Integrating Visualization, Landform Shaping and Geomorphic Analysis for Eastern Surface Mine Reclamation

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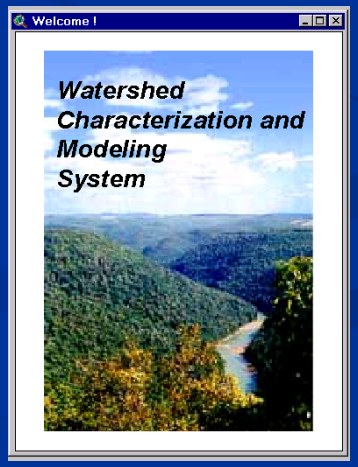
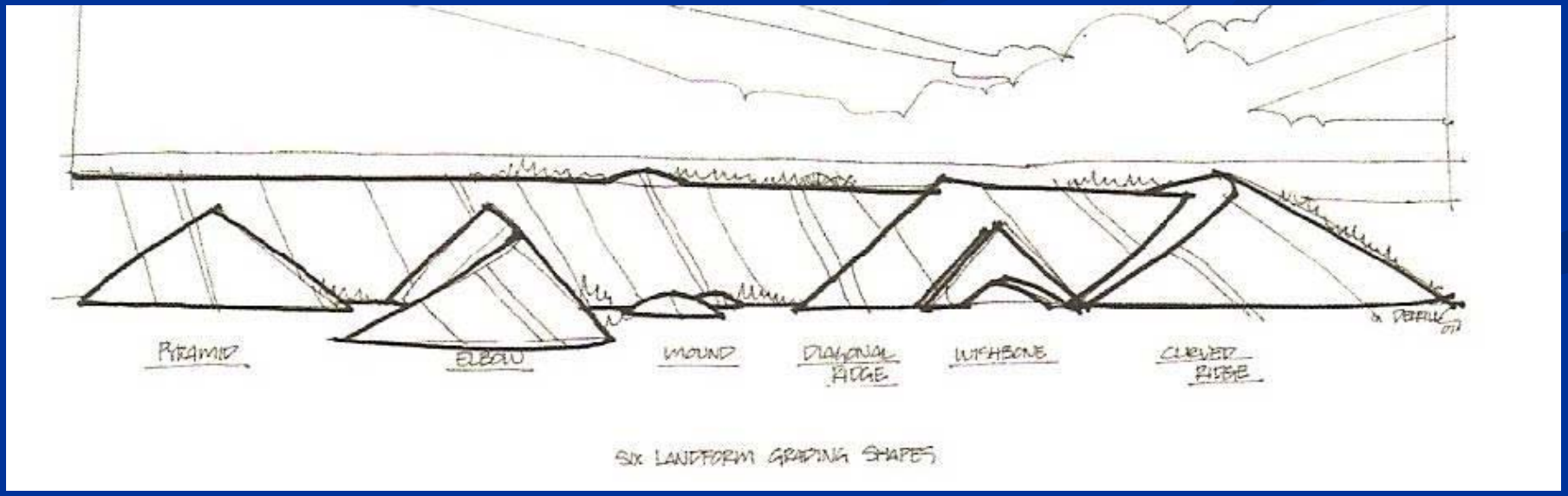
And Michael Hasenmyer
West Virginia University

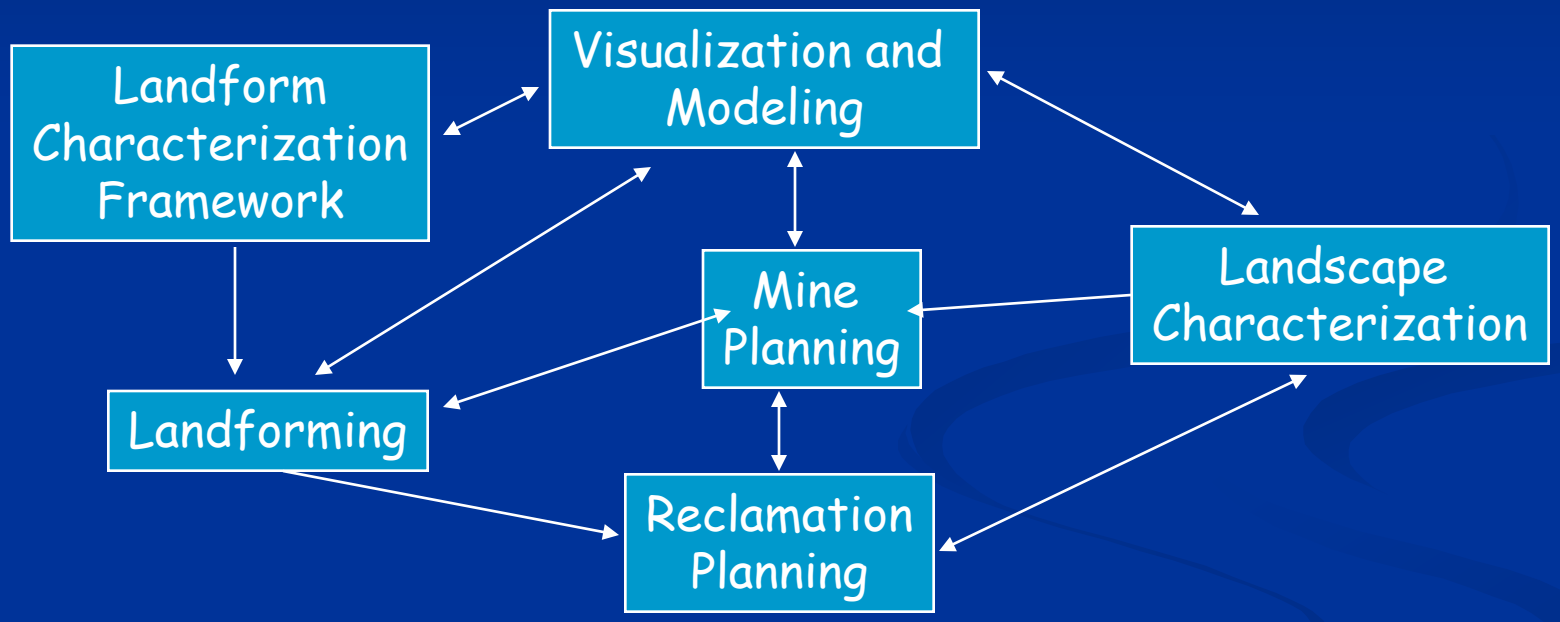


A working definition

- *Geomorphic landforming* – what is it?
  - Regrading disturbed or altered landscapes respecting and working with….
    - Natural terrain patterns - the idea of reference terrain
    - Natural geomorphic and hydrogeomorphic processes
    - Natural vegetative patterns
    - Natural processes are allowed to proceed at rates that would be typical for undisturbed landscapes of similar topography.
    - Differs from many other forms of regrading that are designed to optimize the lack of natural processes focusing on immediate stabilization at the expense of the above.



