove the usefulness of a simple geomorphic channel design method

- Demonstrate that it usually takes many years to fully understand the behavior of even an active reclaimed stream channel.

- Show why designers and regulators need to consider geomorphic perspectives of erosion, sedimentation and stability when making decisions regarding watersheds and stream channels.

- Show the usefulness of long-term monitoring to understand and demonstrate channel development.

Coal Basin Mine
Denver
Aurora
Colorado
Colorado Springs
76
270
225
25
34
40
138
287
6
24
285
50
550
85
160
666
87
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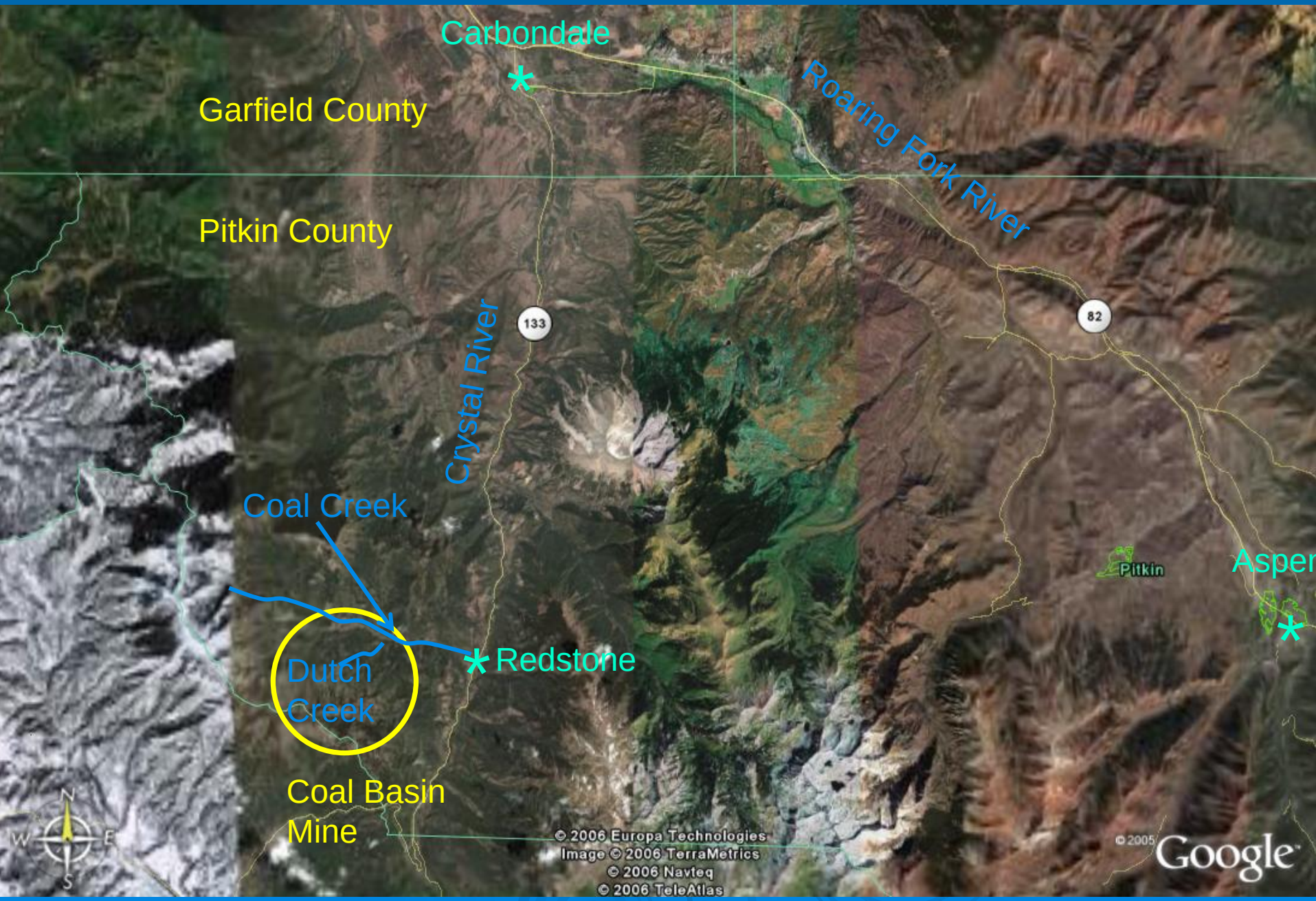
Carbondale
Garfield County
Pitkin County
Roaring Fork River
Crystal River
133
82
Coal Creek
Dutch Creek
Redstone
Coal Basin Mine
Pitkin
Aspen
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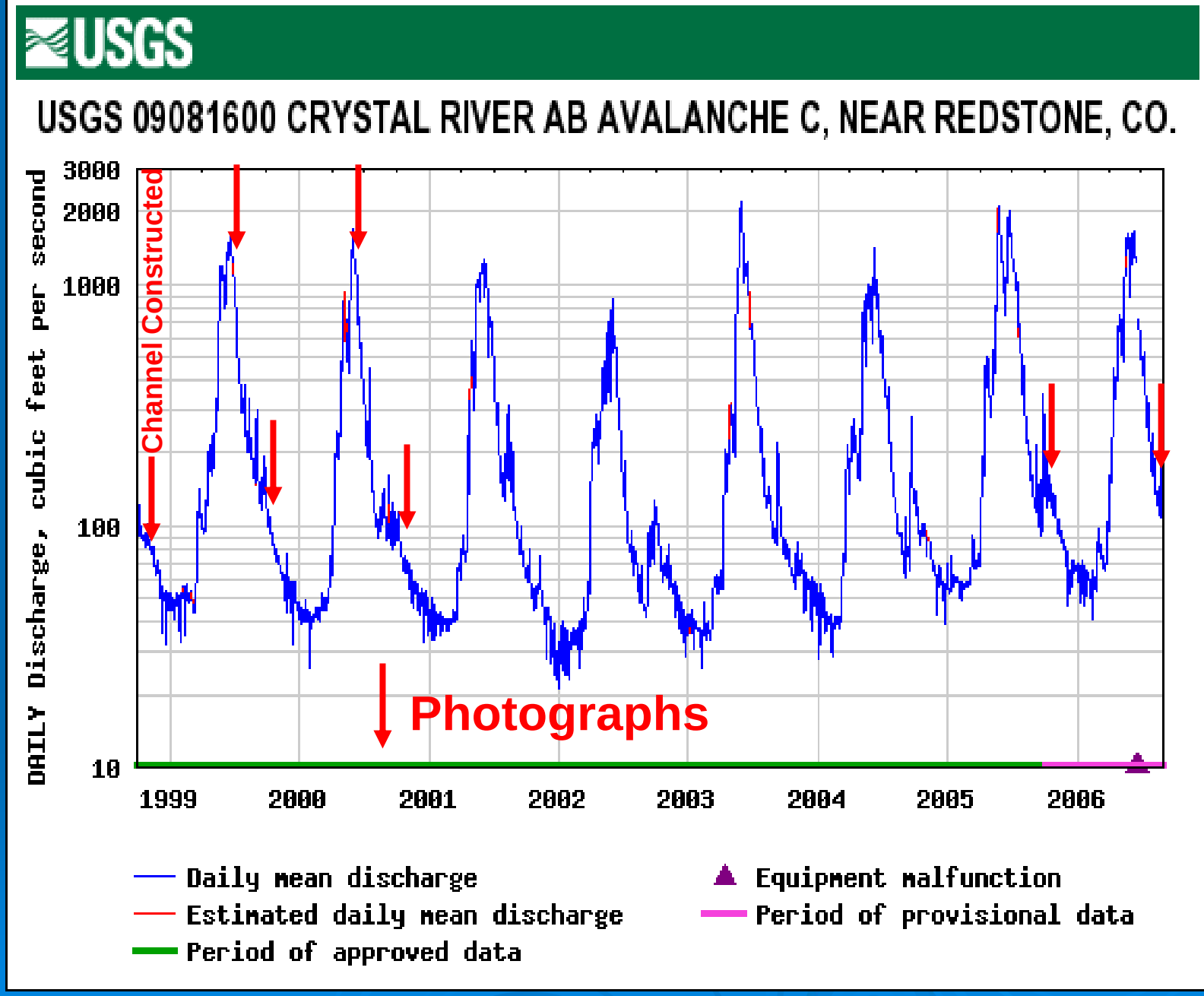
Dutch Creek – a 4.1 square mile watershed:

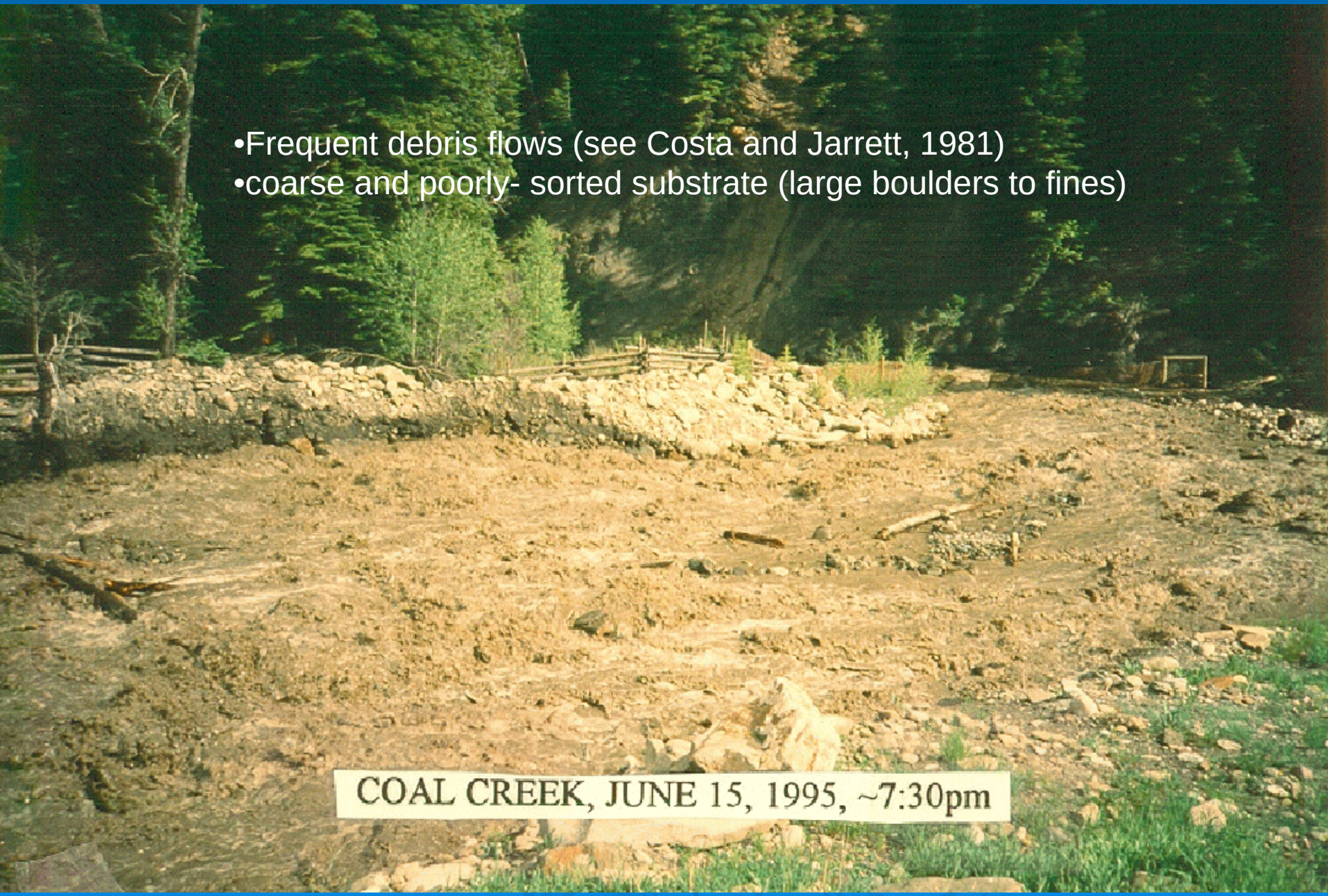
- High elevation (8,000’-10,000’) – subalpine, scenic
- Abandoned coal mine facilities area at watershed mouth
- Bond Forfeiture Site – early to mid 1990s
- Extremely high land values

