Methodology for Applying Geomorphic Reclamation to Excess Spoil Fills in West Virginia

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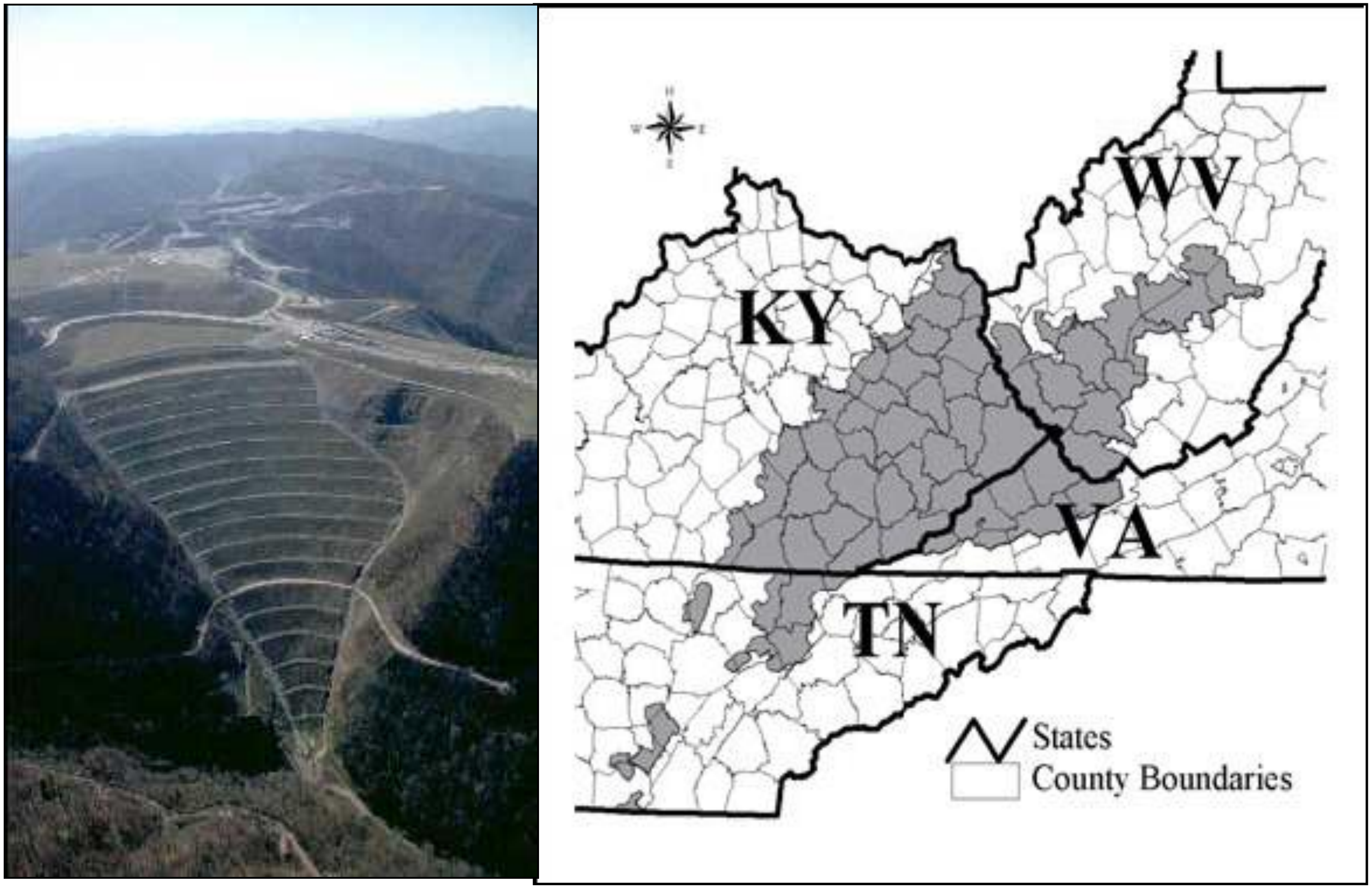
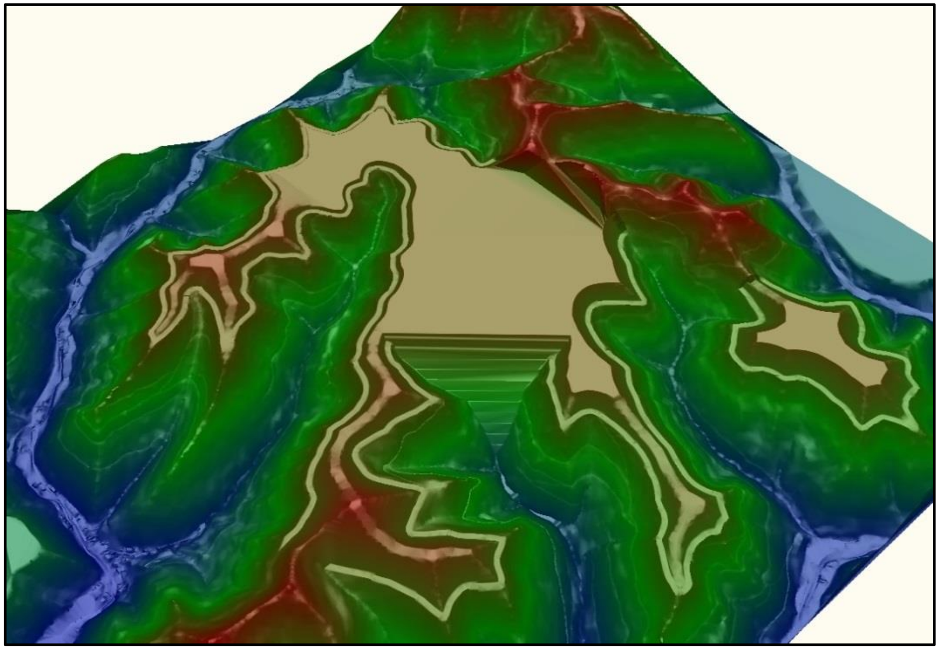
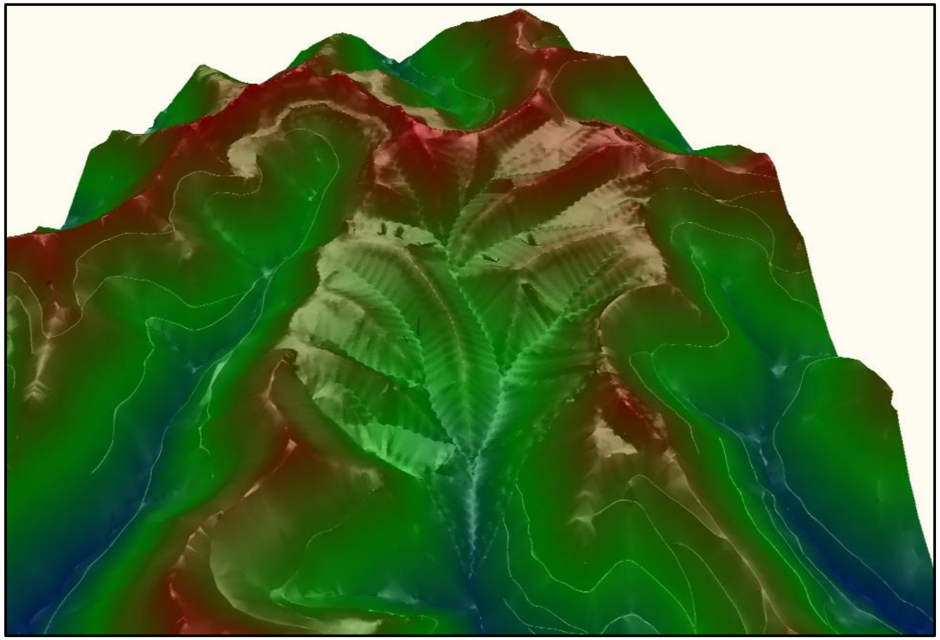


Valley Fills in Central Appalachia; (left) example of a valley fill at a mountaintop mining site; (right) counties with watersheds affected by mountaintop mining and valley fill construction.