An applied research agenda

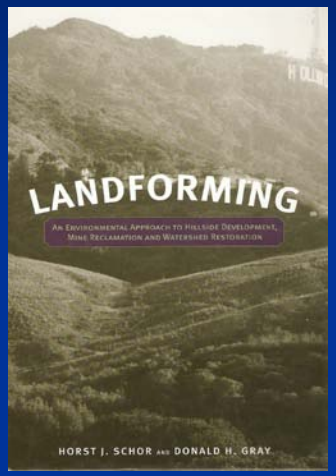


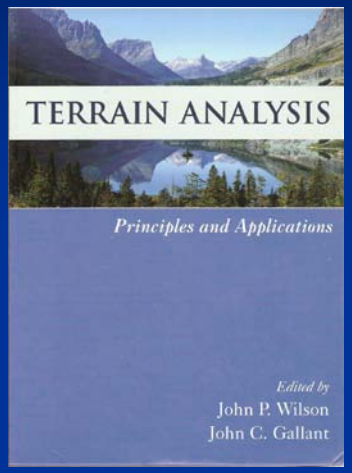
How we visualize the parts fitting together

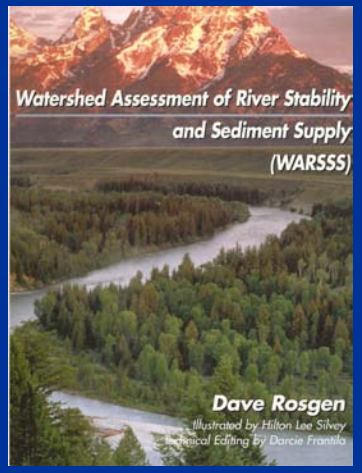
Why an applied research agenda in geomorphic and creative landforming for Eastern coal mines?

- The obvious applicability……and unrealized opportunities
- Active mining
  - Mountaintop mining
    - Emerging concern with land use – forestry, biofuels, energy parks. etc. – example – in southern WV slope / aspect can impact site productivity by + or – 20% independent of soils
    - Grading and land shaping for 0 order watersheds – better drainage area delineation in these areas
    - Grading for upper slopes including drainage course design
    - Where site context is potentially sensitive
    - Mountaintop operations in general
  - Contour mining
    - Regraded and natural slope transitions
    - Drainage channel and stream design

Before we go on… acknowledge some important supporting or parallel work

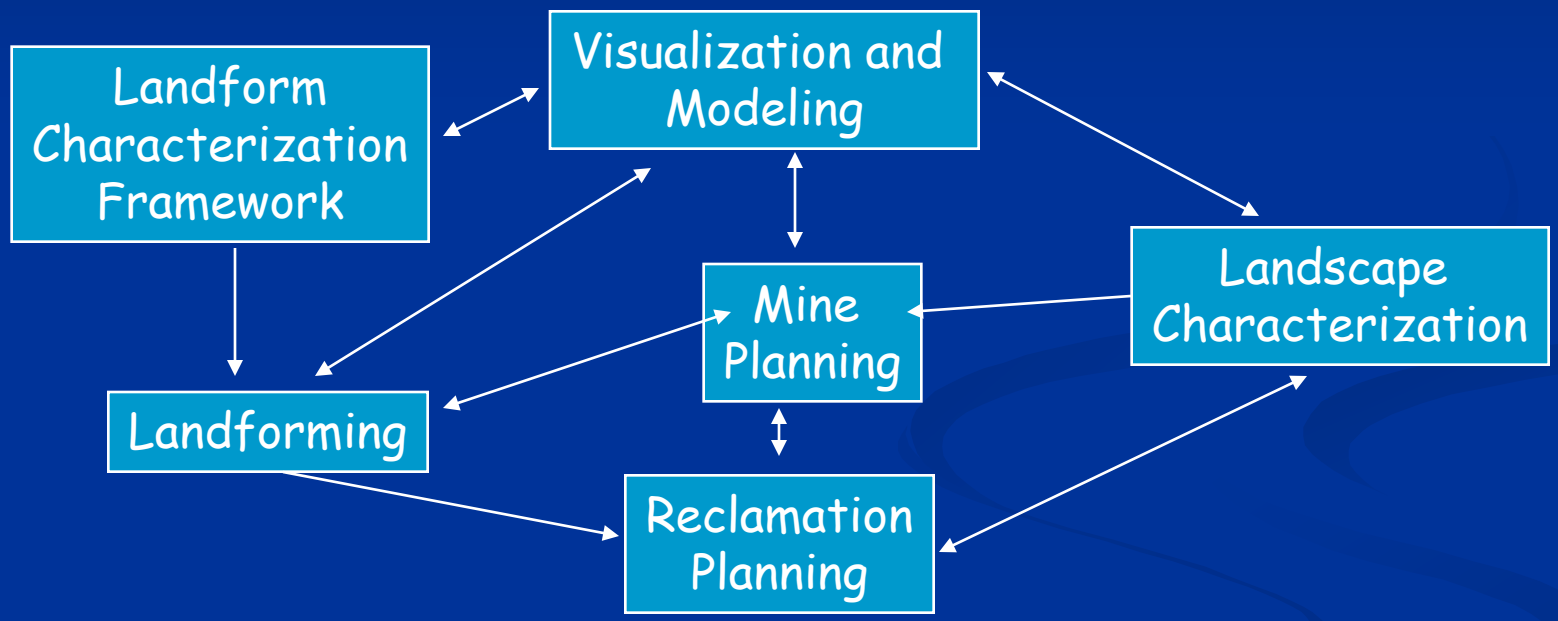






- Current (COTS) applications conceptual leaders are….
  - Geofluv
  - Rivermorph

So back to our framework



So why are visualization and modeling the unifiers in this framework?