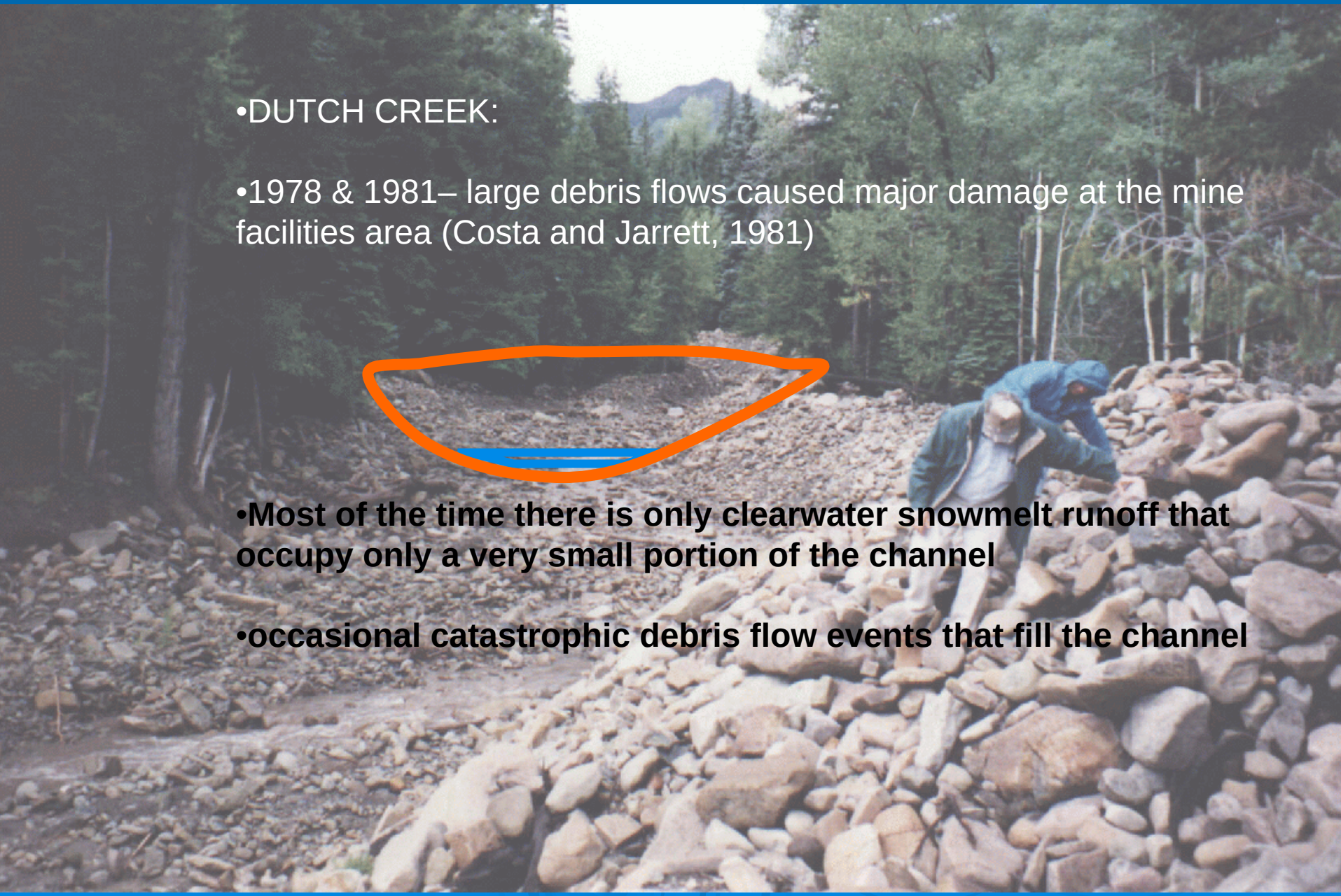
Crystal River @ USGS gage (~ 7 miles downstream of site)



Flows dominated by snowmelt runoff– perennial but highly seasonal
(Dutch Creek flows range from ~5 to 400 cfs)

- Q: What is a flood?
- A: A river that's too big for its bridges


•Frequent debris flows (see Costa and Jarrett, 1981)
•coarse and poorly- sorted substrate (large boulders to fines)
COAL CREEK, JUNE 15, 1995, ~7:30pm



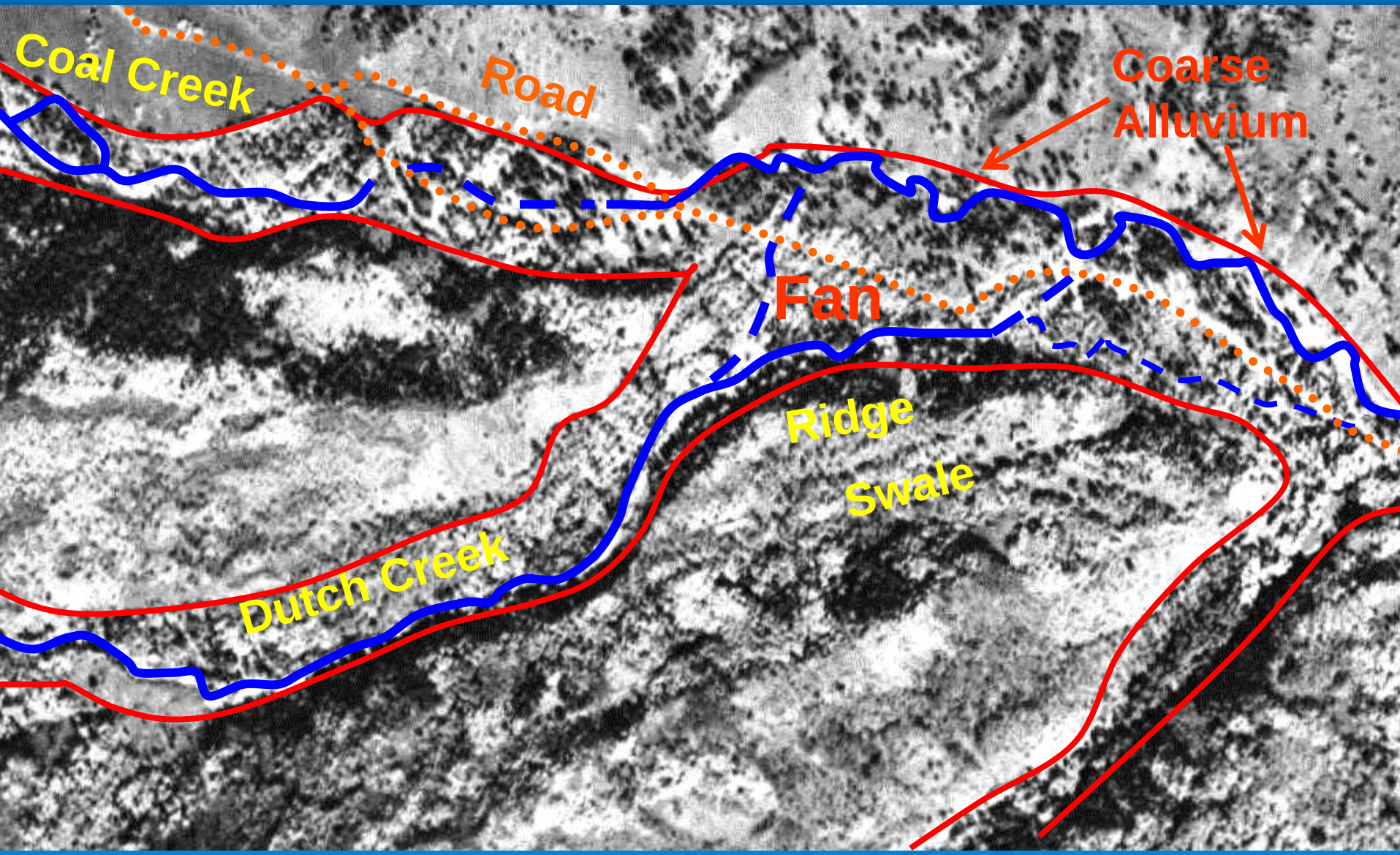
•DUTCH CREEK:

•1978 & 1981– large debris flows caused major damage at the mine facilities area (Costa and Jarrett, 1981)

•Most of the time there is only clearwater snowmelt runoff that occupy only a very small portion of the channel