Can we use *Geomorphic Landform Design (GLD)* principles to rethink valley fill design?

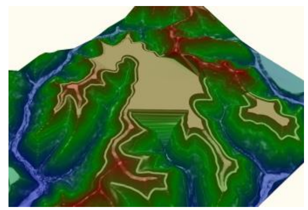
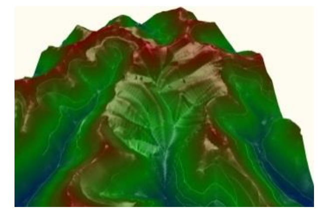


AOC Variance Valley-Fill Design



Conceptual Geomorphic Reclamation Design

Can we use *Geomorphic Landform Design* principles to rethink valley fill design?

	 **Traditional**	 **GLD**
Stability	Uncertain long-term mass stability/significant long-term erosion	Dynamic equilibrium/anticipating what nature would do in the long run
Appearance	Linear/planar/geometric	Natural/curvilinear
Maintenance	Periodic maintenance/remediation (by whom?)	Expected reduction in the need for maintenance/remediation

Geomorphic Land Design (GLD) Procedure

1. **Select multiple stable reference landforms** to obtain geomorphic properties applicable to the physiographic region of the geomorphic design site.

2. **Collect on-site and remote data** from the reference landforms.

3. **Analyze the reference-landform data** and Determine the geomorphic parametric values applicable to the design site.

4. **Generate geomorphic landform designs** based on alternative priorities (channel stability, valley side-slope stability, fill volume)

5. **Evaluate geomorphic landform designs** based on the alternative priorities or "evaluation criteria".

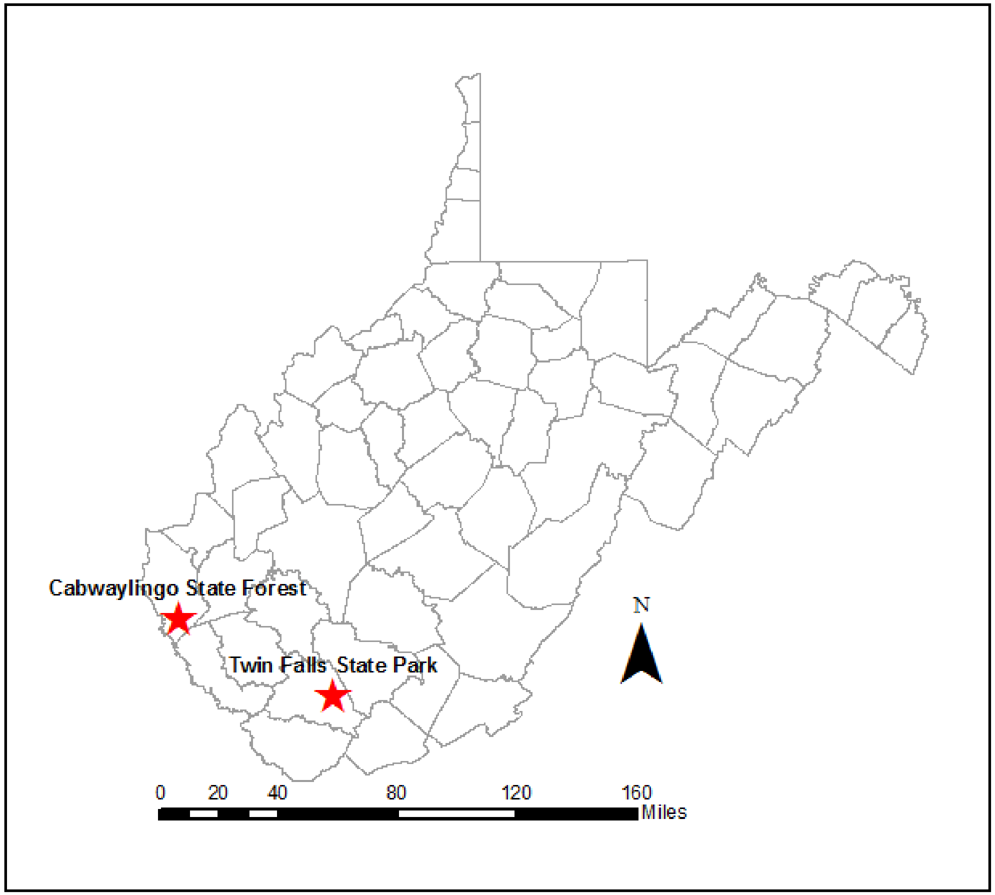
6. **Select the final design**.

Task 1: Obtain and quantify characteristics of mature landforms in West Virginia.

<u>Two Field Site Locations</u>

Twin Falls State Park
- Dixon watershed
- Jackson watershed

Cabwaylingo State Forest
- Wiley watershed



Reference Landform Analysis

1. **Evaluate alternative reference landforms** based on properties such as degree of human land disturbance, topography, history of landform stability, data availability, in-field accessibility, hydrology, and vegetation.

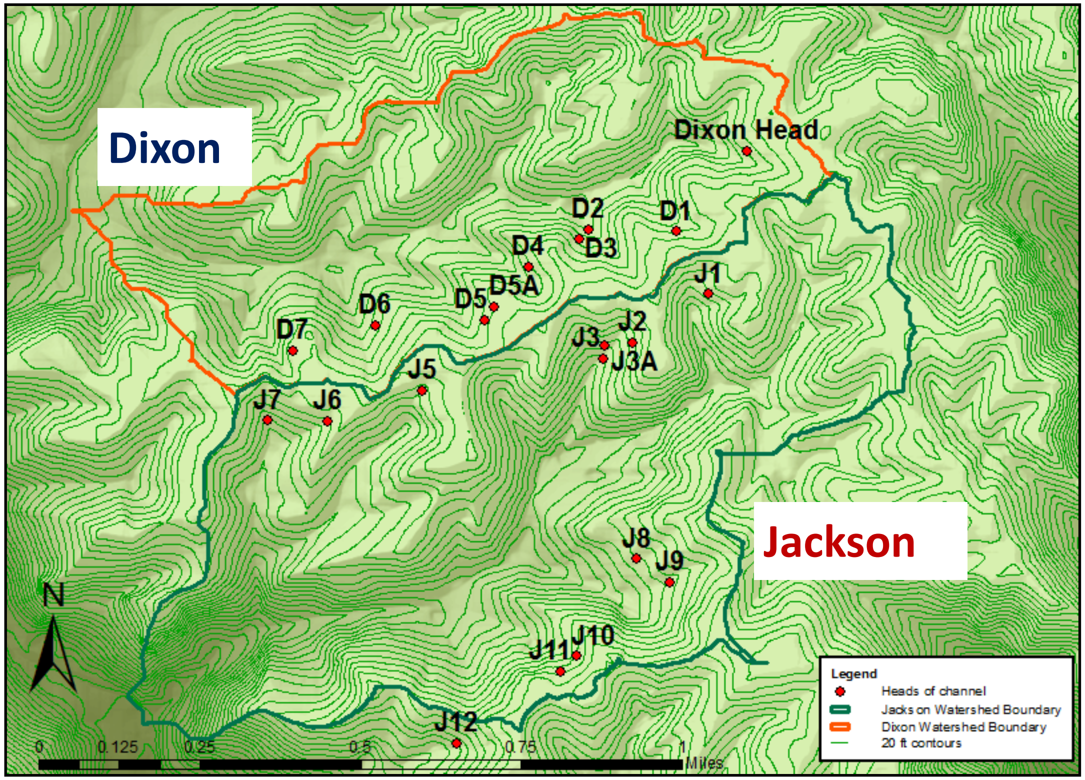
2. **Select reference landform location(s)** at which field data will be collected.

