Challenges of Applying Geomorphic and Stream Reclamation Methodologies to Mountaintop Mining and Excess Spoil Fill Construction in Steep Slope Topography (e.g. Central Appalachia)

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Counties in the Appalachian Coalfield Region with watersheds affected by valley fills.

From: Mountaintop Mining/Valley Fill (MTM/VF) EIS (2005).

Example of reclaimed mountaintop mining and excess spoil fill construction in Central Appalachia, as currently practiced.

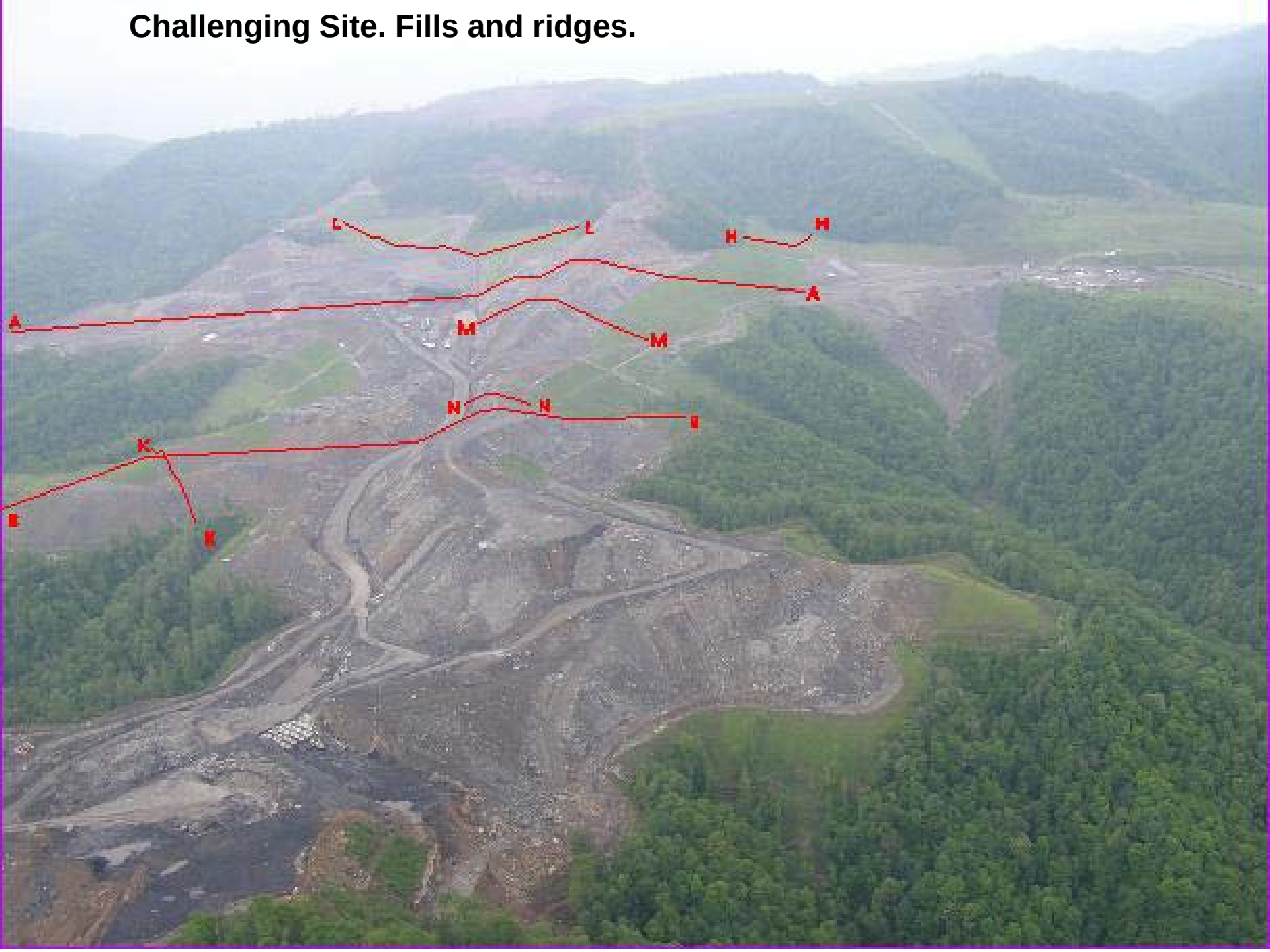
Current Federal Requirement Closest to Geomorphic Reclamation

Approximate Original Contour (AOC),

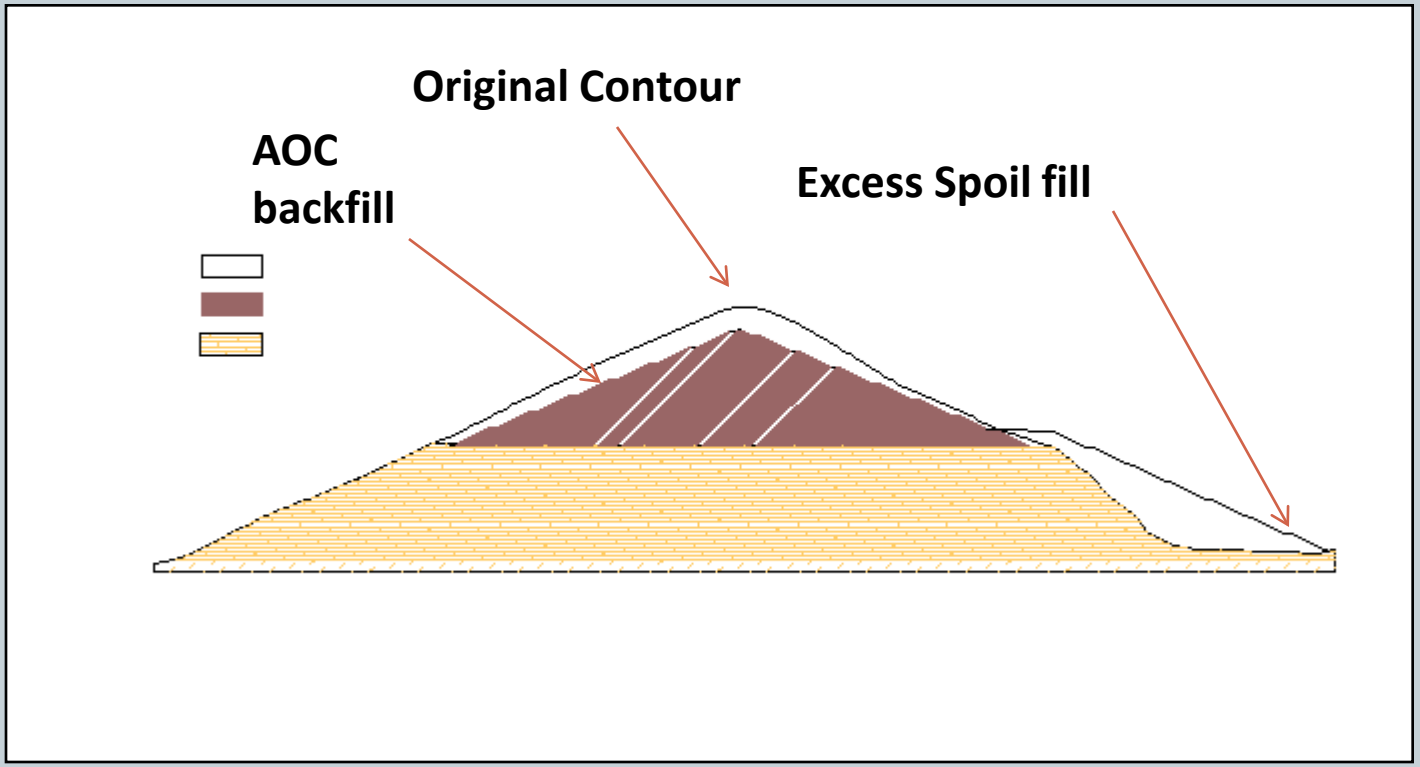
defined as:

"That surface configuration achieved by backfilling and grading of the mined areas so that the reclaimed area...closely resembles the general surface configuration of the land prior to mining and blends into and complements the drainage pattern of the surrounding terrain...."

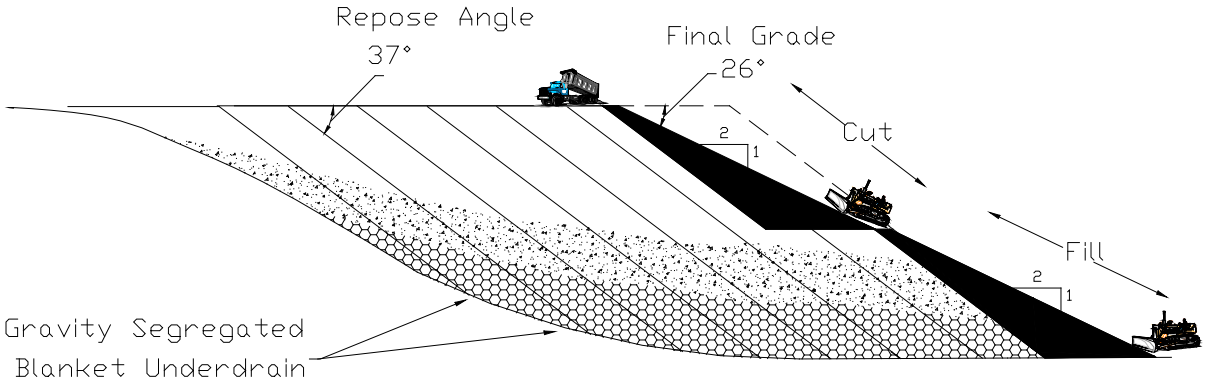
Challenging Site. Fills and ridges.



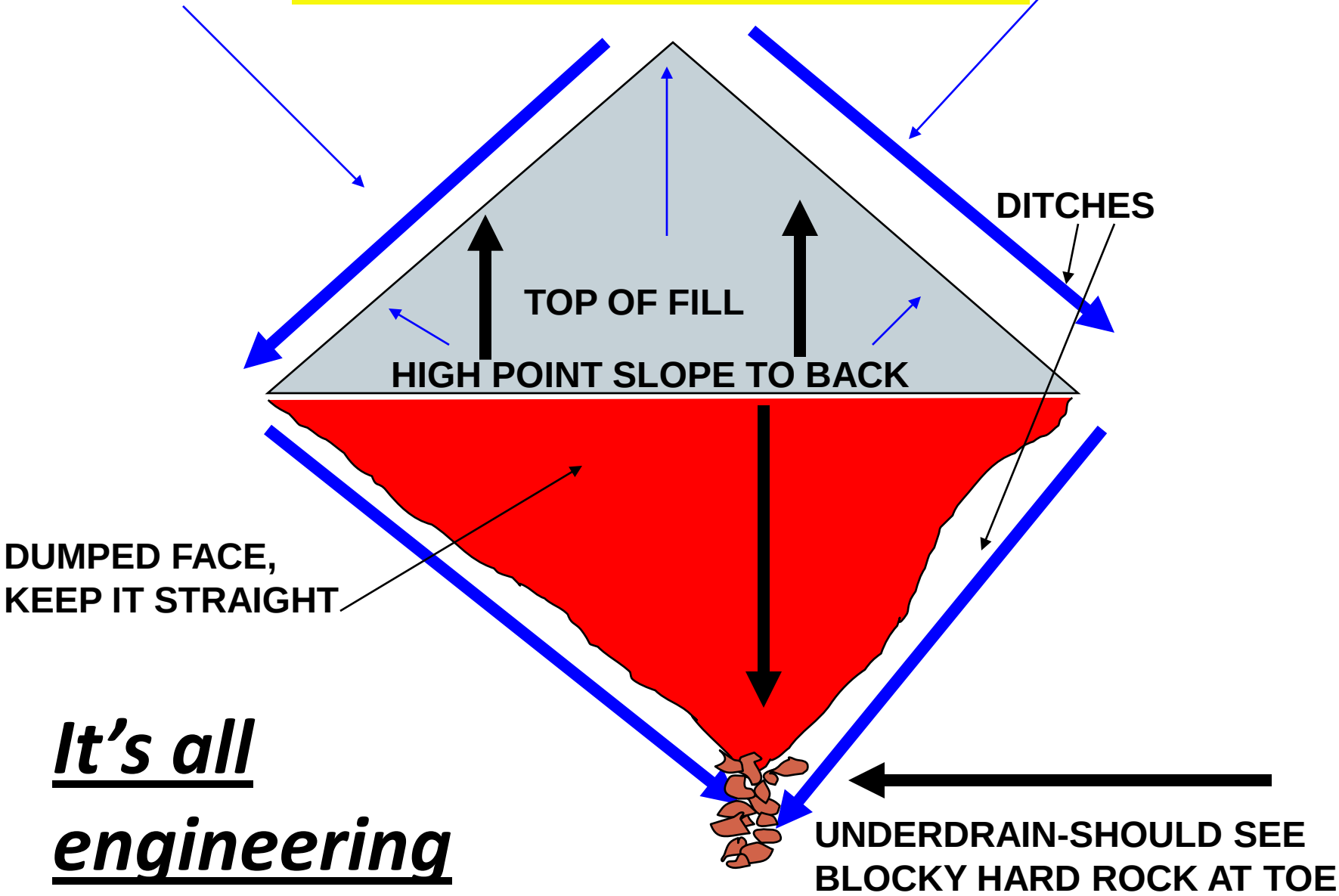
Generation of Excess Spoil Fills



Durable Rock Fills



Design and Performance Requirements



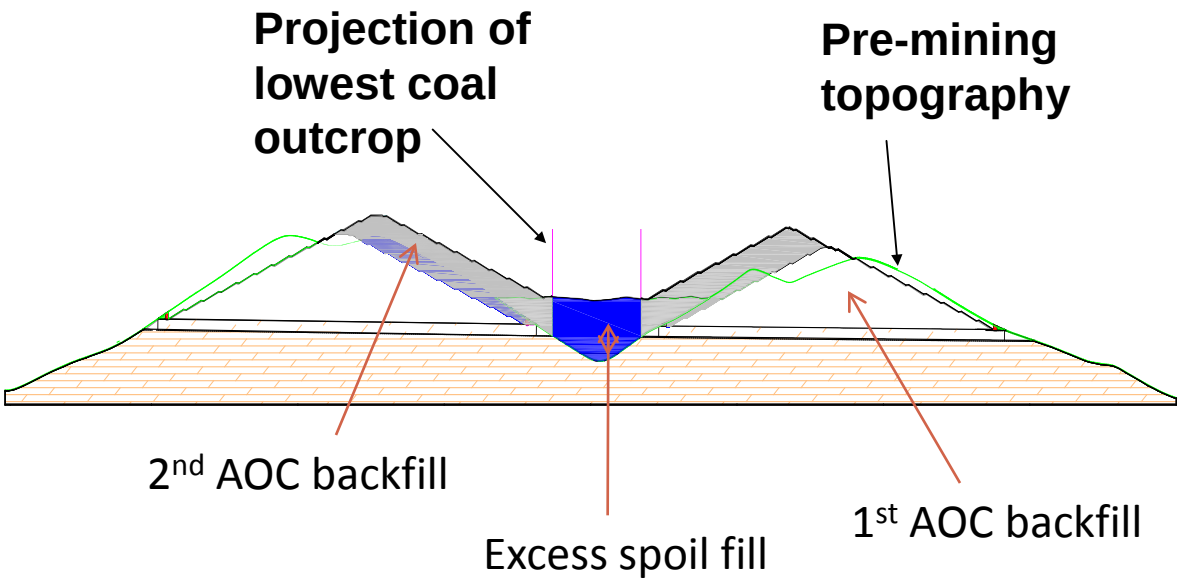
It's all engineering in the regs.

Recent Regulation Changes to Limit the Adverse Effects of Excess Spoil Fill Construction

Changes to SMCRA regulations require:

- Limit the amount of excess spoil generated at a mine site;
- Limit the size of fills constructed;
- Consideration of alternative configurations for excess spoil disposal; and
- Development of a disposal plan that would minimize adverse impacts to the environment.

Spoil Placement Optimization to Limit Excess-Spoil Fill Disturbance of Land and Water



PAST AND CURRENT ENGINEERING AND ENVIRONMENTAL ISSUES REGARDING VALLEY FILLS

Effective Gravity Segregated Underdrains for Durable Rock Fills.

(Related Issue: Sampling and Testing for Rock Durability)

Stream Disturbance and Burial

...but also Long-Term Stability of Elevated Excess Spoil Fills on Steep Foundation Slopes.

Contemporaneous Reclamation

Erosion and Flooding

Enter Geomorphology!!

Goals

- Back to Basics- what nature builds will stay put?
- What about reclamation and engineering?
- How can it work in mountain top mining with steep areas?

Geomorphology Defined

Simply put: ***<u>the study of landforms</u>***

- Classification of landforms, based on:

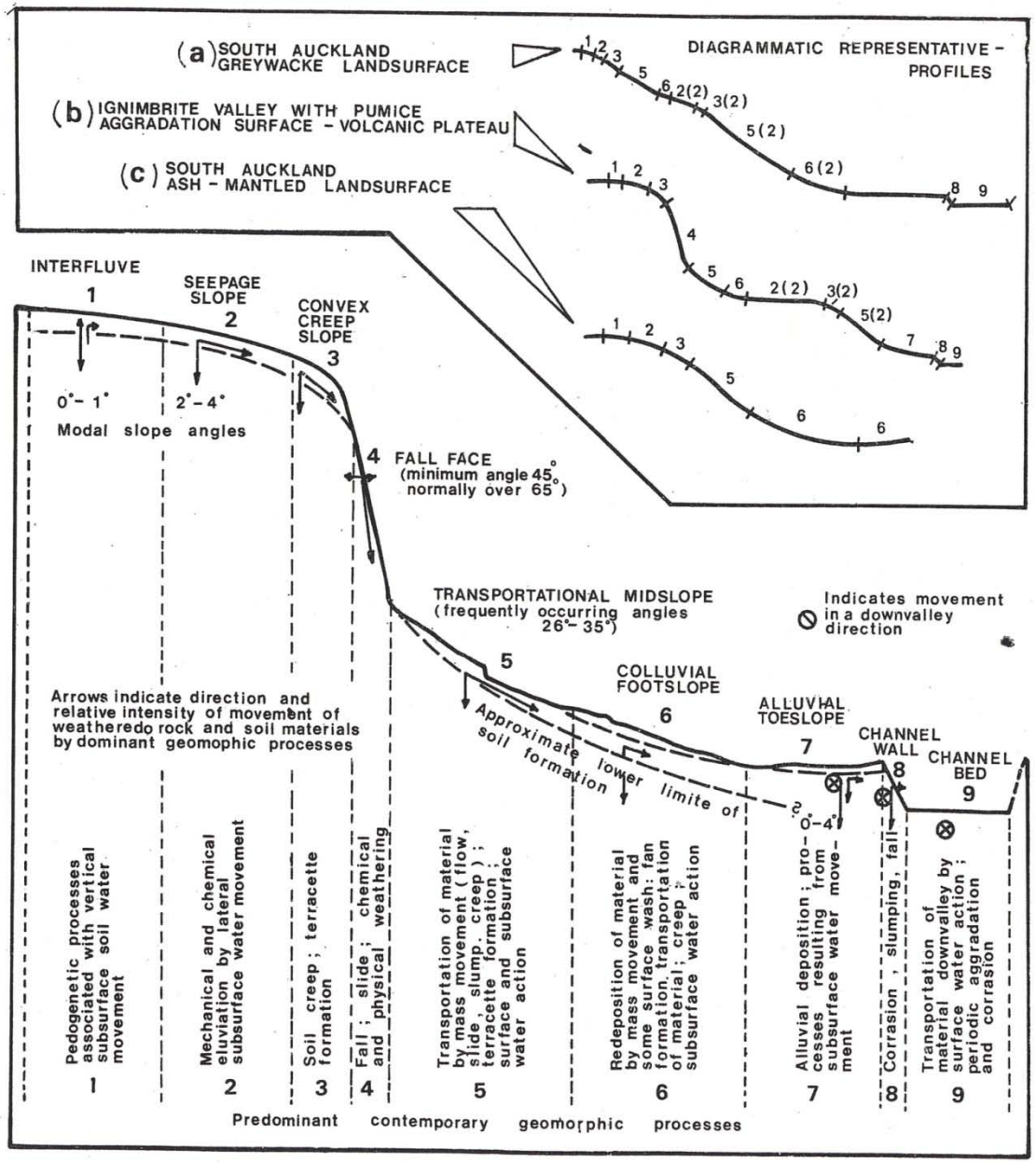
  - Shape ("morphology").

  - Materials they are made out of ("constituent materials").

  - How they formed ("origin").

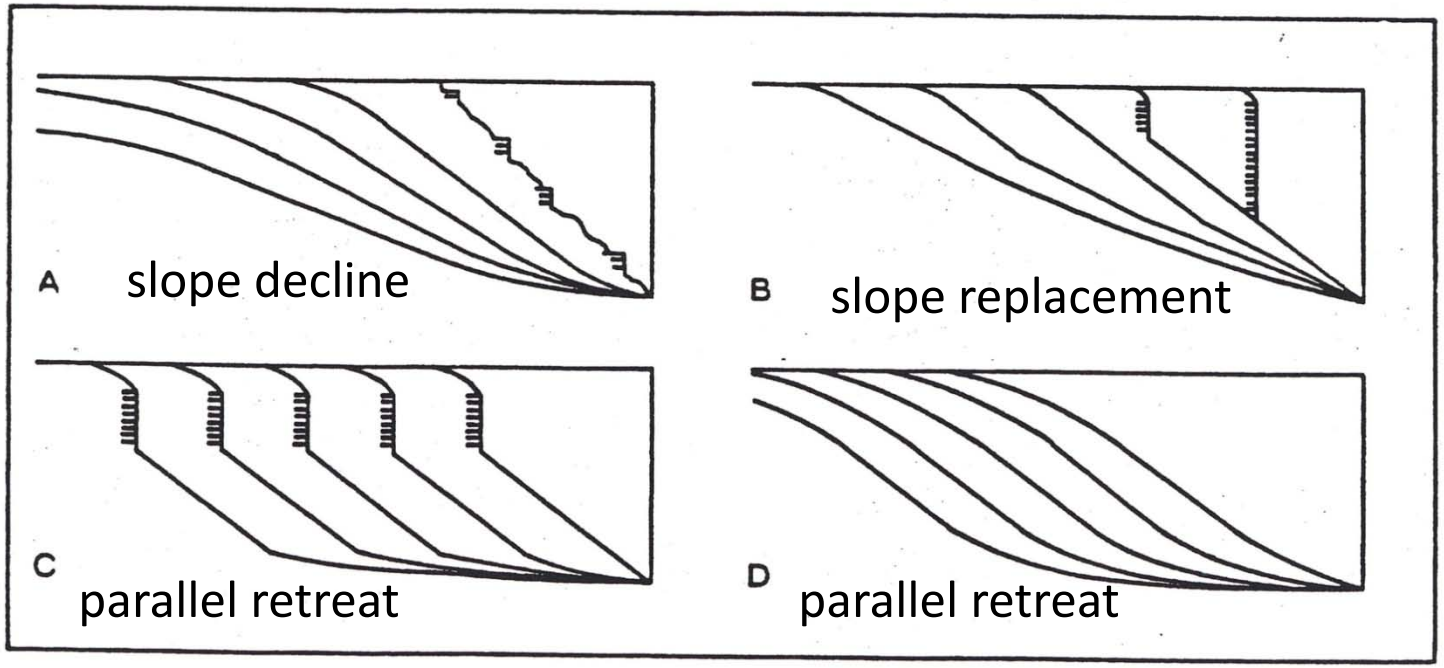
- Study of landforming processes.
- Study of stages of landform development.