•occasional catastrophic debris flow events that fill the channel

1952

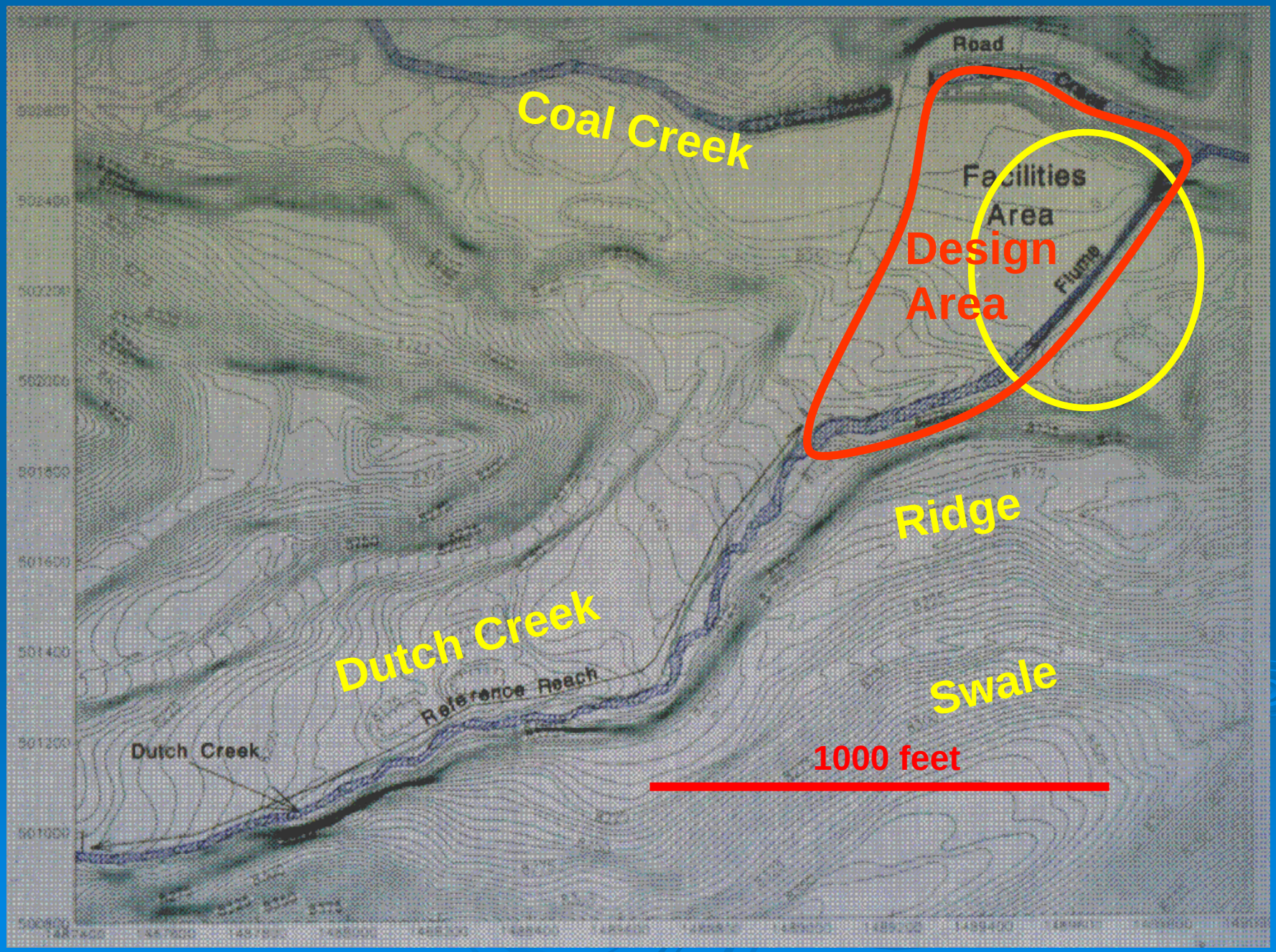

Coal Creek
Road
Coarse
Alluvium
Fan
Ridge
Swale
Dutch Creek

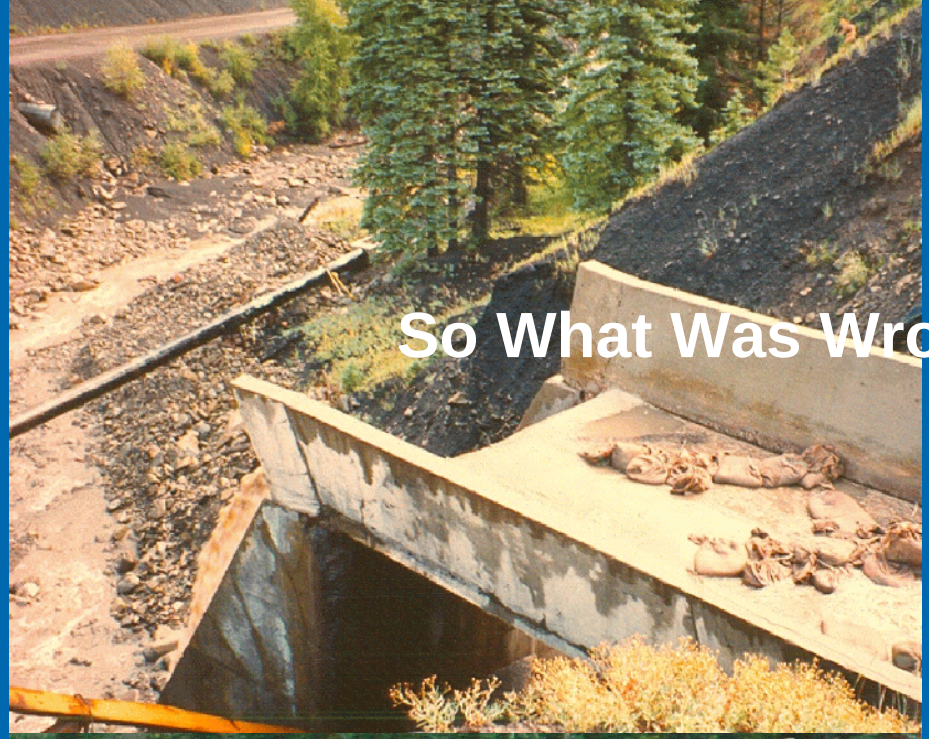
1973

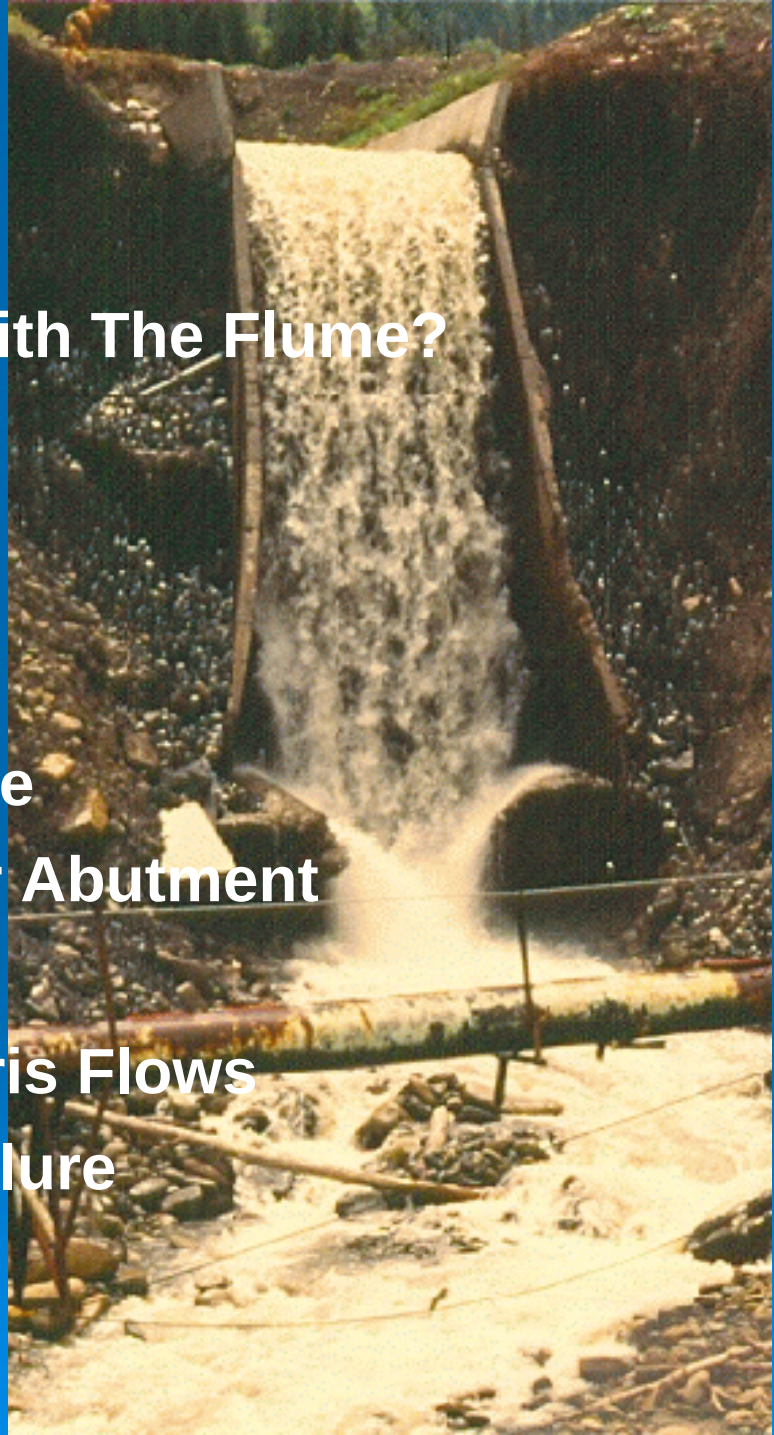
Coal Creek
Facilities and Waste
Occupying Valley Bottom
Ridge
Swale
Dutch Creek

1981

1990

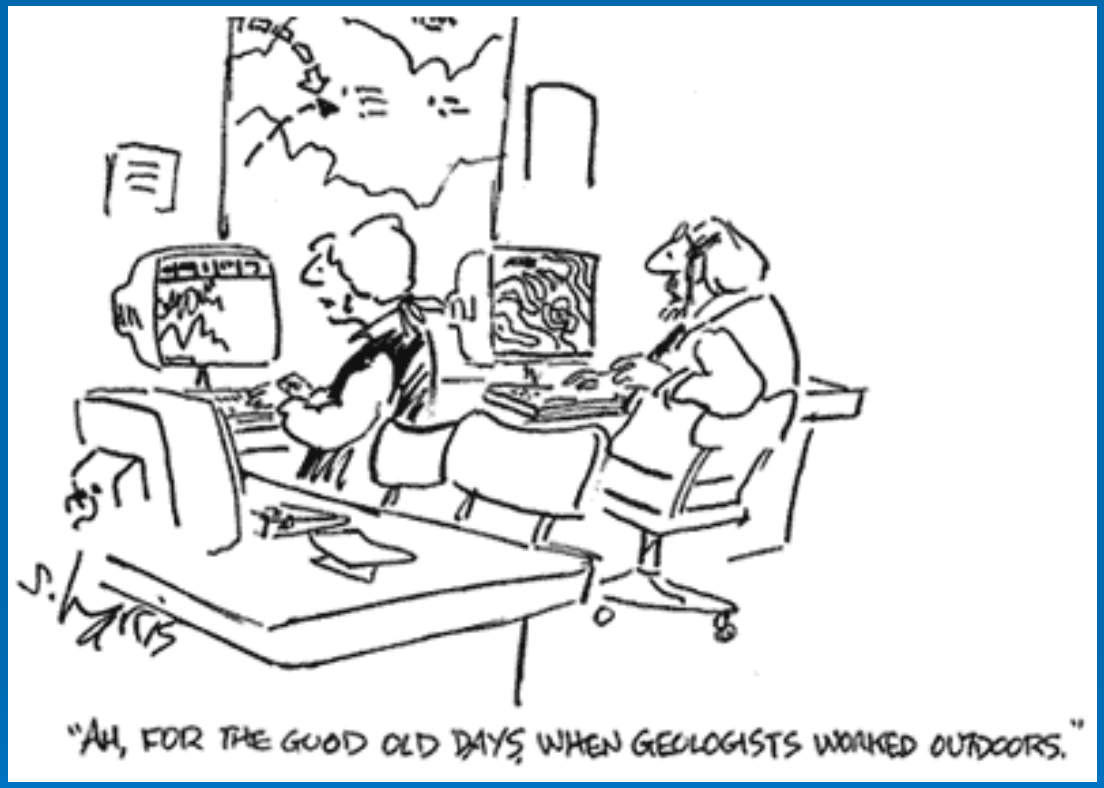

Road
Coal Creek
Facilities
Area
Design
Area
Flume
Ridge
Dutch Creek
Reference Reach
Swale
Dutch Creek
1000 feet





So What Was Wrong With The Flume?

- Thin and Abraded Concrete
- Erosion Behind and Under Abutment
- Buckling Concrete
- Inability to Withstand Debris Flows
- Imminent Catastrophic Failure


"AH, FOR THE GOOD OLD DAYS, WHEN GEOLOGISTS WORKED OUTDOORS."

Stream Channel Design Approach

Geomorphic channel design (1996): Incorporated reference reach basics:

- **6.8% gradient:**
- **tough space constraints between road and Pre-law area**
- **required necessary channel alignment compromise to achieve required length ("kinks" separating nearly straight reaches)**

- **Compound channel – inner channel for water & outer channel for debris flows – two variable design widths**

- **Low sinuosity**

>Hand-Drawn: TRIAL AND ERROR< - EarthVision for volumes and display

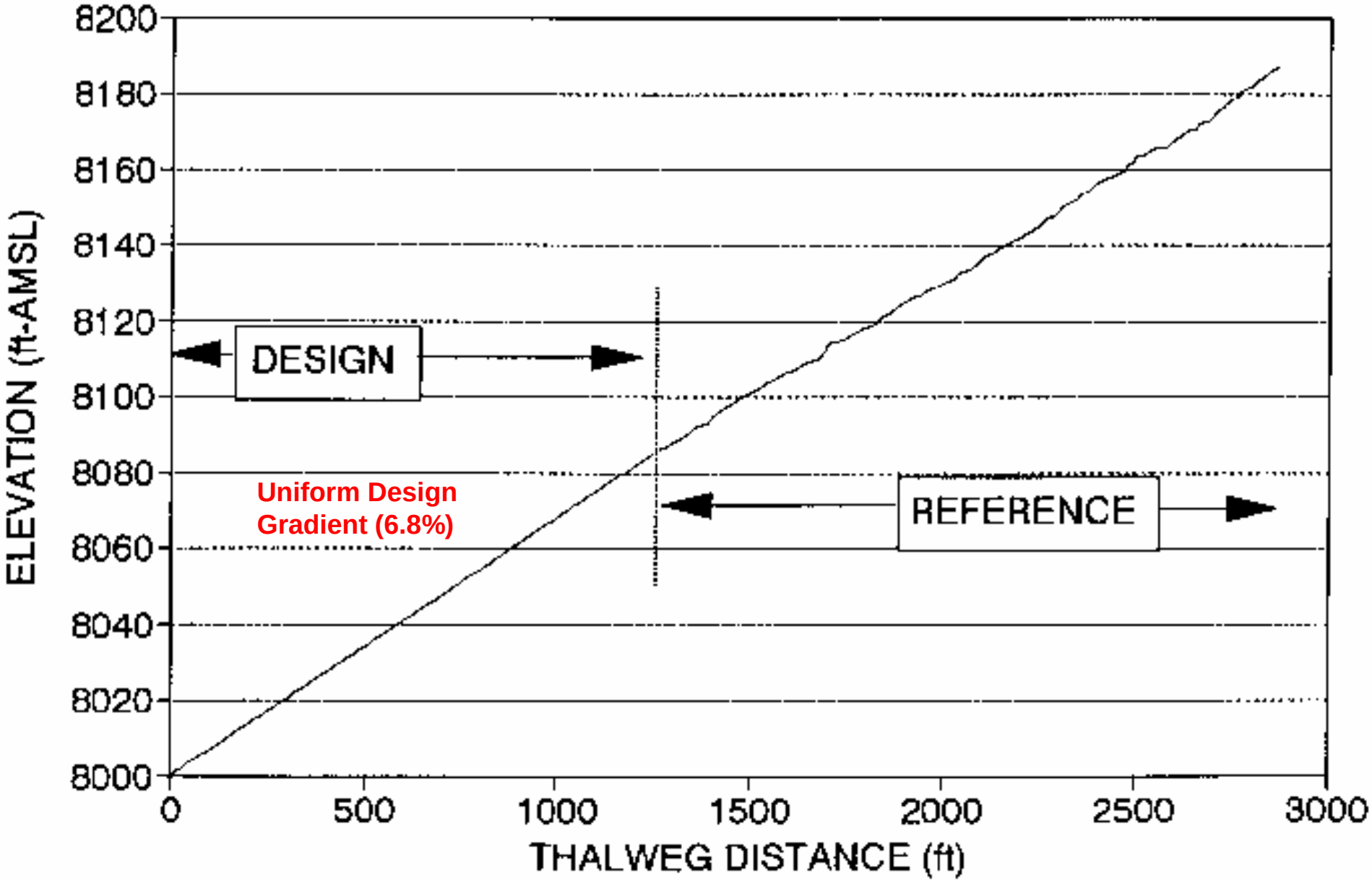
•Cost estimate for a riprap- stabilized channel ~ $1.9 M (1994)

•Actual construction cost ~ $65K (1998)

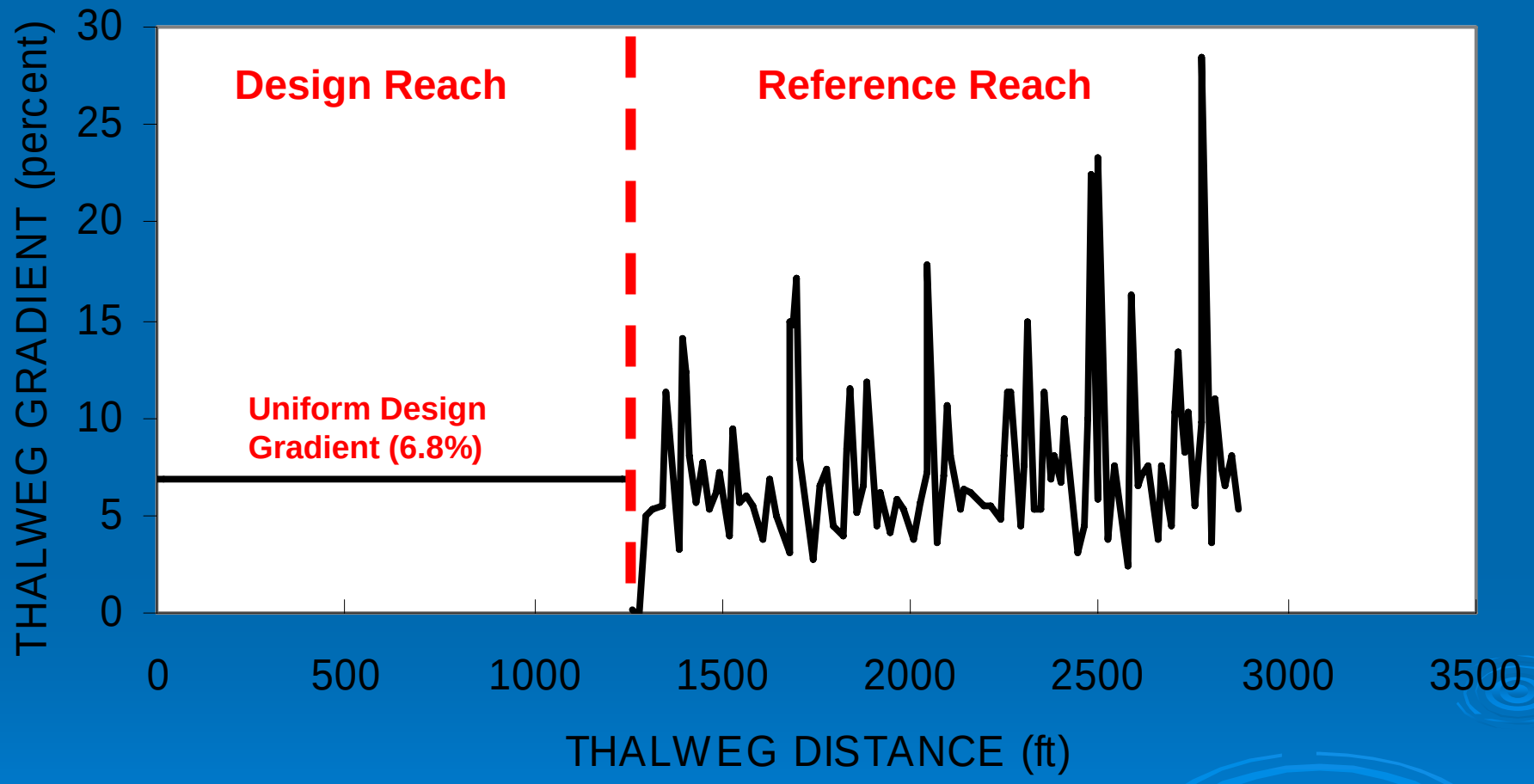
Reference Reach and Design Reach Morphometry Comparison