Faro Mine

The Faro Mine Complex is located in south-central Yukon. It is 15 km north of the town of Faro and almost 200 km northeast of the City of Whitehorse. From Whitehorse, the mine is a 30-minute charter flight or a 4-hour drive away. The mine complex is located in the traditional territory of the Kaska Nation and upstream from the traditional territory of the Selkirk First Nation.

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Faro Mine Closure

The mine complex, has a total footprint of over 25 km^2 (9.65 mi^2) with mining pits over 335 m (1072 ft) deep and surrounded by approximately 500 million tons of waste rock, and 55 million tons of stored mine tailings.

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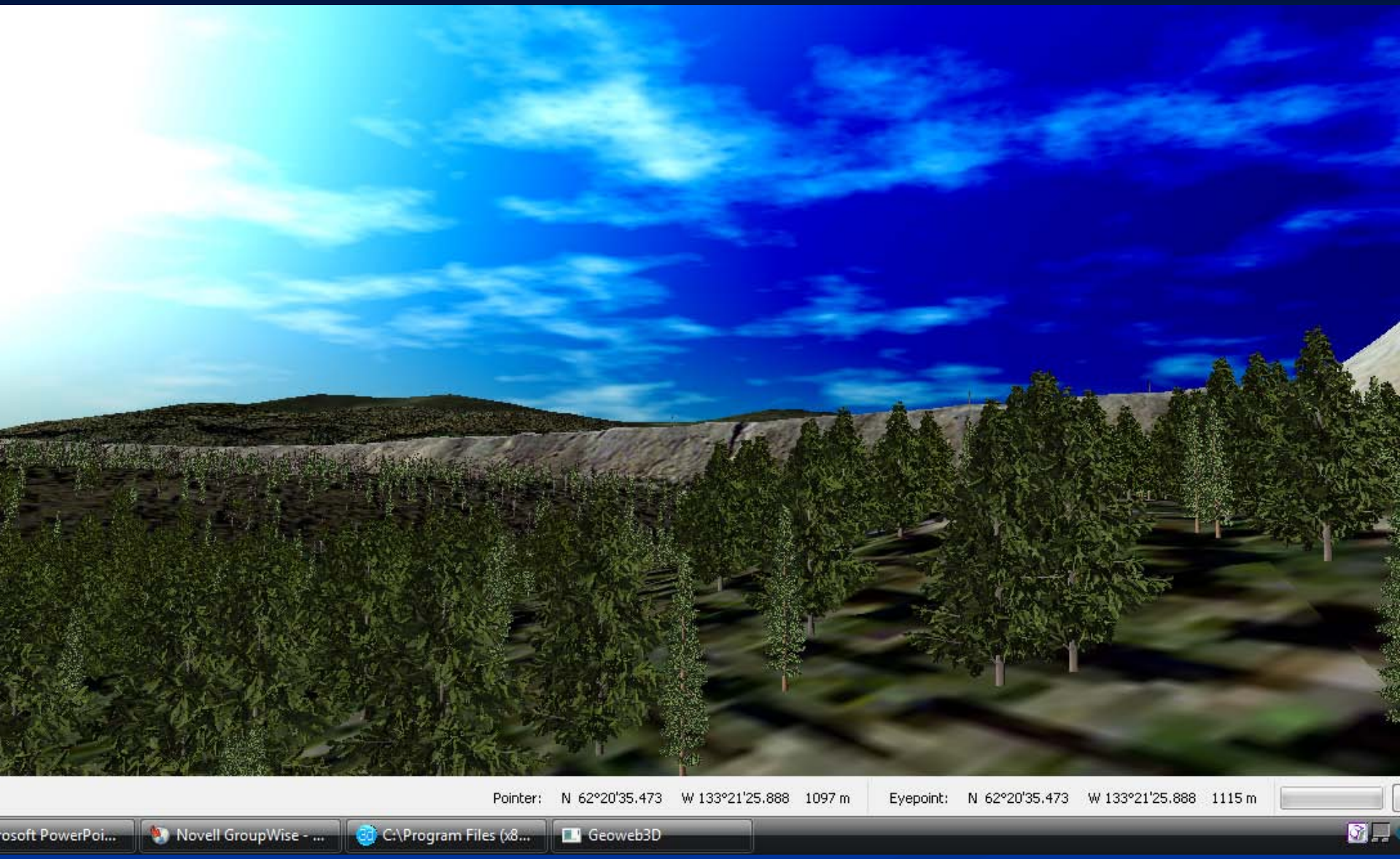
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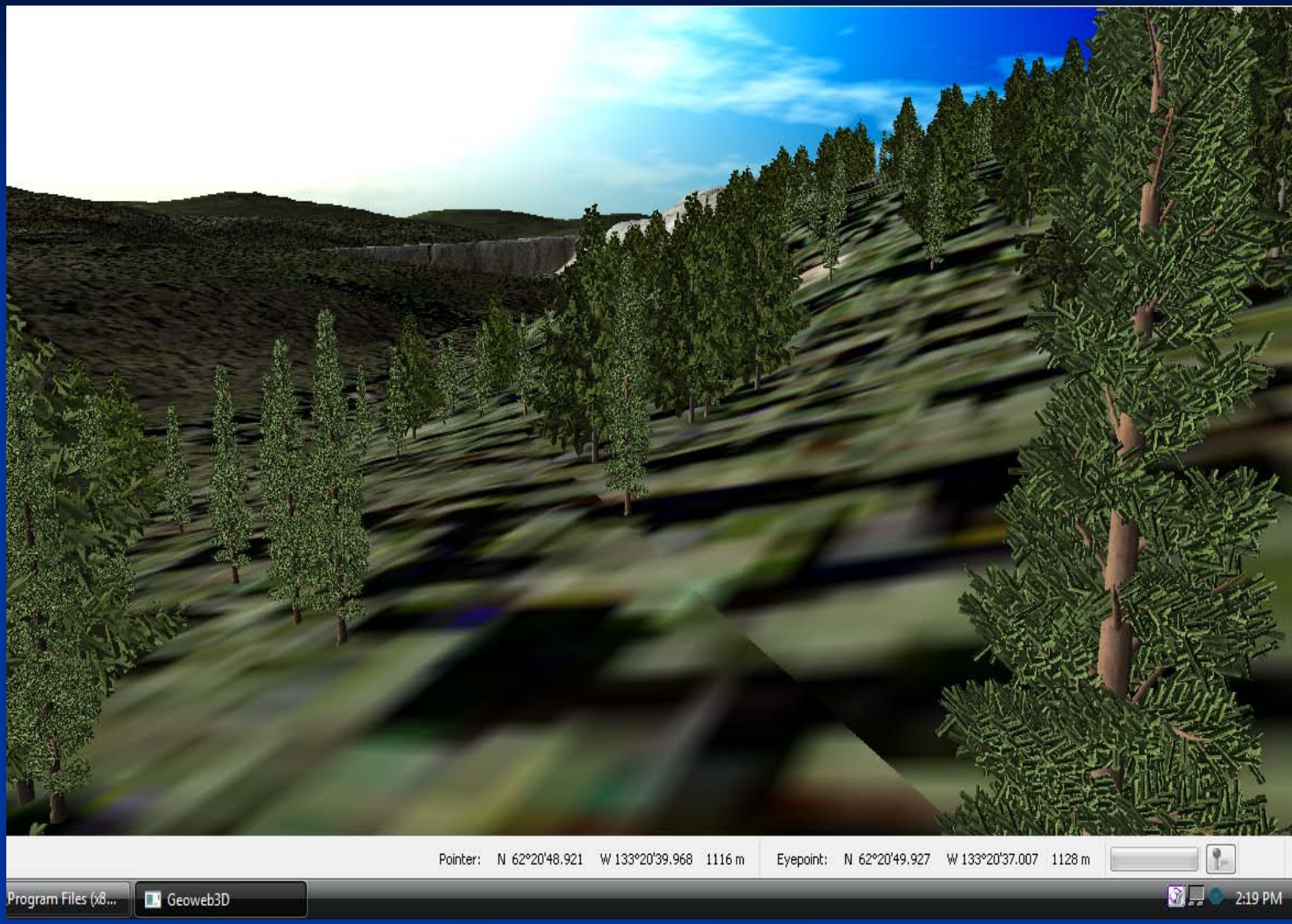
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Geoweb3D