Study of landforming processes.



"Nine-Unit Land Surface Model" (after Dalrymple *et al*., 1968)

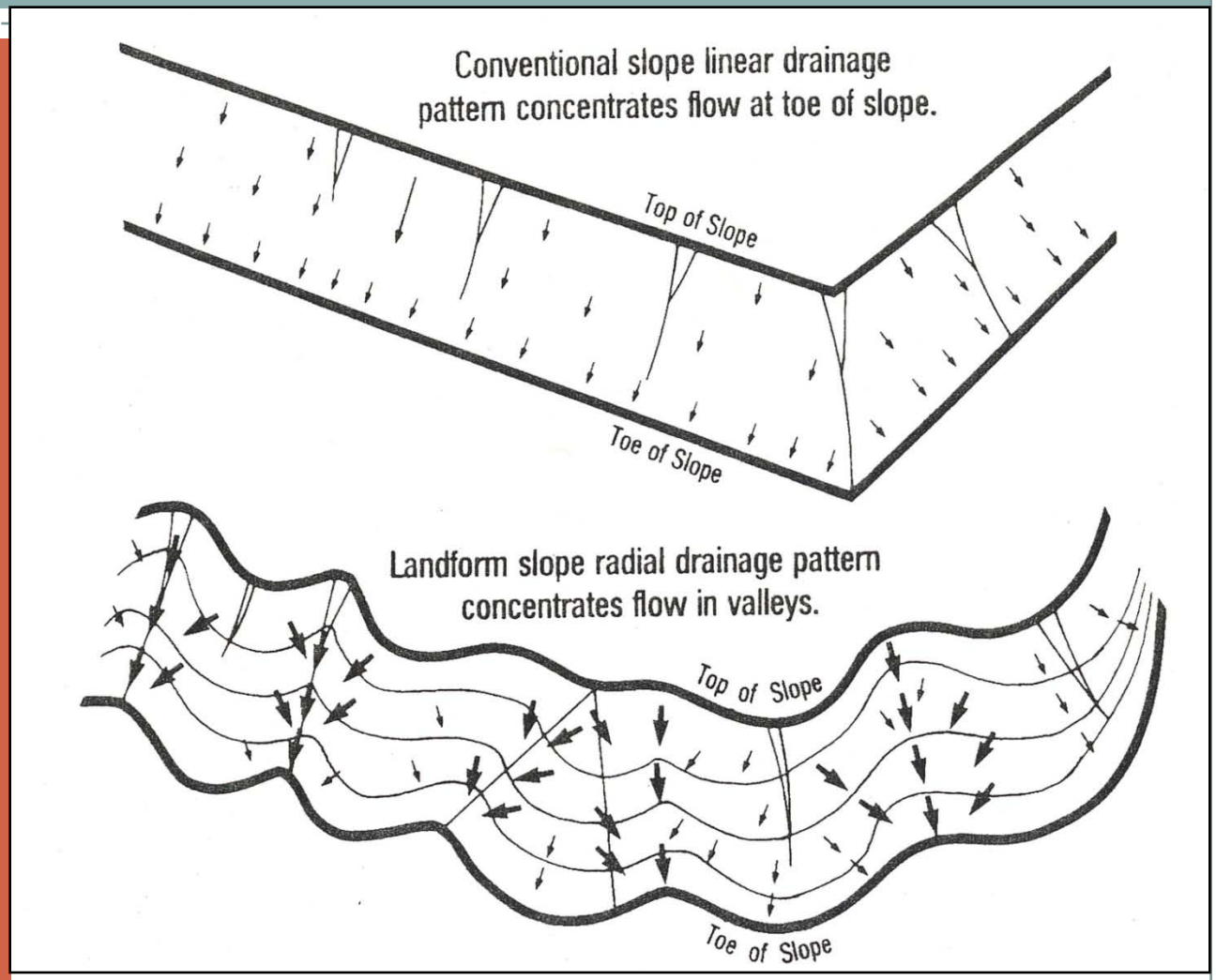
Study of landform development. (after Young, 1972)



Geomorphic Reclamation, or "Landforming."

- Definition:
  - Application of principles and insights gained from the study of geomorphology to land modification and reclamation.
- The benefits:
  - Aesthetically more pleasing.
  - **Greater stability (less erosion and less chance of mass instability).**
- The objectives:
  - Constructing artificial landforms that blend in with the surrounding natural landscape.
  - Constructing artificial landforms that are naturally stable (i.e. stable landforms that nature would form).
  - **Rephrasing: constructing artificial landforms that are stable in the long-term and maintenance free. And look they they belong.**

Comparison of surface water-flow regime in a landform graded slope as opposed to a conventionally graded slope.



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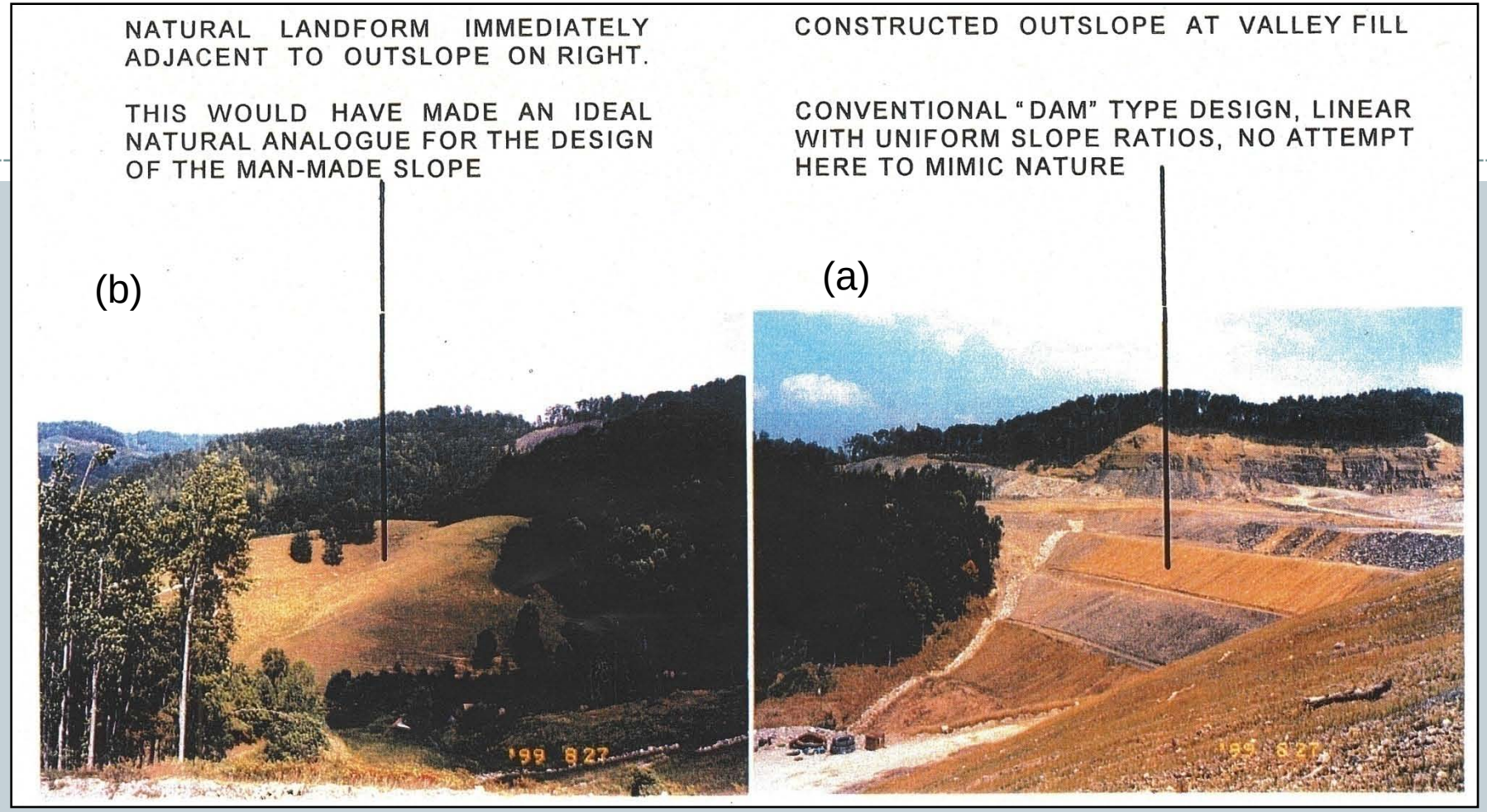


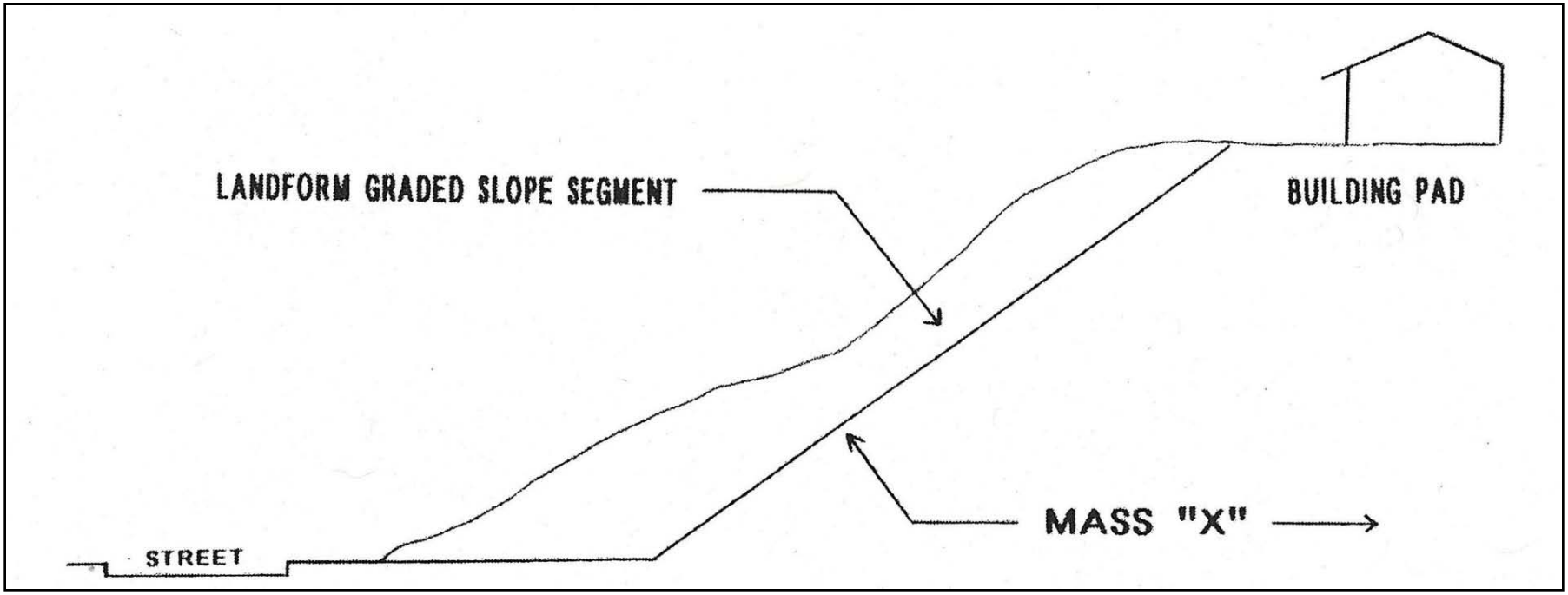
Tailings-disposal fill configurations: (a) "outward"-facing slope of valley fill once constructed and graded and (b) adjacent natural slope, whose topographical form would have made an ideal natural analog for the "outward" slope. (from Schor and Gray, ©2007 John Wiley and Sons, Inc., reprinted with permission of John Wiley and Sons, Inc.)

Example of landforming on
mountain top in WV

Challenges to Landforming in Steep-Sloped Central Appalachia

How can we incorporate natural landform design to these site conditions? Would nature form a valley fill like this?

Relative amounts and location of earth movement by conventional as opposed to landform grading.



<u>The point of this diagram</u>: Landform grading is applied only to the surficial veneer of earth material, minimizing increases in labor costs. Will the cost increase still prohibit landforming in steep-slope topography?

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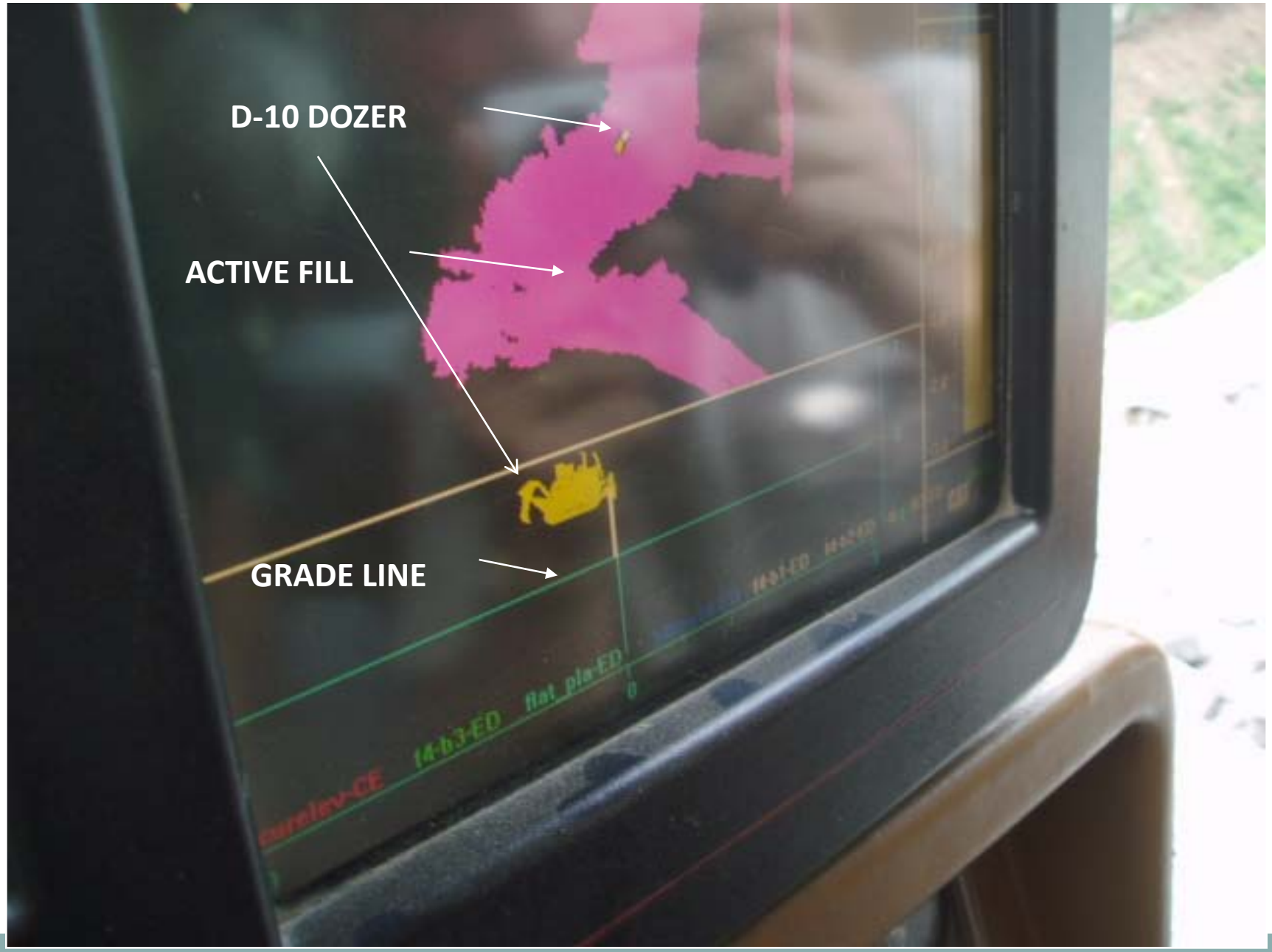
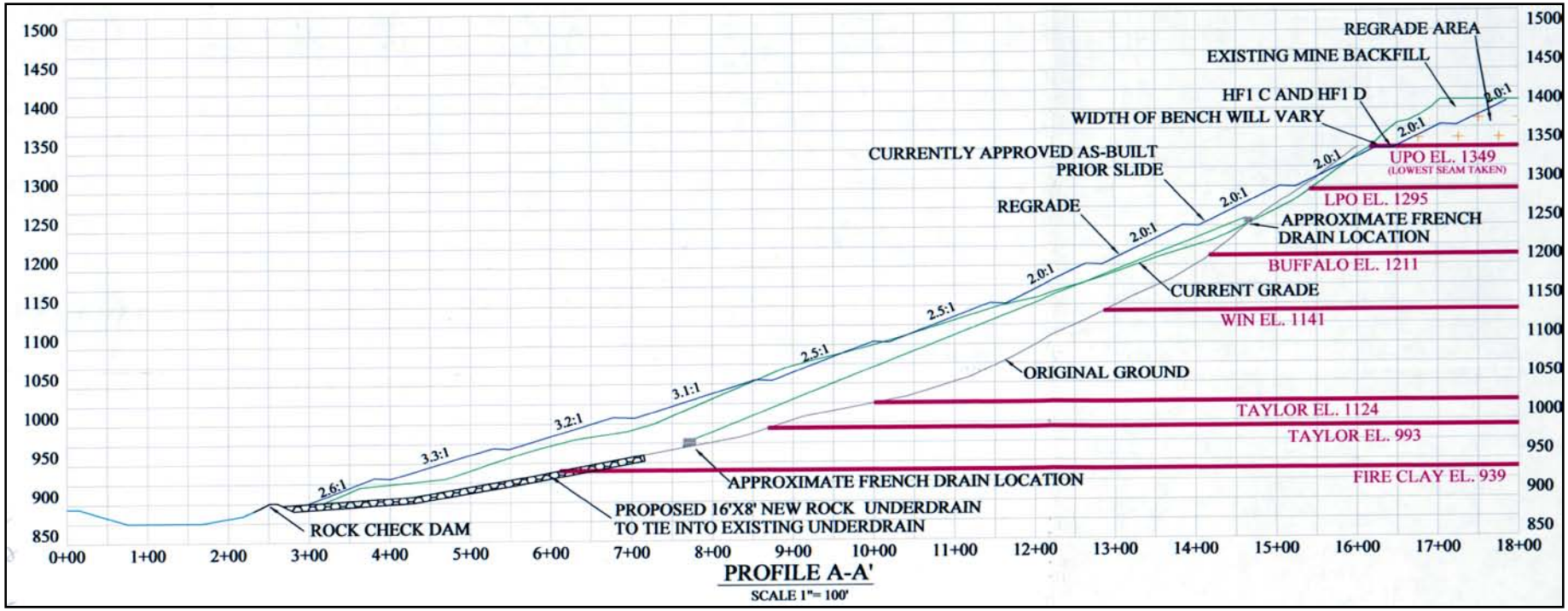
COMPUTER-GPS ON D-10 DOZER

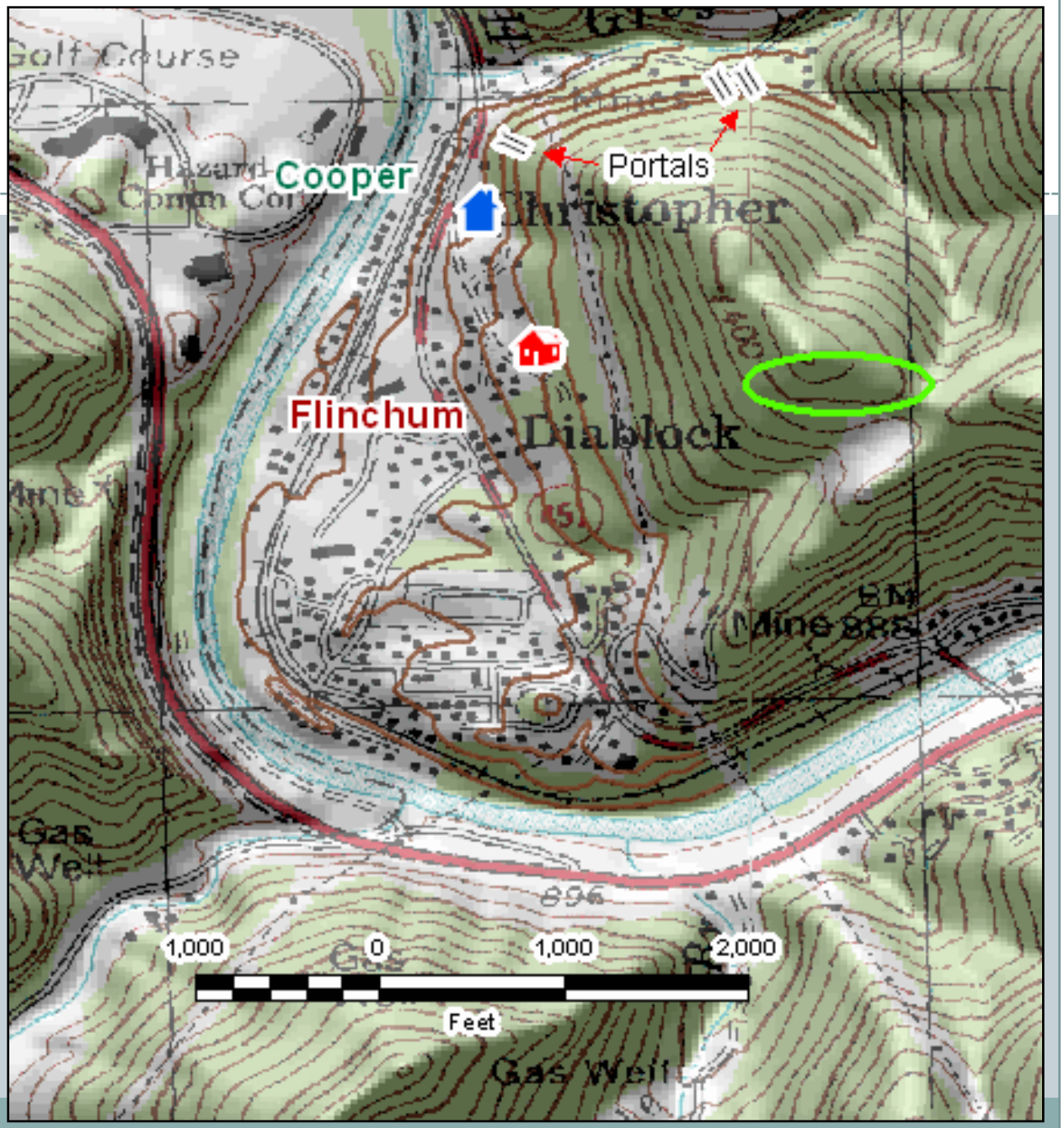


Geomorphic reclamation should not deter contemporaneous reclamation.