"Inner" Channel Parameter	Reference Reach Mean	Reconstructed Reach
Thalweg Gradient (%)	6.3	6.8
Top Width (ft)	17.7	12 – 16
Mean Maximum Depth (ft)	1.6	2*
Sinuosity	1.05	1.13

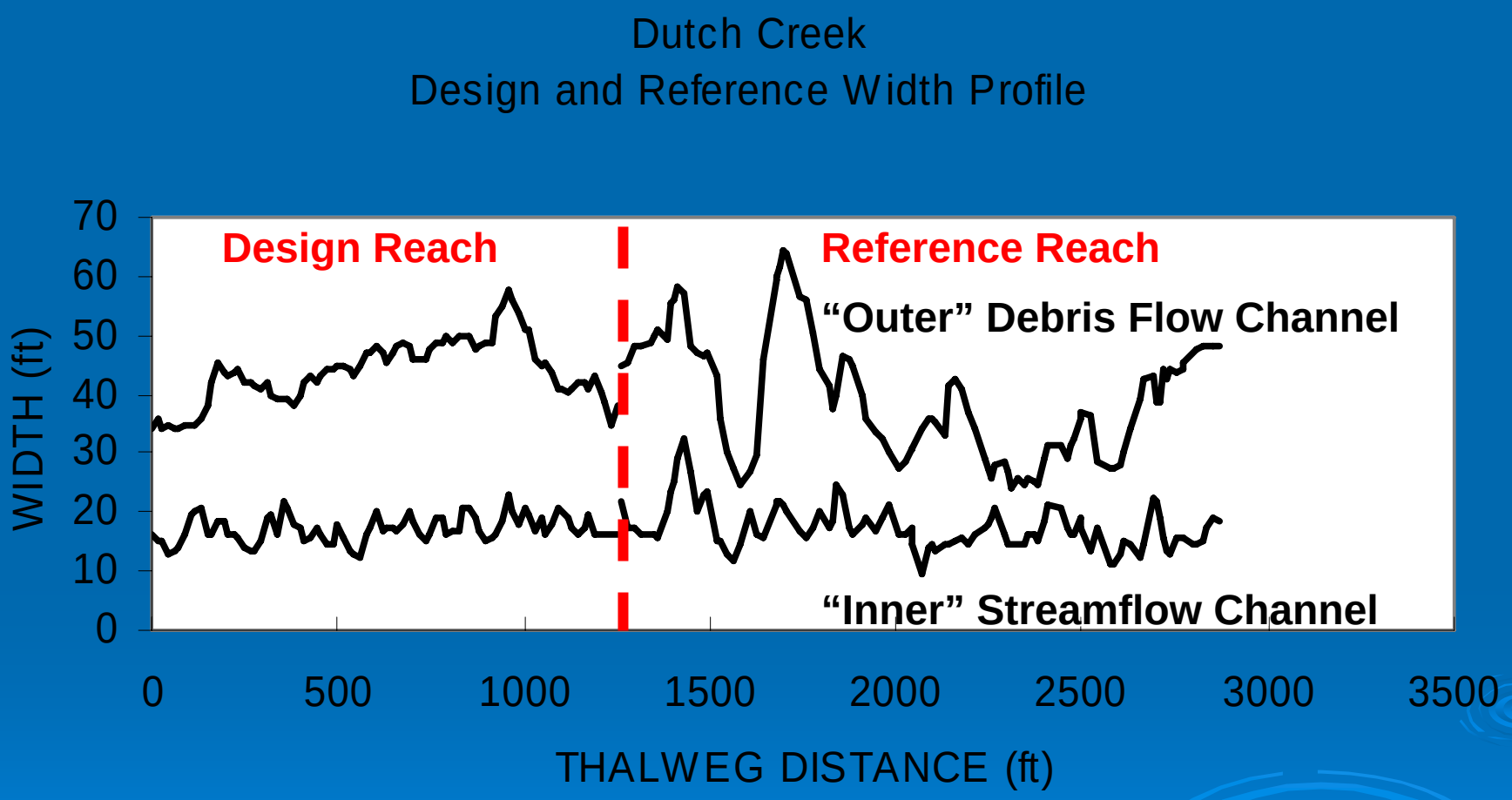
Dutch Creek
Design and Reference Reach Profiles



Thalweg Gradient Profile - Design and Reference Reaches

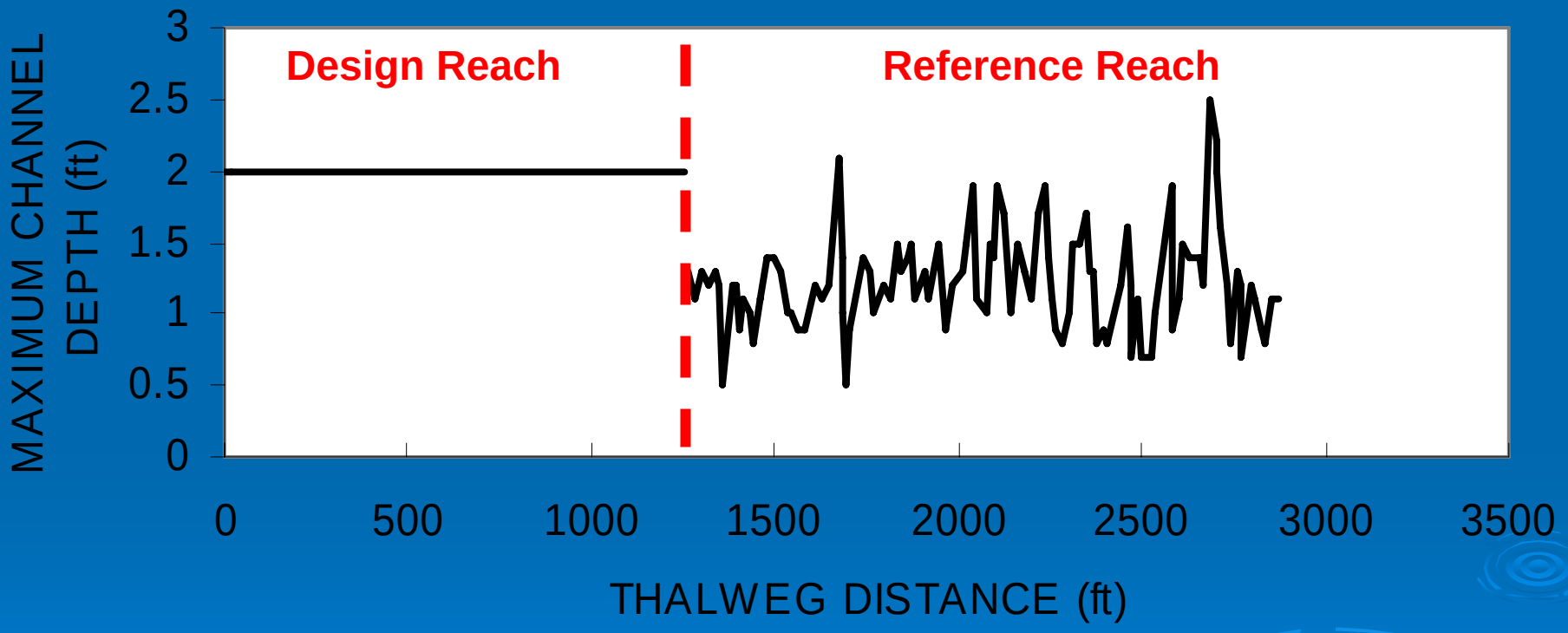


Uniform Design Gradient



Two Width Ranges Incorporated Into the Design

Dutch Creek
Design and Reference Max. Depth Profile

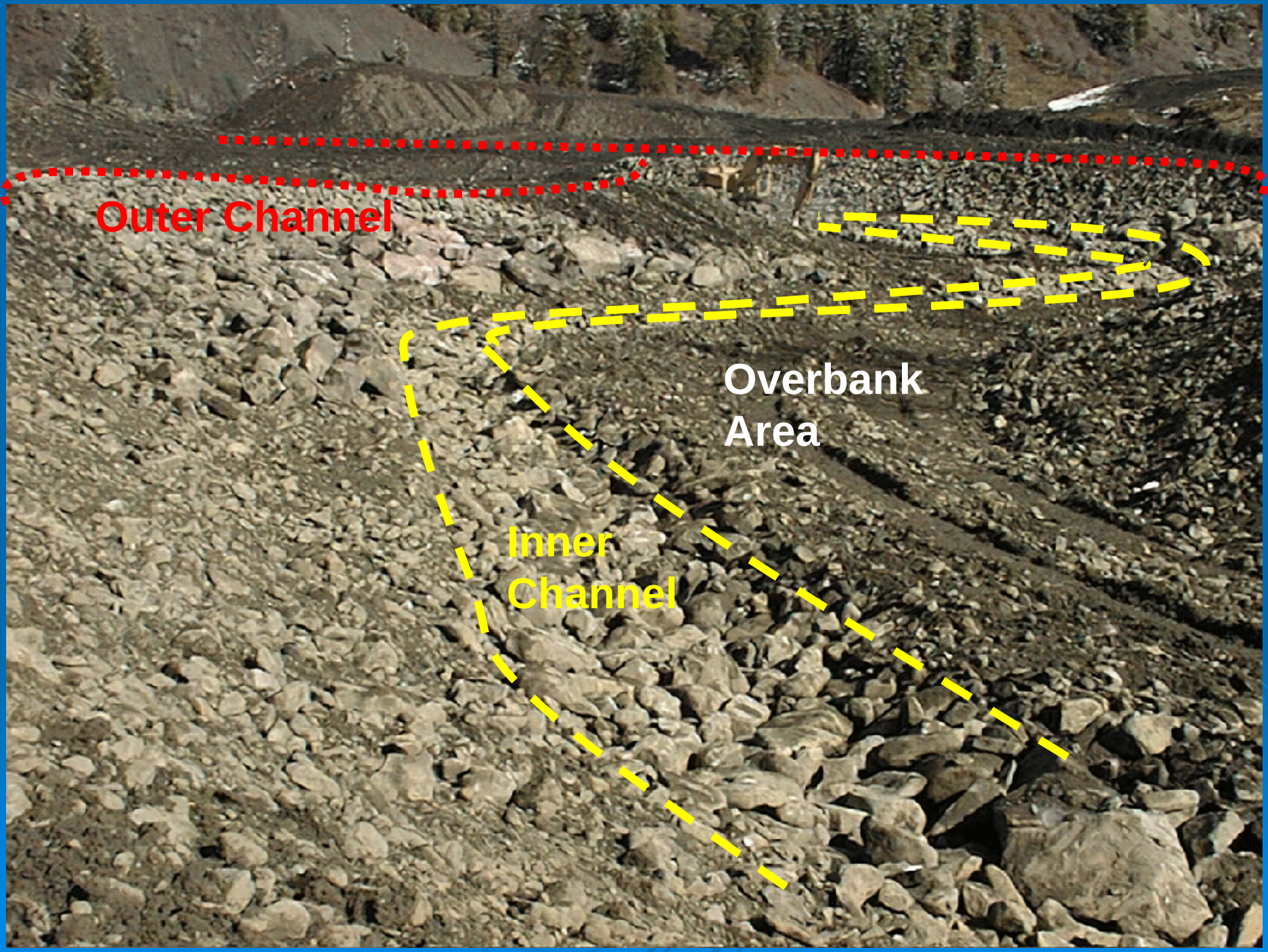


Uniform Design Depth*

CHANNEL CONSTRUCTION

“Outer” (Debris Flow) Channel Excavated

Then “Inner” (Streamflow) Channel Excavated (Notice Native Coarse Debris)


Outer Channel
Overbank
Area
Inner
Channel

Channel Development During the First Two Runoff “Seasons”

Near end of construction (October 1998)

Near peak of first runoff season (June, 1999)

After Two Runoff Seasons (August, 2000)

