Recreating a Headwater Stream System on a Head-of-Hollow Fill: A Kentucky Case Study

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Geomorphic Reclamation at Coal Mines
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Introduction

- Headwater streams comprise 60-80% of channel length in mountainous areas
- Headwater streams are vital to ecosystem
  - Primary pathway for H_2O, sediment, OM
  - Support large, diverse populations
- Over 330 miles streams impacted by MTR/VF from 1985-1999

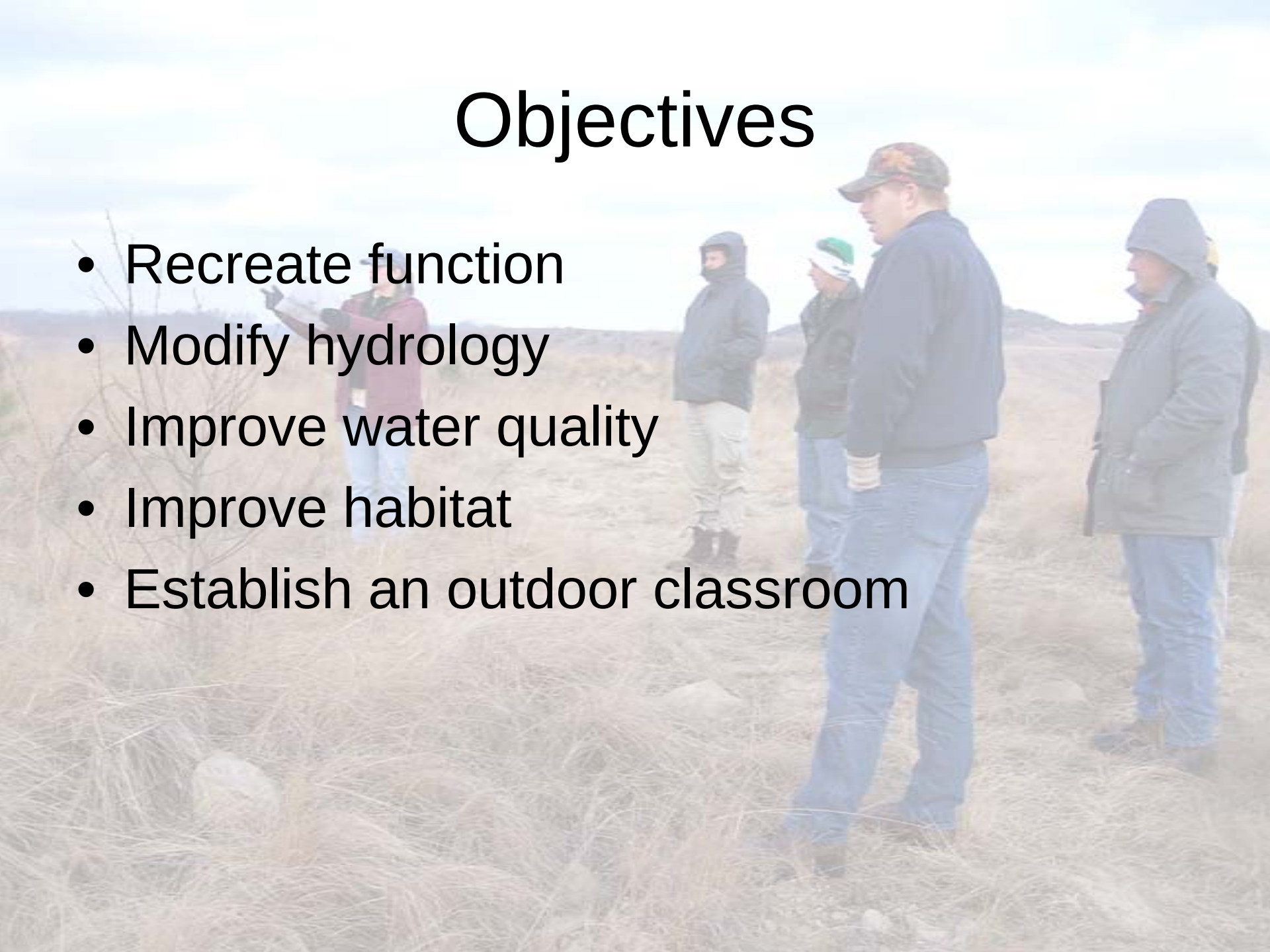
Form vs. Function

Created Ephemeral

Natural Ephemeral

Objectives

- Recreate function
- Modify hydrology
- Improve water quality
- Improve habitat
- Establish an outdoor classroom