Elevated valley fills in steep-slope topography can be pretty thin to begin with.

Constructing fills that simply blend in with an erosional landscape is not enough….



…….They also must be stable.

Conclusions

- The authors support the concept of geomorphic mine land reclamation in Central Appalachia and elsewhere.
- We particularly like its implications for long-term, post-bond-release stability of reclaimed surfaces, especially excess spoil fills.
- Challenges to the application of landforming and stream restoration on surface mines in steep-slope topography include:
  - Absence of explicit references in the Federal regulations to geomorphic reclamation.
  - A potential conflict with recently promulgated rules for excess spoil (fill) limitation.
  - Potential increased time and cost relative to current practices.
  - Designing and constructing stable landforms within an otherwise youthful, erosional landscape.

Can Appalachian Mine Reclamation Be Called Sustainable Using Current Practices?

29 April 2009
OSM Technical Interactive Forum
Geomorphic Reclamation and Natural Stream Design at Coal Mines
Bristol, Virginia

Nicholas Bugosh
GeoFluv
GeoFluv™ Technical Director
Carlson Software

Who has *Natural Regrade* worldwide?

Economic competition demands most efficient use of resources

- **Coordinating mine development, operational, and closure plans adds efficiency**
- **Leads to *land use sustainability***

‘Land Use Sustainability’

definitions share recognition of the need to maintain:

environmental **functions related to landforms when conducting**

economic **development activities for the benefit of**

future users **of the land.**

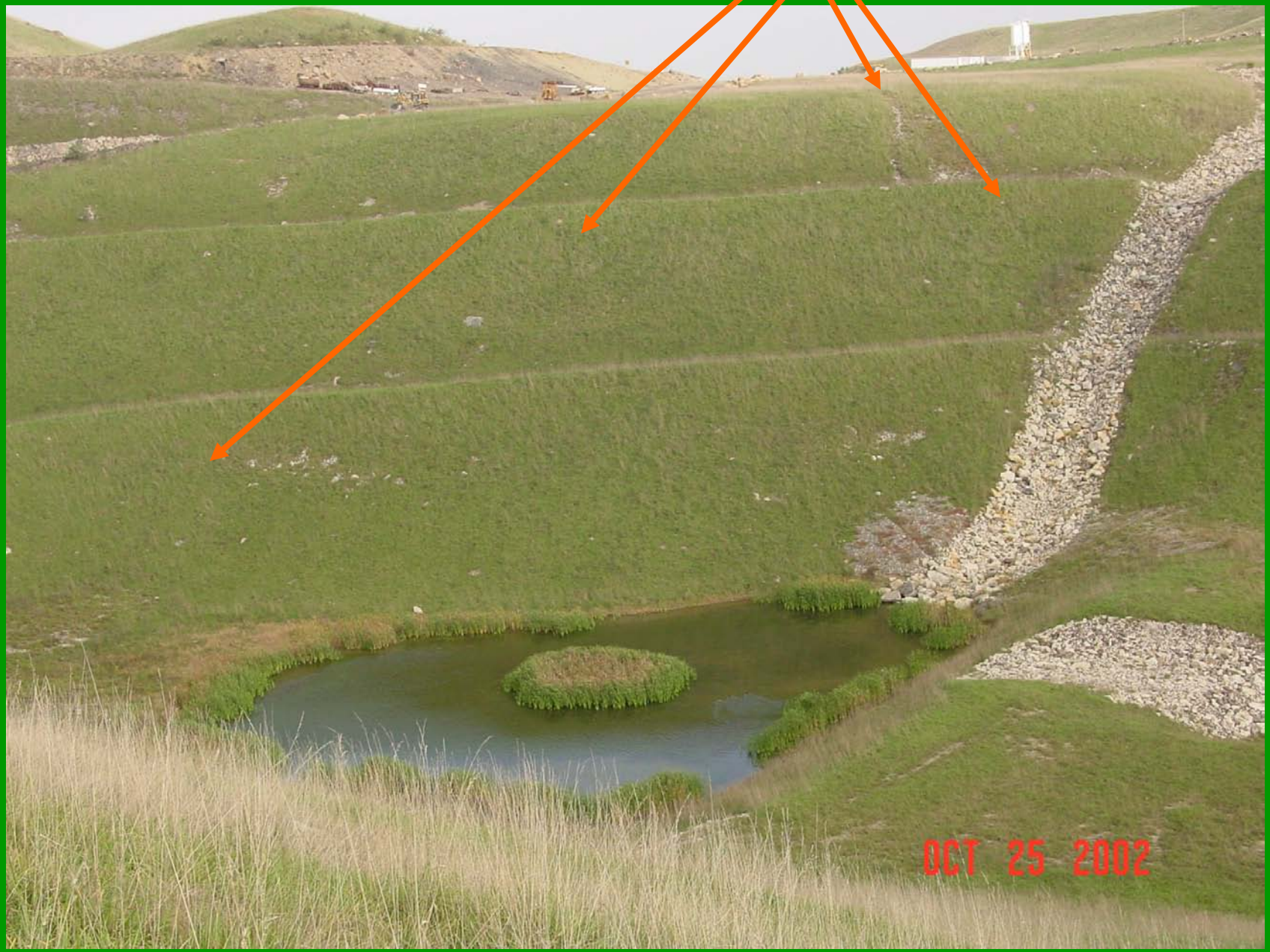
“The triple bottom line”

- Rajaram, V., Dutta, S., Parameswaram, K. , 2005

What are traditional design criteria?

- Smooth surfaces
- Route water away
- Minimize footprint

If you don't add *drainage density*, nature will !!

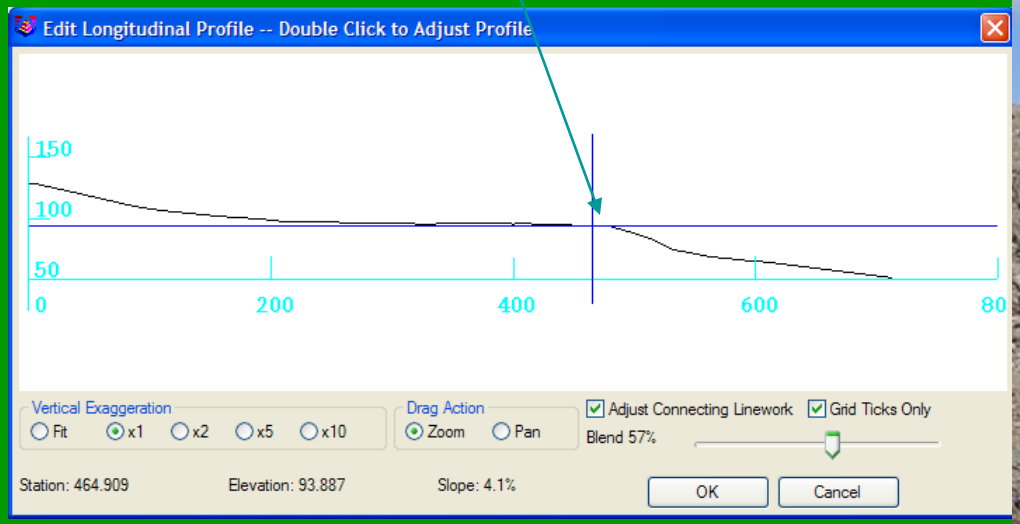


constant gradient
no drainage density

Slope is creeping, landslide beginning

Will these houses be buried?

Knickpoints can be BIG problems



(AK)

One storm corrects longitudinal profile !

Terraces can be expensive to build and maintain (*if you don't see it in nature, don't do it!*)

Something just tells you it isn't right . . .

Coal mine reclamation in the region

"... has not been accompanied by widespread replacement of forests disturbed by mining."

- Appalachian Regional Reforestation Initiative (ARRI)

Traditional Reclamation Landforms:

- **fewer ecological niches = *monoculture***
- **or worse, are *unsuitable* for the desired species while inviting *invasive* species**

Natural Regrade module with GeoFluv™ (Patent Pending)

The *GeoFluv™* approach asks,

What would be a stable, natural landform?

and designs and builds that

GeoFluv landform has diversity similar to the native, undisturbed land

- provides the optimal niches for native species productivity
- simultaneously provides natural invasive species control
- promotes suitable water quality

What other requirements are related to *sustainable* landform design?

- Free from maintenance, ‘forever’
- NPDES storm water discharge (sediment)
- Vegetation composition & diversity
- COE 404 permit
- Stream ‘mitigation’
- Prove stability against erosion, ‘forever’
- Post-mining land use
- Low cost to achieve these criteria
- Bond release

View of "A" channels and ridges designed using Natural Regrade,

to replace constant 3:1 slope.

BRS ENGINEERING

GeoFluv design and natural

BRS ENGINEERING

Rip-rap downdrains blow out repeatedly

Water & Earth Technologies, Inc.
Water Resources and Environmental Consulting

GeoFluv™ landform and existing quarry

three days of rain; no problems

a mountaintop removal?

Water & Earth Technologies, Inc.
Water Resources and Environmental Consulting

Dept. of Interior “National” and “Best of the Best” 2004 reclamation awards

There is something new happening in landform design.
It’s the future. It’s natural. ***Be a part of it.***

Before *Natural Regrade* GeoFluv design

– Dan Hause, Indiana AML

After *Natural Regrade* GeoFluv design

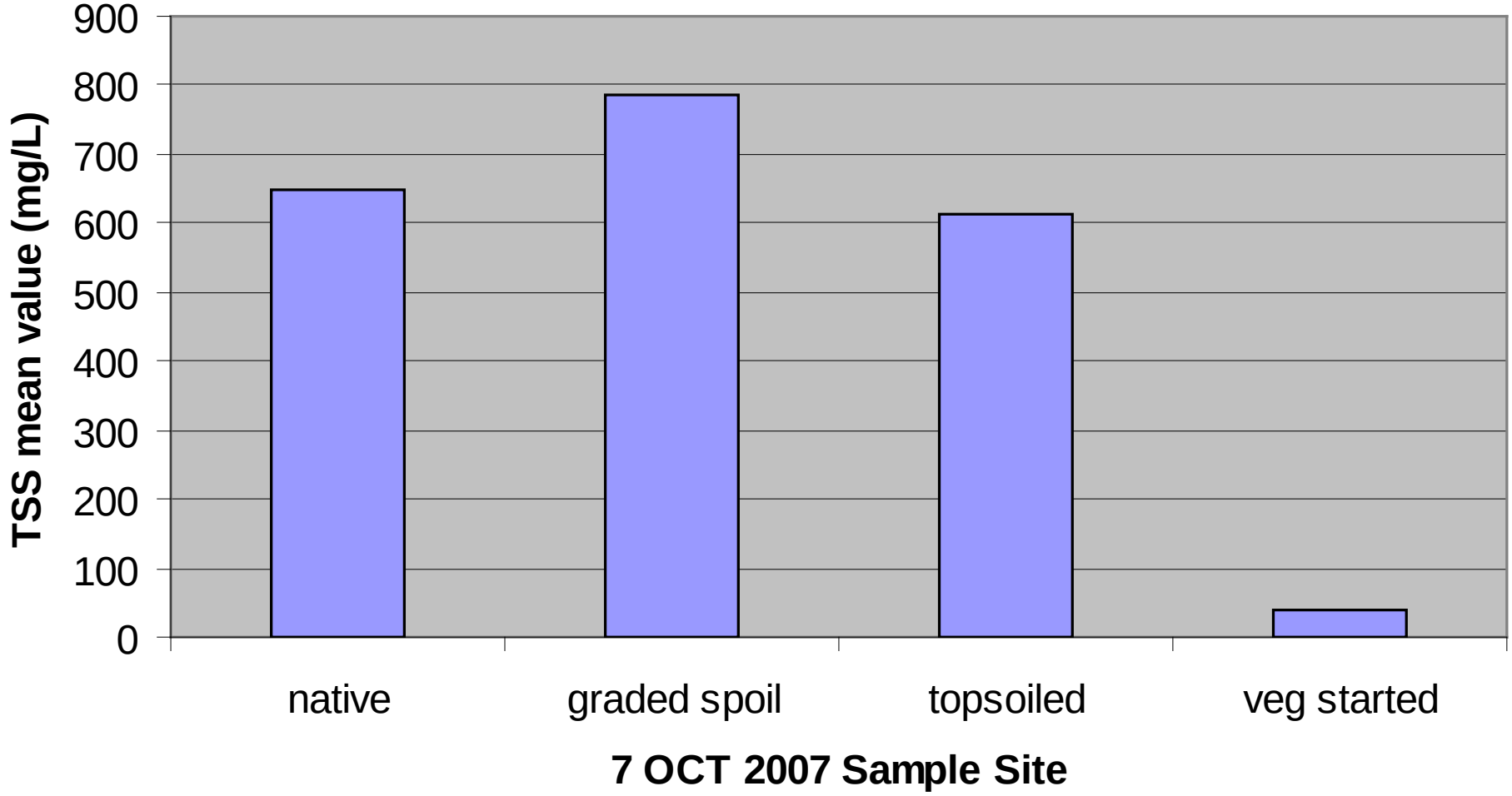
Mid Continent Regional Award

- Log Creek Church AML, *Indiana DNR*

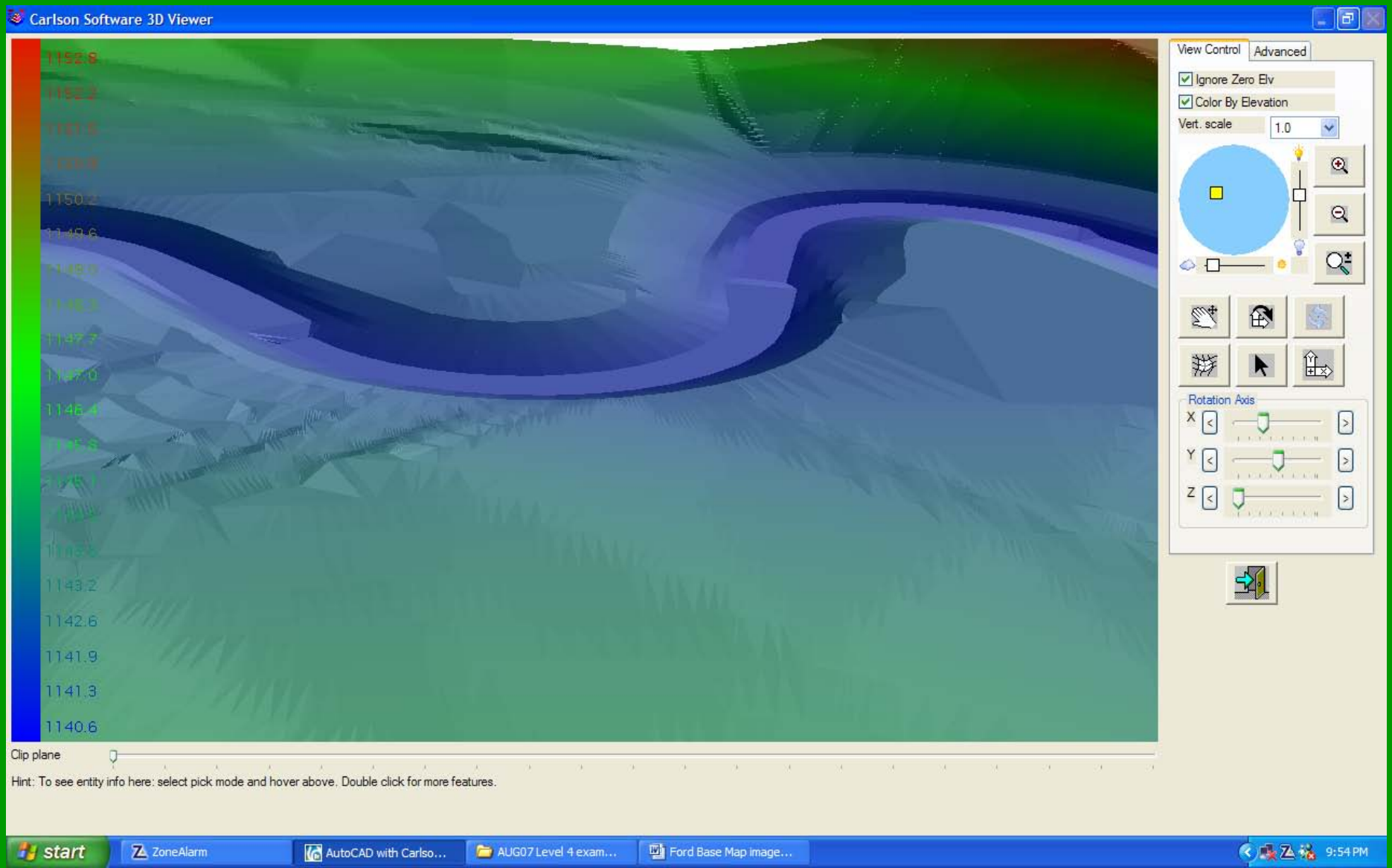
- sequestered >70 acres of acid producing waste
- established forested wetlands
- *sustainable* geomorphic stream channels and upland areas
- natural slopes replaced 4,000 feet of highwall

highwall to ‘wildlife enhancement feature’
(~370,000 cubic yards not moved)

Storm Water Total Suspended Sediment at Native and GeoFluv-designed sites



Contoured at 0.2 foot contour interval, vertices densified to enhance 3D view detail of RIVERMorph riffles and pools



Carlson Natural Regrade 2009 with AutoCAD - NOT FOR RESALE [CRD: NONE] - [C:\Documents and Settings\Nicholas Bugosh\My Do

File Edit View Draw Inquiry Settings Points Natural Regrade Surface Watershed Structure Network Window Help Express

Standard

CTR ByLayer ByLayer

Carlson GeoFluv, ver.2.2.2

C:\Sme example.geo

File... Settings...

Setup Channels Output DWG

Preview

Draw Design Surface...

Data for GeoFluv work area:

Valleys (ft.)	3518.35
Area (ac.):	26.87
Drainage Density(ft/ac):	131

Comparison Surface

C:...egrade 1_1 15 oct 08.tin

No inclusion polylines were used.

No exclusion polylines were used.

Update Cut / Fill

Cut (c.y.):	66513
Fill (c.y.):	195210
Cut / Fill (%):	34.07

Summary Report...

Reread Valley Bottoms

Exit Help

GeoFluv data on channel 'Denver Gulch'

Station (ft.):	868.72
Watershed area (ac.):	11.84
Bankfull Qpk (cfs):	6.38
Floodprone Qpk (cfs):	21.25
Bankfull width (ft.):	4.26
Bankfull depth (ft.):	0.34
Flood prone width (ft.):	8.97
Flood prone depth (ft.):	0.93
Slope at station:	-3.81%
Flood prone area (sq.ft.):	4.90
Bankfull area (sq.ft.):	0.99
Bottom width (ft.):	1.53
Right side slope:	26.41%
Left side slope:	23.92%

Y

X

Carlson Natural Regrade 2009 with AutoCAD - NOT FOR RESALE [CRD: NONE] - [C:\Documents and Settings\Nicholas Bugosh\My

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Standard

CTRINDEX ByLayer ByLayer

Carlson GeoFluv, ver.2.2.2

C:\Sme example.geo

File... Settings...

Setup Channels Output DWG

Preview

Draw Design Surface...

Data for GeoFluv work area:

Valleys (ft.)	3048.88
Area (ac.):	26.87
Drainage Density(ft/ac):	113

Comparison Surface

C:...egrade 1_1 15 oct 08.tin

No inclusion polylines were used.

No exclusion polylines were used.

Update Cut / Fill

Cut (c.y.):	125671
Fill (c.y.):	120519
Cut / Fill (%):	104.28

Summary Report...