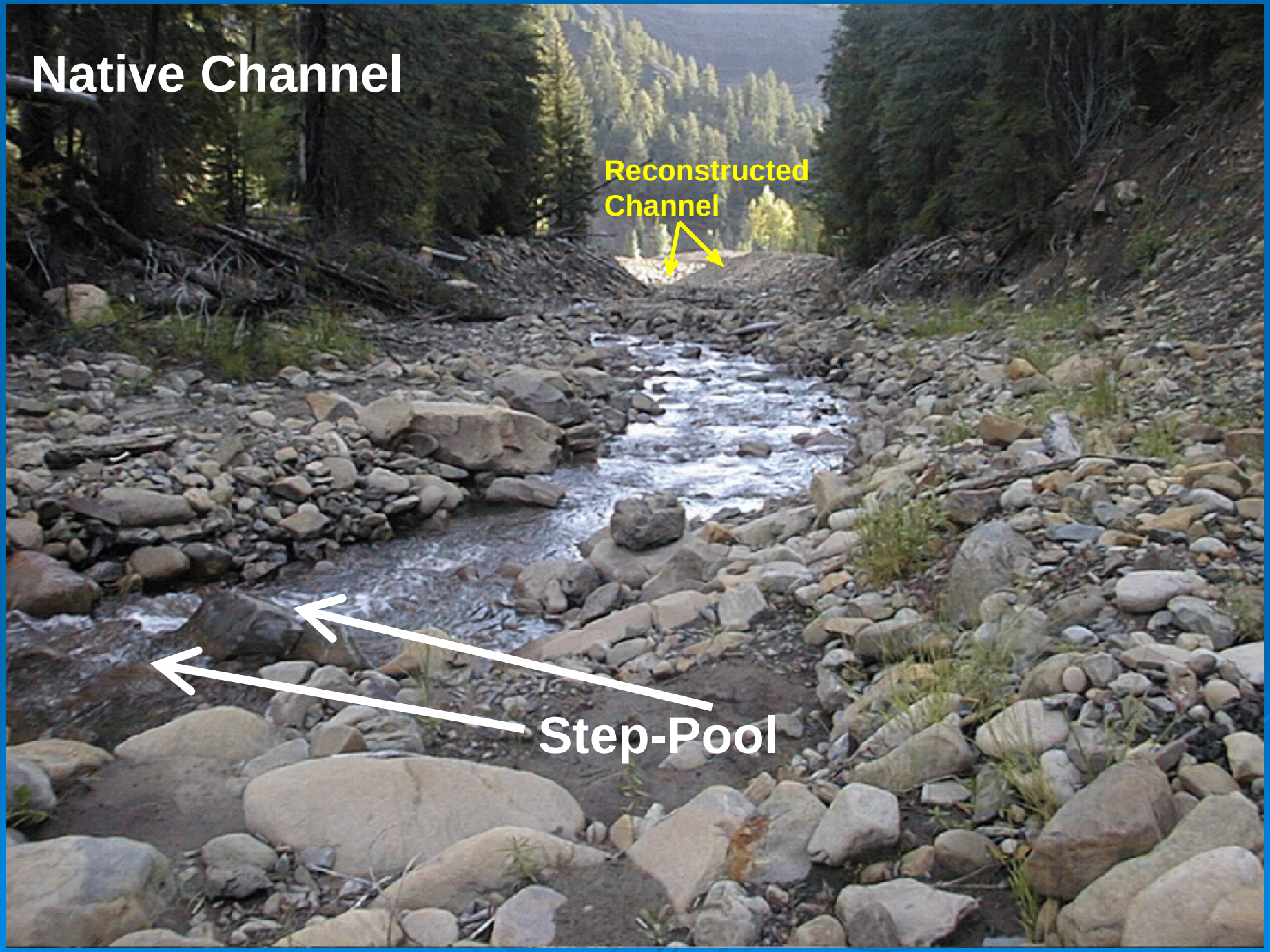
Near end of construction (October 1998)
Notice Relatively Smooth
Constructed Channel Bed

During Peak of First Runoff Season, June 1999

After Second Runoff Season, August 2000
Redistribution of Bed Material Into Step-Pools

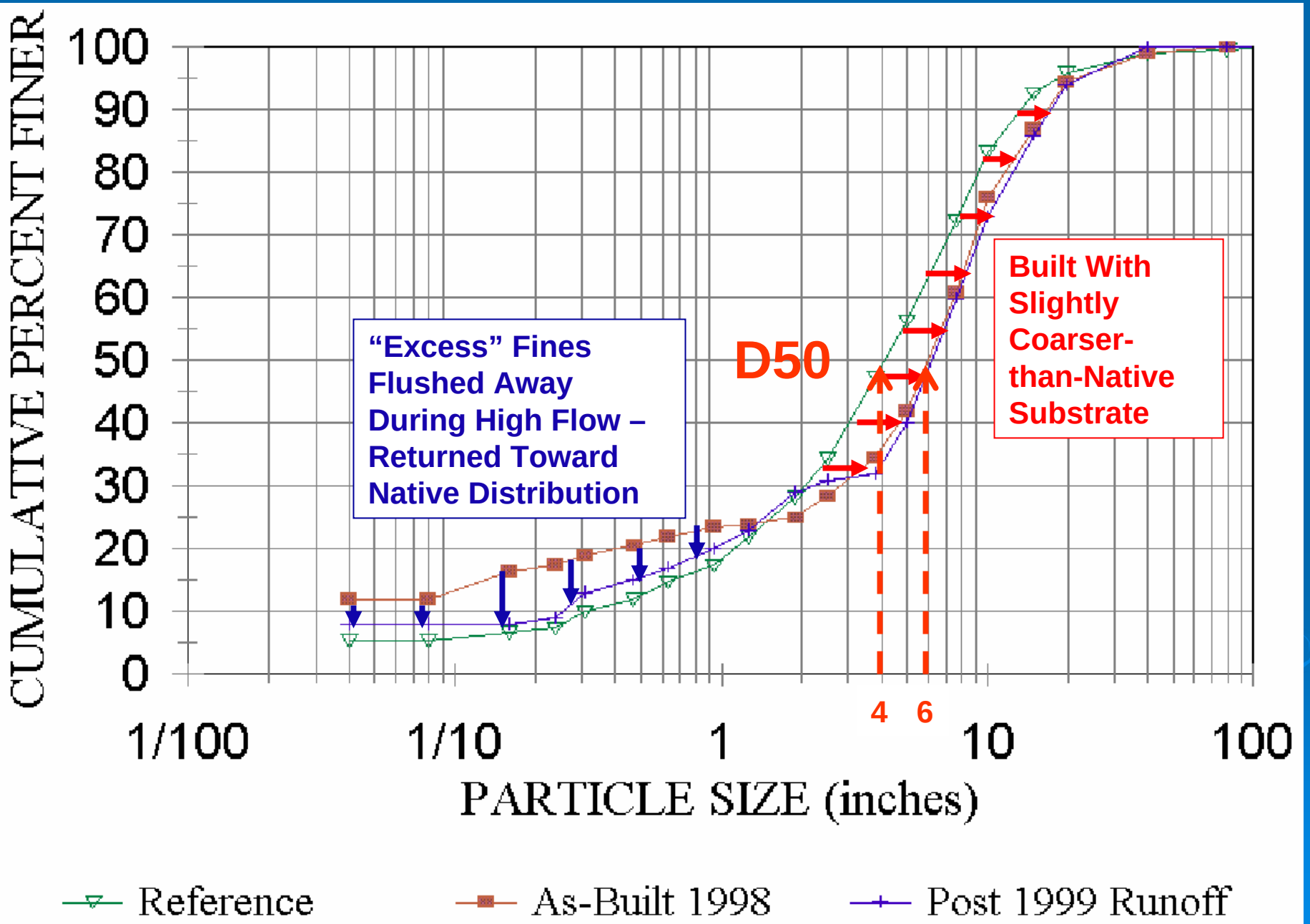
Native Channel

Reconstructed Channel After One Runoff Season (August, 1999)