Forestry Reclamation Approach

- Select best available growth medium
- Minimize compaction
- Select appropriate tree species
- Use compatible ground cover
- Use proper tree planting techniques

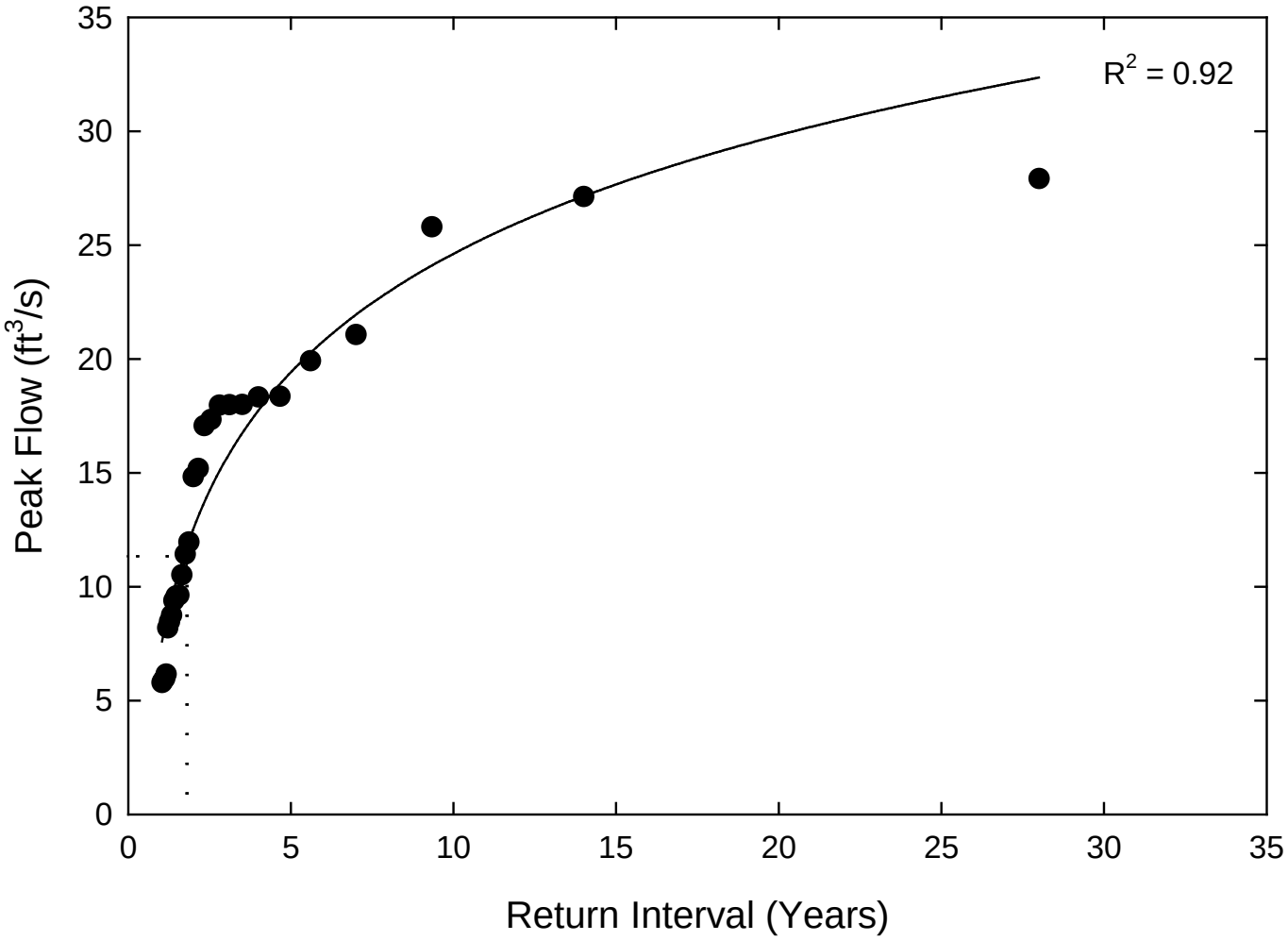
http://arri.osmre.gov/FRApproach.htm

Can FRA Help Guide Stream Restoration Decisions?