Reread Valley Bottoms

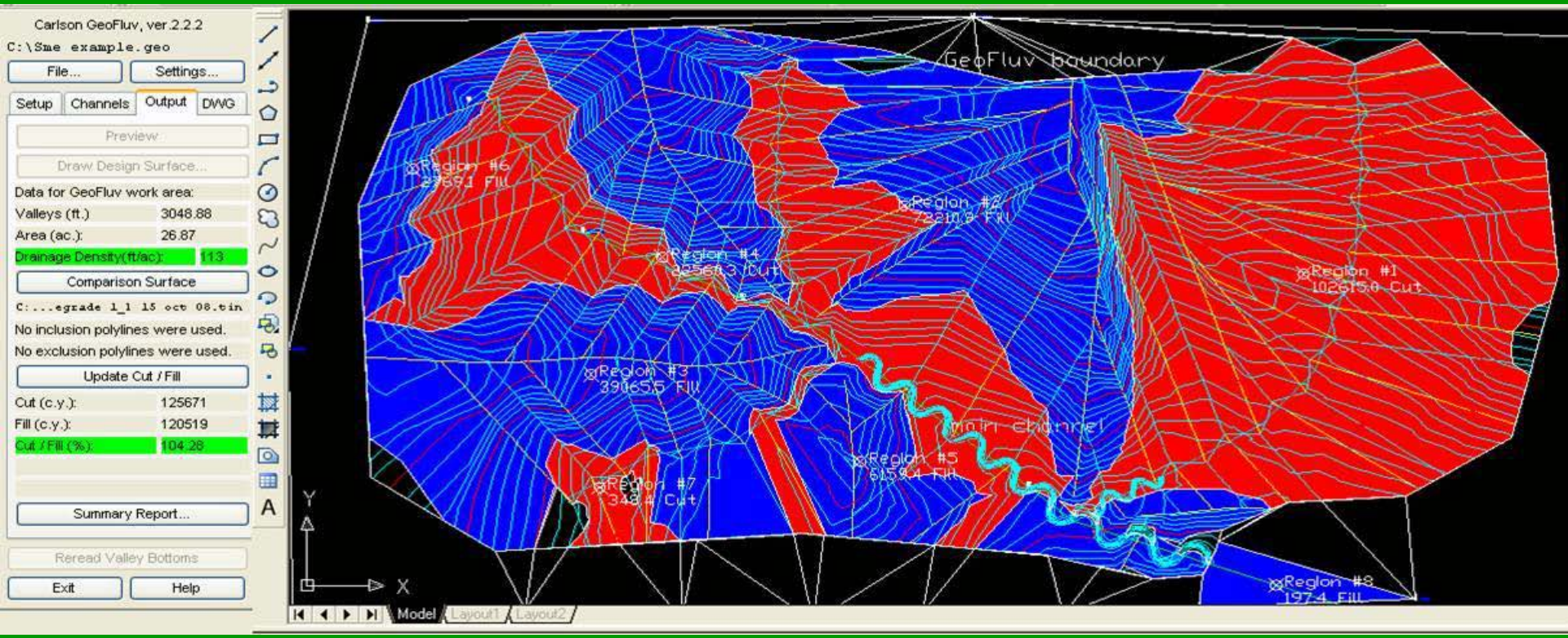
Exit Help

GeoFluv data on channel 'Denver Gulch'

Station (ft.):	907.35
Watershed area (ac.):	13.08
Bankfull Qpk (cfs):	7.04
Floodprone Qpk (cfs):	23.48
Bankfull width (ft.):	4.49
Bankfull depth (ft.):	0.36
Flood prone width (ft.):	9.50
Flood prone depth (ft.):	0.98
Slope at station:	-3.74%
Flood prone area (sq.ft.):	5.47
Bankfull area (sq.ft.):	1.10
Bottom width (ft.):	1.62
Right side slope:	19.83%
Left side slope:	33.63%

Y X

Material Cut / Fill Centroids



Material Quantities & Haul Distances

Cut & Fill Centroid Report

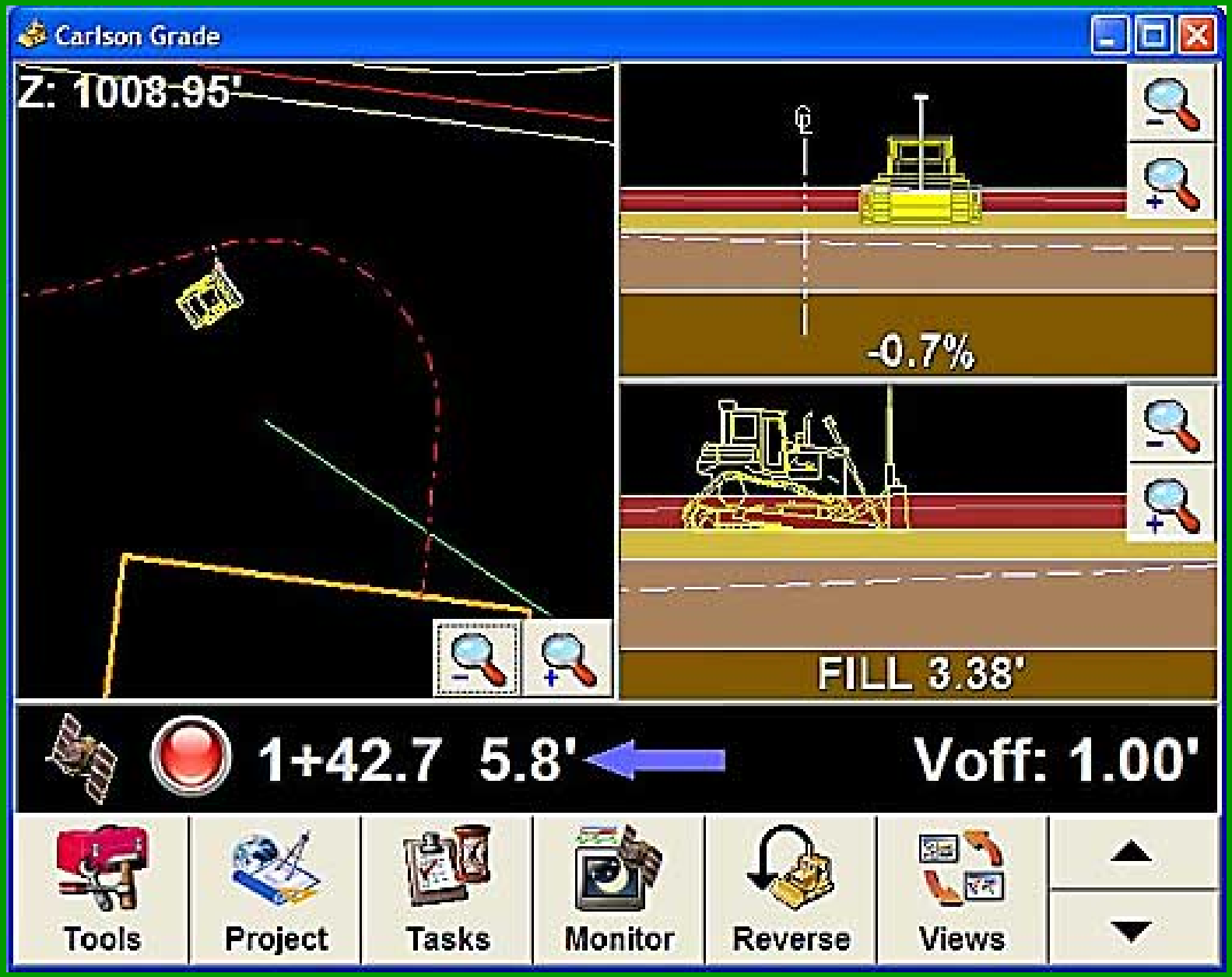
Original Ground: C:\Documents and Settings\Niche
Design Surface: C:\Documents and Settings\Niche
Cut/Swell factor: 1.0000
Fill/Shrink factor: 1.0000

Region	Volume(C.Y.)		Northing	Easting
1	102615.0	Cut	704.33	1529.54
2	72210.9	Fill	808.78	972.20
3	39065.5	Fill	552.21	535.43
4	22560.3	Cut	729.57	635.31
5	6159.4	Fill	419.29	911.36
6	2769.1	Fill	864.02	286.55
7	348.4	Cut	379.93	547.71
8	197.4	Fill	231.31	1491.28

Earth Movement Report:

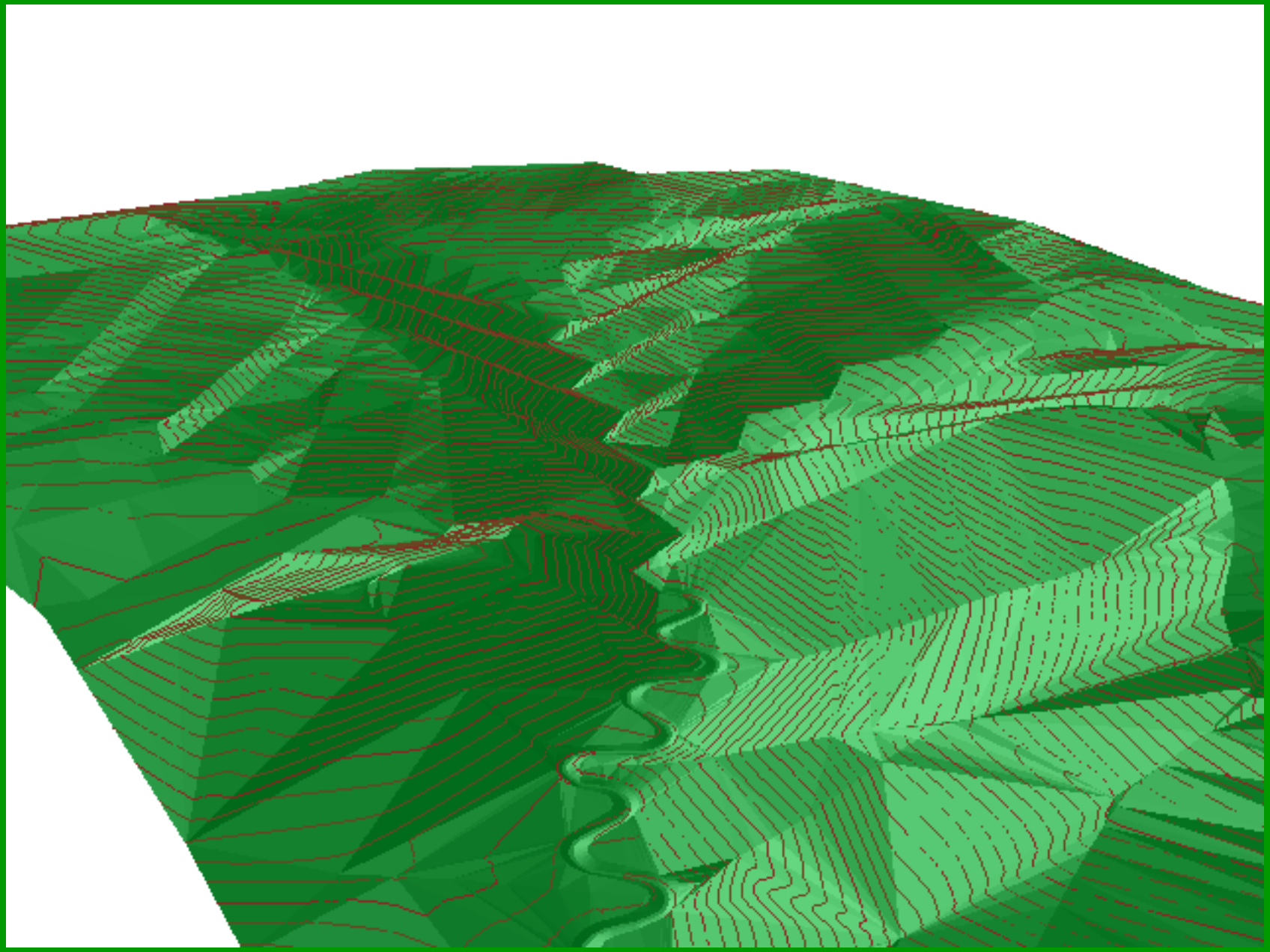
From Region	To Region	Volume(C.Y.)	Distance
1	2	72210.9	567.04
1	3	16156.8	1005.68
1	5	6159.4	680.73
1	6	2769.1	1253.20
1	8	197.4	474.57
4	3	22560.3	203.55
7	3	348.4	172.71

Grade Operator Screen with three views

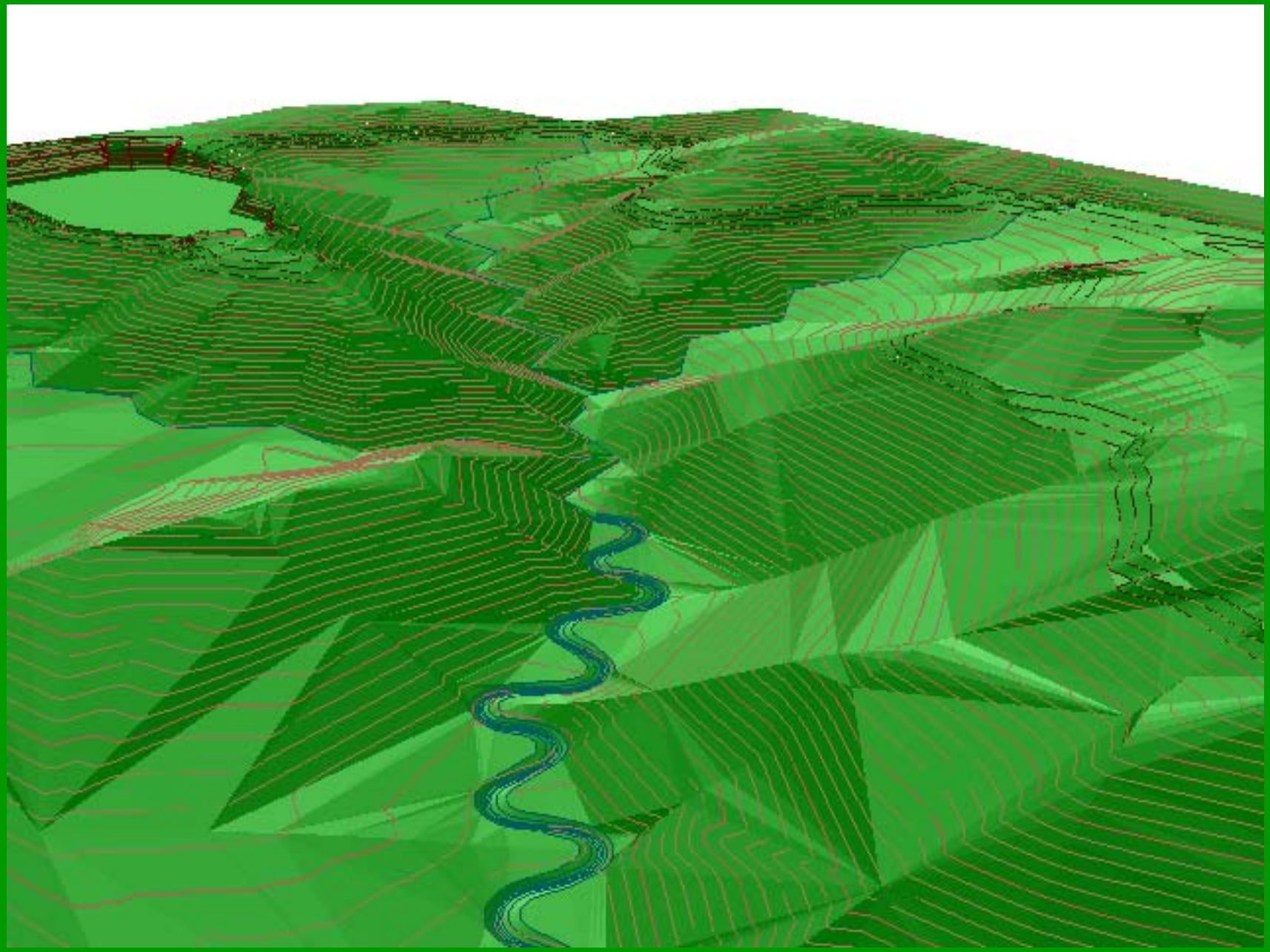


What about steep mountain terrain and valley fills?

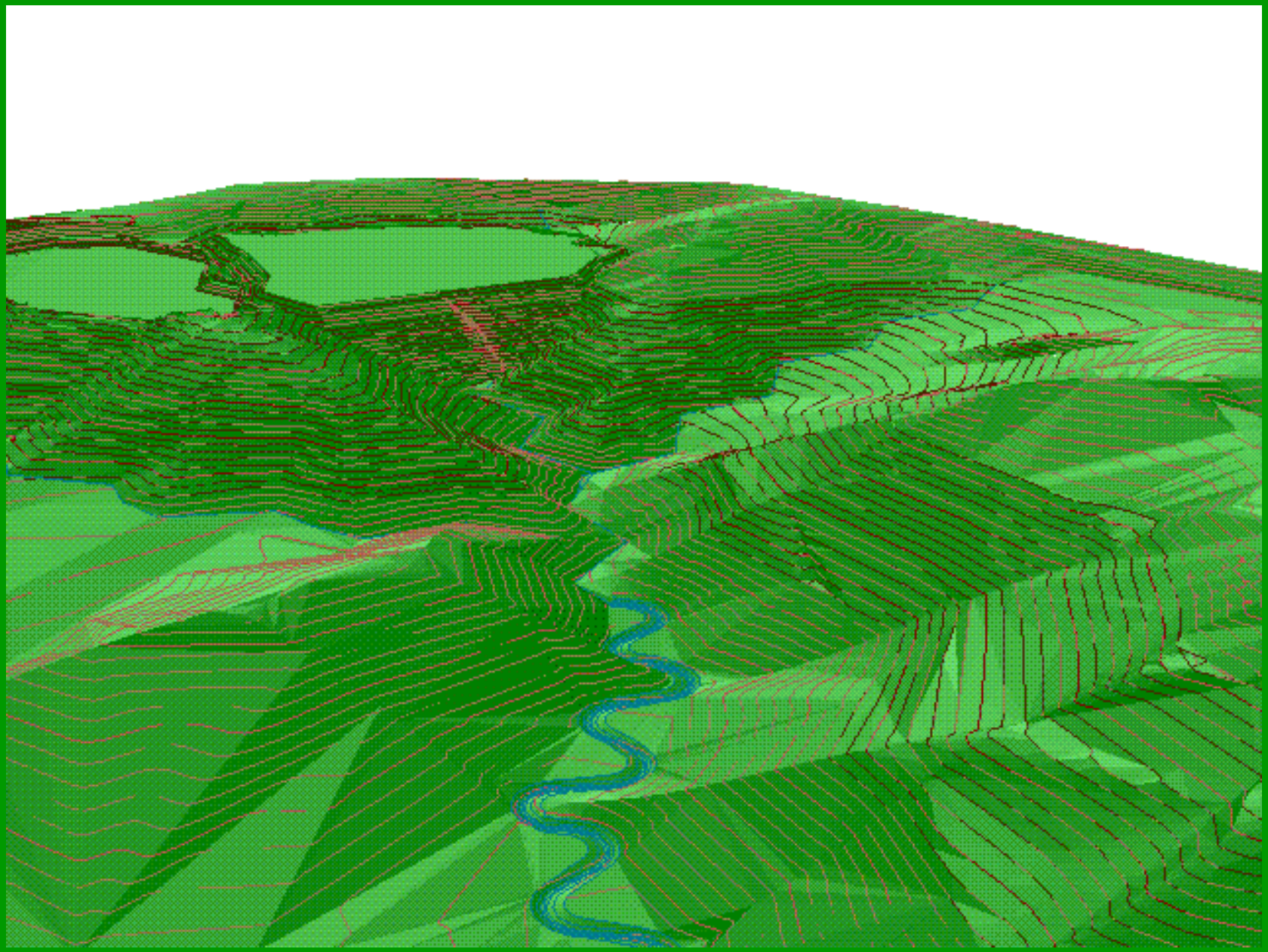
Undisturbed mountain landform



Mountain top removal



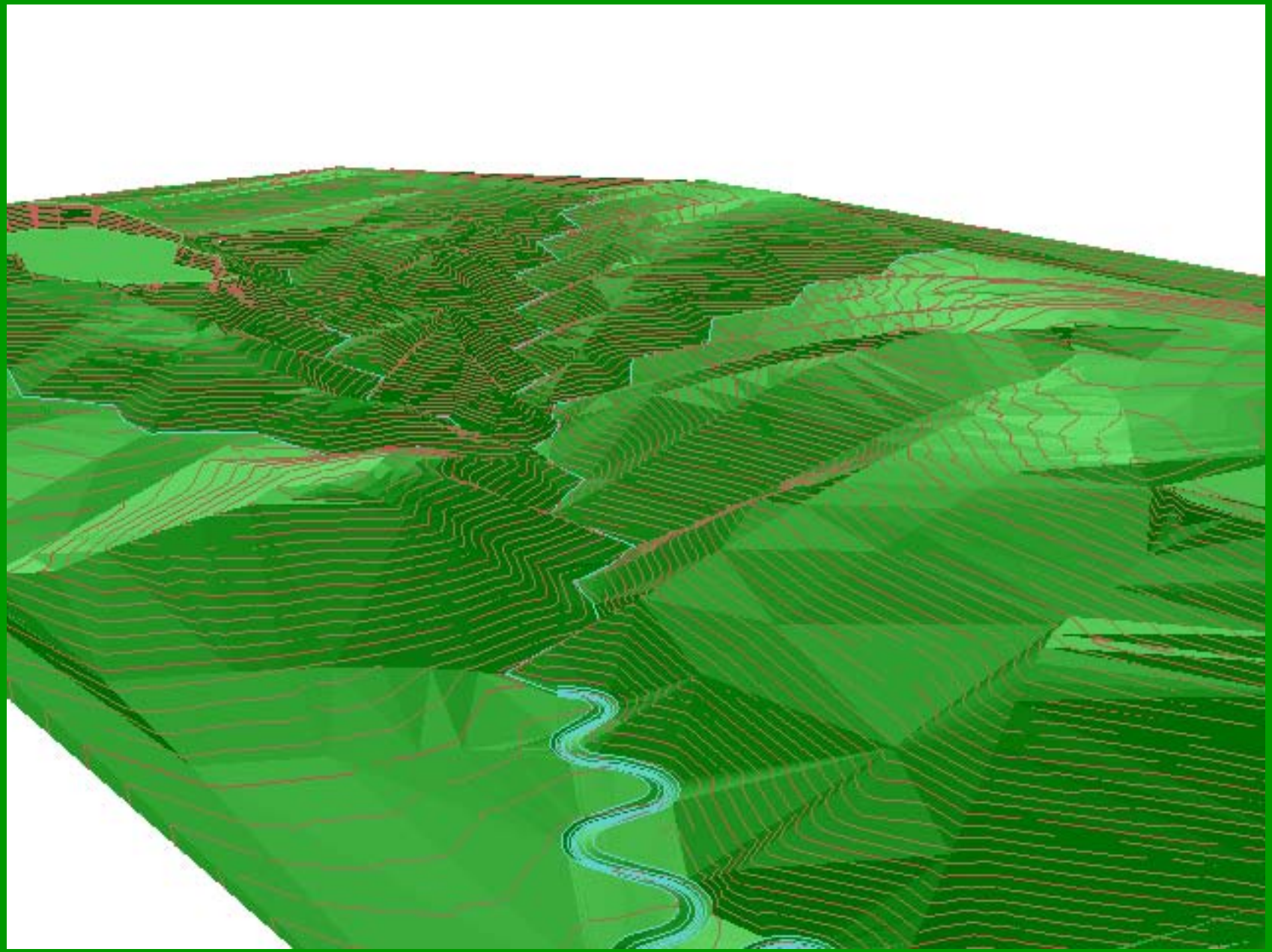
Mountain top removal with traditional valley fill



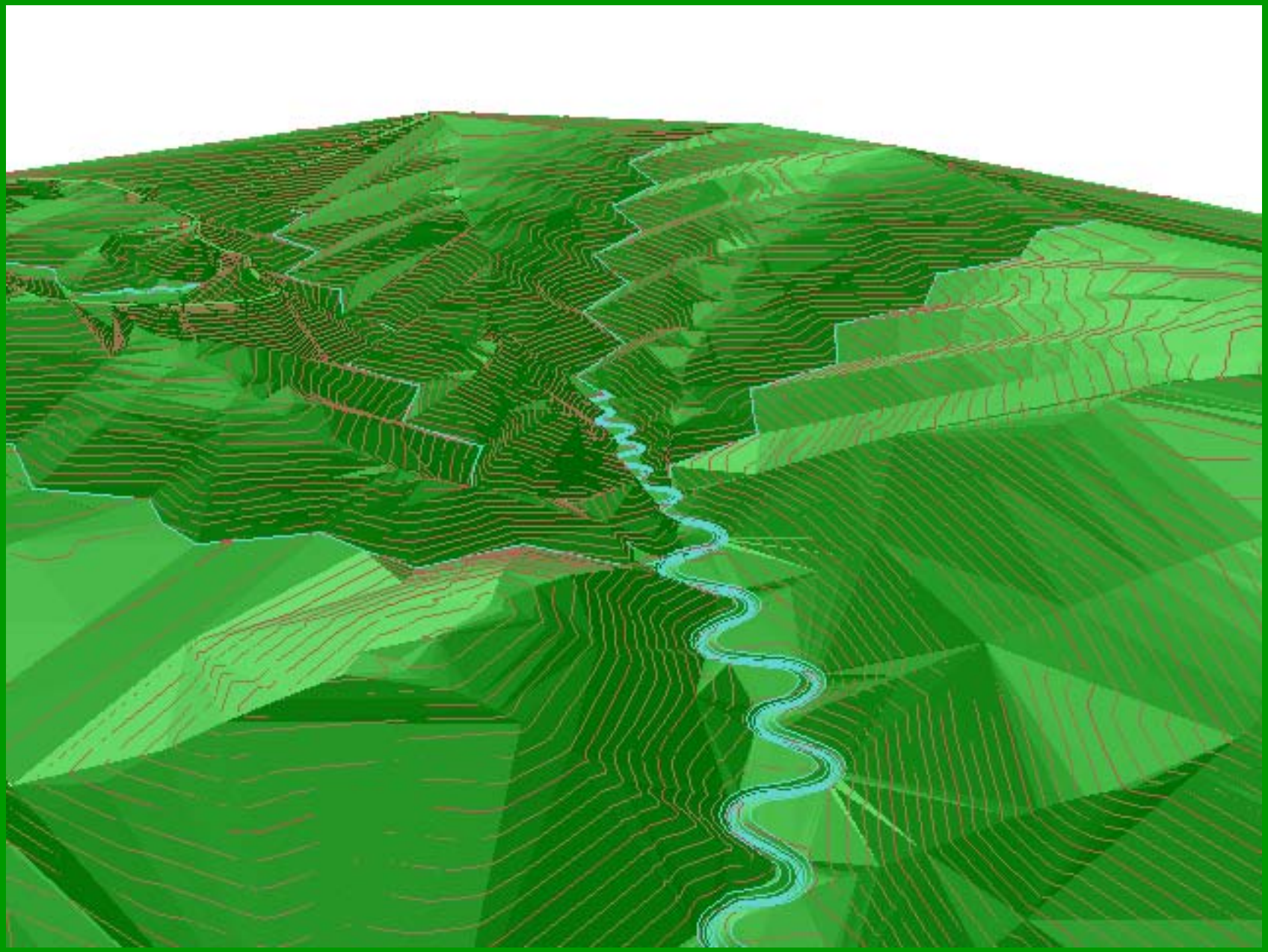
What is a natural analogy?