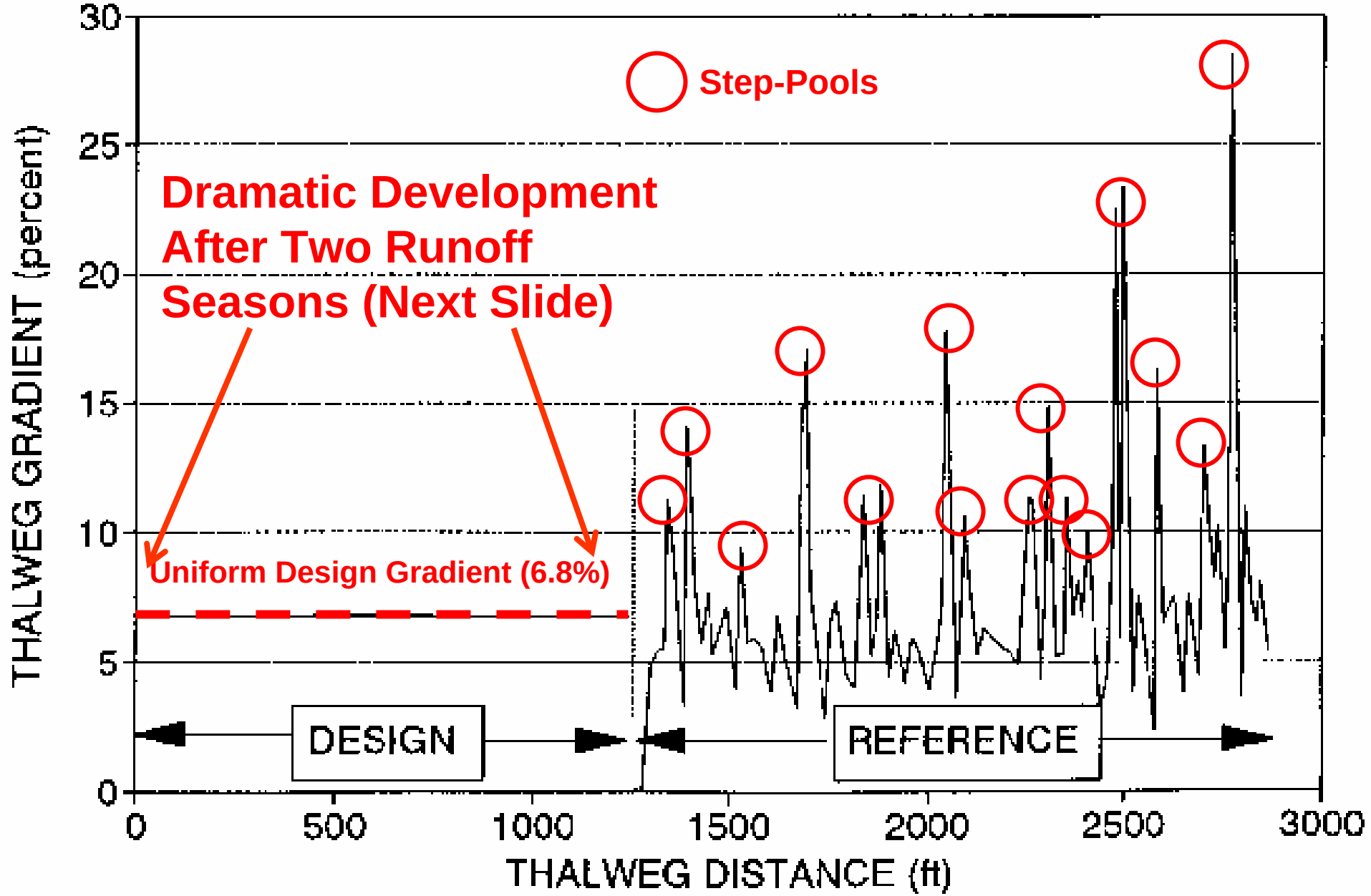

Native Channel
Reconstructed Channel
Step-Pool

Reconstructed Channel After One Runoff Season (August, 1999)
Step-Pools

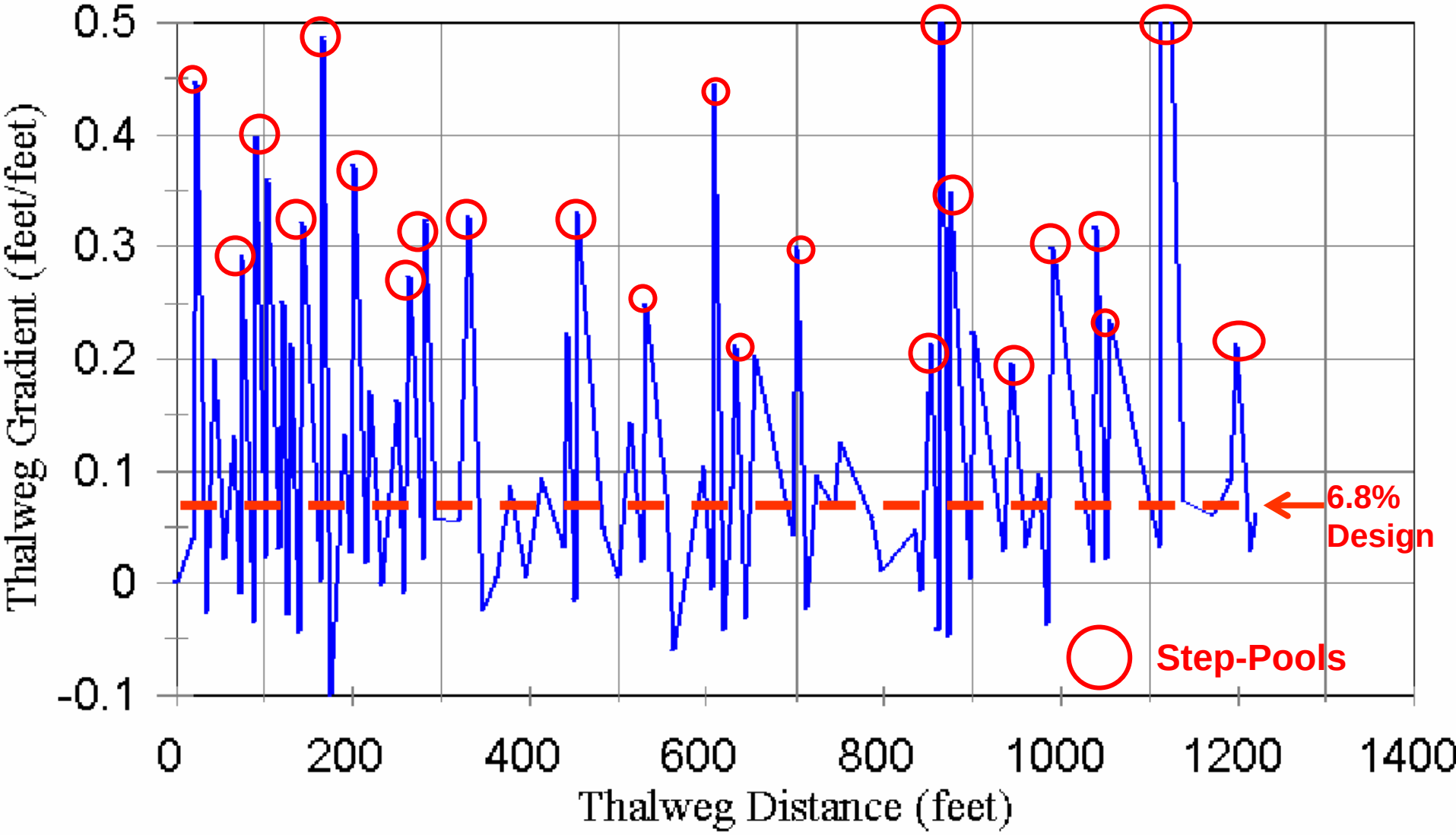
"Inner" Channel Substrate After Two Runoff Seasons (2000) vs. Reference Reach



Thalweg Gradient Profile - Design and Reference Reaches

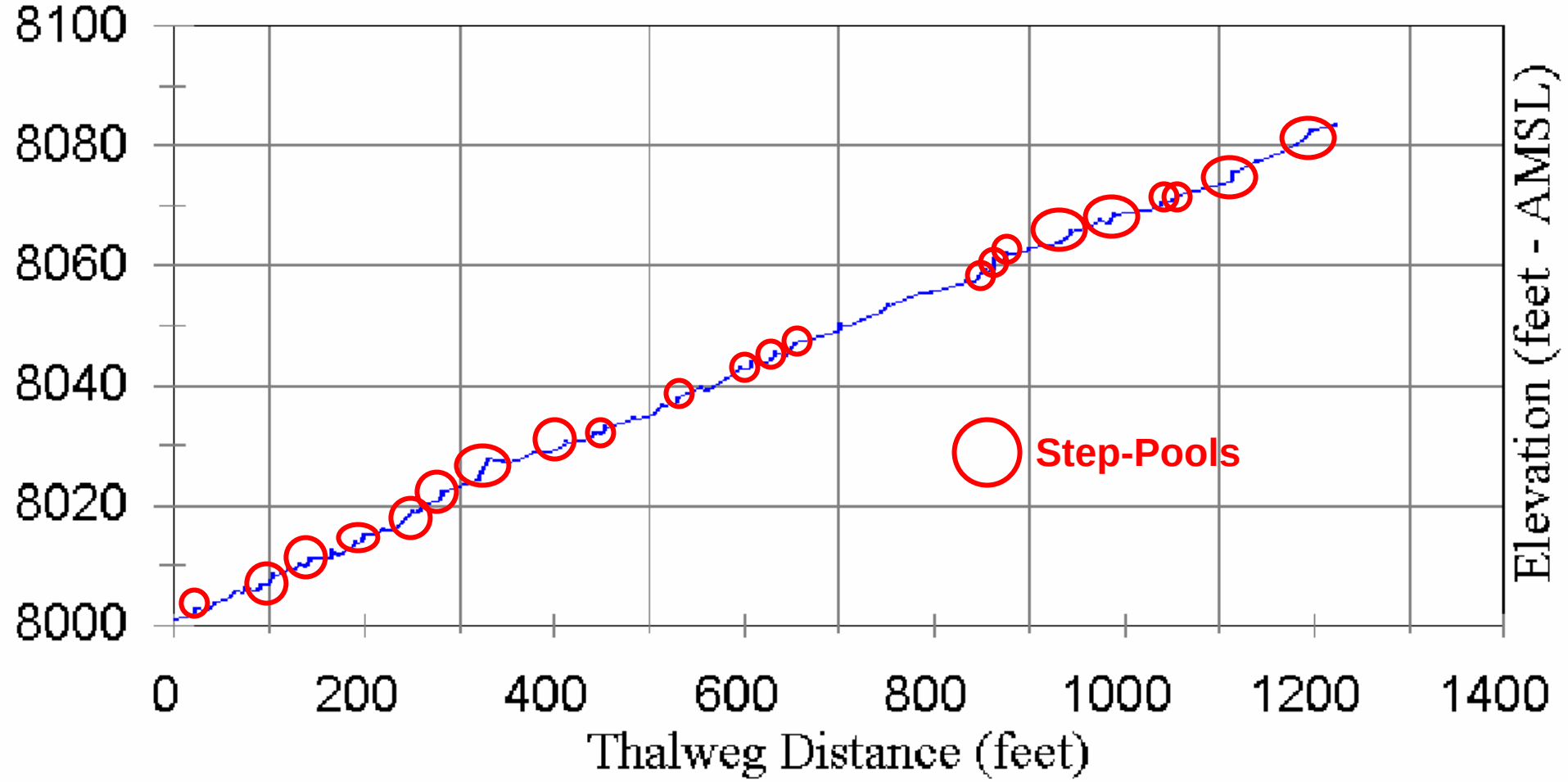


Reconstructed Reach After Two Runoff Seasons (August, 2000)



Coarse Sediment Mobilized into Step-Pools

Reconstructed Reach After Two Runoff Seasons (August, 2000)



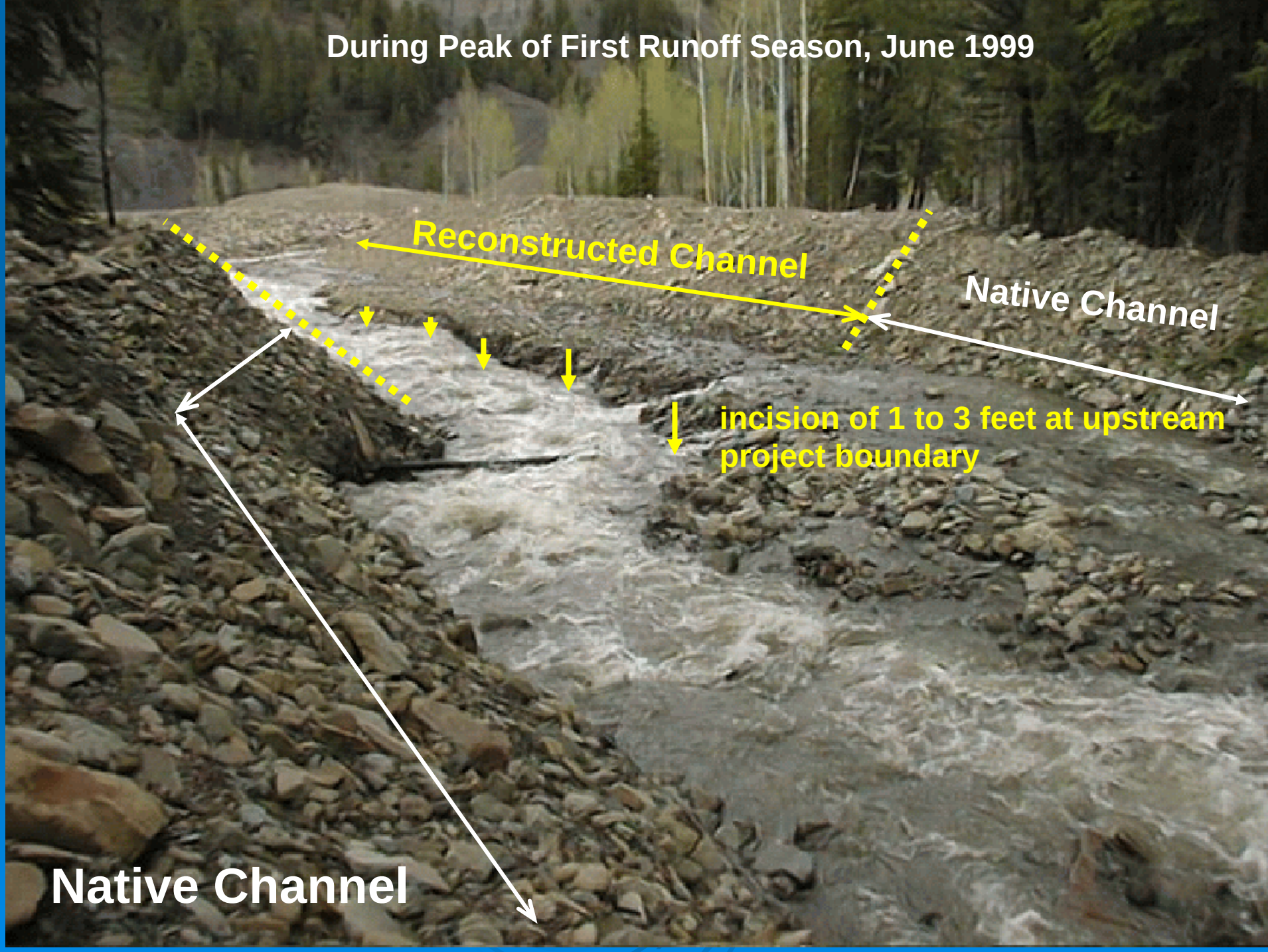
Shortly After Water Was Released into the Channel . . .
Step Pools Formed

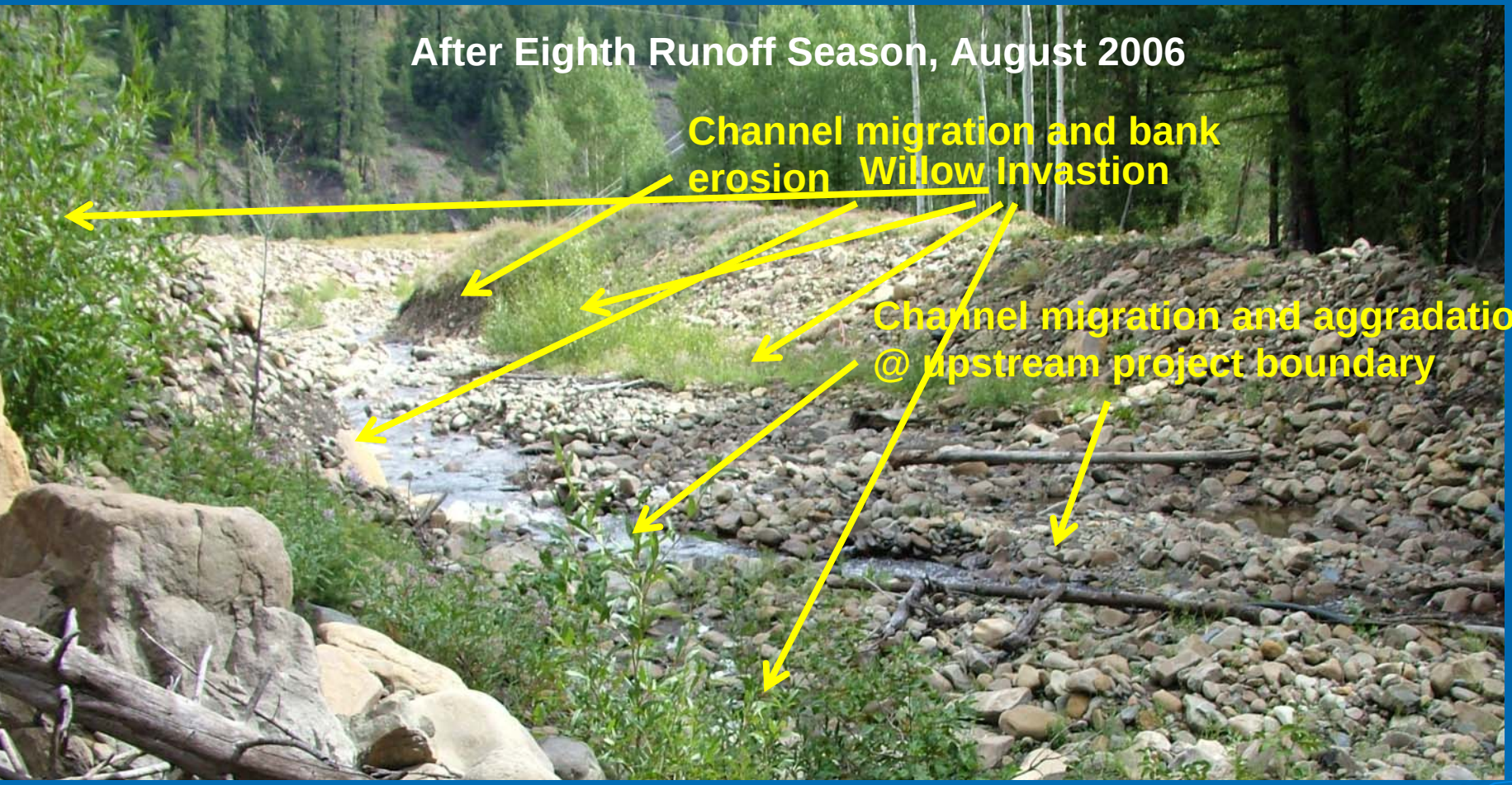
Aesthetics – an important but unquantifiable value

“Time is nature's way of keeping everything from happening all at once.”