3. **Collect parametric data** from the reference landforms to be applied to the GLD valley fill design.

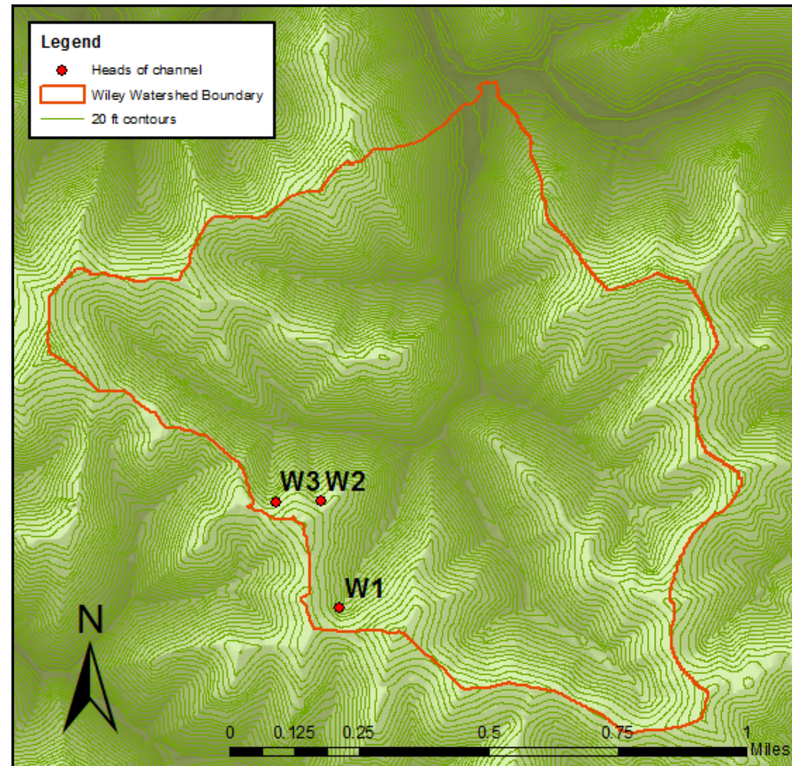
4. **Supplement field data with geospatial analysis** to fully quantify landform properties that could not be adequately documented in the field.

5. **Determine specific or range of geomorphic property values** to be used in completing geomorphic design.

Field data were collected at 8 heads of channel in Dixon, 11 in Jackson, and 3 in Wiley.



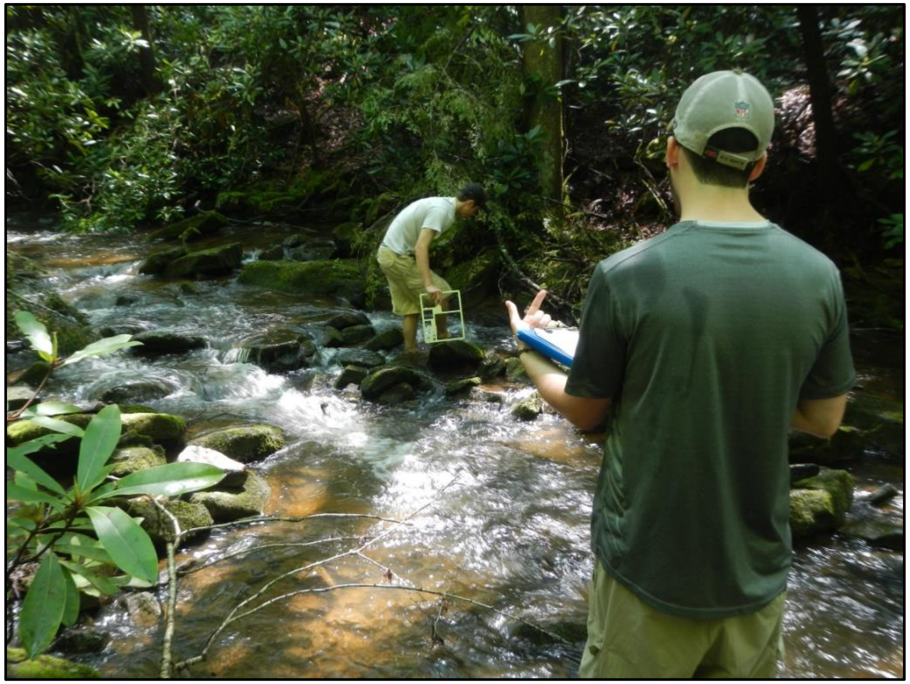
Wiley



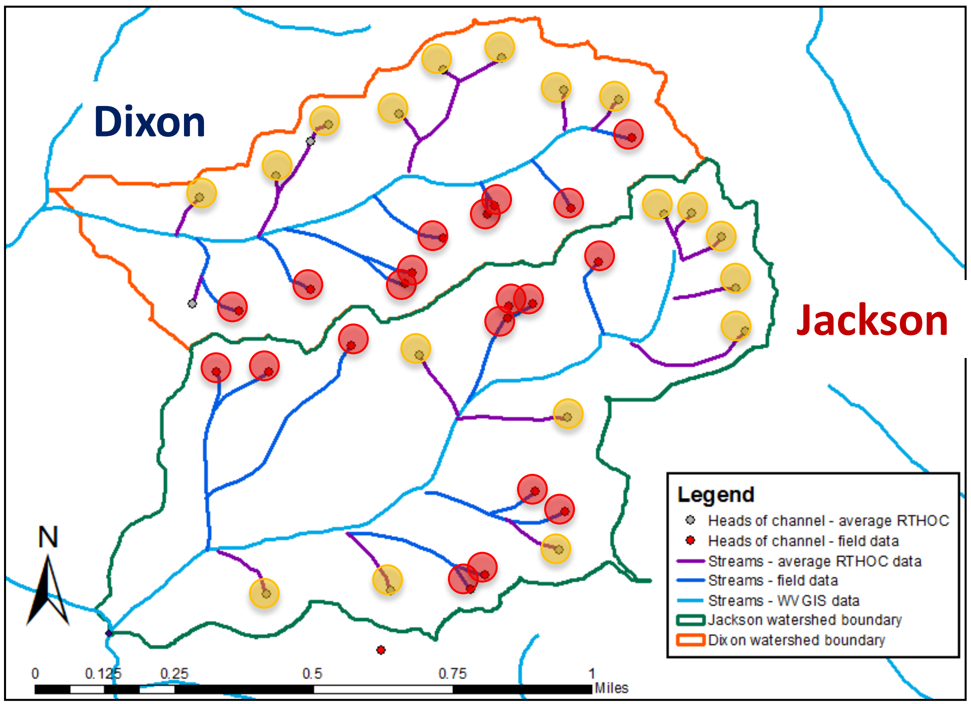
Ridge to head of channel distance: Head of channel locations and ridge points were surveyed with a Topcon GPS.