Stream re-routed to side of valley

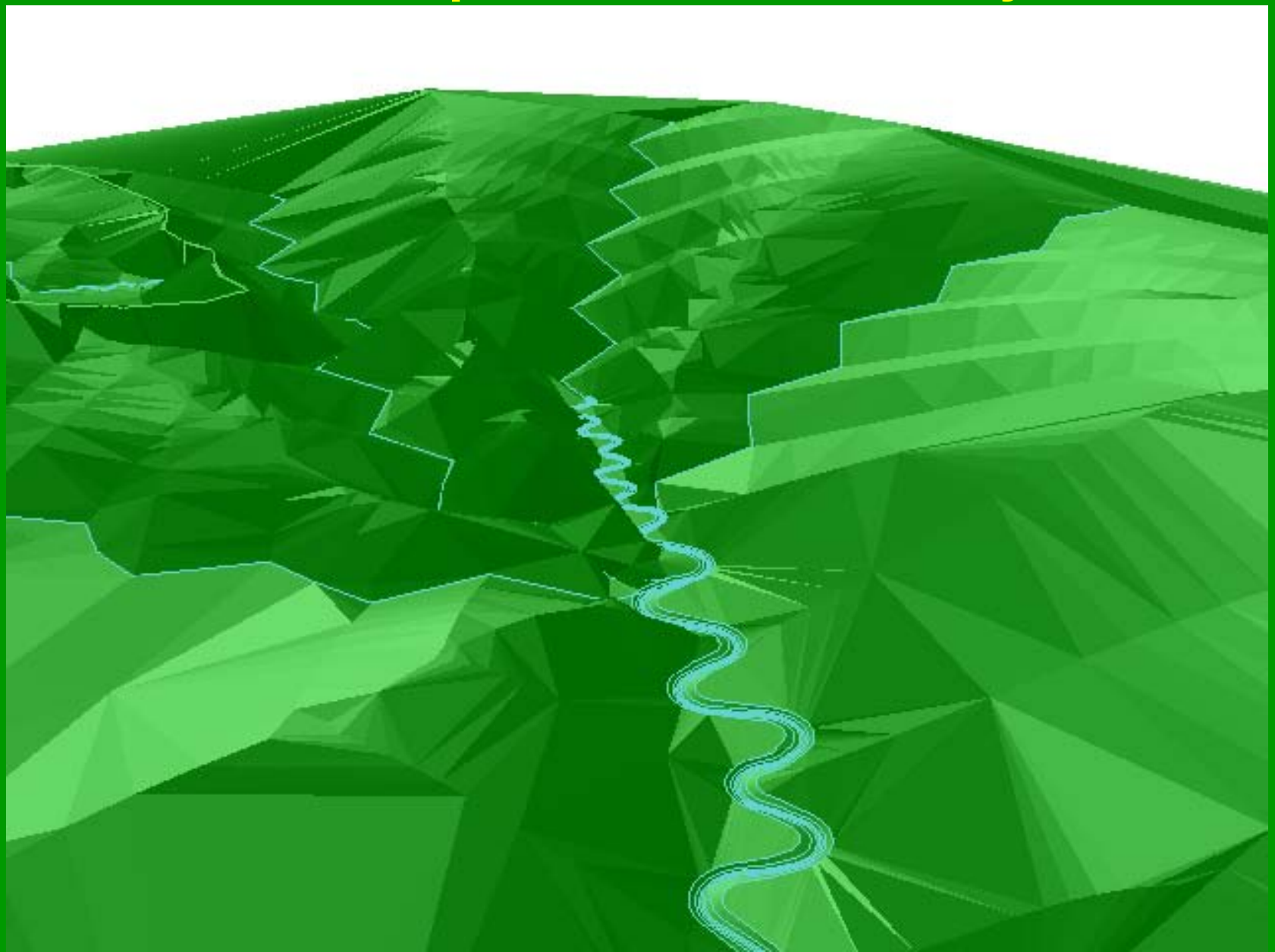
One possible GeoFluv valley fill



GeoFluv -designed mountain top and valley fill



GeoFluv - designed mountain top and valley fill
Can this provide sustainability?

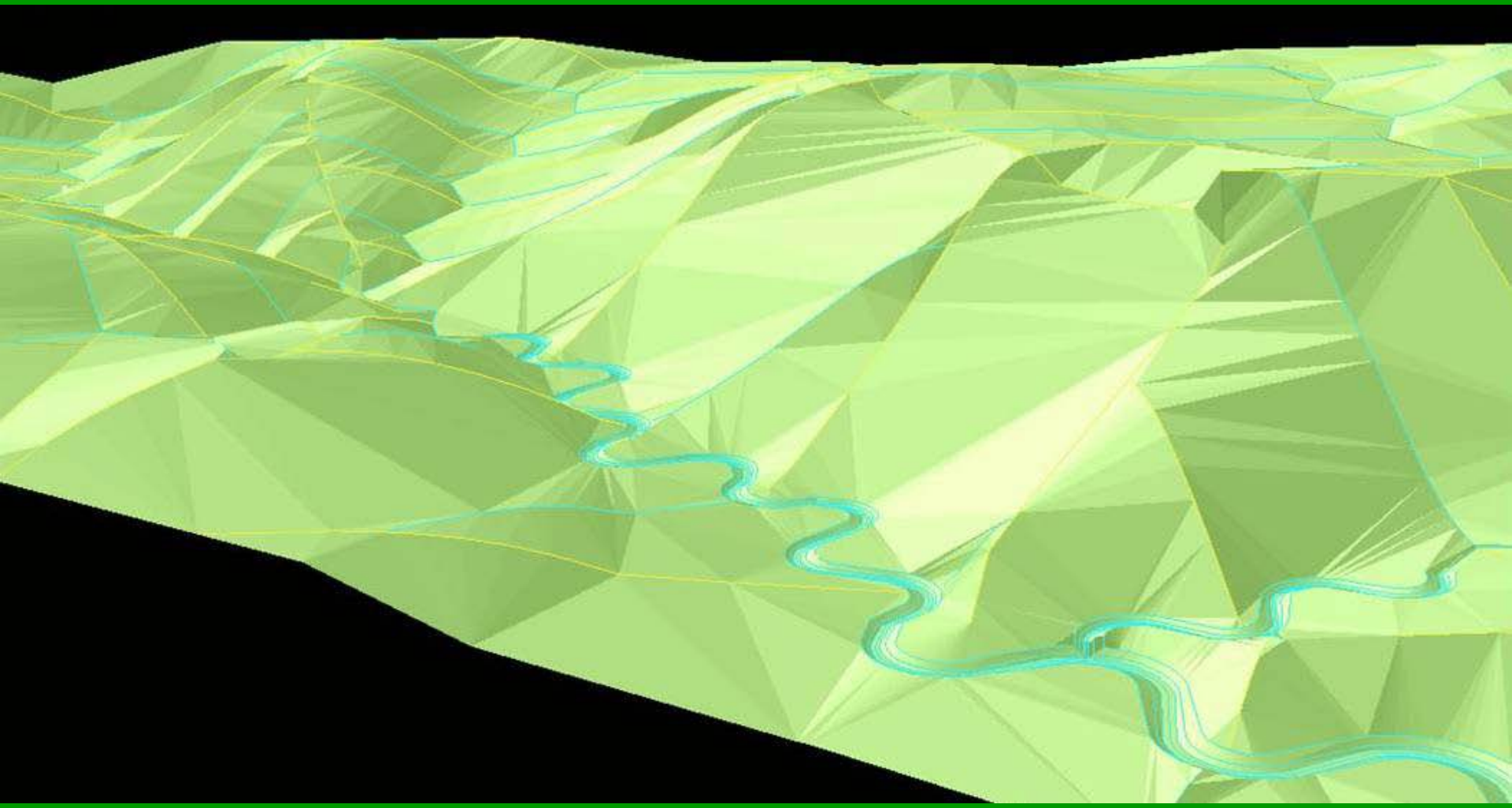


Highwall and contour mining alternatives?

A stable GeoFluv alternative for highwalls and contour mining

July 2006 received ~ 200-yr, 3-hr event

3D GeoFluv design in *Natural Regrade*



3D GeoFluv design in *Natural Regrade* provides

environmental **functions related to landforms when conducting**

economic **development activities for the benefit of**

future users **of the land**

"The triple bottom line"

GeoFluv-designed waste dump reclamation
Natural Regrade

GeoFluv channel and uplands

Thank you

There is something new happening in landform design.

It's the future. It's natural.

Be a part of it.

Modeling Sediment Loss on Geomorphic Graded Reforestation Lands in Kentucky

Geomorphic Reclamation and Natural Stream Design at Coal Mines: A Technical Interactive Forum

Richard C. Warner, Carmen T. Agouridis, and Christopher D. Barton

April 29, 2009

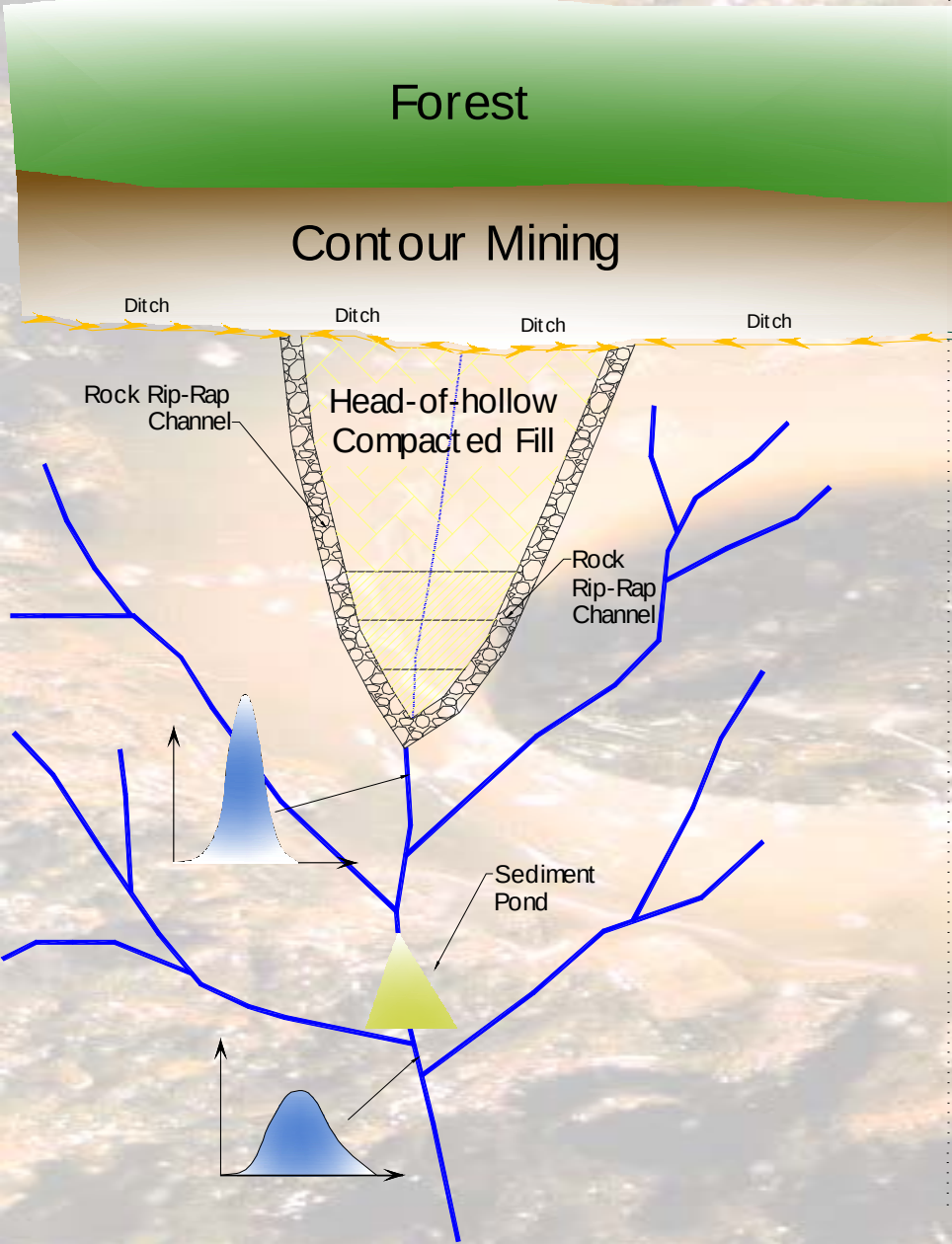
Sustainable Mining/Reclamation

- Similar (minor changes)
  - Hydrology
  - Sediment
  - Water quality
    - chemistry
    - organic material
    - nutrients
  - Visual
    - geomorphic
      - land form
      - natural streams
    - forest

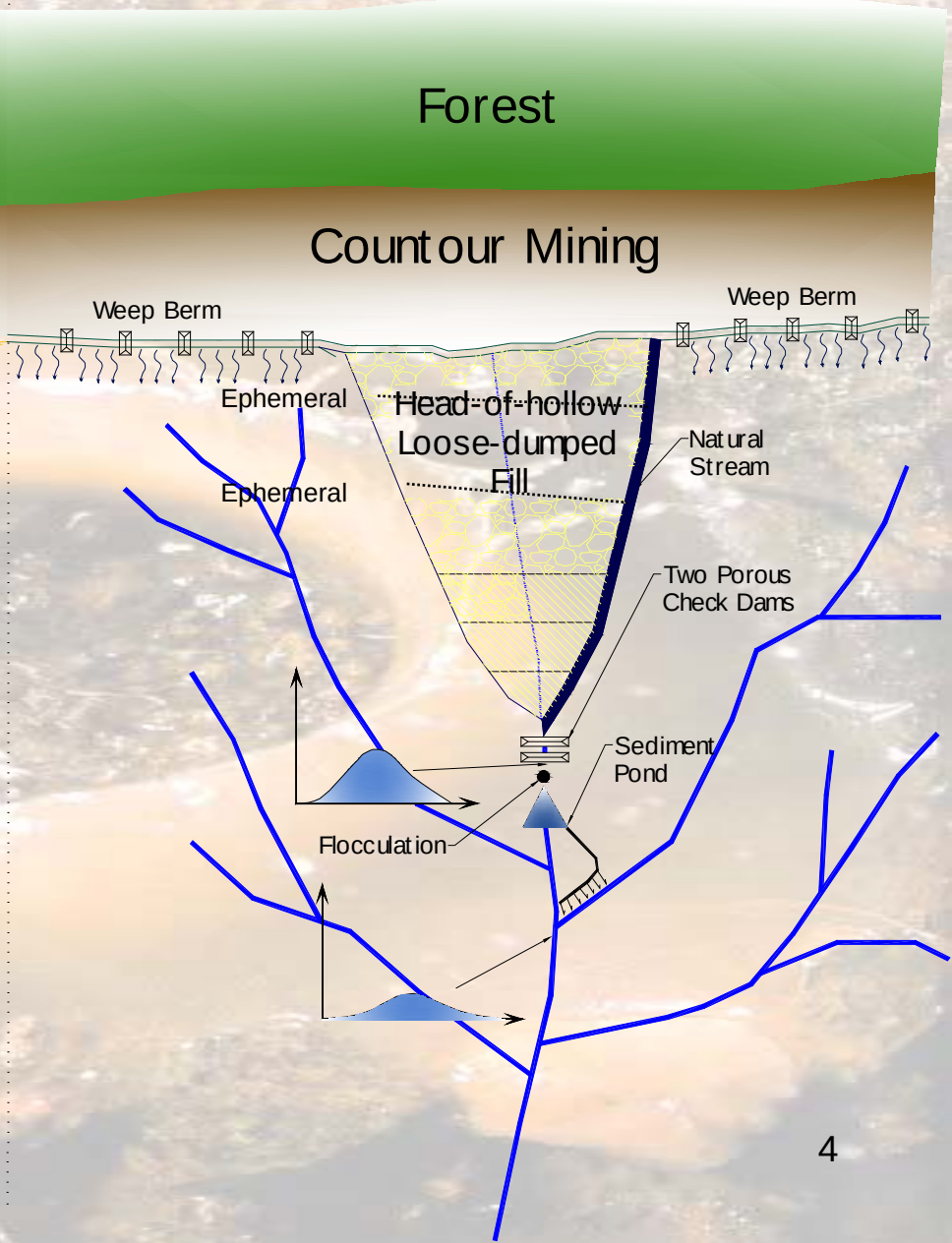
Objective

- Contrast hydrologic and sediment response of two alternative head-of-hollow fill design and reclamation techniques
  - Traditional (compacted spoil with grass cover)
  - Geomorphic (landform, natural streams and Forest Reclamation Approach)

CURRENT



FUTURE



Objective

- Design a head-of-hollow fill that mimics the natural landform, forest, hydrology and erosion of pre-development natural Appalachian forest
  - peak flow
  - runoff volume
  - hydrograph characteristics
  - erosion rates
  - sediment concentration and loads

Key Modeling Timeframes

- Natural forest
- Traditional head-of-hollow fill
  - compacted spoil
  - grass vegetated cover
- Geomorphic head-of-hollow
  - loose-dumped spoil overlays compacted fill
  - ephemeral and intermittent streams
  - forest cover

Key Modeling Parameters

- Hydrologic
  - curve number
  - time of concentration
  - unit hydrograph shape
- Sedimentologic
  - erodibility (K)
  - eroded particle size distribution (EPSD)
  - cover factor (C)
  - length-slope factor (LS)
  - slope geomorphic shape

Little Millseat Storm Events

- **Pre-Development Monitoring**
- Robinson Forest Data
  - 12 storm events
  - 2000-2004
  - 28.4 to 67.6 mm rainfall
- **CN Mean – 83**
- CN= **73** currently used in **KY Permit** Applications

Natural Forest Curve Numbers: Literature

Location	Area (ha)	CN	Source
Southern Ohio	20	77	Bonta et al. (1997)
Eastern Kentucky	82	**85**	Hawkins (1993)
Eastern Kentucky	116	**93**	Hawkins (1993)
Eastern Kentucky	93	**91**	Hawkins (1993)
Eastern Kentucky	93	86	Springer et al. (1980)
Eastern Kentucky	93	88	Springer et al. (1980)
Eastern Kentucky	93	88	Springer et al. (1980)
Eastern Kentucky	202	**83**	Taylor et al. (2009)
Western North Carolina	46	55	SCS (1972)

Compacted Mine Spoil

- **Hydrology** - Flooding (increase peak flow)
- **Sediment** - High erosion rates (until vegetation establishment)
- **Visual** - Not a forest, no stream, flat

Compacted Spoil Curve Numbers: Literature

Location	Area (ha)	CN	Reclamation Method	Source
Western Kentucky	-	82-86	Constructed profile; heavy compaction	Ward (1981)
Southern Ohio	10-17	87-97	Graded spoil; planted to grass and trees	Bonta et. al. (1997)
Pennsylvania	3-32	83-88	Graded spoil; topsoil and revegetation	Ritter and Gardner (1991)
North Dakota	8.8×10^{-4}	96-97 [1]	Unspecified	Schroeder (1987)

Compacted Spoil Study Site Characteristics

- Drainage area: 7.7 ha (19.3 ac)
- Slopes: 1.3% upper catchment, 14% lower catchment
- Soils
  - Weathered spoil (sandstone and shale)
  - Compacted
  - Infiltration rate ~ 2 mm/hr (0.08 in/hr)
- Hydrologic soil group B

Compacted Spoil

- **Monitoring**
- 42 storm events
- May 1990 to Sept. 1991
- Rainfall 6 to 59 mm
- **CN Mean: 85** (P. Taylor et al., 1995)
  - Range 62 to 94

Ohio

Kentucky
31 12:34PM

West Virginia

Tennessee

Loose-dumped Spoil Curve Number

- Highland Coal (1984) – Bowser-Morner, Inc.
- head-of-hollow (end-dumped)
- generated rainfall
  - antecedent application of 2.1 in
  - 2.5 in/hr for ½ hour
- measure runoff volume
- curve number = 35

Loose-dumped Spoil Curve Number

- Starfire (May – Nov, 2000) – UK Agr. Engr.
- Loose-dumped spoil surface runoff plots
- 3 monitoring locations – spoil and diversion
- natural rainfall
  - RF7 – 14 events, RF8 – 0 events, RF9 4 events
- runoff only from adjacent outslope and diversion

Loose-dumped Spoil Curve Number

- Starfire (1998 - 2000) – UK BAE.
- Loose-dumped spoil surface infiltration plots
- 38 5m X 5m lysimeters
- Spoil 6 to 8 ft deep (ROM)
- Annual infiltration rate – 32.2%
- Natural Appalachian forest - ~ 30 – 35%

Loose-dumped Spoil Curve Number

- Depression Storage Calculation
- Starfire Mine – UK BAE
- Depressions will contain >6 in rainfall
- Conclusion: no surface runoff except for spoil piles at boundary adjacent to streams

Loose-dumped Spoil Curve Number

- Bent Mountain (July 2005 – Nov 2006) – UK
- Loose-dumped spoil
  - Brown weathered sandstone
  - grey un-weathered sandstone
  - ROM sandstone and shale
- 6 monitoring locations –
- natural rainfall
  - 12 events
  - measure runoff volume
- No surface runoff
- Mean curve number (interflow) – 77