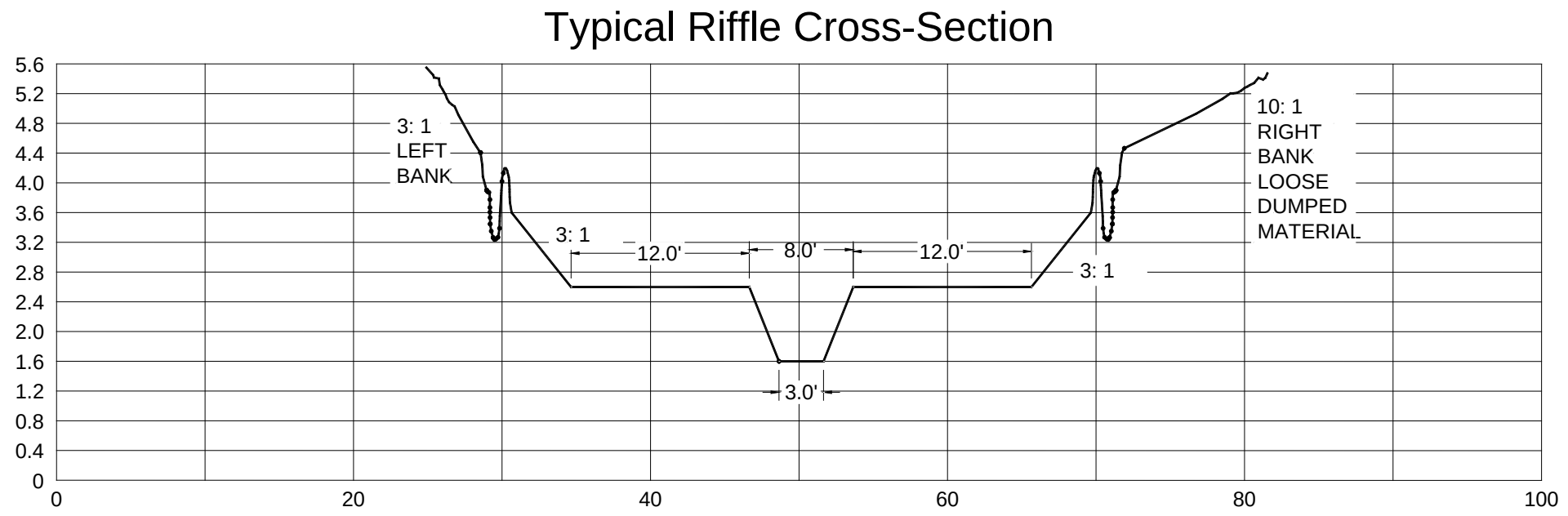
The Guy Cove Project

Design Components

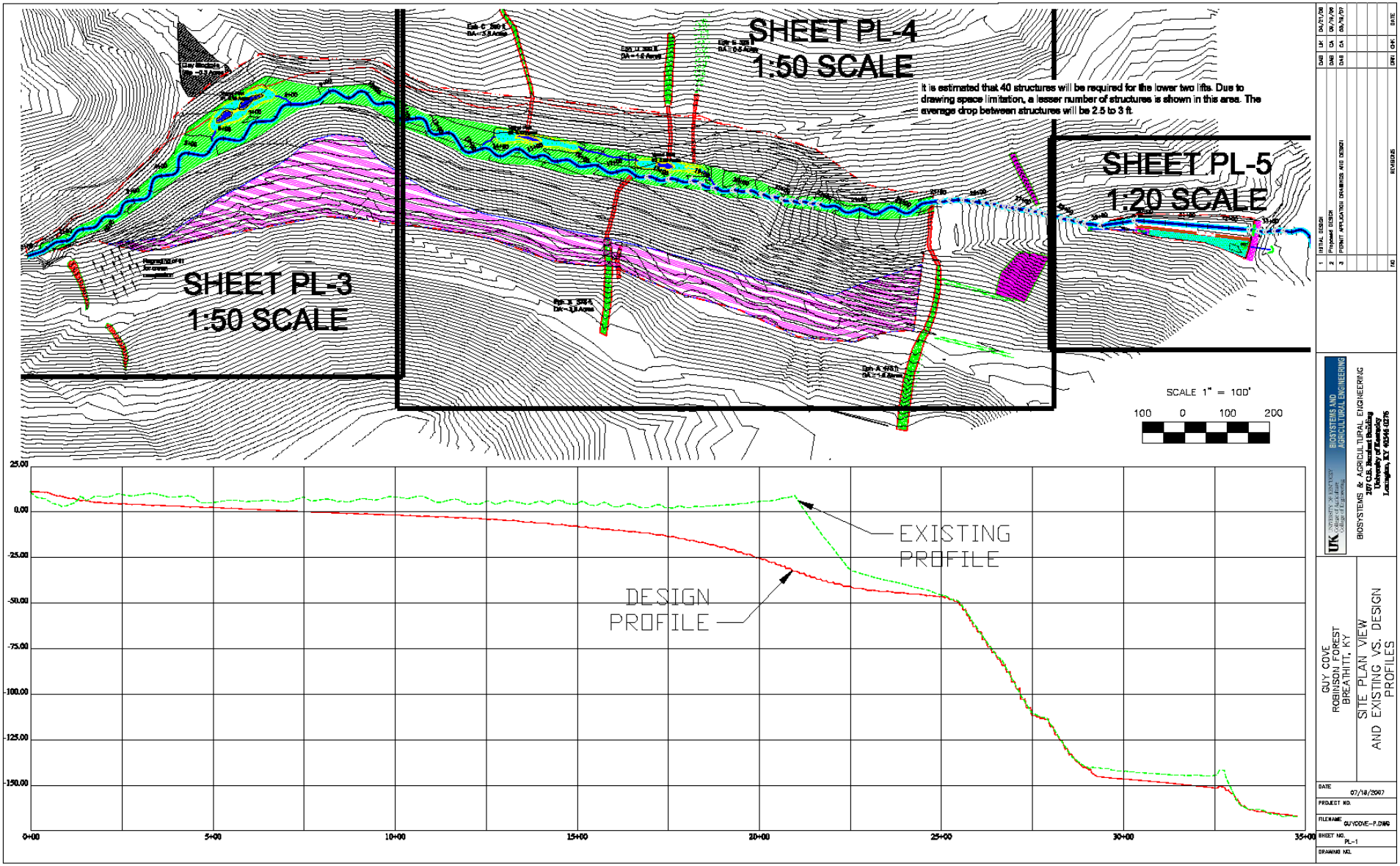
- Reference reaches
- Valley reconfiguration
- Hydrologic modifications
- Main channel
- Ephemeral channels
- Bioreactor-wetland treatment system
- Vernal ponds
- Plantings
- Monitoring


35
30
25
20
15
10
5
0
0
5
10
15
20
25
30
35
Peak Flow (ft3/s)
Return Interval (Years)
R2 = 0.92

Main Channel



C4 B4 B3a A2a+ C4



Newly Constructed Habitat

- Main channel ~ 3,475 ft
- Ephemeral channels ~ 1,825 ft
- Vernal ponds ~ 0.5 to 1 ac
- Wetland treatment area ~ 0.3 ac
- Reforestation ~ 40 ac