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Exposure 1.29 | Focal Length 35 mm
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- 90m_dem1.img
  - Elevation
- area image.ecw
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- Mine3m.tif
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- Minesite_detail.ecw
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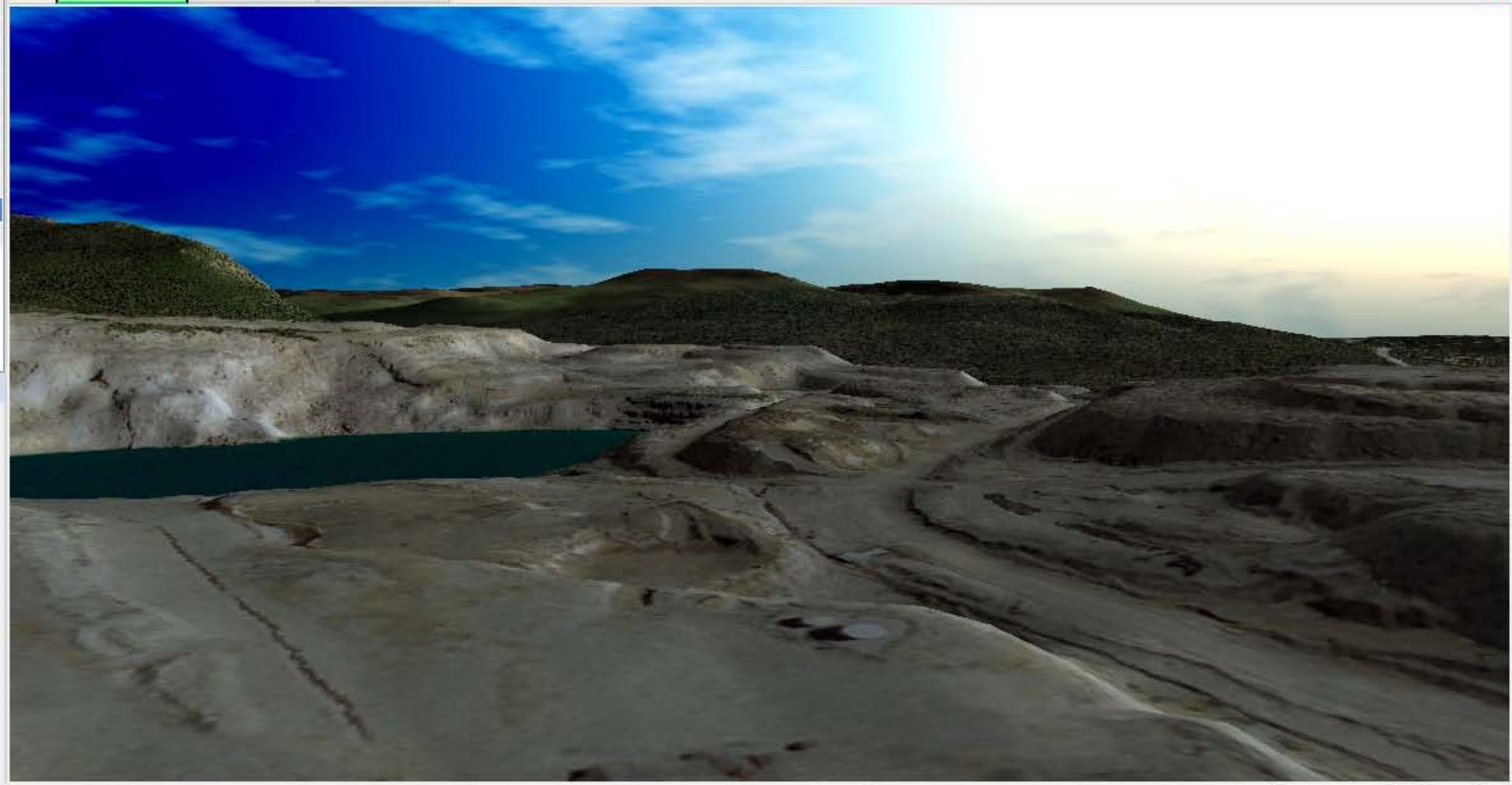
Attribute Mapping