Curve Numbers Measured at Study Sites

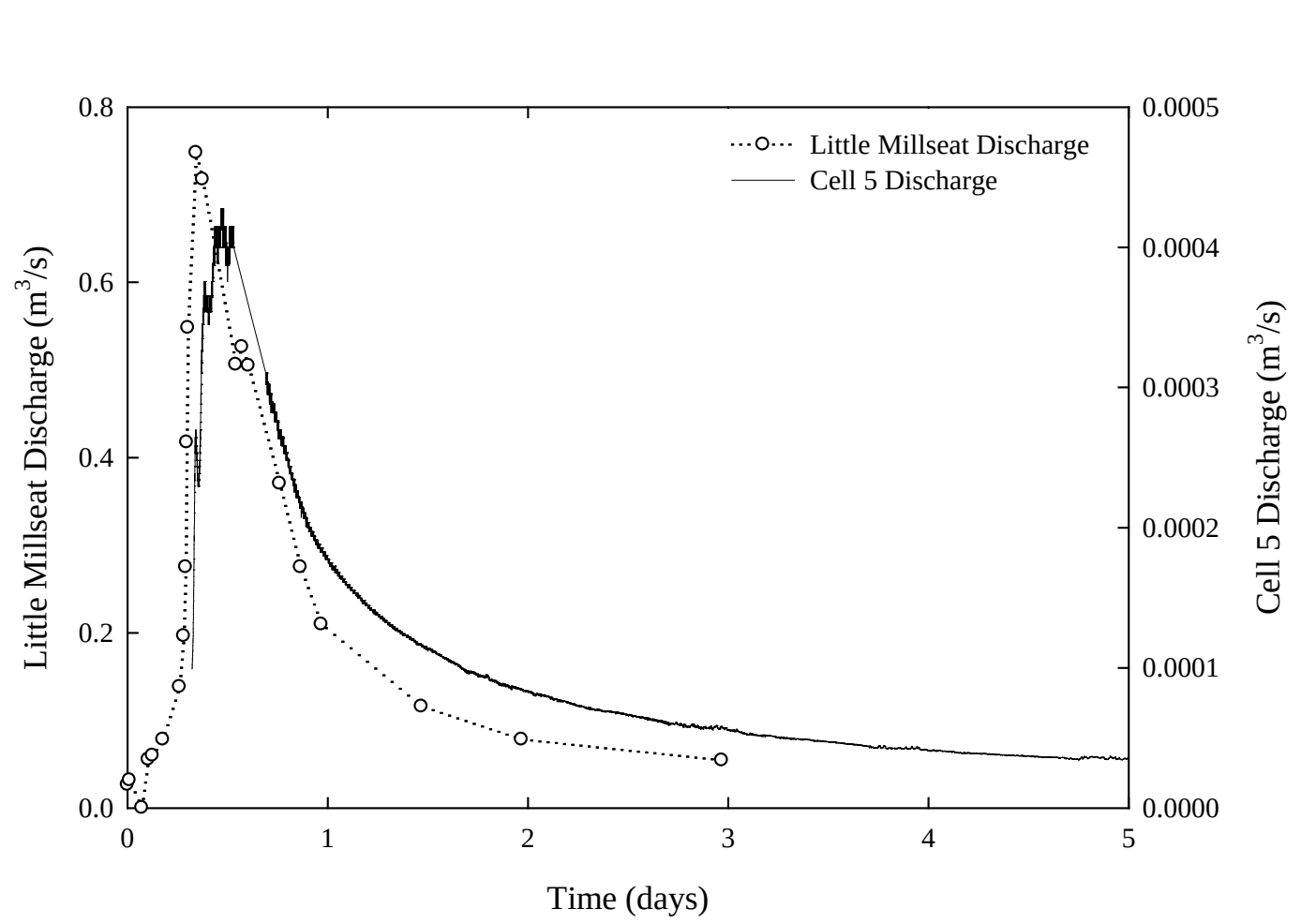
- Forested (Little Millseat)
  - Mean: 83 (T. Taylor et al., 2007)
- Compacted spoil (Starfire)
  - Mean: 85 (P. Taylor et al., 1995)
- Loose-dumped spoil (Bent Mountain)
  - Mean: 77 (T. Taylor et al., 2007)
  - no surface runoff

Starfire - 10 years growth

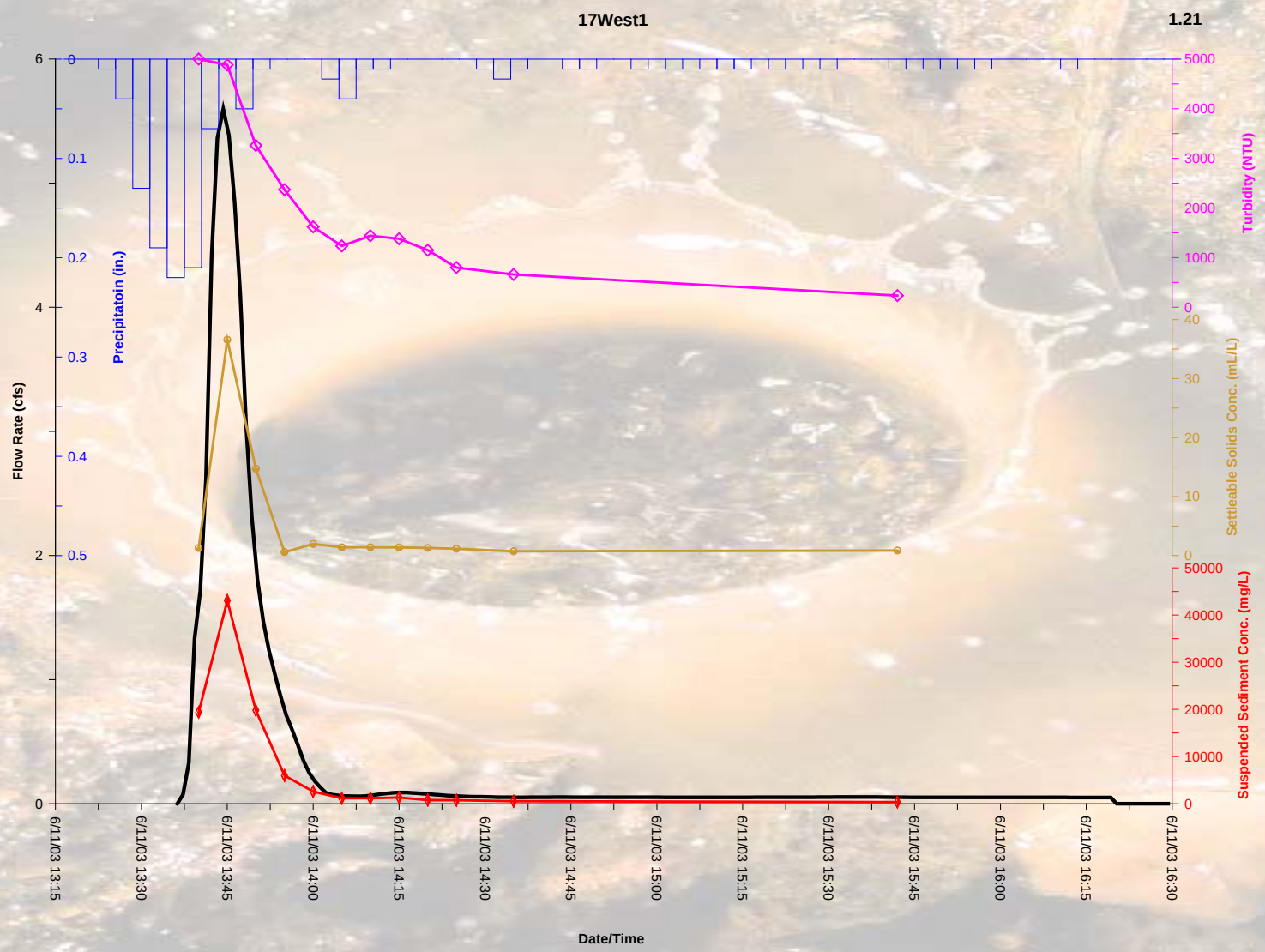
Loose-dumped versus Compacted

- Hydrologic Inputs
  - Time of concentration
    - forest (few hours)
    - loose-dumped (many hours)
    - compacted (fraction of an hour)
  - Unit hydrograph shape
    - forest loose-dumped (slow to very slow)
    - compacted (medium to fast)

Natural Forest & Loose-dumped Spoil Hydrographs



Compacted Spoil Hydrograph



Geomorphic Head-of-Hollow Fill Reclamation Approach

- **Advantages**
- **Hydrology (similar to pre-mining forest)**
  - Reduce peak flow
  - Increase flow duration (intermittent streams)
  - Increase evapotranspiration
- **Sediment**
  - Erosion rate and sediment load (similar to pre-mining forest)
- **Visual**
  - Reconstruct a forest
  - Watershed provides for the natural stream
    - nutrients/carbon
    - forest liter
- **Water chemistry**

Key Modeling Parameters

- Hydrologic
  - curve number
  - time of concentration
  - unit hydrograph shape
- Sedimentologic
  - erodibility (K)
  - eroded particle size distribution (EPSD)
  - cover factor (C)
  - length-slope factor (LS)
  - slope geomorphic shape

K-factors

- Starfire Mine Soil & Spoil Analysis
- K-factors
  - Undisturbed forest topsoil (0.206 – 0.256)
  - 0-2 month old spoil (0.126 -0.133)
  - 2 to 6 month old spoil (0.139 – 0.145)
- Modeling inputs
  - forest – 0.23
  - 0-2 month spoil – 0.13
  - 2 – 6 month spoil – 0.14

C -factor

- Function of
  - Vegetation (forest or grass)
  - Surface roughness
  - Surface rock fragment
- Forest (0.002)
- Compacted spoil with grass cover (0.1)
- Loose-dumped spoil (without forest) (.02)

Slope shape and length factors

- Slope shape
  - Convex
  - Uniform
  - Concave
  - Complex
- Gradient
- Length

Slope inputs

- Forest
  - L 25ft, S 50%, Complex
- Traditional Compacted Spoil (crown)
  - L 150ft, S 2%, Uniform
- Geomorphic Loose-dumped Spoil (crown)
  - L 20ft, S 40%, Uniform

SEDCAD Modeling Inputs

- Area: 100 ac forest, 80 ac crown
- Design storm: 2.5 in NRCS Type II -24 hour
- Forested
  - Time of concentration: .36 hr
  - Unit hydrograph shape: slow
- Compacted spoil
  - Time of concentration: .22 hr
  - Unit hydrograph shape: fast
- Loose-dumped spoil
  - Time of concentration: 1.5-2 hr
  - Unit hydrograph shape: slow

SEDCAD Results

LandUse	Peak flow (cfs)	Runoff Vol. (ac-ft)	Sediment (tons)	Peak Sediment (mg/L)
Forest	40.1	5.9	4.4	980
Geomorphic	12.5	4.5	5.7	1340
Traditional	93.2	8.6	14.9	2470

The Alternative

Geomorphic Reclamation and Natural Stream Design at Coal Mines

U.S. DEPARTMENT OF THE INTERIOR
OFFICE OF SURFACE MINING

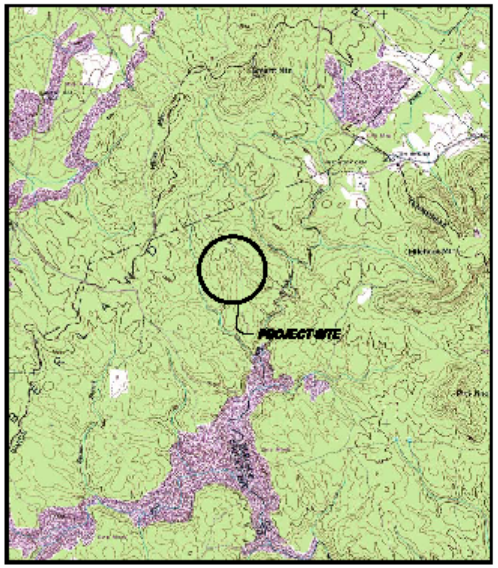
April 28-30, 2009 ◆ Bristol, VA

UT TO BIG BRUSH CREEK STREAM RESTORATION

SEQUATCHIE COUNTY, TENNESSEE

INDEX OF SHEETS

1 COVER SHEET
2 REACHES 1 & 2 STREAM PLAN & PROFILE
3 REACH 1 STREAM PLAN & PROFILE
4 REACH 1 STREAM PLAN & PROFILE
5 PLANTING PLAN
6 STREAM RESTORATION DETAILS
7 STREAM RESTORATION DETAILS
8 TYPICAL CROSS-SECTIONS
9 GENERAL NOTES
10 PLANTING TABLE

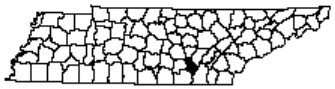


VICINITY MAP

LEGEND

- 12+00 — PROPOSED CENTERLINE
- EXISTING CONTOURS
- PROPOSED CONTOURS
- STEP POOLS
- LOG VANE
- ROOT WAD / J-HOOK
- PROPOSED GCI LINER

Note
Survey information shown on these plans was provided by IRTEC, Inc., Caryville, Tennessee, and is based on a Survey performed in March 2007.

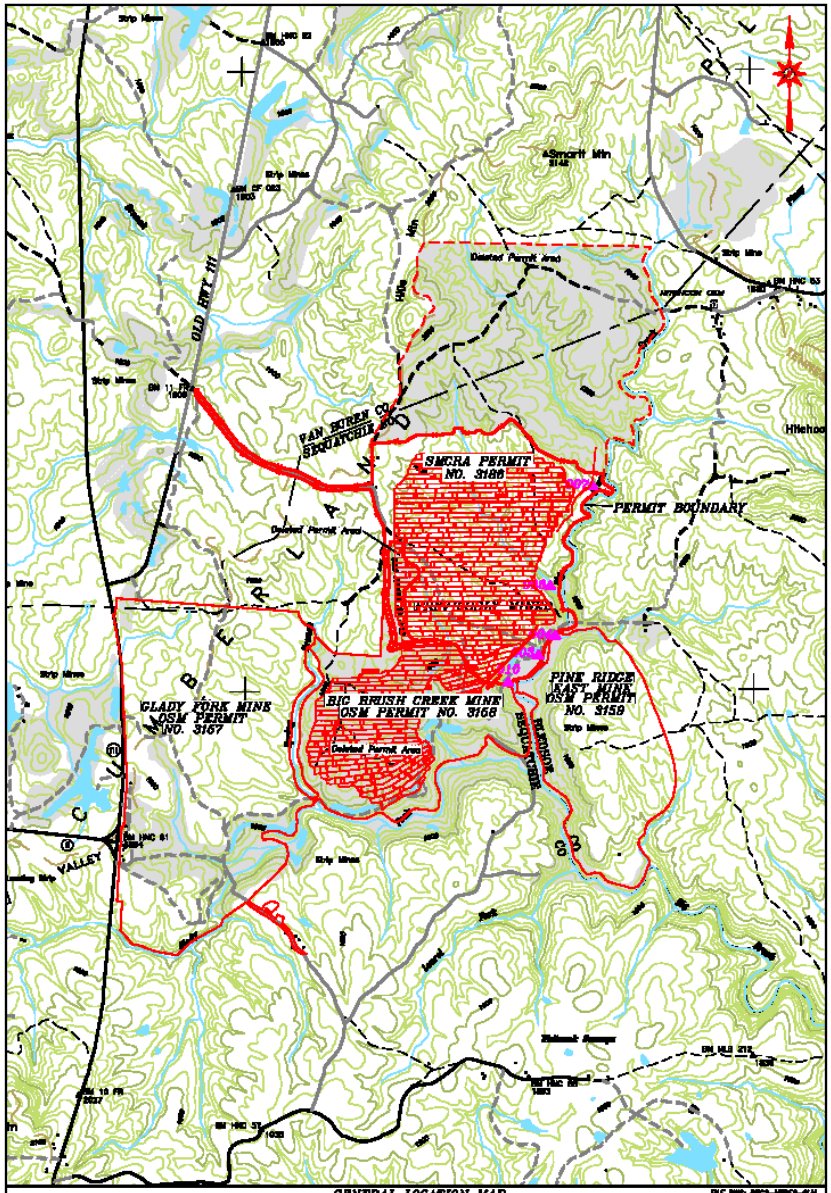


HALF-SIZE PRINT **FINAL**

FSM ENGINEERS

COVER SHEET
DRAFT DESIGN
UT TO BIG BRUSH CREEK
STREAM RESTORATION
SEQUATCHIE COUNTY, TENNESSEE

05.07.2008 09:32



GENERAL LOCATION MAP

SCALE: 1"=2000'
SMARTT MOUNTAIN QUAD.

FILE DWG: BBC3-NPES-GLM
07-11-08

LCC TENNESSEE, LLC
200 WEST VINE ST, SUITE 300
LEXINGTON, KENTUCKY 40507
NPDES Permit No. TN0054151

PREPARED BY
IRTEC

SEQUATCHIE/VAN BUREN COUNTIES
BIG BRUSH CREEK MINE #2
SMCRA NO. 3186, 558.0 Ac.
▲ DISCHARGE MONITORING POINT

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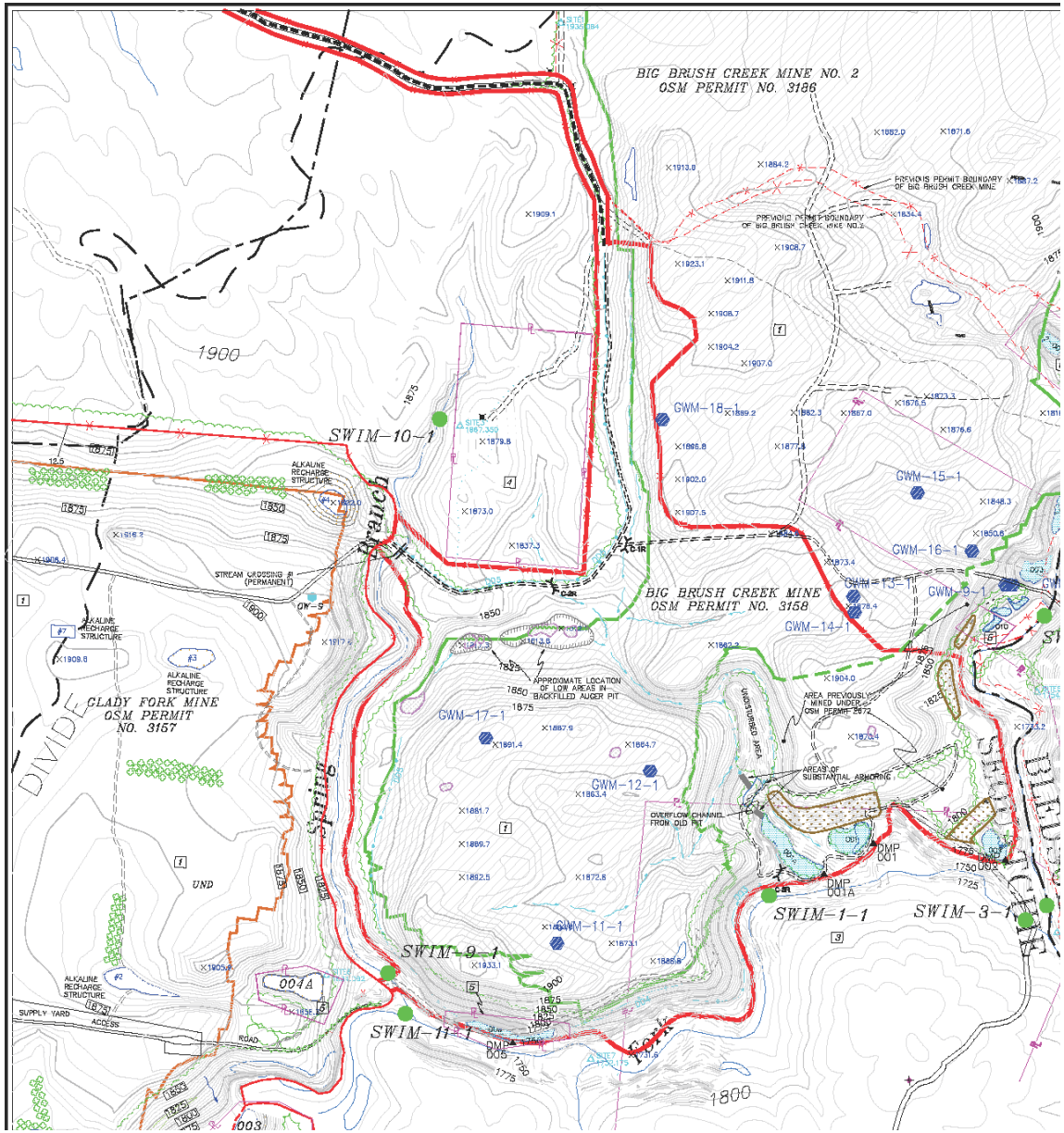
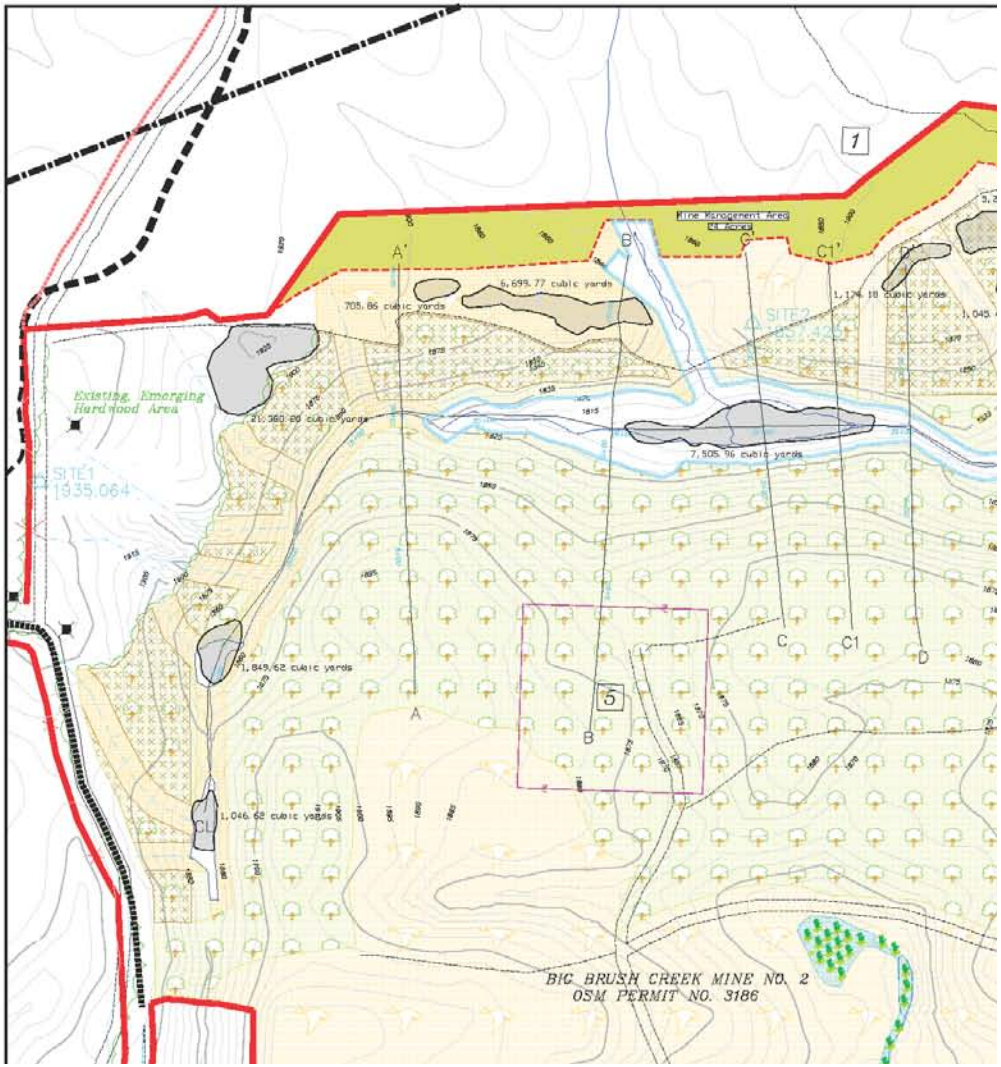
VISITORS