Desired Outcomes

- Change head-of-hollow fill design
  - Establish headwater stream system
  - Recreate forested watershed
  - Improve water quality and habitat
- Technology transfer
- Continue research

Before


After


CAT


CAT


CAT
CAT
325D


TURBO CHIEF
POWERSCREEN

Improving Water Quality and Habitat

Treatment System

Habitat Wetlands

Mine Drainage

$$FeS_{2(s)} + 3.75\ O_2 + 3.5\ H_2O \longrightarrow Fe(OH)_{3(s)} + H_2\ SO_4$$

-produces sulfuric acid and proton acidity

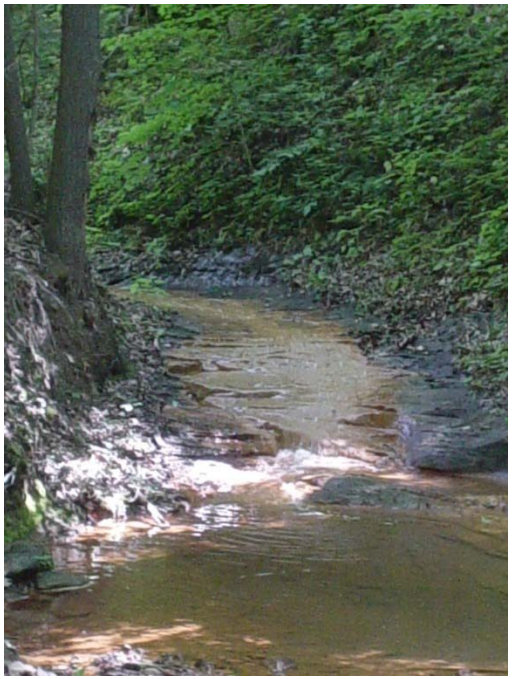
$$Ca(Fe, Mg, Mn)(CO_3)_2 + 4H^+ \leftrightarrow Ca(Fe, Mg, Mn)^{2+} + 2H_2CO_3$$