Tour From Upstream to Downstream

Cirrhosis of the river.


During Peak of First Runoff Season, June 1999
Reconstructed Channel
Native Channel
incision of 1 to 3 feet at upstream project boundary
Native Channel

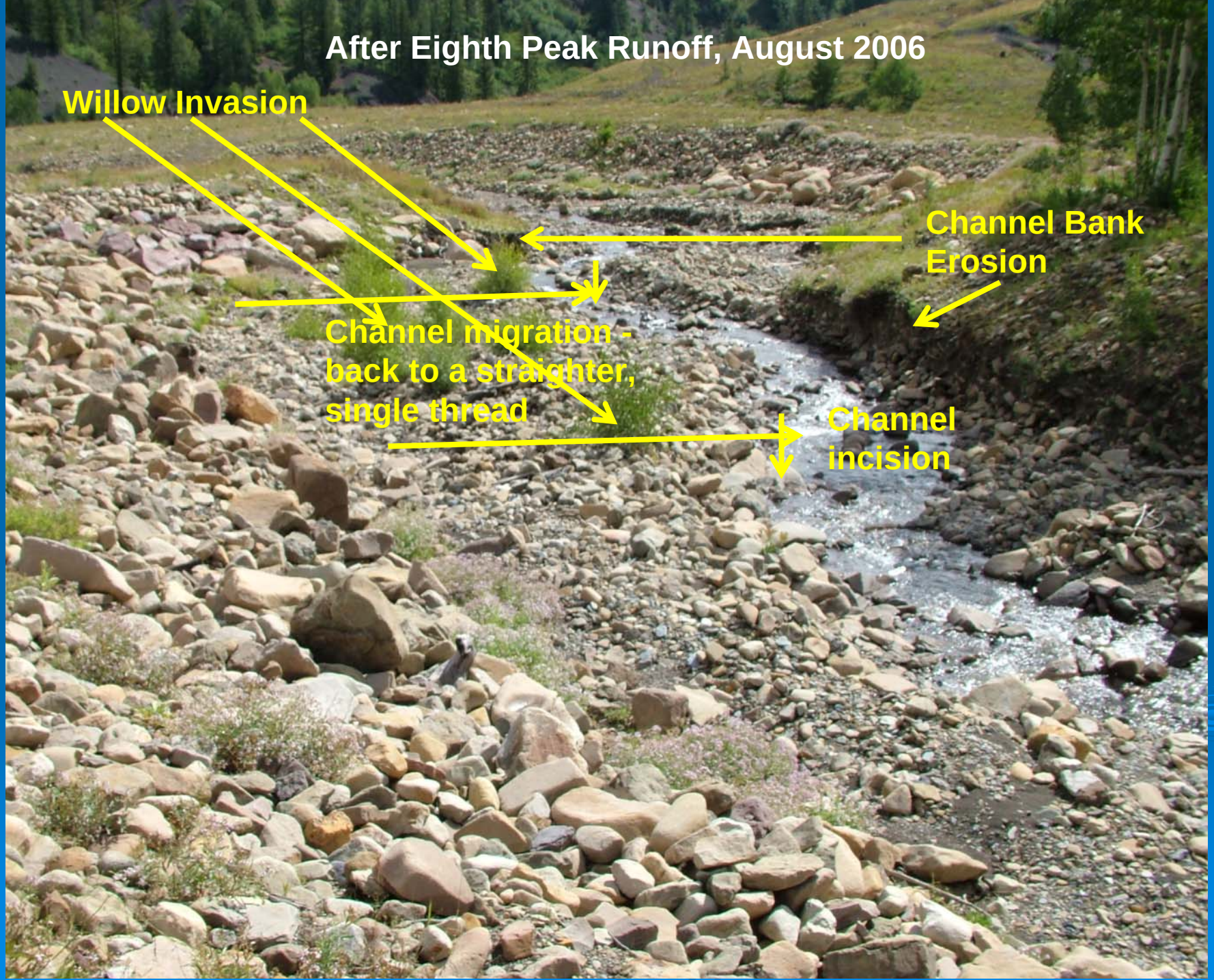

After Eighth Runoff Season, August 2006
Channel migration and bank erosion
Willow Invastion
Channel migration and aggradation @ upstream project boundary

June 1999

August 2006

Before Flow Returned, October 1998

After First Peak Flow, August 1999
Immediate Braiding


After Eighth Peak Runoff, August 2006
Willow Invasion
Channel Bank Erosion
Channel migration - back to a straighter, single thread
Channel incision

August 1999

August 2006

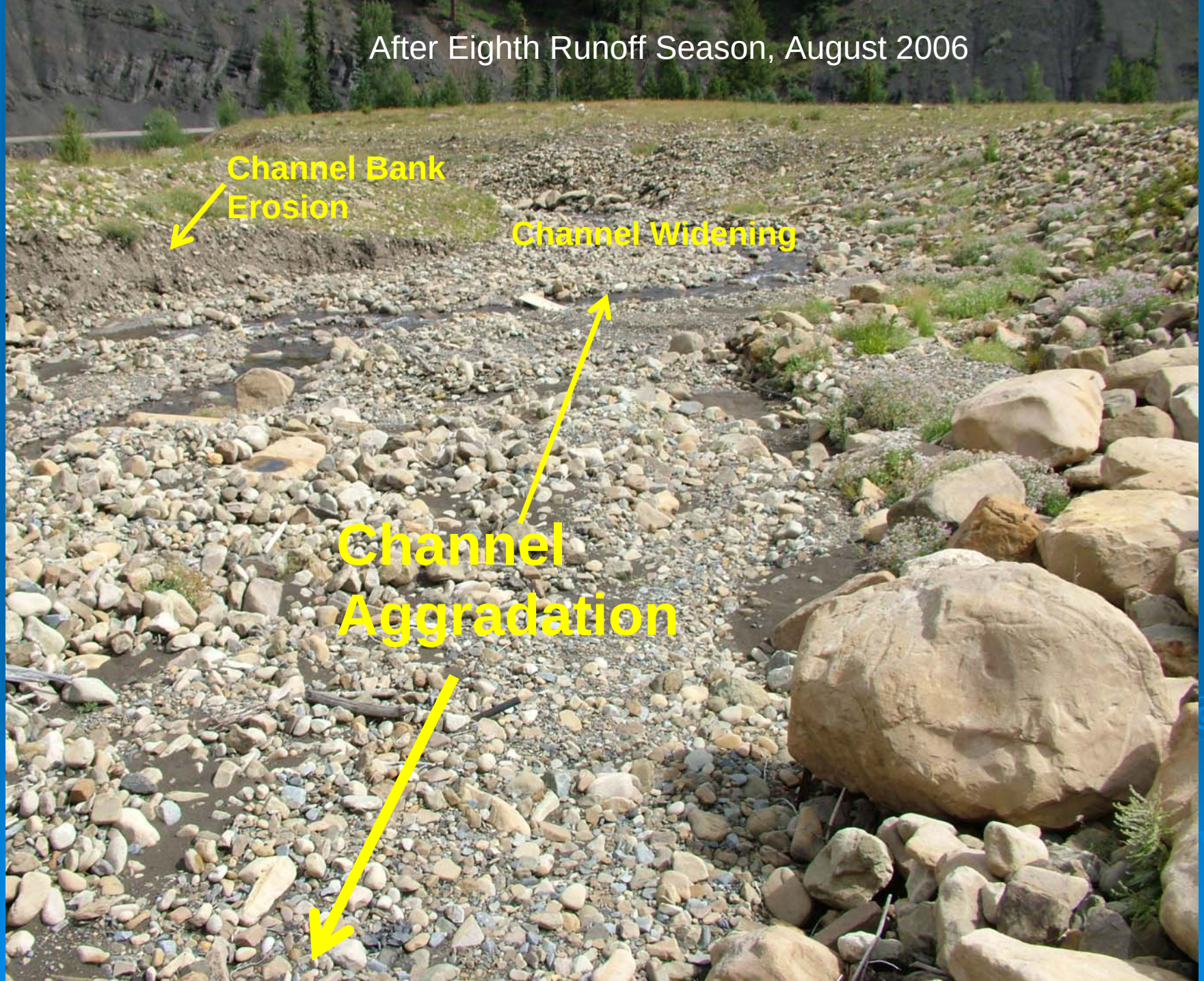
After First Peak Flow, August 1999

After Seventh Peak Runoff, August 2005
Channel Bank Erosion
Channel Incision
Channel Aggradation

After Eighth Peak Runoff, August 2006
More Channel
Bank Erosion
Channel
Widening

Rapid and Continuing Changes in This Reach

After First Runoff Season, August 1999

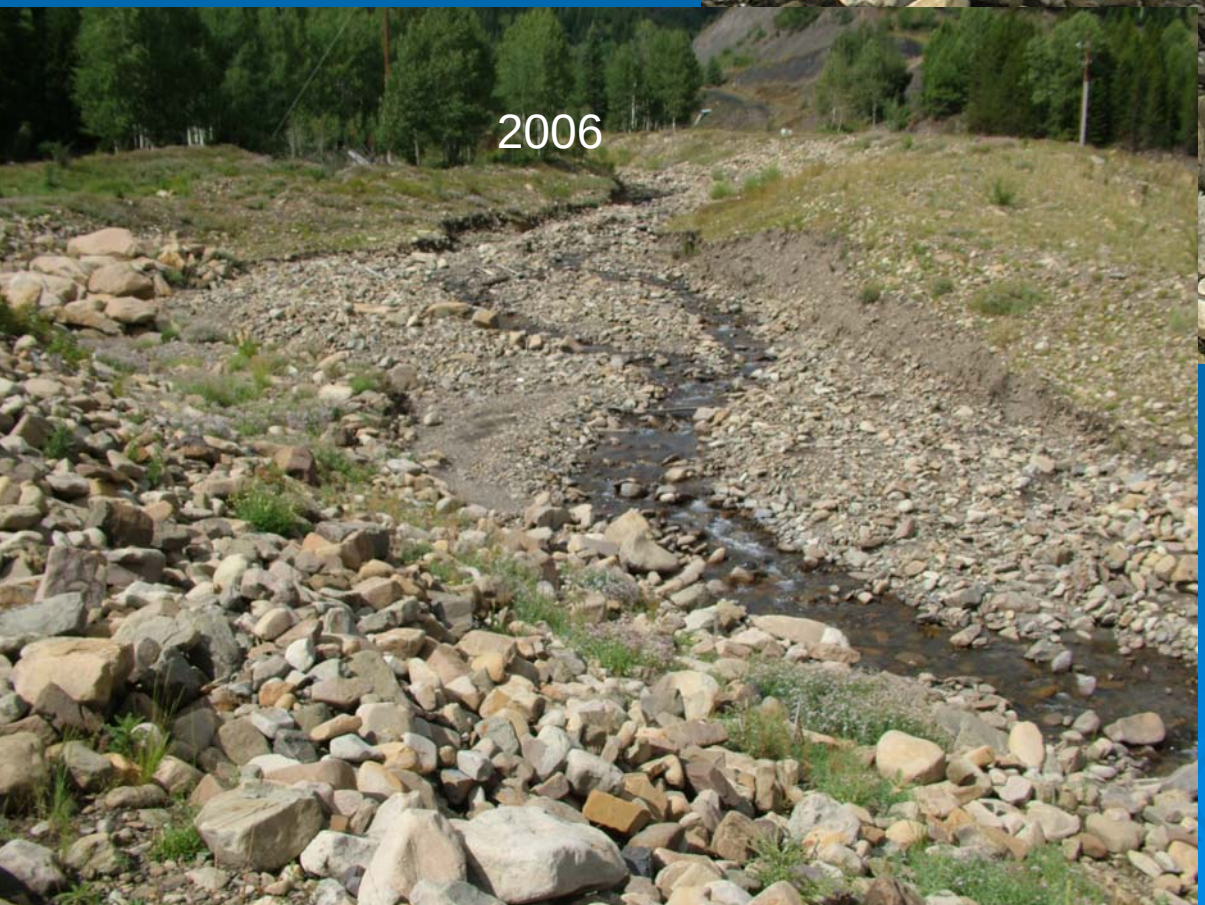

After Eighth Runoff Season, August 2006
Channel Bank Erosion
Channel Widening
Channel Aggradation