10 6 '94

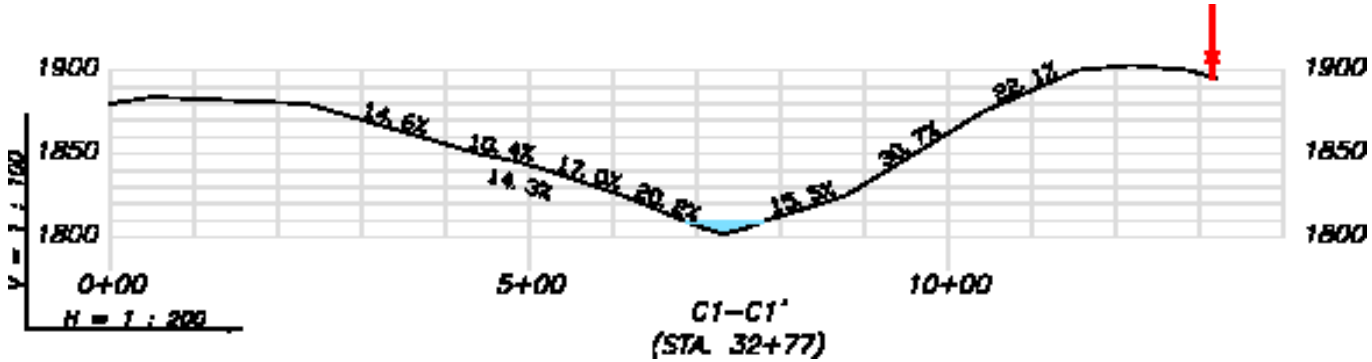
'92 11 19

9 28 '95


BIG BRUSH CREEK MINE NO. 2
OSM PERMIT NO. 3186
PREVIOUS PERMIT BOUNDARY OF BIG BRUSH CREEK MINE
PREVIOUS PERMIT BOUNDARY OF BIG BRUSH CREEK MINE NO.2
1900
SWIM-10-1
GWM-18-1
GWM-15-1
GWM-16-1
GWM-13-1
GWM-14-1
BIG BRUSH CREEK MINE
OSM PERMIT NO. 3158
ALKALINE RECHARGE STRUCTURE
STREAM CROSSING #1 (PERMANENT)
ON-5
GLADY FORK MINE
OSM PERMIT
NO. 3157
DIVIDE
APPROXIMATE LOCATION OF LOW AREAS IN BACKFILLED AUGER PIT
GWM-17-1
GWM-12-1
UNDISTURBED AREA
AREA PREVIOUSLY MINED UNDER OSM PERMIT 2672
AREAS OF SUBSTANTIAL ARMORING
OVERFLOW CHANNEL FROM OLD PIT
DMP 001
DMP 001A
SWIM-1-1
SWIM-3-1
GWM-11-1
SWIM-9-1
SWIM-11-1
004A
SUPPLY YARD ACCESS ROAD
DMP 005
1800
003


1
Mine Management Area
A'
B'
C
C1'
6,693.77 cubic yards
705.86 cubic yards
1,174.18 cubic yards
Existing Emerging
Hardwood Area
21,360.80 cubic yards
7,505.96 cubic yards
SITE1
1935.064
1,849.62 cubic yards
1,046.62 cubic yards
A
B
C
C1
D
5
BIG BRUSH CREEK MINE NO. 2
OSM PERMIT NO. 3186

MAY 12 2006


1900
1850
1800
V = 1 : 100
0+00
H = 1 : 200
5+00
10+00
13.6%
10.4%
14.3%
17.0%
20.8%
15.5%
30.7%
22.1%
C1–C1'
(STA. 32+77)

03.22.2006 13:49

08.31.2007 11:25

0.40
0.30
WATER•MARK
0.20
0.10
.44
.42
.38
.36
.34
.32
.28
.26
.24
.22
.18
.16
.14
.12
.08
.06
.04
.02

01.24.2008 11:26

05.21.2008 09:47

07.23.2008 18:26

735
10.07.2008

ORICA
TREAD
CORPORATION
TREAD
CORPORATION
OXIDIZER
1993
10.07.2008

F-350
SUPER DUTY
POWER STROKE V8
TURBO DIESEL
10.07.2008

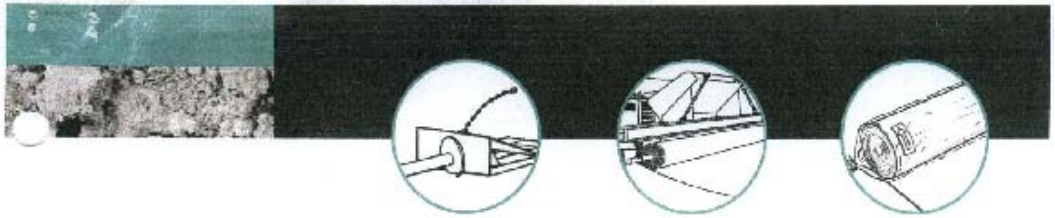
08.22.2008 14:28

10.06.2008

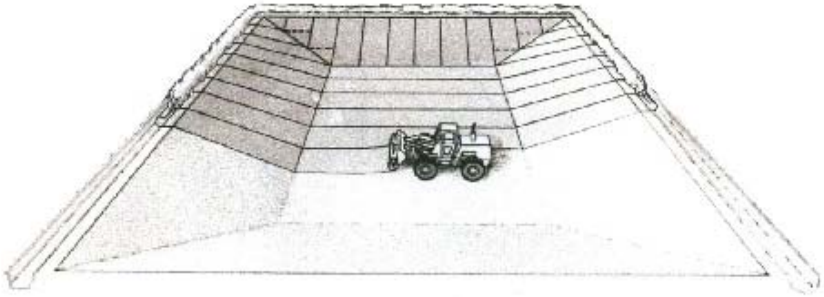
CATERPILLAR

416B
CAT

03.11.2009 17:27



Installation Guidelines



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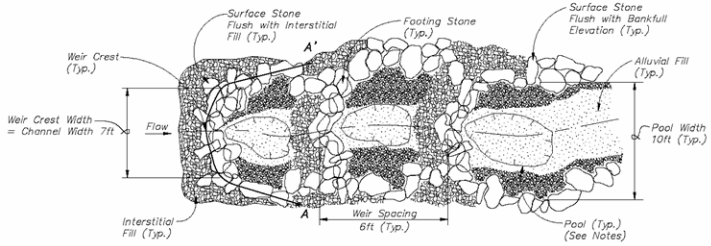
NOTICE: This document is intended for use as a GENERAL GUIDELINE for the installation of CETCO's GCLs. The information and data contained herein are believed to be accurate and reliable. CETCO makes no warranty of any kind and accepts no responsibility for the results obtained through application of this information. Installation guidelines are subject to periodic changes. Please consult our CETCO Engineering Website @ www.cetco.com/ETE for the most recent version.

CHI
4168

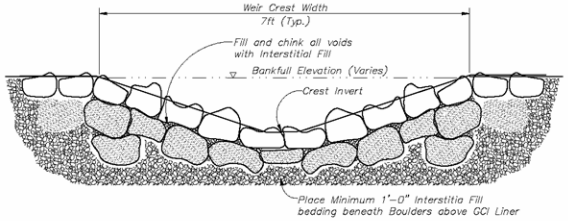
02.06.2009 13:36

03.11.2009 17:44

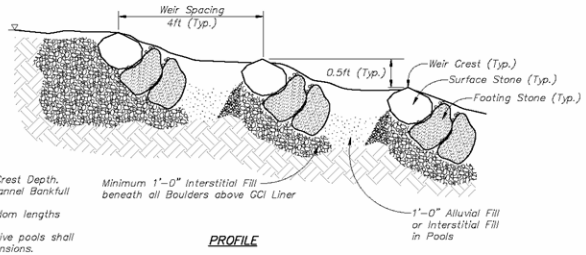
02.15.2007 17:39



PLAN



SECTION A–A'

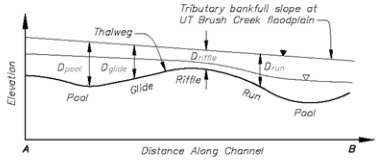


PROFILE

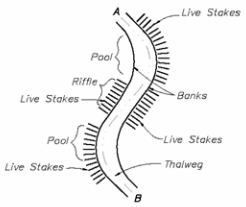
NOTES:

1. Pool Depth = 1.5 to 2.5 x Crest Depth.
2. Weir Crest Width = Local Channel Bankfull Width, refer to table.
3. Weir Spacing varies, use random lengths 1 to 4 x Weir Crest Width.
4. Not more than five consecutive pools shall have the same finished dimensions.
5. Refer to longitudinal Profile for Weir Crest elevations.

1/6 DETAIL – STEP POOL CHANNEL
NOT TO SCALE



Profile

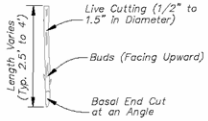


Plan

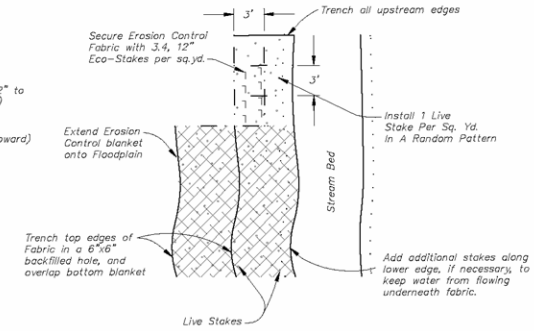
Notes

1. Install live stakes along outside of meander bend and along both banks of riffle.
2. Live stakes shall be planted in an irregular pattern.

3/6 DETAIL – TYPICAL RECONSTRUCTED MEANDER
Not To Scale

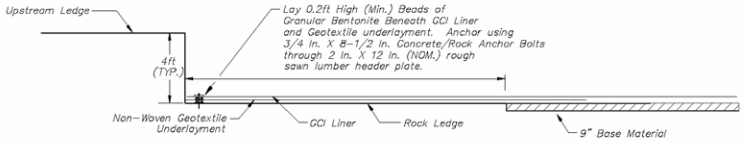


DORMANT LIVE STAKE

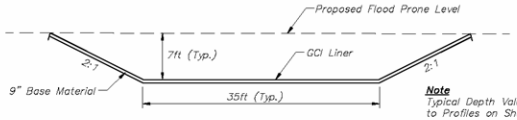


TYPICAL PLAN

4/6 DETAIL – DORMANT LIVE STAKE AND EROSION CONTROL BLANKET
Not To Scale

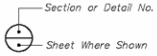


5/6 LINER ANCHOR AND SEAL DETAIL
Not To Scale



Note
Typical Depth Values According to Profiles on Sheets 2 thru 4.

2/6 TYPICAL LINER SECTION
Not To Scale



REFERENCE KEY

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1501 Nelson Miller Parkway, Louisville, Kentucky 40223-2177
502-213-5200

FMSM ENGINEERS
LEXINGTON LOUISVILLE CINCINNATI COLUMBUS ST. LOUIS

Fuller Mossbarger Scott & May

STREAM RESTORATION DETAILS

DRAFT DESIGN
UT TO BIG BRUSH CREEK
STREAM RESTORATION
SEQUATCHIE COUNTY, TENNESSEE

PROJECT NO.	LV2007023
DATE	March 2007
DRAWN BY	RHP
CHECKED BY	NSC
CHECKED BY	JGL
SCALE	Not To Scale
REVISED	
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	

SHEET

07.01.2006 11:06

05.20.2008 17:38

10.24.2006 13:31

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

Carmen T. Agouridis, Ph.D., P.E.
Christopher D. Barton, Ph.D.
Richard C. Warner, Ph.D.

Geomorphic Reclamation at Coal Mines

April 29, 2009

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

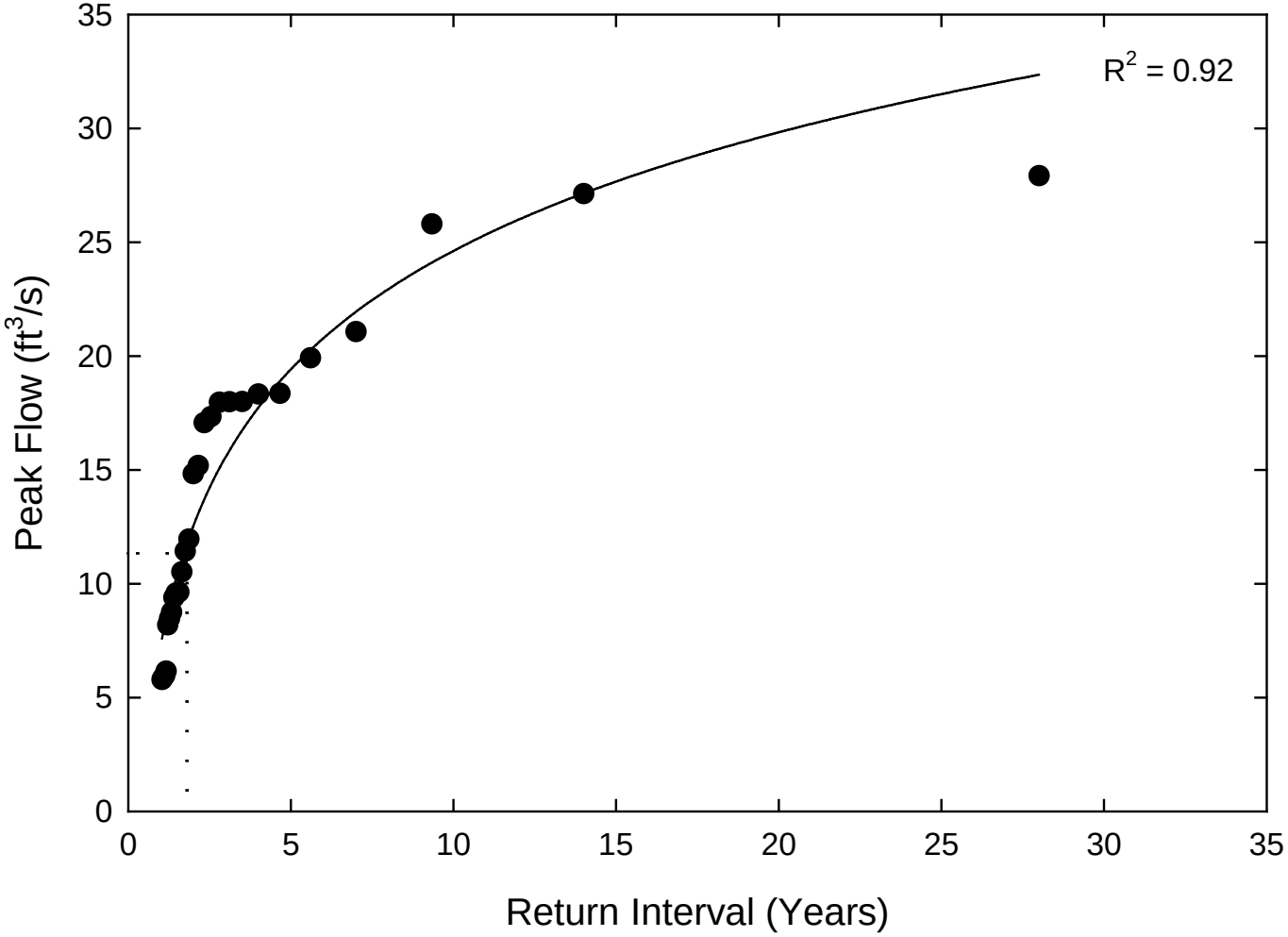
http://arri.osmre.gov/FRApproach.htm

Can FRA Help Guide Stream Restoration Decisions?

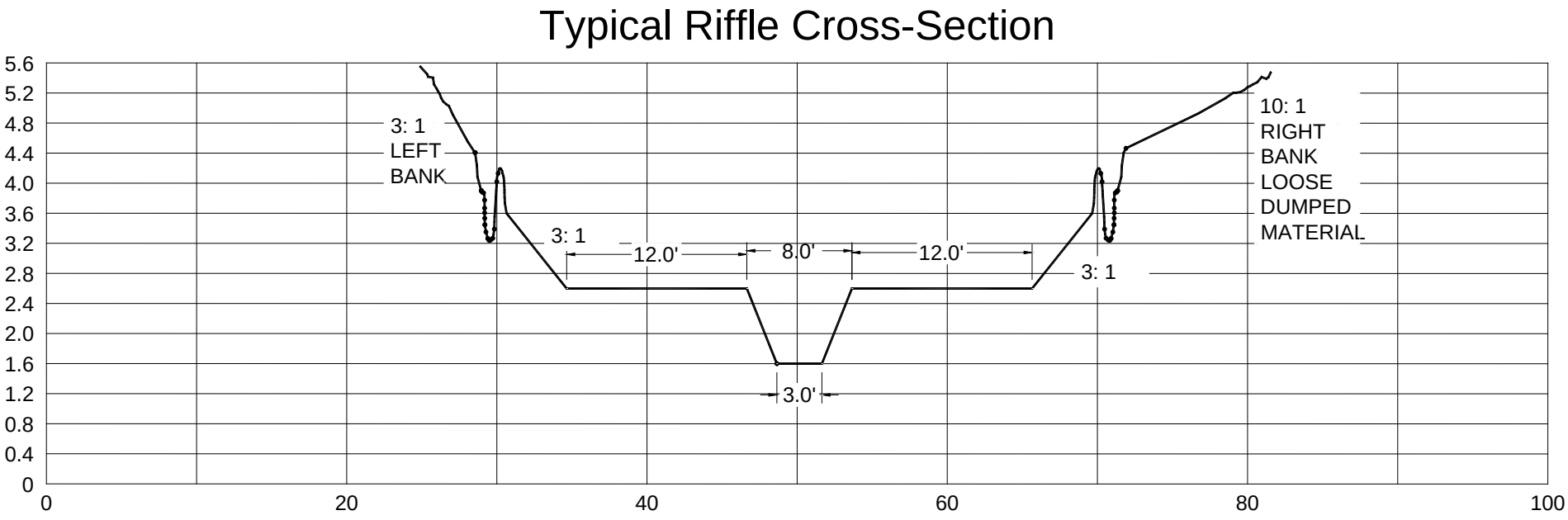
The Guy Cove Project

Design Components

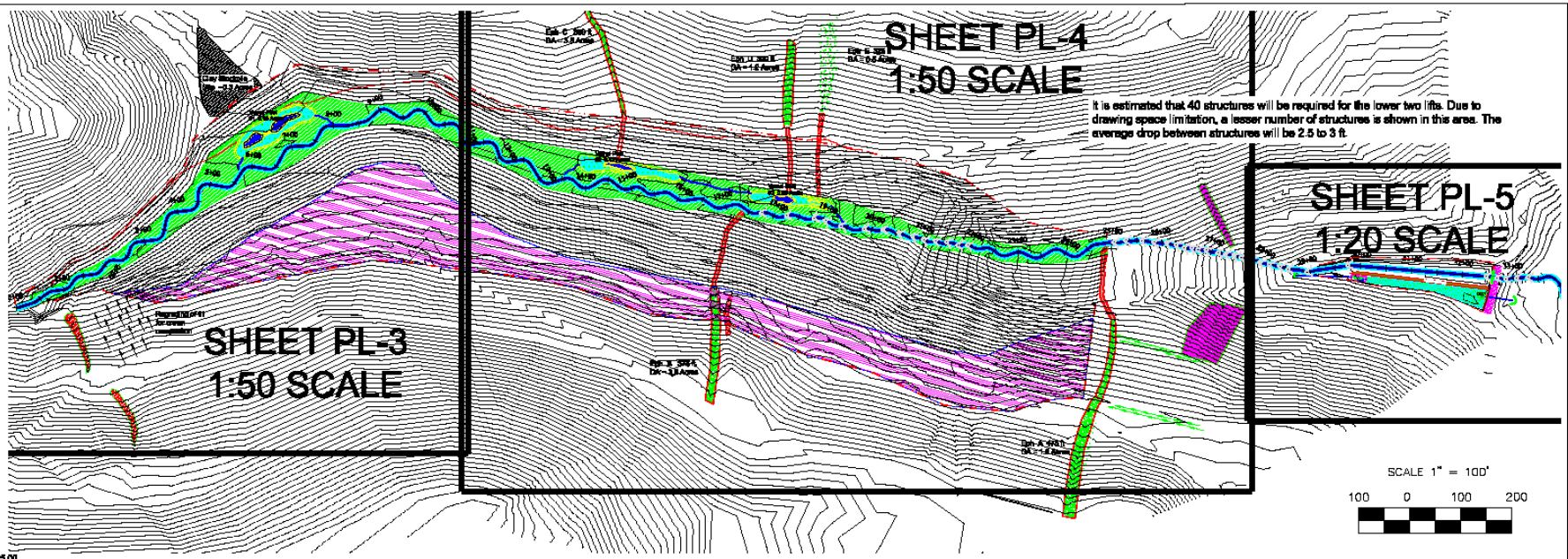
- Reference reaches
- Valley reconfiguration
- Hydrologic modifications
- Main channel
- Ephemeral channels
- Bioreactor-wetland treatment system
- Vernal ponds
- Plantings
- Monitoring

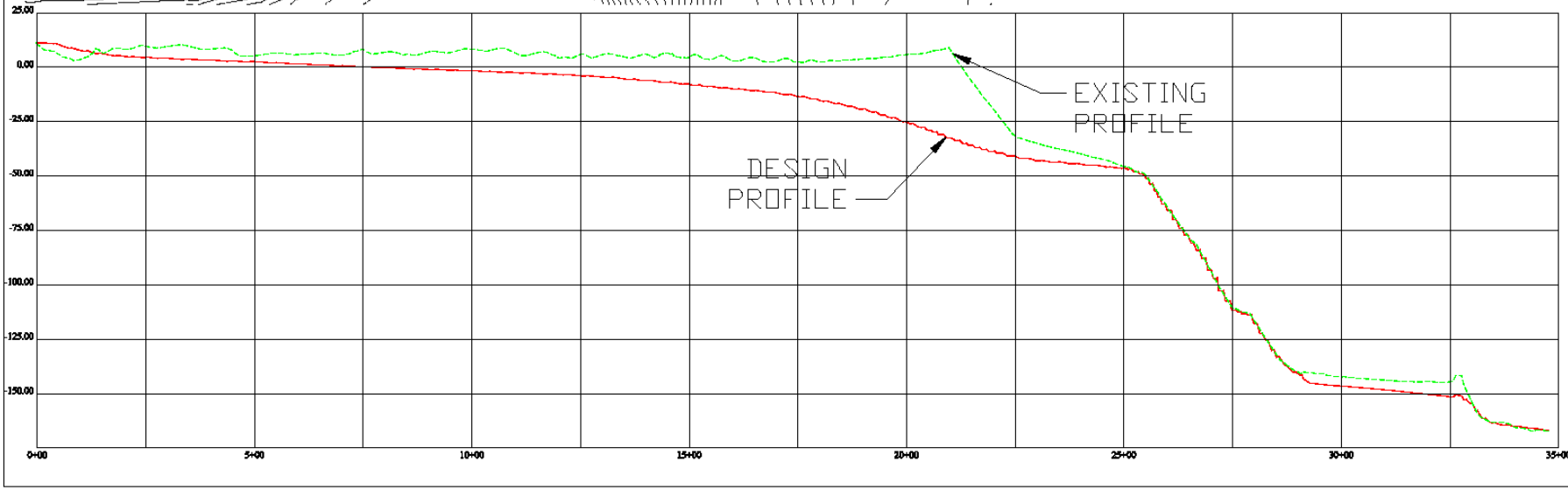

$R^2 = 0.92$
Peak Flow (ft^3/s)
Return Interval (Years)
0
5
10
15
20
25
30
35

Main Channel



C4 B4 B3a A2a+ C4





NO	REVISIONS	DATE
1	INITIAL DESIGN	04/01/06
2	Proposed DESIGN	06/16/06
3	PERMIT APPLICATION DRAWINGS AND DESIGN	06/16/07

DRN	CHK	DATE
DMG	LW	04/01/06
DMG	CA	06/16/06
DMG	CA	06/16/07

UK UNIVERSITY OF KENTUCKY College of Agriculture College of Engineering

BIOSYSTEMS AND AGRICULTURAL ENGINEERING

BIOSYSTEMS & AGRICULTURAL ENGINEERING
207 C.E. Barnhart Building
University of Kentucky
Lexington, KY 40546-0276

GUY COVE
ROBINSON FOREST
BREATHITT, KY

SITE PLAN VIEW
AND EXISTING VS. DESIGN
PROFILES

DATE 07/18/2007

PROJECT NO.