-produces carbonic acid

$$Ca(Fe, Mg, Mn)(CO_3)_2 + 2H_2CO_3 \leftrightarrow Ca(Fe, Mg, Mn)^{2+} + 4HCO_3^-$$

-produces bicarbonate alkalinity

- Neutral to Net Alkaline Mine Drainage

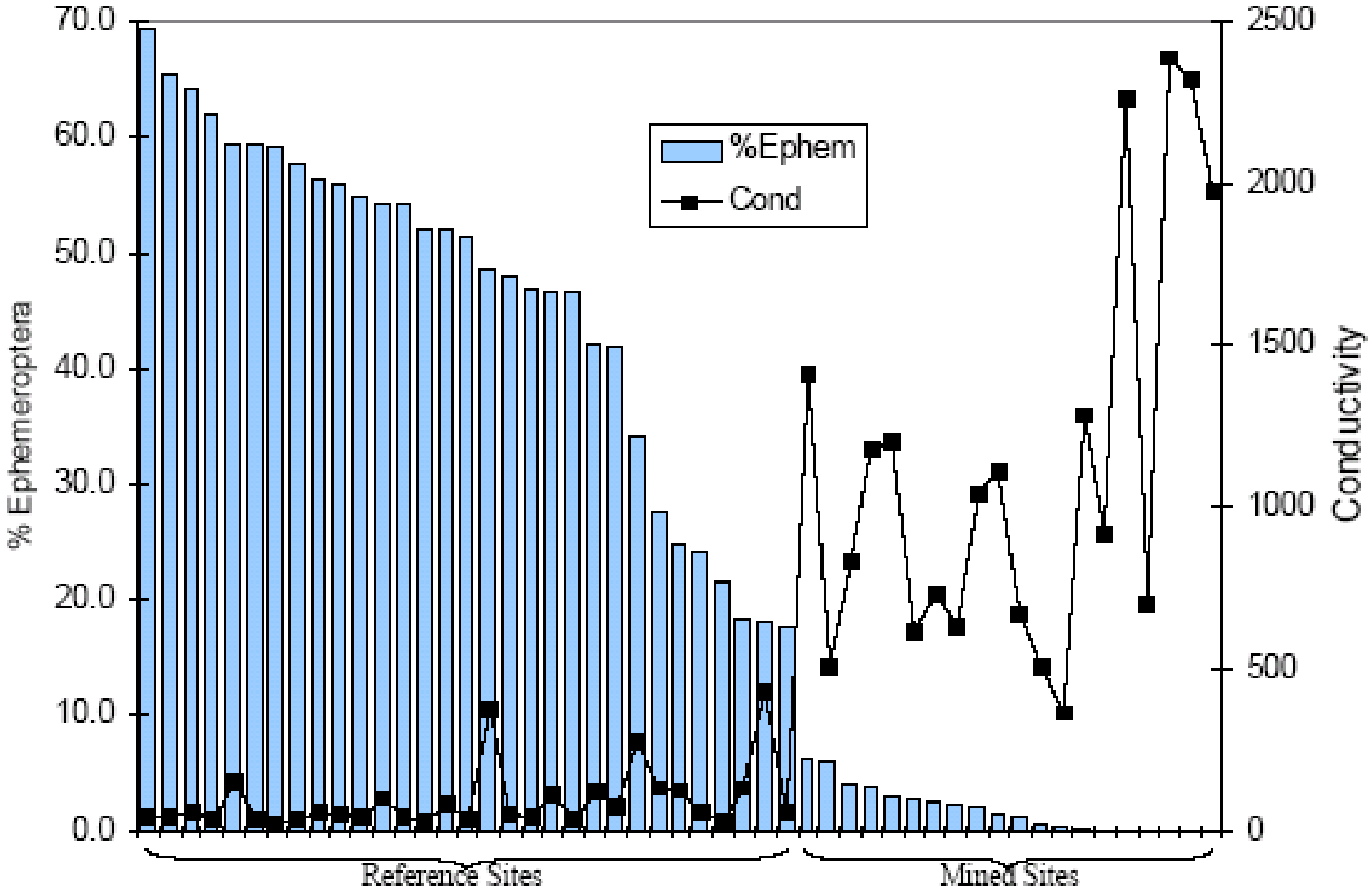


Water Quality Characteristics
Little Millseat and Guy Cove Watersheds