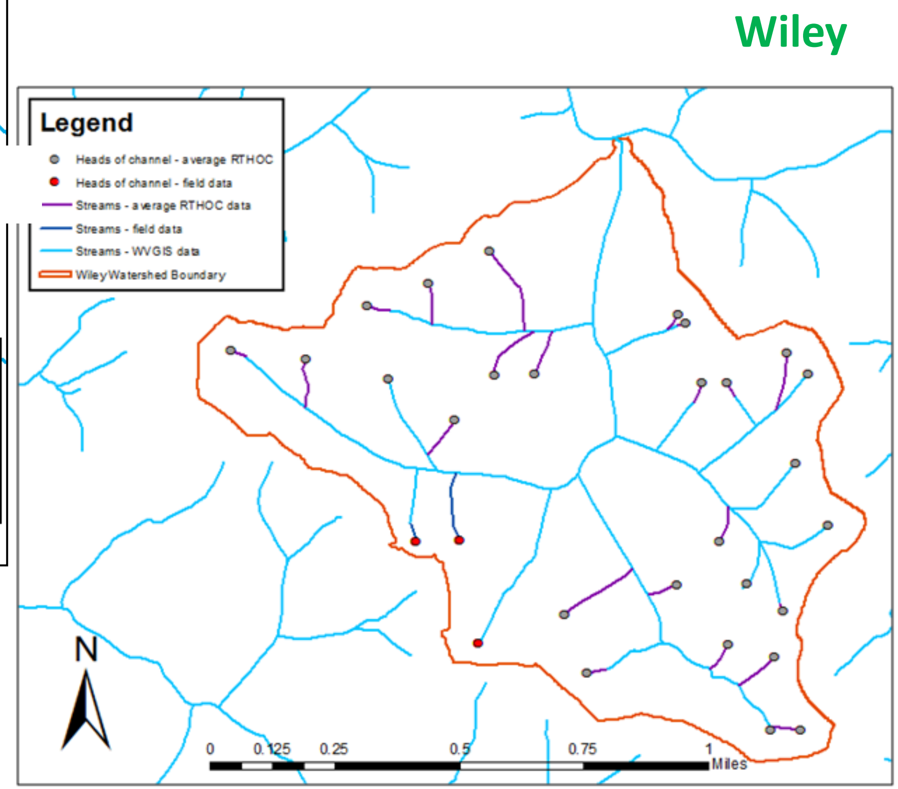
Channel/valley characteristics were defined for each site.

- Channel slope
- Channel cross-section
- Sinuosity
- Discharge
- Grain size
- Vegetation



Drainage density was calculated as 61.7 ft/acre (±23%).

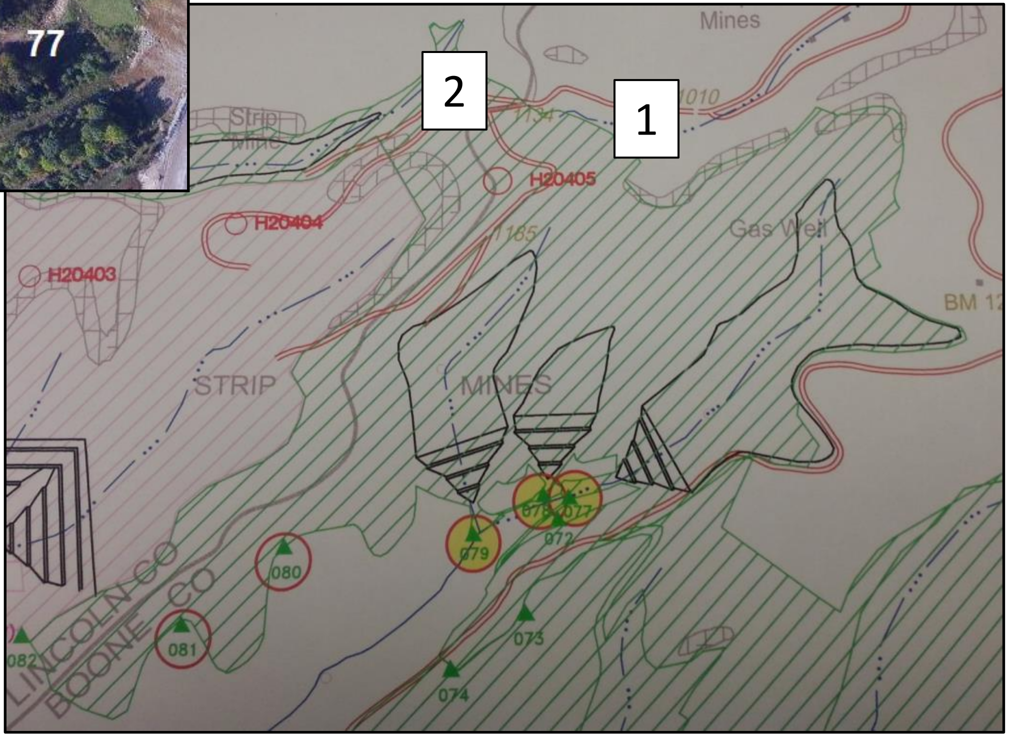




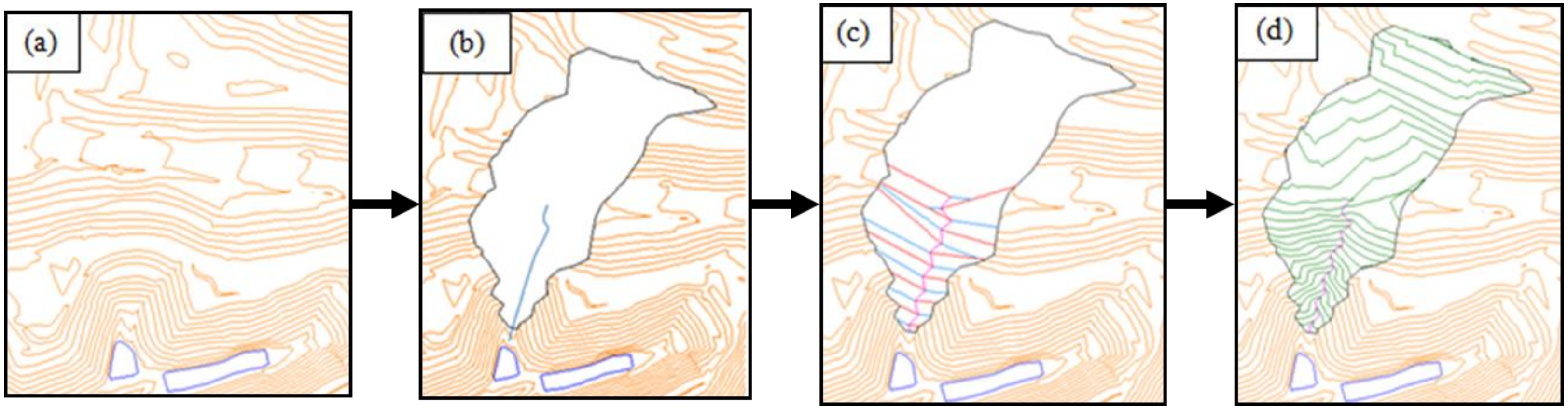
Comparison of software design and field measured parameters

Input Parameter	Natural Regrade value	Field measured value	Final design value used
Maximum distance between connecting channels (ft)	10	NA	10
Ridge to head of channel distance (ft)	80	408	408
Slope at the mouth of main valley bottom channel (%)	-2	-3	Specific to each valley
A' channel reach (ft)	50	NA	50
2-yr, 1-hr precipitation depth (in)	0.6	1.32	1.32
50-yr, 6-hr precipitation depth (in)	2	3.58	3.58
Target drainage density (ft/ac)	100	61.7	61.7
Target drainage density variance (%)	20	23	23

Task 2: Create landform designs for valley fills in southern West Virginia.