1 Field | 2 Map | 3 Add

Geoweb3d | Google Maps | Projects



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Attribute Mapping

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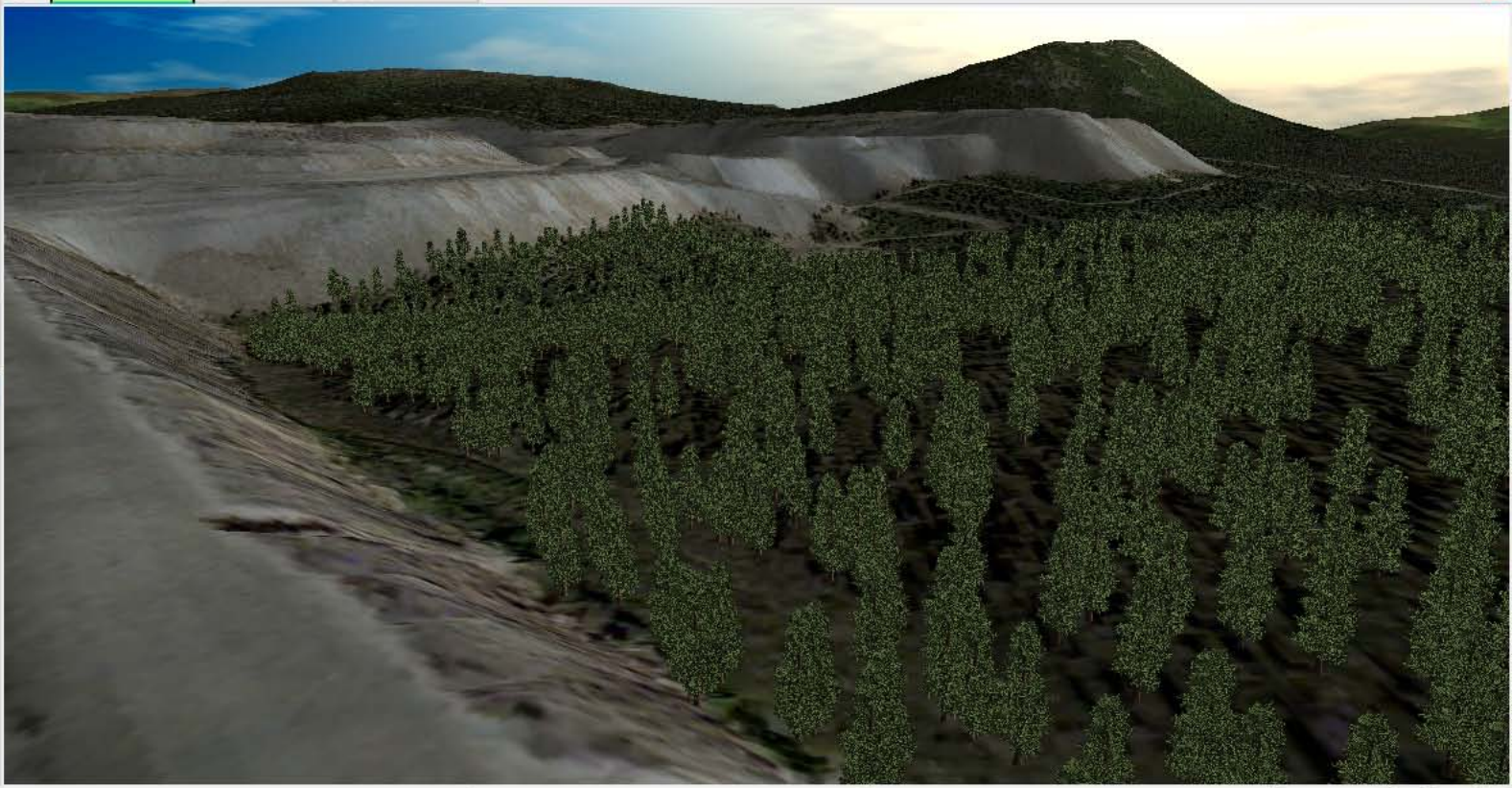