Site	pH	EC (µS)	SO_4 (mg L^{-1})	Fe (mg L^{-1})	Mn (mg L^{-1})
L. Millseat*	6.5	50	10	0.1†	0.9 †
Guy (forest)†	8.3	450	200	0.3	0.3
Guy (effluent)‡	7.0	1930	1300	0.6	21

*Data from 1972-06
†Data from 2006
‡Data from 2004-06

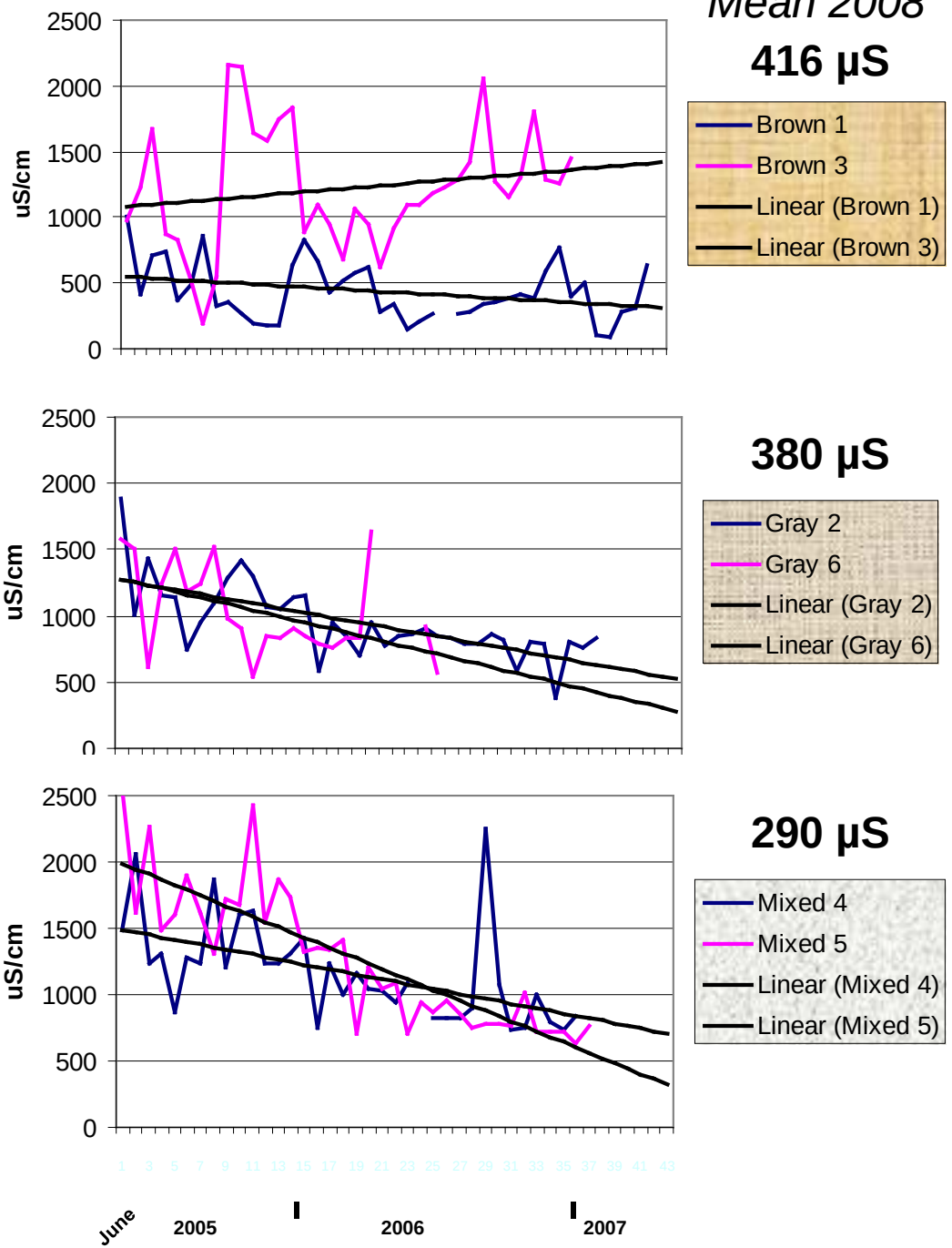
Where have all the mayflies gone?