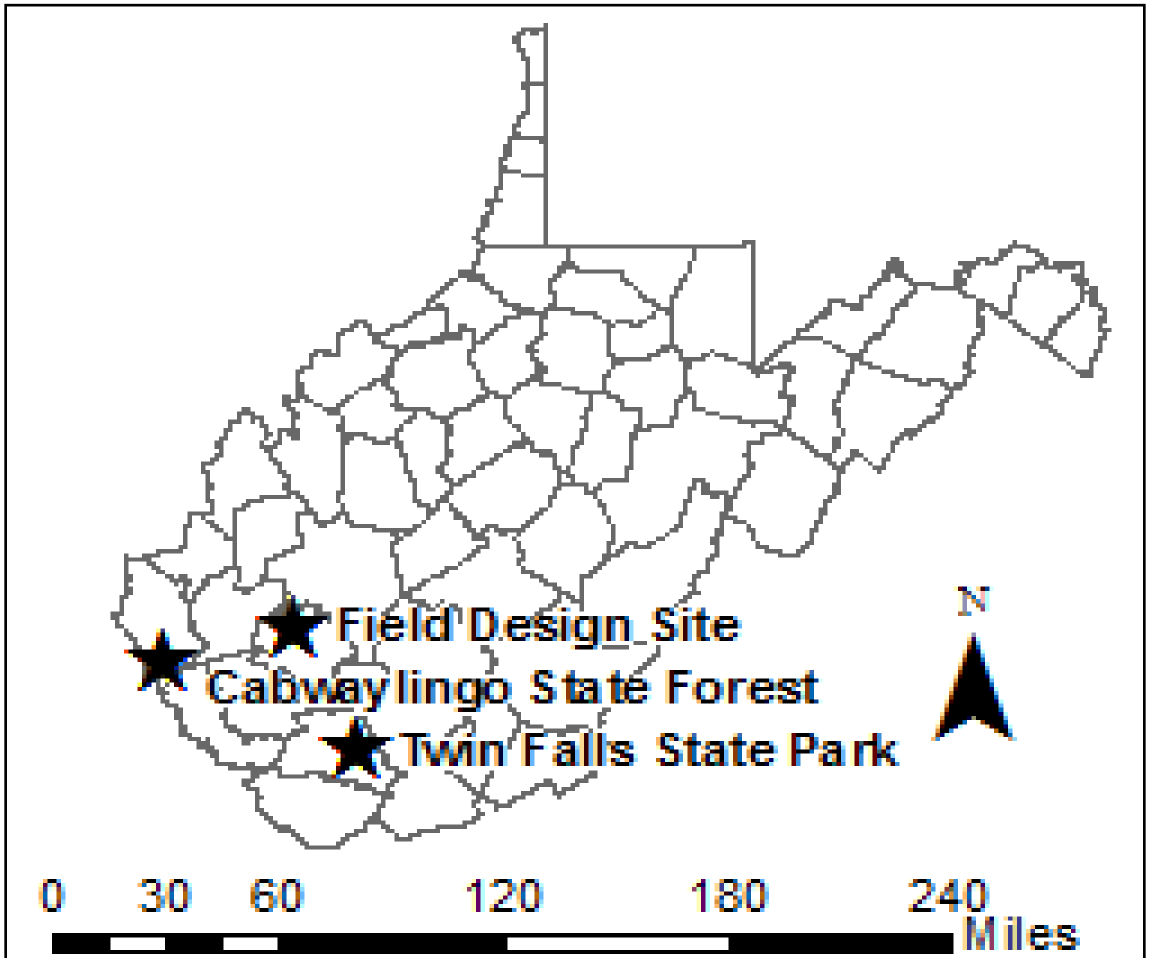


Can stable landforms be designed such that streams are mitigated or preserved on site, while maintaining the same overall footprint as conventional reclamation?

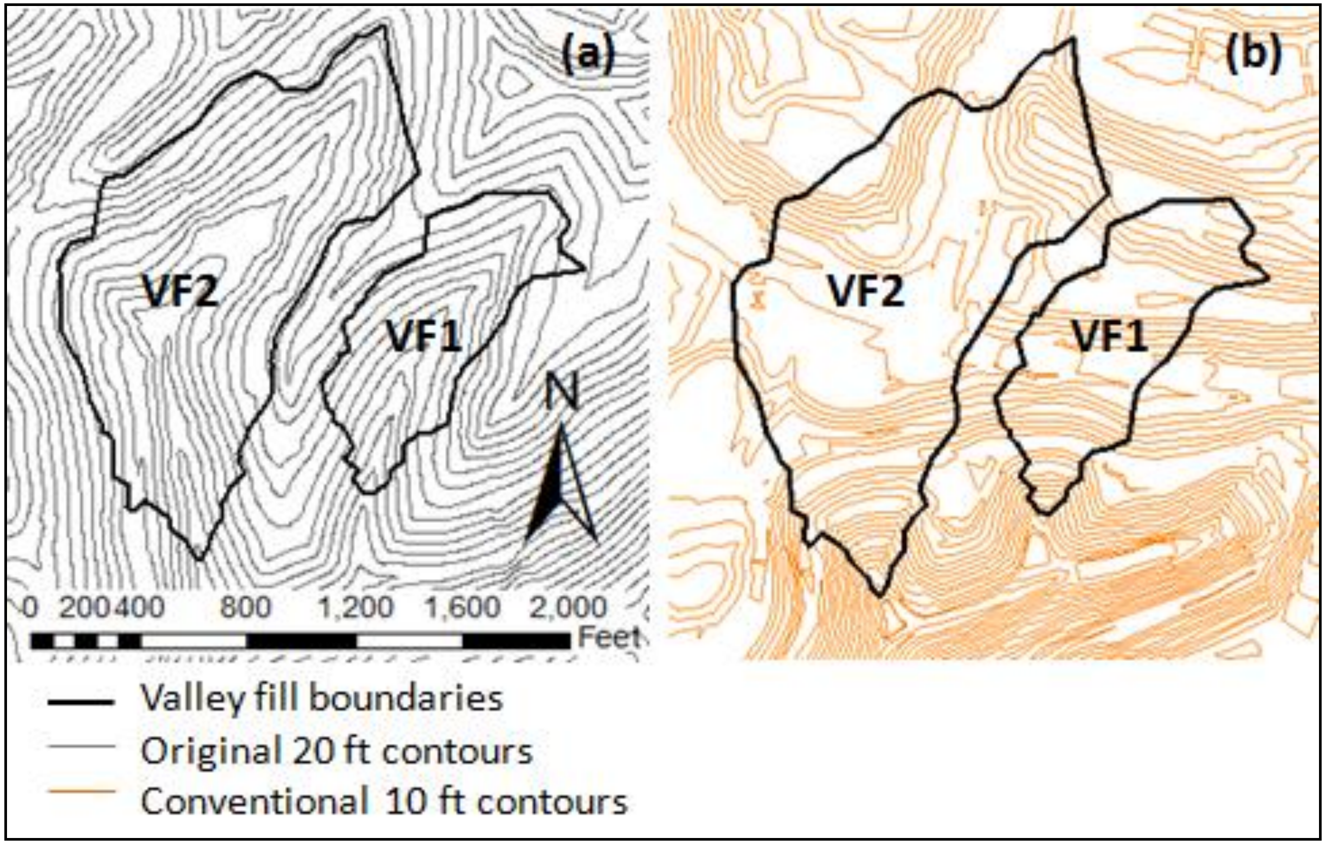


Natural Regrade design process for generating geomorphic landforms: (a) Given an existing topography; (b) Define landform boundary and create a polyline which satisfies input parameters; (c) generate a stream(s) and corresponding ridges and valleys; and (d) develop landform that connect with surrounding topography.

Relative locations of field-design and reference-landform sites.