FILENAME GUYCOVE-P.DWG

SHEET NO. PL-1

DRAWING NO.

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

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CALL 800-227-0534

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

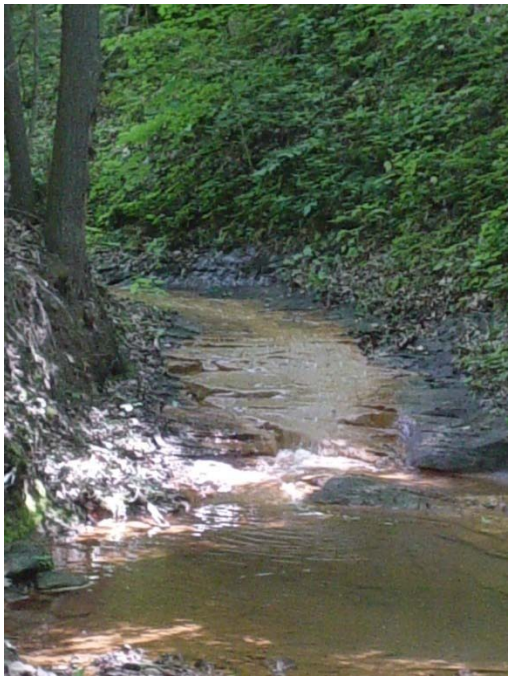
$$Ca(Fe, Mg, Mn)(CO_3)_2 + 4H^+ \leftrightarrow Ca(Fe, Mg, Mn)^{2+} + 2H_2CO_3$$

-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

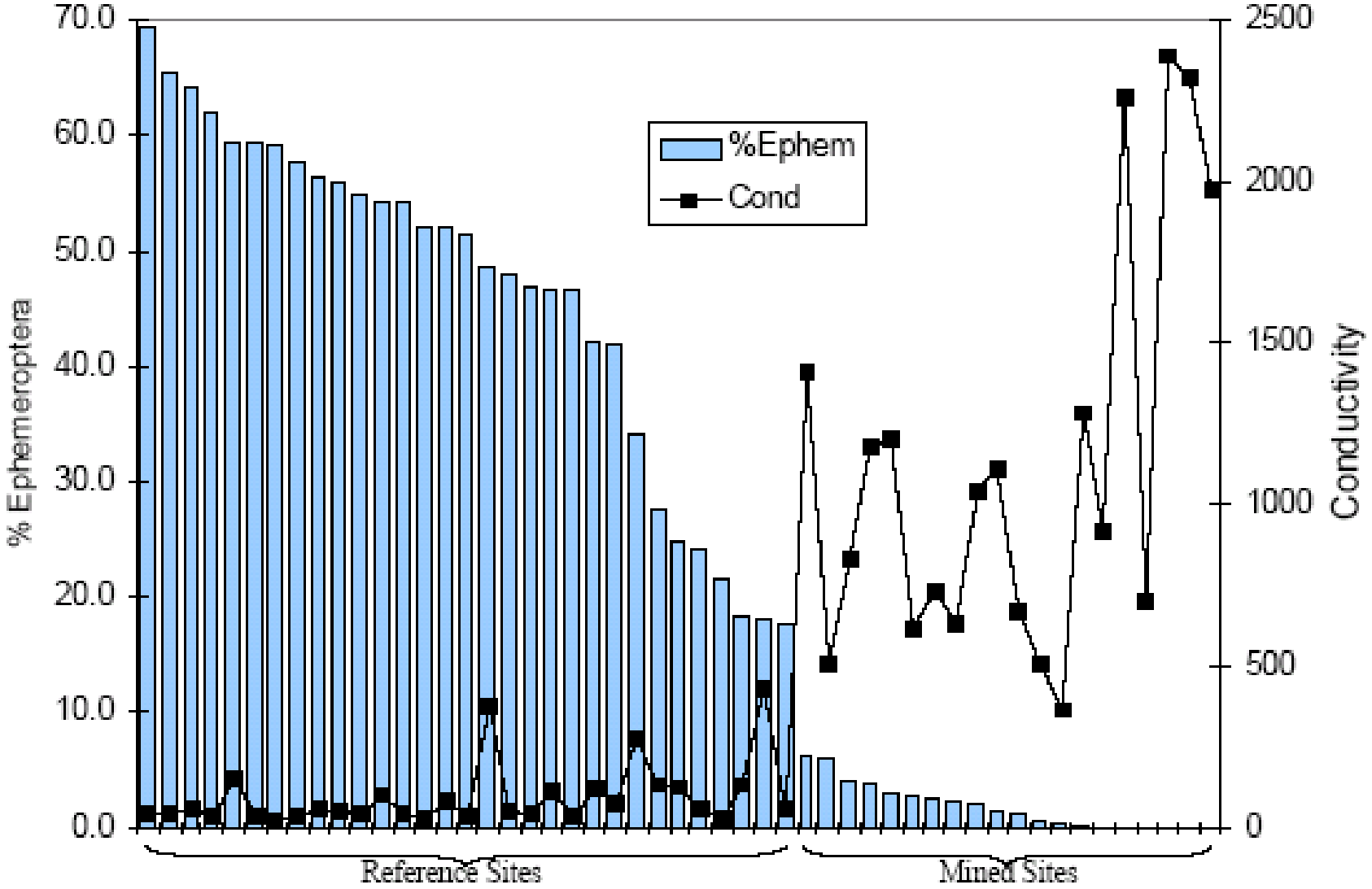


Water Quality Characteristics
Little Millseat and Guy Cove Watersheds

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?



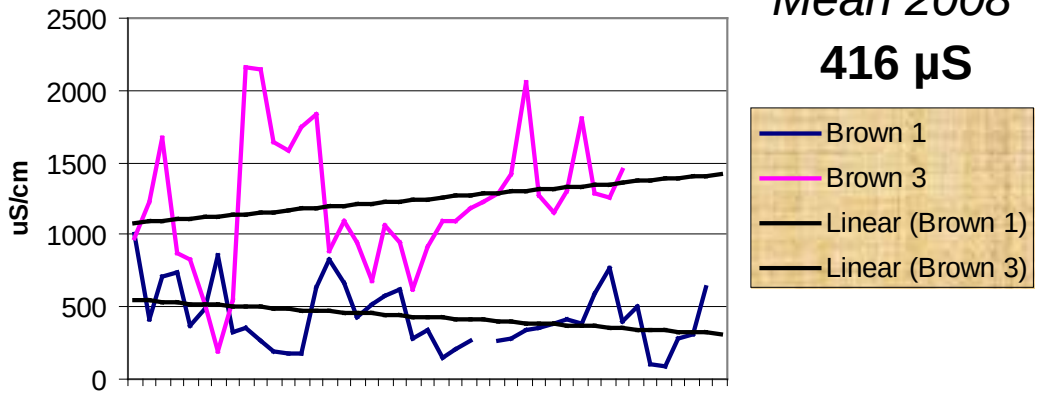
Pond, 2004 and 2007
Pond et al. 2008

Bent Mt.

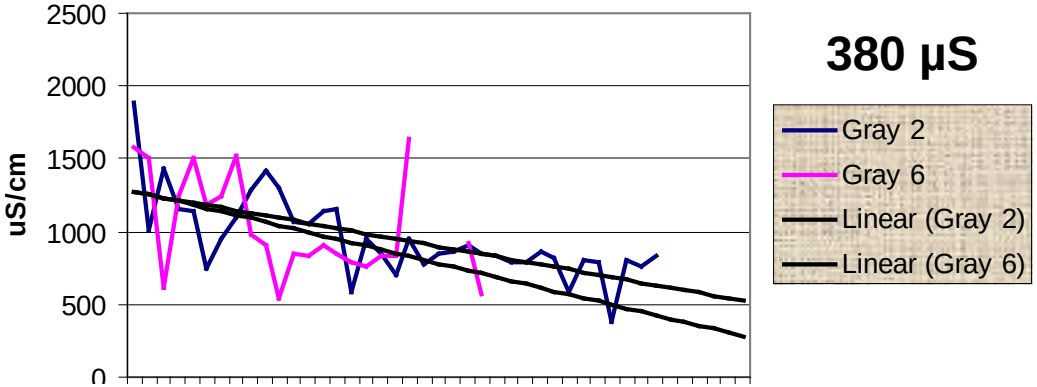
Electrical conductivity trends

Mean 2008

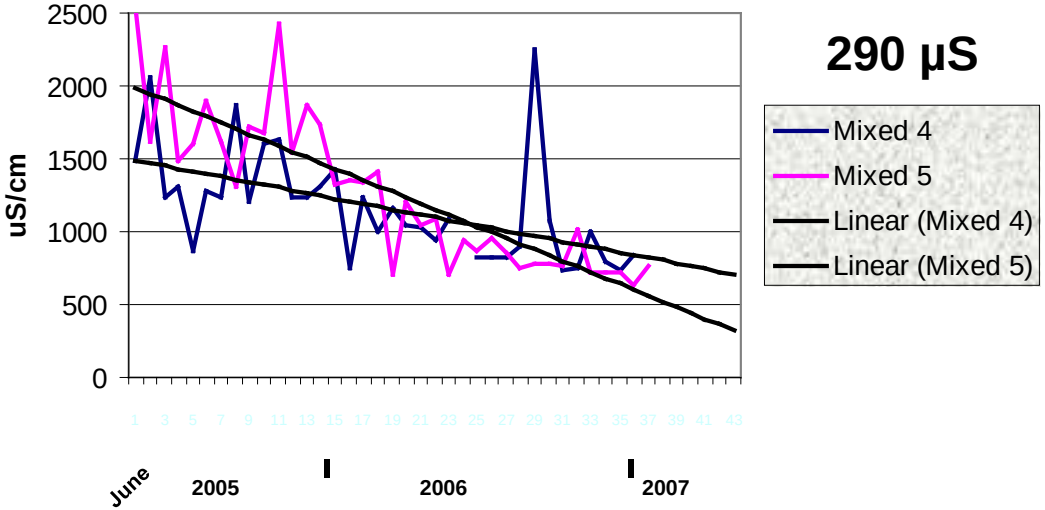
416 µS



380 µS



290 µS



Water Quality Mitigation

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

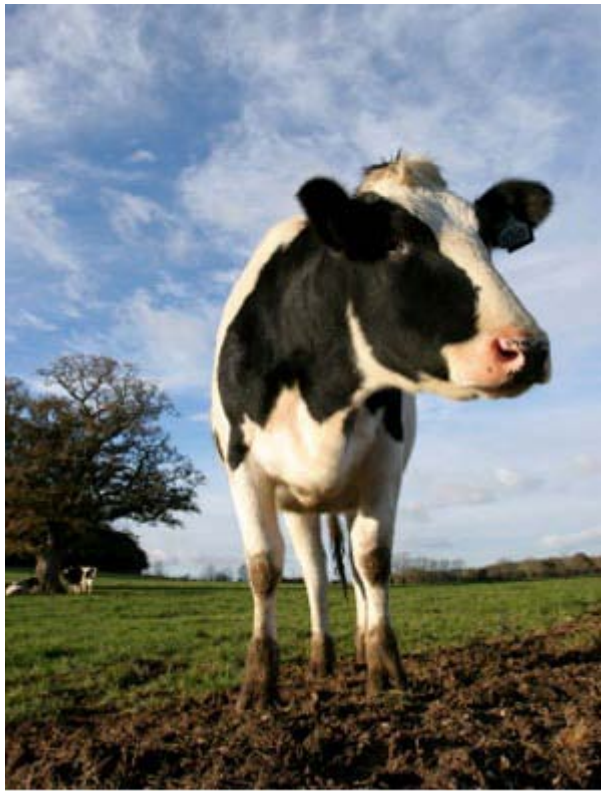
Bioreactor

- 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/

The Use of Natural Stream Channel Design in the Coalfields of Virginia

Geomorphic Reclamation & Natural Stream Design at Coal Mines

April 28-30, 2009

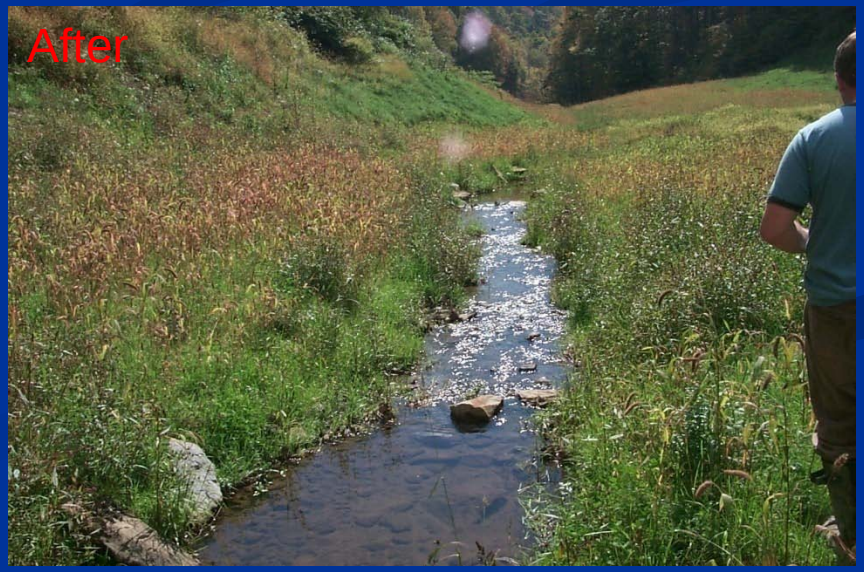
Prepared by: Lance M. DeBord
D. R. Allen & Associates, P.C.

Evolution of Mitigation

- Aquatic resource mitigation plans prior to 2002 consisted of out-of-kind wetland creation and stream restoration
- Stream restoration designs used rip-rap armoring and dimensions based on 100 yr/6hr storm event
- D.R. Allen began using NSD techniques in VA coalfields in 2002

Stream Mitigation Plans

- Goals and Objectives
  - Offset impacts from mining
  - Restore impacted streams to a proper dimension, pattern, and profile
  - Emphasis on restoration of stream and riparian habitats



Design Summary

- Design x-sectional area and bankfull flow based on D.R. Allen & Associates observed field data from stable streams in southwest Virginia
- Compare with VA Ridge & Valley, NC Mountain, and Eastern Regional curve data
- Design parameters based on dimensionless ratios calculated from a reference reach of the same stream type

Dimensionless Ratios

- Pool Depth/Riffle Depth
- Pool Width/Riffle Width
- Max Pool Depth/Mean Bankfull Depth
- Riffle Slope/Avg. Water Surface Slope
- Pool Slope/Avg. Water Surface Slope
- Riffle Max Depth/Mean Bankfull Depth
- Pool Length/Bankfull Width
- Pool to Pool Spacing/Bankfull Width

Laurel Branch

January 2005

- Lower reach of stream channel is trapezoidal rip-rap channel
- Mouth of stream channel had a steep slope (~35-40%), acting as a barrier for fish migration

Site History – Upper Reach

January 2005

- Upper reach of stream channelized due to fill placement from construction of nearby railroad tunnel, circa 1955
- Minimal or non-existent flood plain has resulted in areas of excessive erosion and lack of habitat

Channel Construction

Looking downstream at fill removal effort

- Reconfigure upstream fill to construct new flood plain
- Construct new stream channel adjacent to old channel

Channel Construction

Construction of cross vane and pool

Before/After Comparison

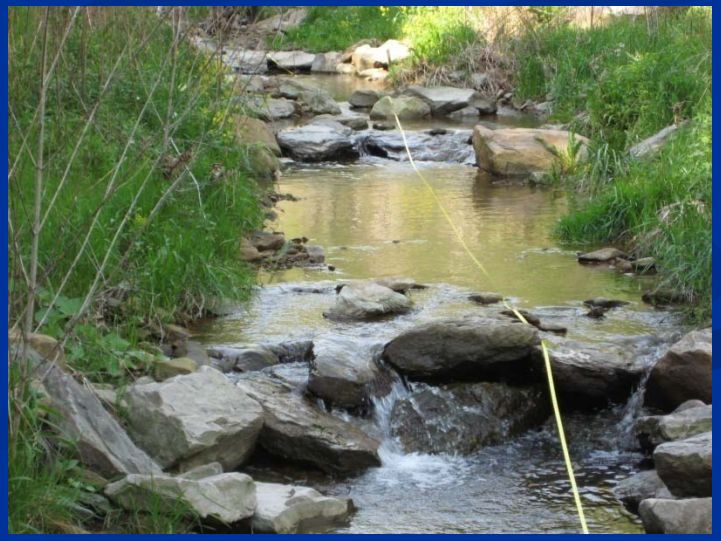
Chaney Creek

- Design Criteria
  - 1.6 sq. mi. drainage area
  - Stream Type B3, B3c, B3a
  - Slopes 1% - 6%
  - Width/Depth Ratio 10 – 13
  - Sinuosity 1.2 – 1.3
  - Bankfull Width 13.3 – 15.2
  - Max Pool Depth 3.0 – 3.5
  - Pool Length 14.7 – 25.9
  - Max Riffle Depth 1.4 – 1.7
  - Pool Spacing 26.6 – 53.2

Chaney Creek

Cane Creek

- Design Criteria
  - 2.9 sq. mi. drainage area
  - Restored on old fill
  - Stream Types B4 & C4
  - Slopes 0.25% - 3%
  - Width/Depth Ratio 10 – 30
  - Bankfull Width 11 – 15
  - Max Pool Depth 2 – 3 ft.
  - Pool Length 8 – 80 ft.
  - Max Riffle Depth 1.0 ft.
  - Pool Spacing 19-140



Riparian Corridor Establishment

Restoration Monitoring

Monitoring Event	Walk & Photograph	As-Built Survey	Fluvial Geomorphic Survey	Benthos	Fish	Riparian Zone Success
Immediately After Construction	X	X	-	-	-	-
Year 1	X	-	X	X	X	-
Year 2	X	-	-	X	X	-
Year 3	X	-	X	X	X	X
Year 4	X	-	-	X	X	-
Year 5	X	-	X	X	X	X

Monitoring Results

Laurel Branch						
Year	**MBI**	**Cond.**	**Habitat**	**Fish (#species)**	**Trees /acre**	**EKSAP**
2006	0.48	729	166	231 (3)	-	0.50
2007	0.52	768	166	547 (3)	750	0.51
2008	0.58	725	167	95 (3)	710	0.54
2009	0.66	452	173	94 (3)	1140	0.62
Chaney Creek						
2007	0.54	622	169	156 (5)	700	0.52
2008	0.59	500	181	89 (6)	-	0.56
2009	0.66	455	183	171 (6)	-	0.62

Fisheries Data

Species	Catch
Chaney Creek	
blacknose dace (*Rhinichthys atratus)*	**104**
pumpkinseed *(Lepomis gibbosus*)	**1**
bluegill (*Lepomis macrochirus*)	**1**
bluntnose minnow (*Pimephales notatus*)	**1**
central stoneroller (*Campostoma anomalum*)	**45**
creek chub (*Semotilus atromaculatus*)	**19**
Laurel Branch	
central stoneroller (*Campostoma anomalum*)	**6**
creek chub (*Semotilus atromaculatus*)	**5**
blacknose dace (*Rhinichthys atratus)*	**83**

Family Level Macroinvertebrate Data

- Laurel Branch
  - Perlodidae – 35
  - Perlidae – 3
  - Baetidae – 2
  - Ephemerellidae – 1
  - Limnephilidae – 3
  - Hydropsychidae – 25
  - Elmidae – 3
  - Chironomidae – 1
  - Corydalidae – 4
  - Tipulidae - 5
- Chaney Creek
  - Perlidae – 13
  - Nemouridae – 44
  - Chloroperlidae – 3
  - Peltoperlidae - 1
  - Baetidae – 2
  - Heptageniidae – 5
  - Limnephilidae – 1
  - Hydropsychidae – 36
  - Psephenidae - 9
  - Elmidae – 2
  - Chironomidae – 4
  - Corydalidae – 4
  - Tipulidae – 4
  - Oligochaeta – 1
  - Gomphidae - 1