1999

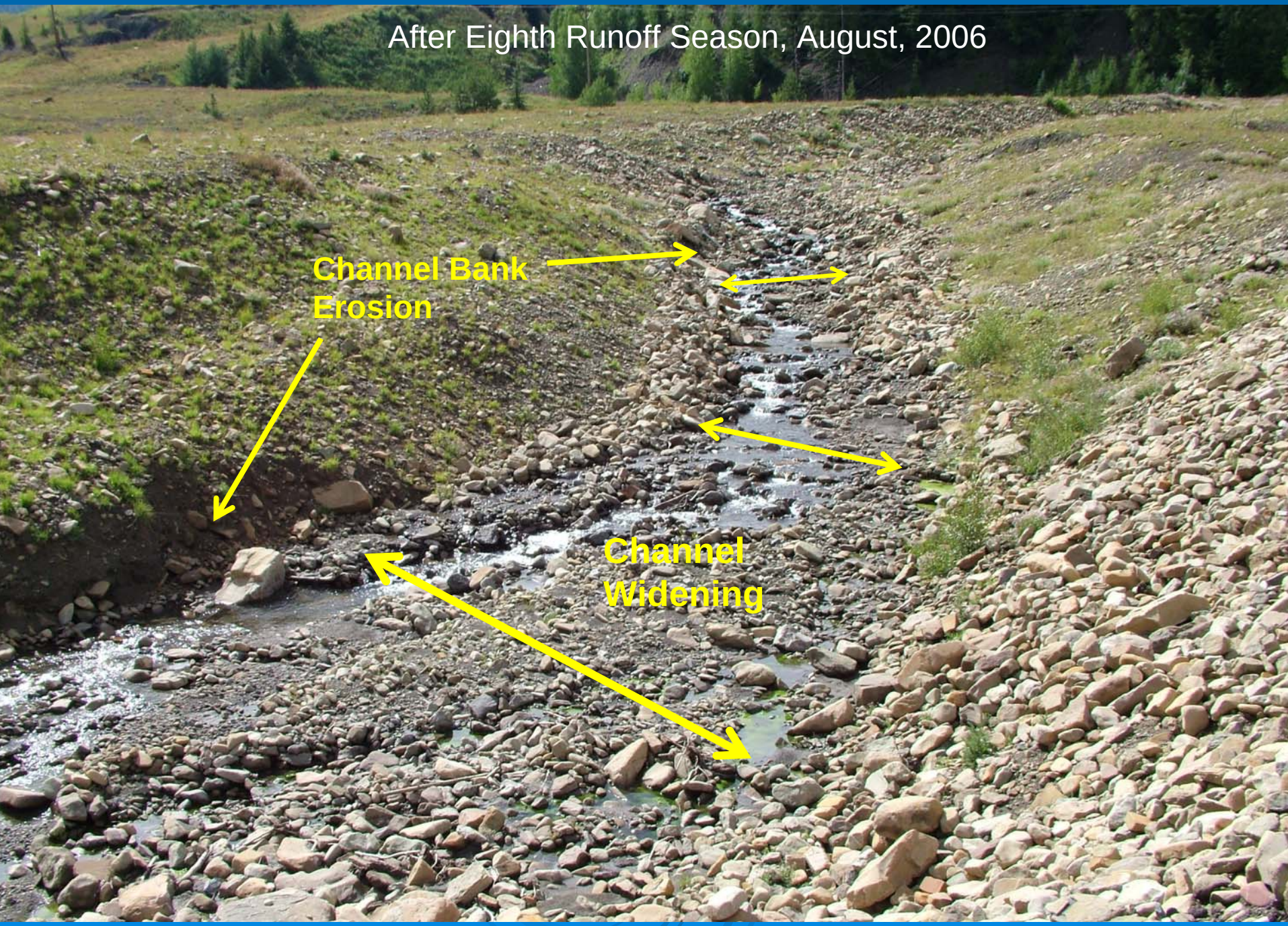
Same Reach as Previous, Looking Upstream, After First Runoff Season, August 1999

After Eighth Runoff Season, August 2006

1999


2006

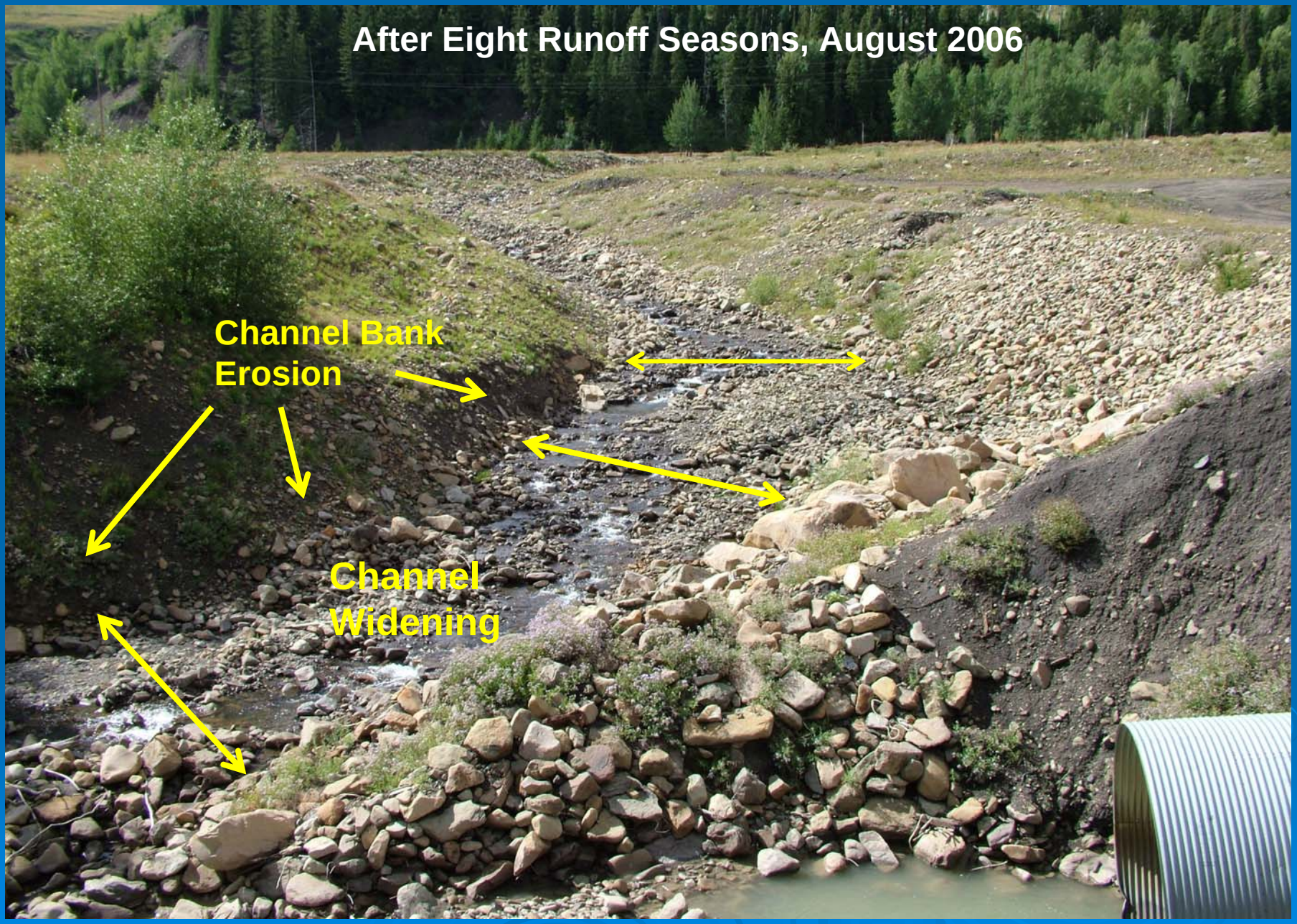
After Second Runoff Season, August, 2000


After Eighth Runoff Season, August, 2006
Channel Bank Erosion
Channel Widening

2000

2006

During Construction, October 1998


After Eight Runoff Seasons, August 2006
Channel Bank Erosion
Channel Widening

1998

2006

During Construction, October 1998

At peak of first runoff season, June 1999

During low flow after two runoff seasons, August 2000

During low flow after eight runoff seasons, August 2006

1998

Channel Incision (I); Aggradation (A); Widening (W); Channel Migration (M); Bank Erosion (Eb); Braiding (Br)

Systematic Changes in Lower 1/2

Very Complex Pattern of Changes to The Reconstructed Channel in Upper 1/2 Where Channel "Kinked" Too Much

Largest Unforeseen Stream Channel Adjustment Since Construction

?
?
?

1000 feet

SIMPLIFIED CHANNEL DESIGN METHOD

MATCH THE SHAPE; MATCH THE MATERIALS

- Two Main Factors Control Forces Causing and Resisting Erosion:
  - **Channel Morphometry**: width, depth, slope sinuosity, etc. - easy
  - **Channel Substrate**
    - For for this project -
      - Abundant native coarse debris flow/fan material available
      - Completely unconsolidated native deposit
      - Little effect from fine substrate material or vegetation
    - **More difficult in most other projects** –
      - Stratification & cementation of substrate
      - Vegetation effects can be HUGE

- **Geomorphic Design Restores Original Degree of Channel Function (Balance of Sediment Erosion, Deposition and Sediment Transport), Stability and Appearance**

Stream Channel or Watershed Restoration Projects

Shouldn't:

- initiate atypically high levels of erosion (e.g., gullies) that could migrate into or destabilize a slope or channel network or inhibit the postmining land use
- contribute *additional* sediment to streamflow or to the landscape, including *beyond* the minimum bond release period
- require maintenance for the long term

Should:

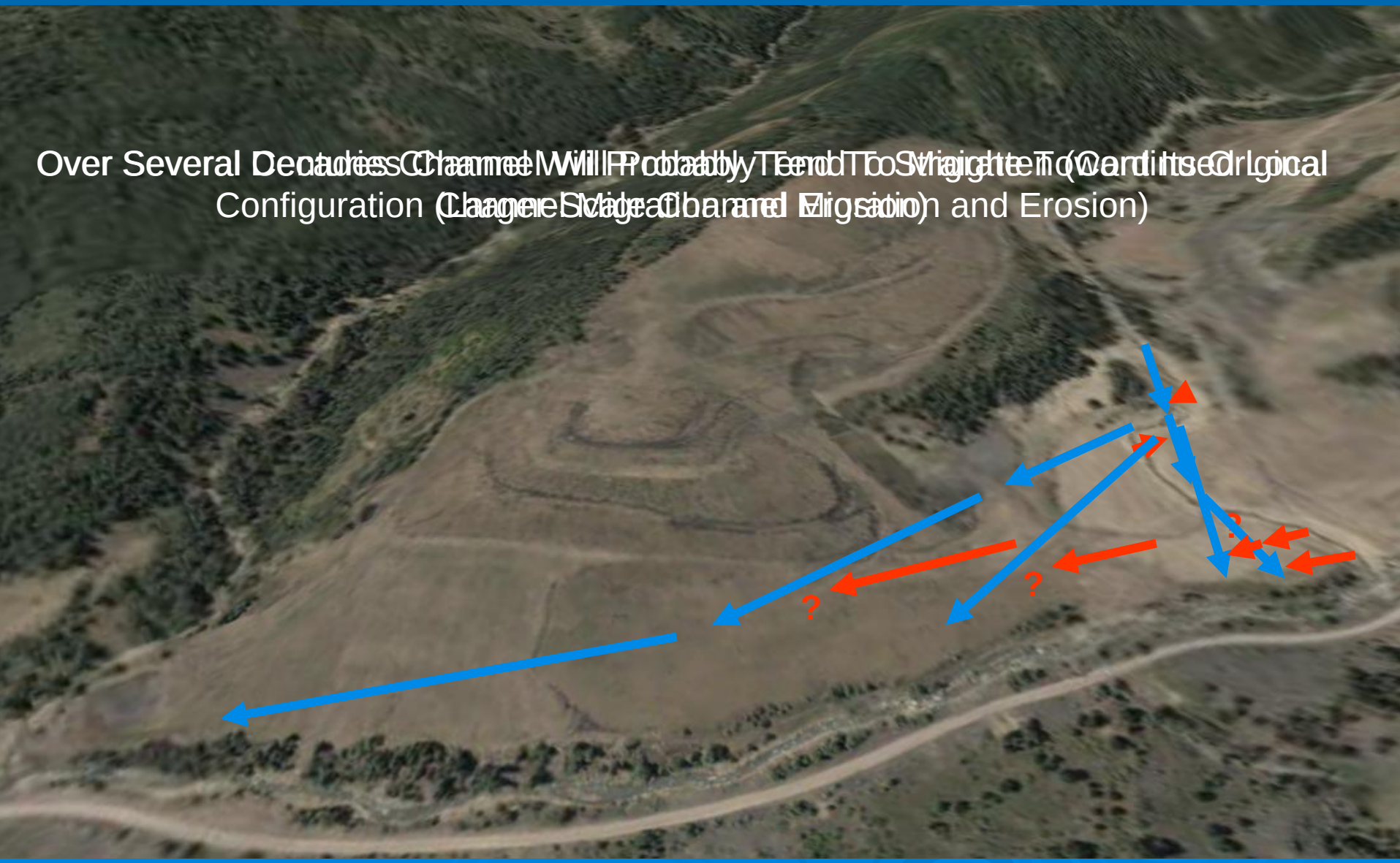
- have a form and function that blends into the adjoining landscape as closely as possible, realizing the potentially drastic differences between native intact bedrock, soil, alluvium and vegetation, and spoil, respread soil and postmining vegetation
- be designed to have the same range of variability of erosion, deposition and transport of sediment for similar hydrologic conditions that are found in the adjoining landscape
- require no long-term maintenance

CONCLUSIONS:

- **A very simple geomorphic channel design method can work well (but you need to work out the, um, KINKS). Constructing fine channel details is often unnecessary in stream channels.**

- **It can take many years to fully understand the behavior of an actively changing reclaimed stream channel – even longer for less active channels.**

- **Designers and regulators need to consider geomorphic perspectives of erosion, sedimentation and stability in the context of sometimes drastically disturbed mine reclamation setting when making decisions regarding watersheds and stream channels.**

- **Long-term surveying and/or photographic monitoring helps to understand and demonstrate how a channel is developing.** "No experiment is a complete failure; it can always be used as a bad example."

Speculation on Long-Term Stream Channel Development