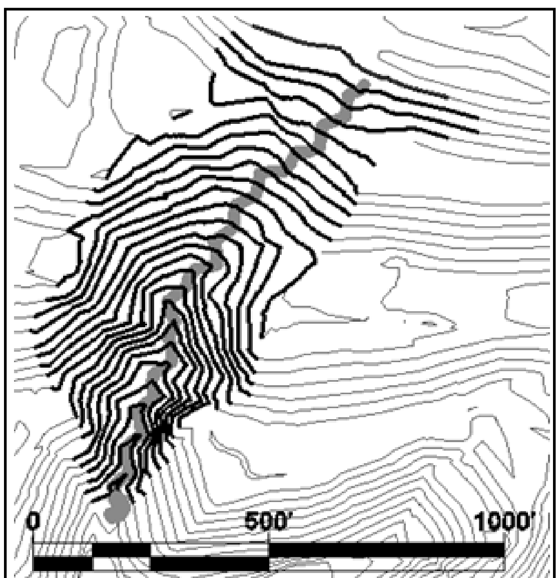
VF1 and VF2 locations on (a) original contours; (b) conventional reclamation contours

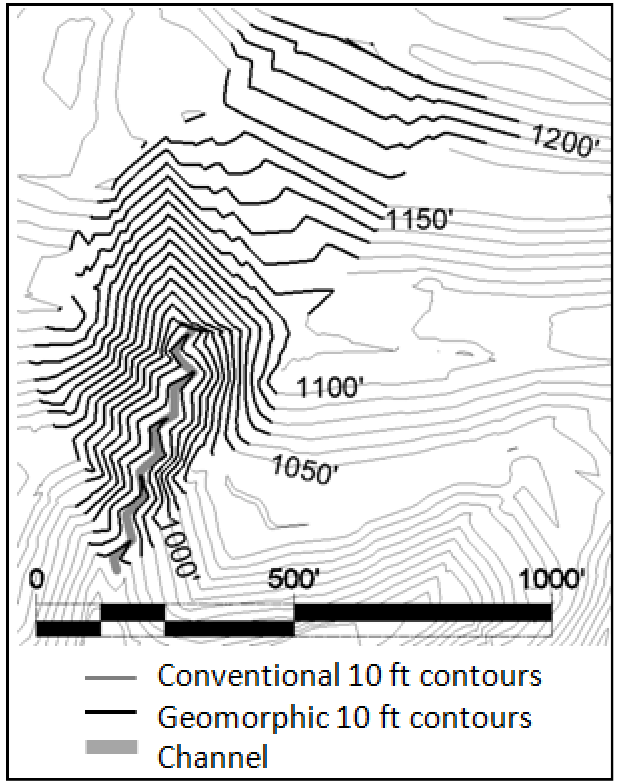


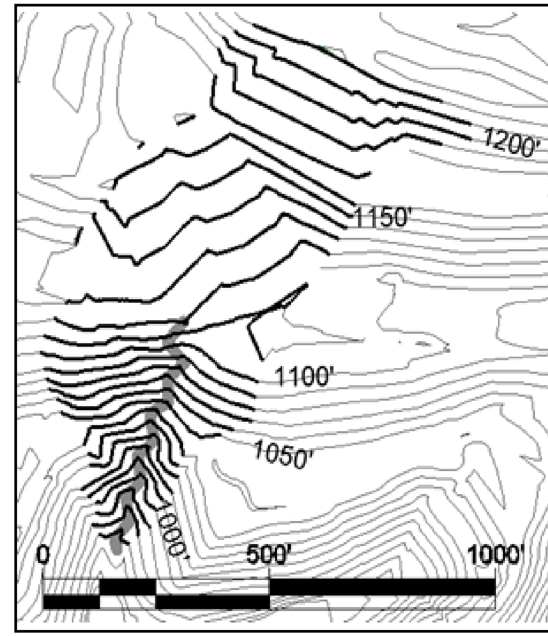
Design Iterations

- Use the Natural Regrade default design parametric values.
- Investigate the effect of low, mean, and high drainage density values;
- Investigate the effect of maximizing channel stability;
- Investigate the effect of maximizing fill volume placement;
- Examine the results of various trade-offs in priority among channel stability, hillslope stability and fill volume; and

Example designs for Valley Fill 1 based on software default values (left), maximizing channel stability with design values (center) and maximizing fill volume with design values (right)







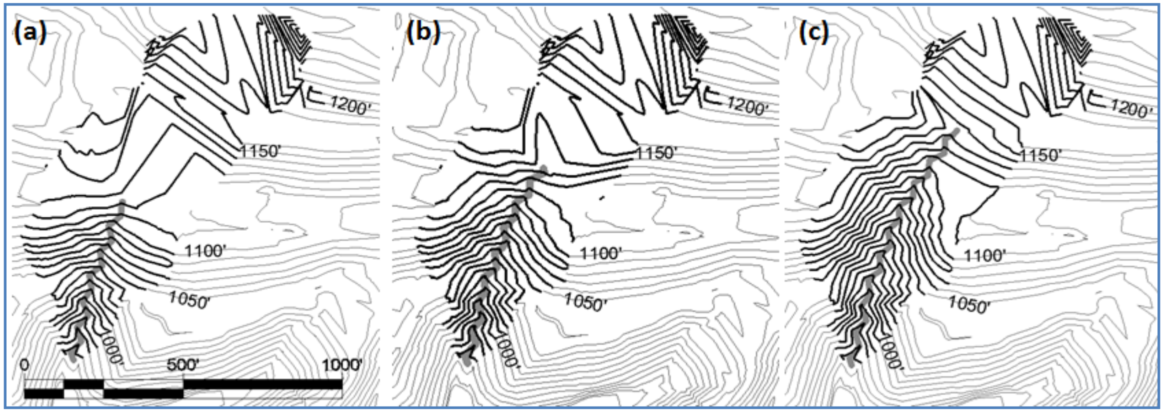
GLD Evaluation Criteria

- **Channel stability**: The channel design should have the ability to convey a design storm without mobilizing large (e.g. boulder-size) bed particles?

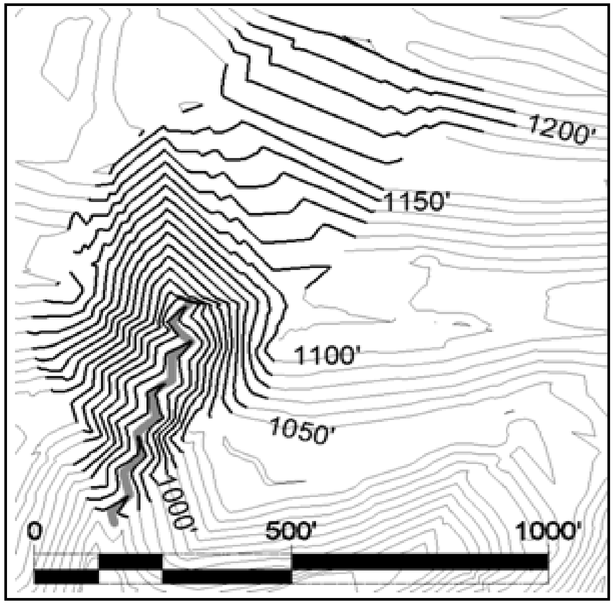
- **Valley side-slope stability**: Natural Regrade does not have a built-in check for slope stability. Gradients > 2:1 (50 %) are assumed to be unstable.

- **Fill volume**: The volume of spoil used in the geomorphic design should equal the volume of a conventional valley fill for the same area. If not, a plan for excess spoil placement at other locations must be developed.