Pond, 2004 and 2007
Pond et al. 2008

Bent Mt.

Electrical conductivity trends



Water Quality Mitigation

- Stream Channel (surface flow)
- Reforestation (ET ≈ 55% of Precipitation)
- Passive Treatment System (Bioreactor/Wetland)

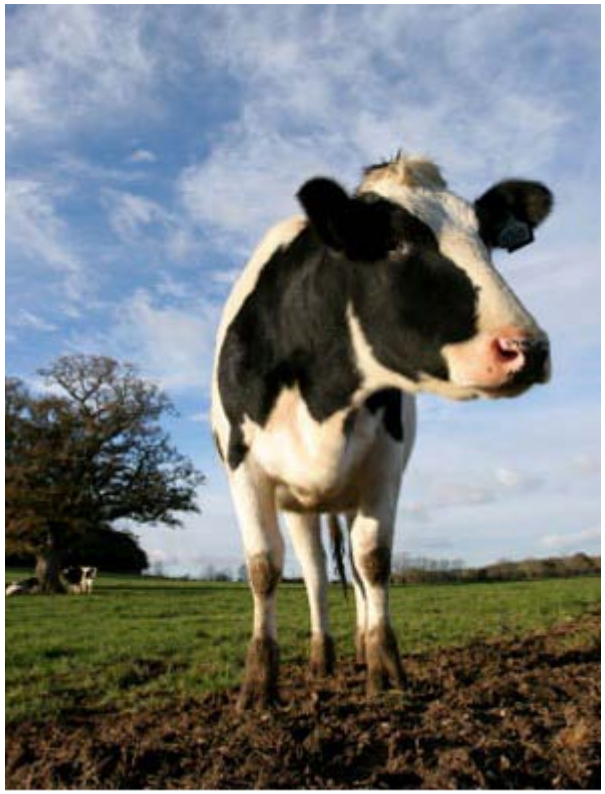
Bioreactor

- Sulfate reduction occurs through the reduction of sulfate to sulfide following the equation:
  - $2CH_2O + SO_2^{-4} + 2H^+ \rightarrow H_2S + CO_2 + H_2O$
- where CH_2O represents an organic compound (organic matter).
- Subsequently, the sulfide can form a bond with many metals present in mine drainage following the equation:
  - $H_2S + M^{2+} \rightarrow MS_{(s)} + 2H^+$
- Where M represents a metal such as Mn, Fe, Zn, Ni and Pb
- Creating a highly insoluble metal sulfide

Bioreactor (How It Works)

SRB Require 4 Components to be Successful

- pH = 5.5 – 8
- Eh ≤ -100 mV
- Source of Organic Carbon
- Sulfate = Pyrite
- SRB & Adhesion Sites



Development

- Edwards (2008) column batch experiments testing different organic substrates: corn mash, soy bean oil, hardwood mulch, compost, sorghum syrup, and biosolids

- 15 gal plastic tanks filled with mulch and creek sediment (x3) and mulch, biosolids and creek sediment (x3); 1,500 mg/L SO_4, 50 mg/L Mn

- Removal
  - **90% of the Manganese**
  - **70% of the Sulfate**

➢ Guy Cove reactor modeled after Edward's research

Development

Status

Stream:

- 75% reduction in EC from pre-restoration level on crown of the fill.
- Presence of salamanders and aquatic invertebrates in pools (abundant)

FRA:

- ≈30,000 trees planted
- Trees & Shrubs: American Beech, American Sycamore, Eastern Hemlock, Rhododendron, Green Ash, Swamp Chestnut Oak, Swamp White Oak, Silver Maple, River Birch, Black Willow, Flowering Dogwood Cypress, Tupelo, Buttonbush, Buckeye

Wetland-Bioreactor:

- Eh levels maintained at < -300 mv, pH neutral, Mn, Fe, and SO_4 reductions observed

Questions?

http://www.bae.uky.edu/UKReclamation/