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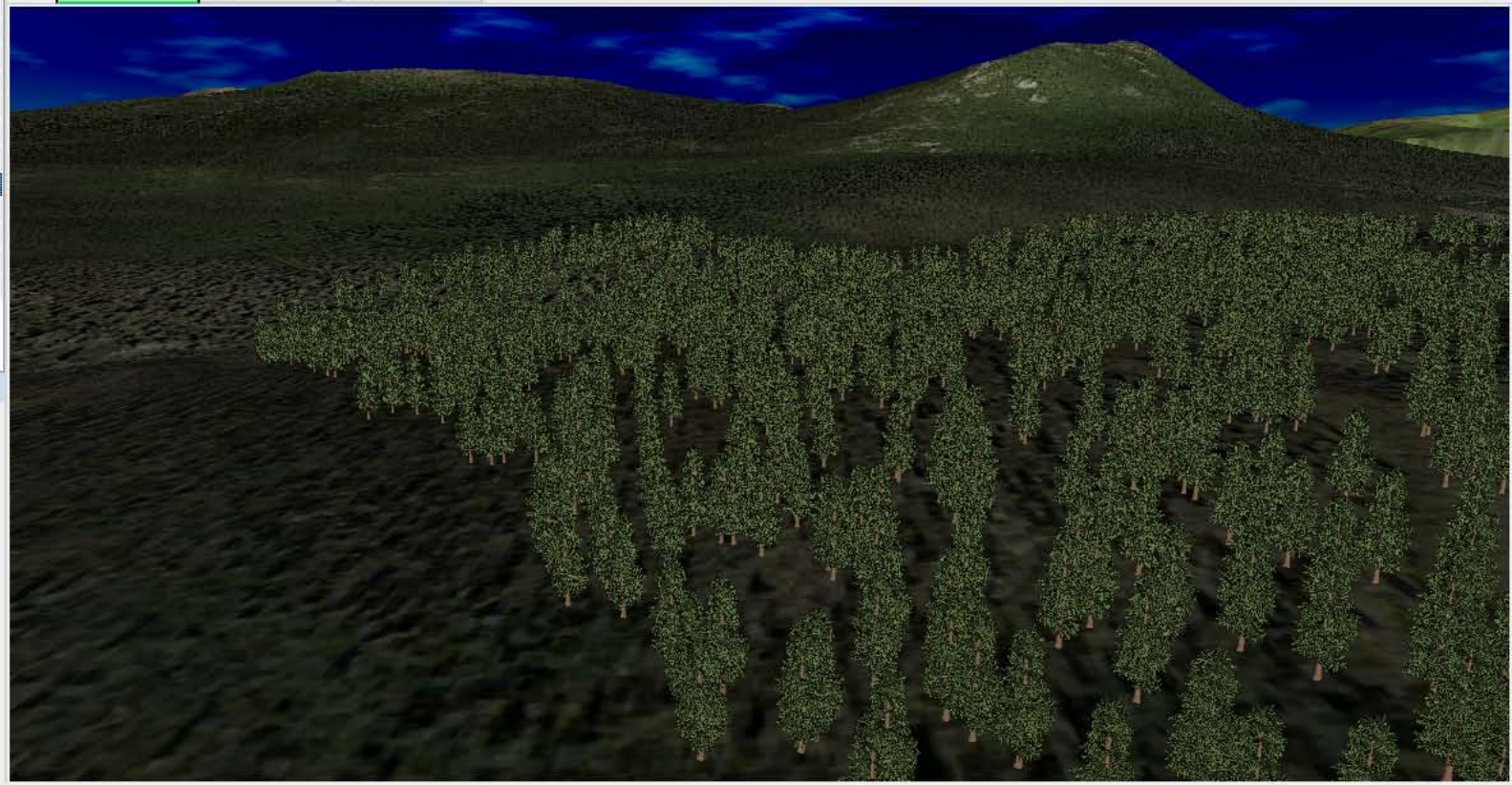