Effects of different drainage densities

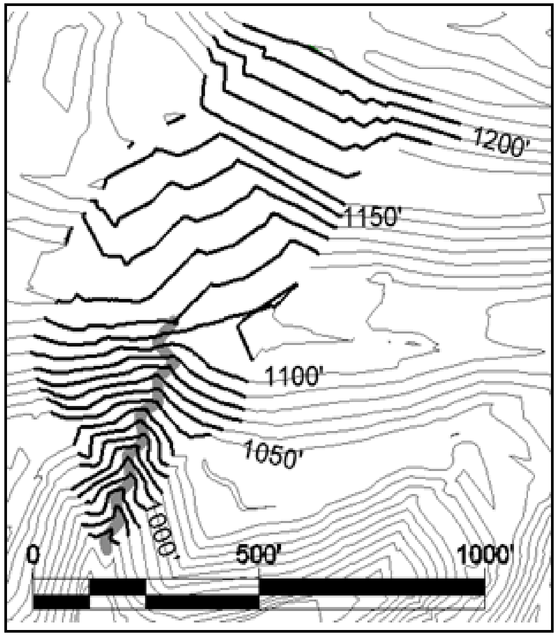


Design	Valley fill	DD (ft/ac)	V_{GLD}/V_{CV} (%)
1	1	48.2	83
2	1	60.8	73
3	1	74.8	66
4	2	48.3	77
5	2	60.7	63
6	2	72.4	49



Maximizing channel stability

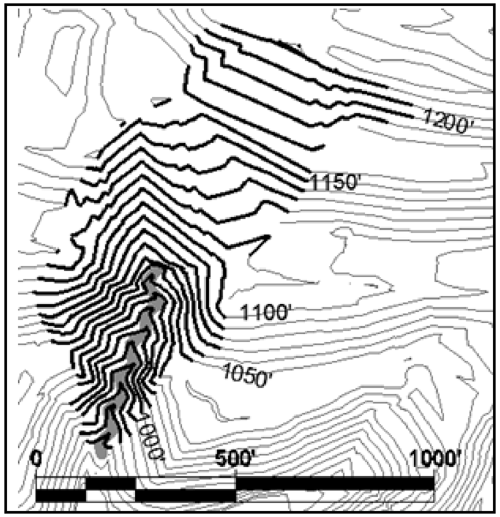
Design	Valley fill	S_C (%)	τ_{max} (psf) (BF;FP)	P_{HS} (%)	V_{GLD}/V_{CV} (%)
7	1	6.7-12	2.84; 3.67	33	65
8	2	6.7-12	4.09; 5.28	26	53

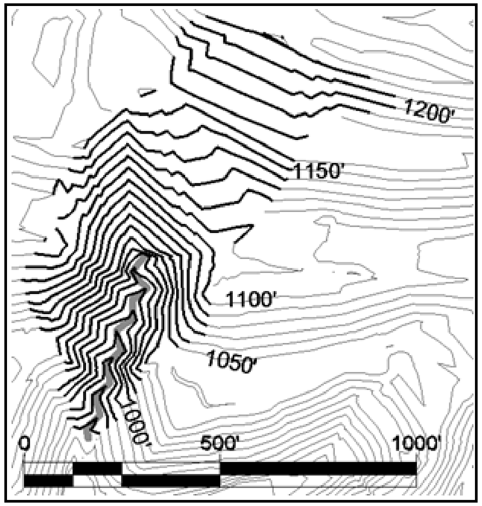


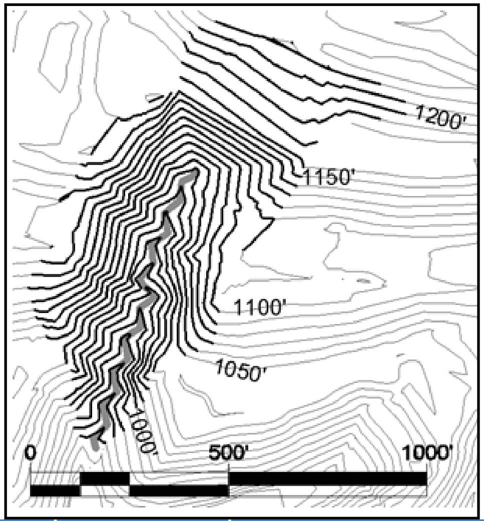
Maximizing fill volume and hillslope stability

Design	Valley fill	S_C (%)	τ_{max} (psf) (BF;FP)	P_{HS} (%)	V_{GLD}/V_{CV} (%)
9	1	9.7-35	8.24; 10.64	6.1	99
10	2	8.5-24	8.09; 10.45	4.4	85

Trade-off between stability and fill volume

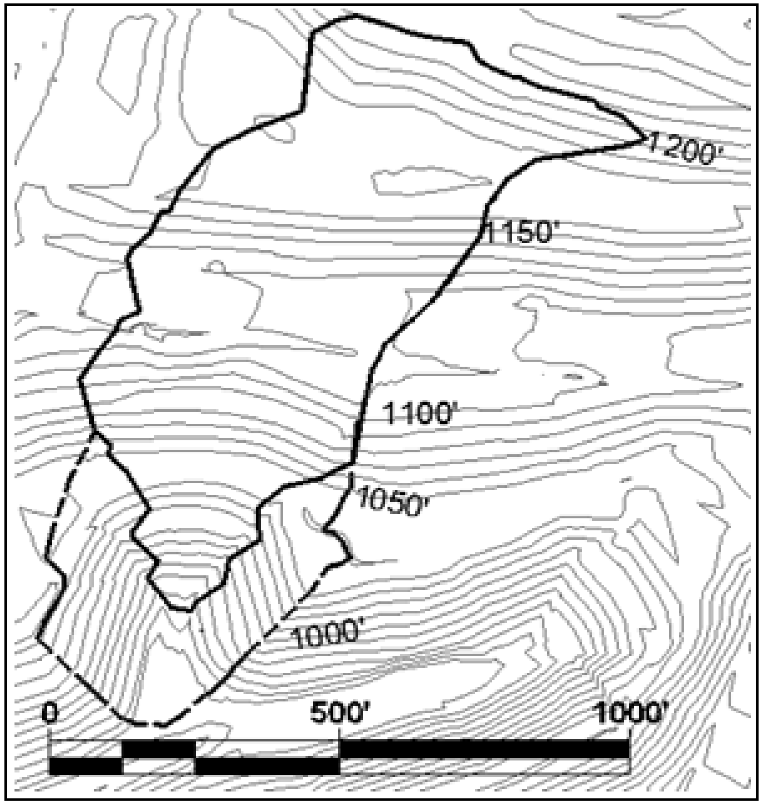


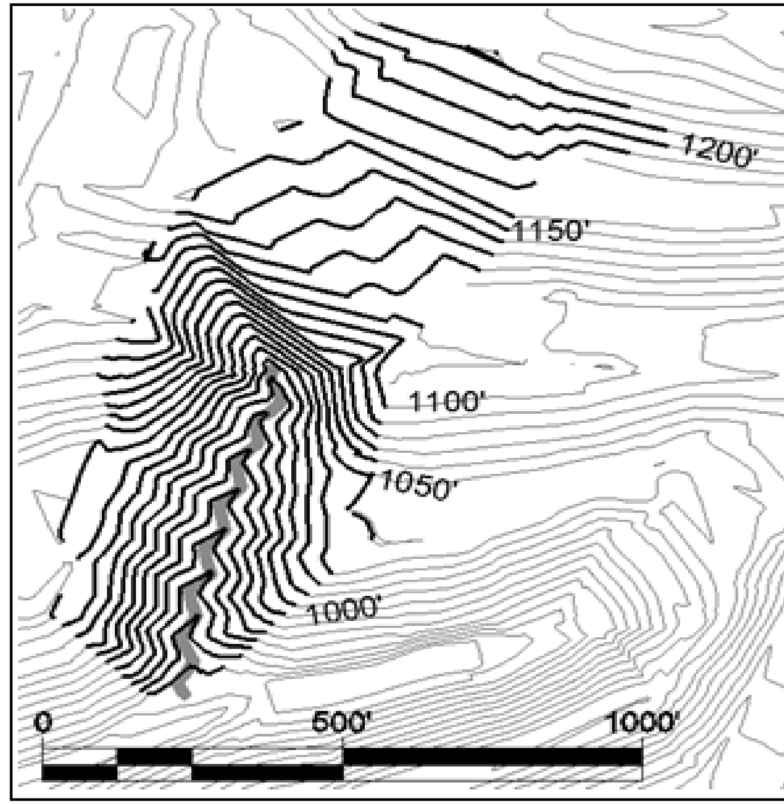




Design	Channel	S_C (%)	τ_{max} (psf) (BF;FP)	P_{HS} (%)	V_{GLD}/V_{CV} (%)
11	Stable at BF	8.6-18	4.30; 5.56	14	78
12	Stable at FP	8.0-14	3.33; 4.30	21	72
13	Stable at FP with high DD	8.2-13	3.33; 4.30	39	54

Expansion of Valley Fill 1 (left) and design of expanded valley fill 1 based on stable channel at flood prone flow (right)





Characteristics of landforms developed with an expanded impact area for valley fill 1. Designs were completed for three cases of channel stability

Design	Channel	S_C (%)	τ_{max} (psf) (BF;FP)	P_{HS} (%)	V_{GLD}/V_{CV} (%)
14	Preserved	6.7-12	3.25; 4.19	27	79
15	Stable at BF	8.2-24	4.33; 5.60	9	114
16	Stable at FP	8.2-12	3.35; 4.32	17	102

Analysis of design criteria for geomorphic designs for VF1

Design case	Fill volume	Landform stability	Channel stability
7	x	x	√
9	√	+	x
11	+	+	+
12	+	x	√
13	x	x	√
14	+	x	√
15	√	+	+
16	√	+	√

x Criteria not met

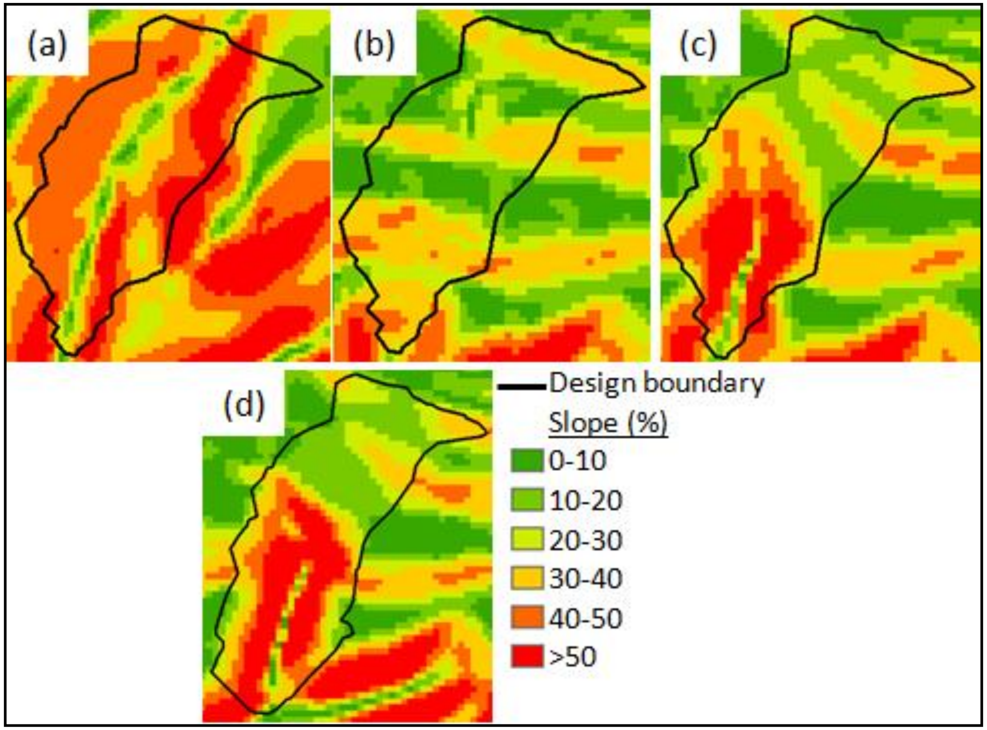
\+ Criteria moderately met

√ Criteria met

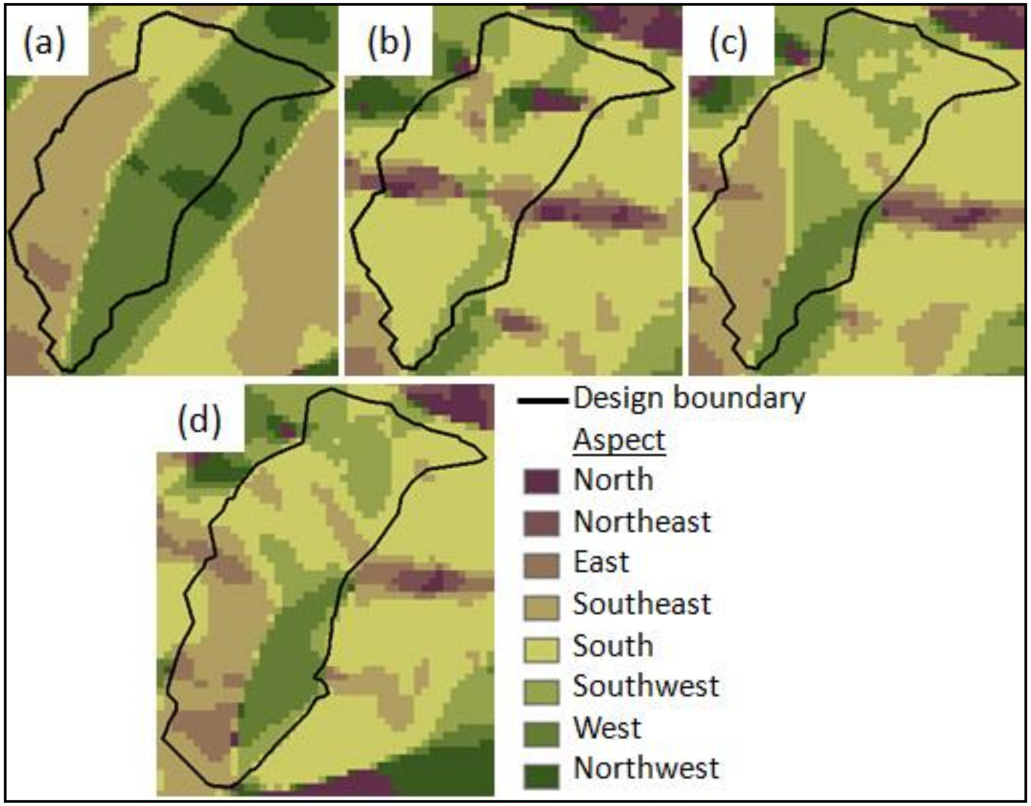
Environmental/Ecological Benefits from GLD Applications

- More stream length relative to conventionally constructed valley fills
- Variation of slope gradient
- Variation of slope aspect
- Continuity with surrounding landscape

Slope distribution of (a) pre-mined topography; (b) conventional reclamation; (c) geomorphic design 12; (d) geomorphic design 16.



Aspect distribution of (a) pre-mined topography; (b) conventional reclamation; (c) geomorphic design 12; (d) geomorphic design 16.



Conclusions

- The authors of this paper are of the opinion that the potential application of valley fill geomorphic design in Central Appalachia should continue to be evaluated.

- Although difficulties with reconciling stream channel and slope stability with fill volume maintenance has been quantitatively verified, potentially significant environmental benefits has also been quantitatively confirmed.

Future Topics/Issues

- Accounting for effect of phreatic surface
- Construction methodology
- Feasibility of using boulder-size particles in limited stream reaches
- Ridge-centered design in place of stream-centered design (for small fills)
- Multiple channel networks or sub-basins and storage ponds (for larger fills)
- Flow regime modeling
- Minimizing acid mine drainage and dissolved solids
- All of the above (field demonstration)

Thanks!