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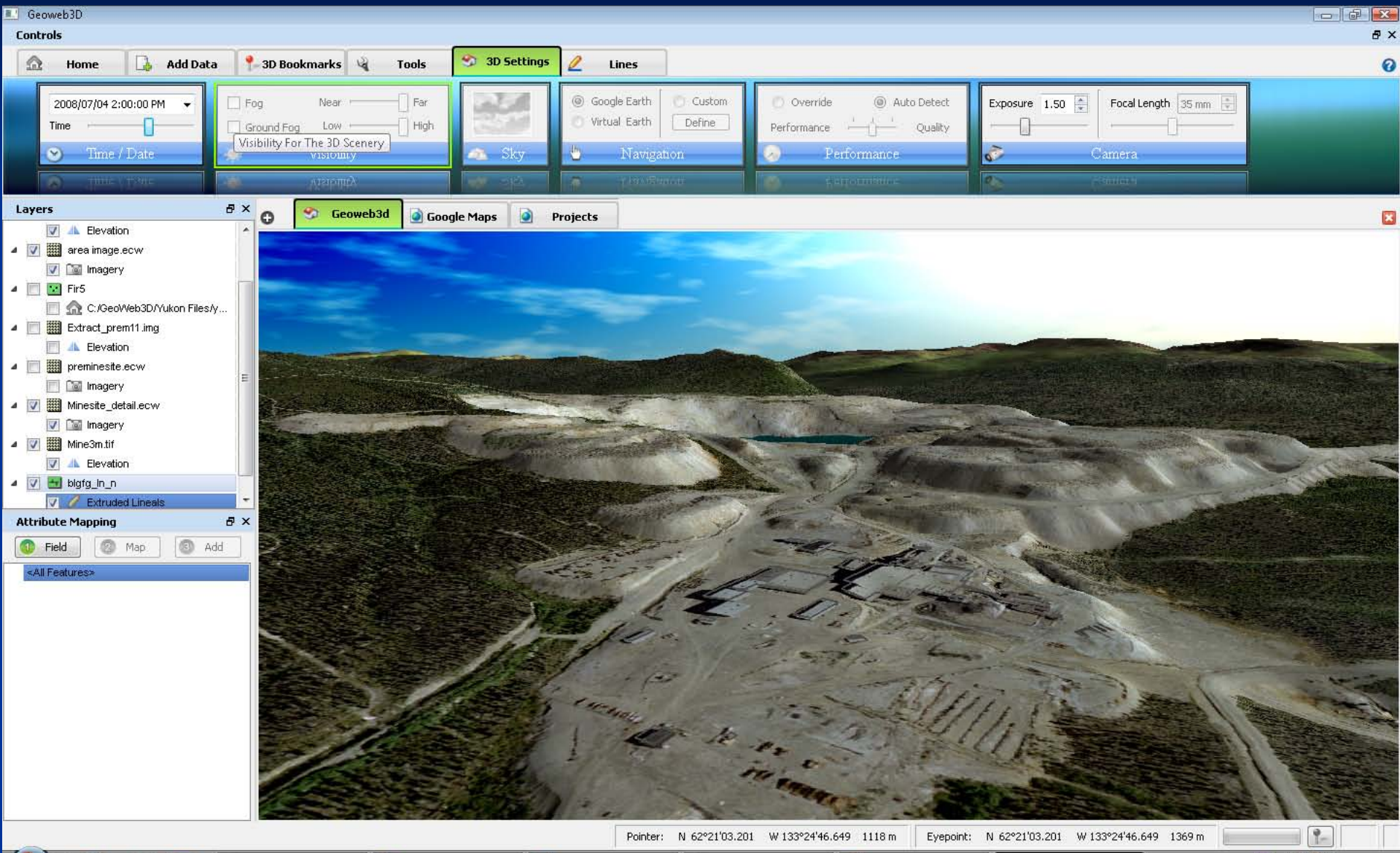
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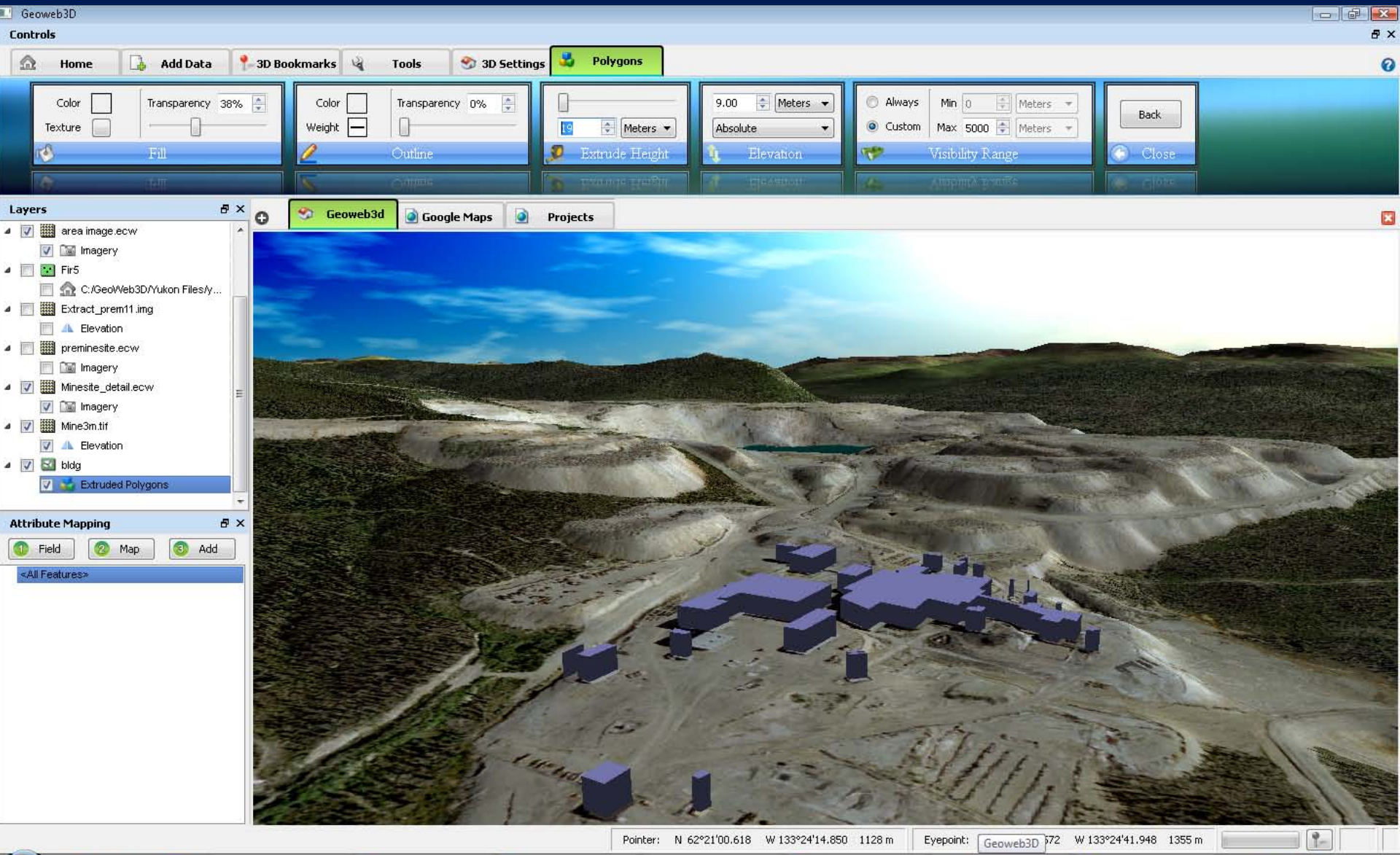
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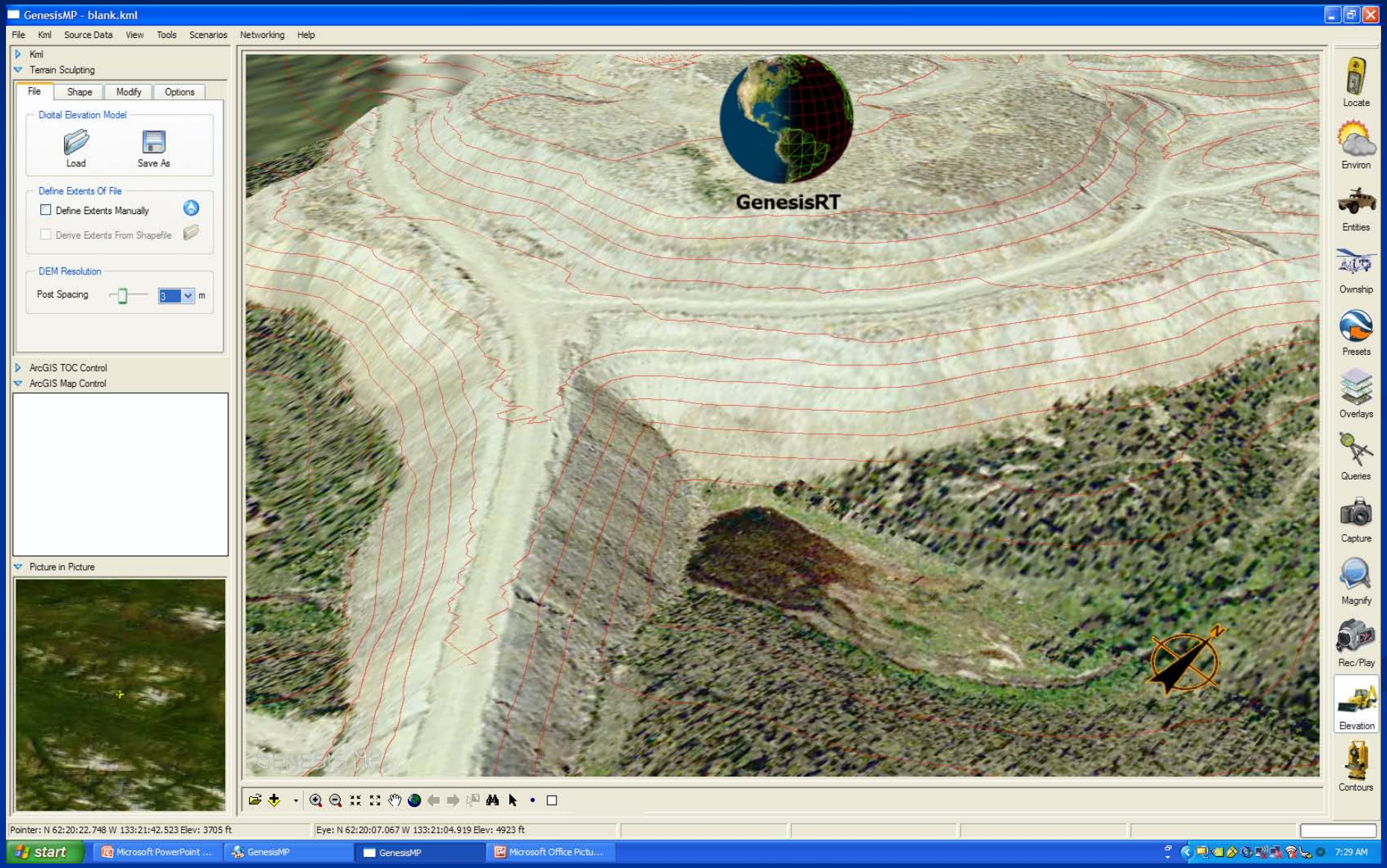
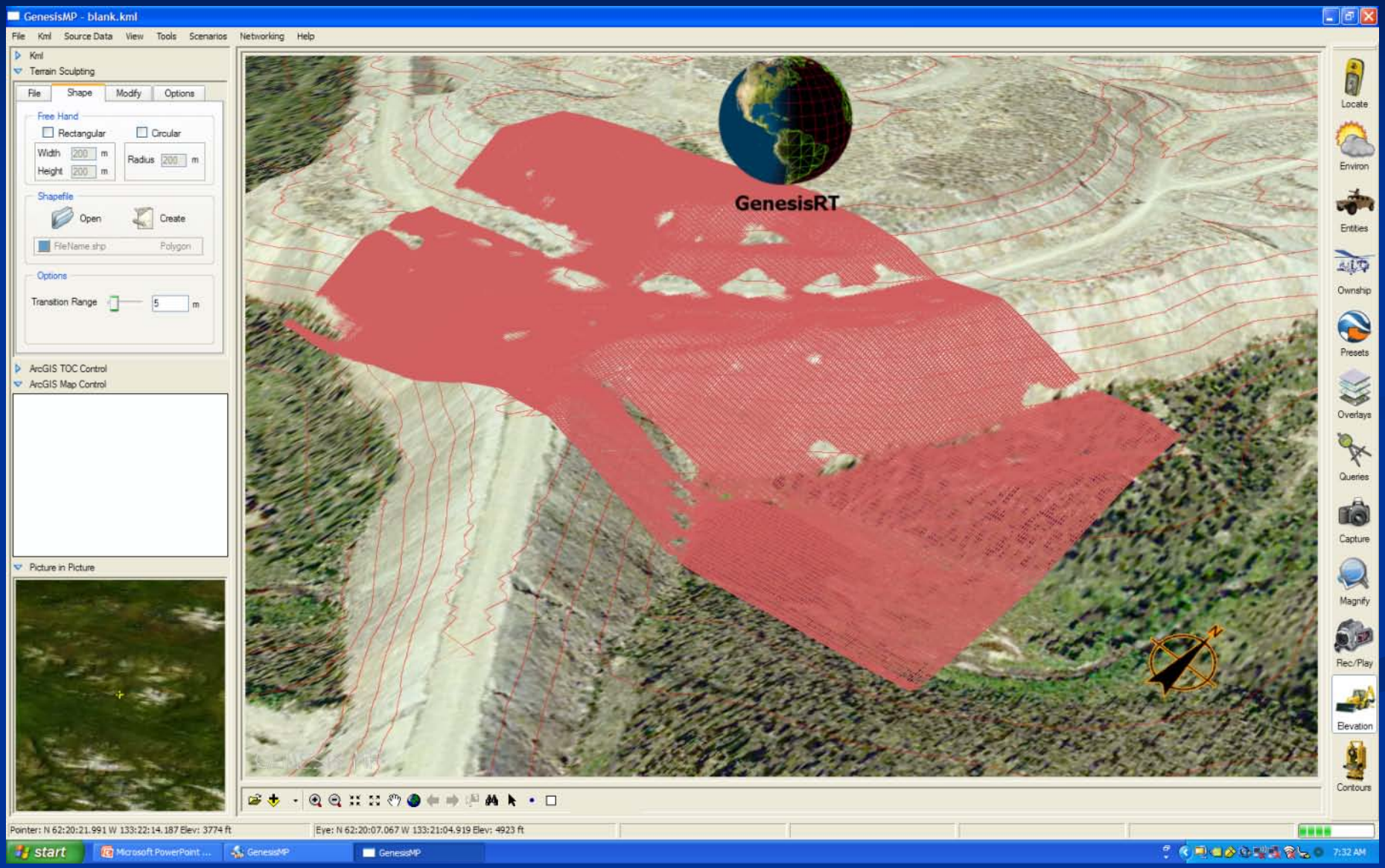
Linking landshaping with visualization

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We can then take the results of this landform manipulation to analysis software for evaluation on the fly.

Project status – initial plans have been developed for spoil regrading, tailings stabilization, the mill, and surface water – preparing to visualize those plans.

Leads us to… Methods for examining and hopefully integrating aspects of geomorphic reclamation into eastern active mining more fully

- Methods for understanding and engineering / designing landforms
- Methods for hydrologic system design
- Methods for detailed landform engineering

- Again visualizing such a process

For examining landform…we wanted an approach that

- Would be useful as a research tool and potentially be applicable in real situations
- Be implementable
- Would be useful for landform stability, erosion, land cover, and hydrologic assessments

So what evolved was a multi stage approach that considered….

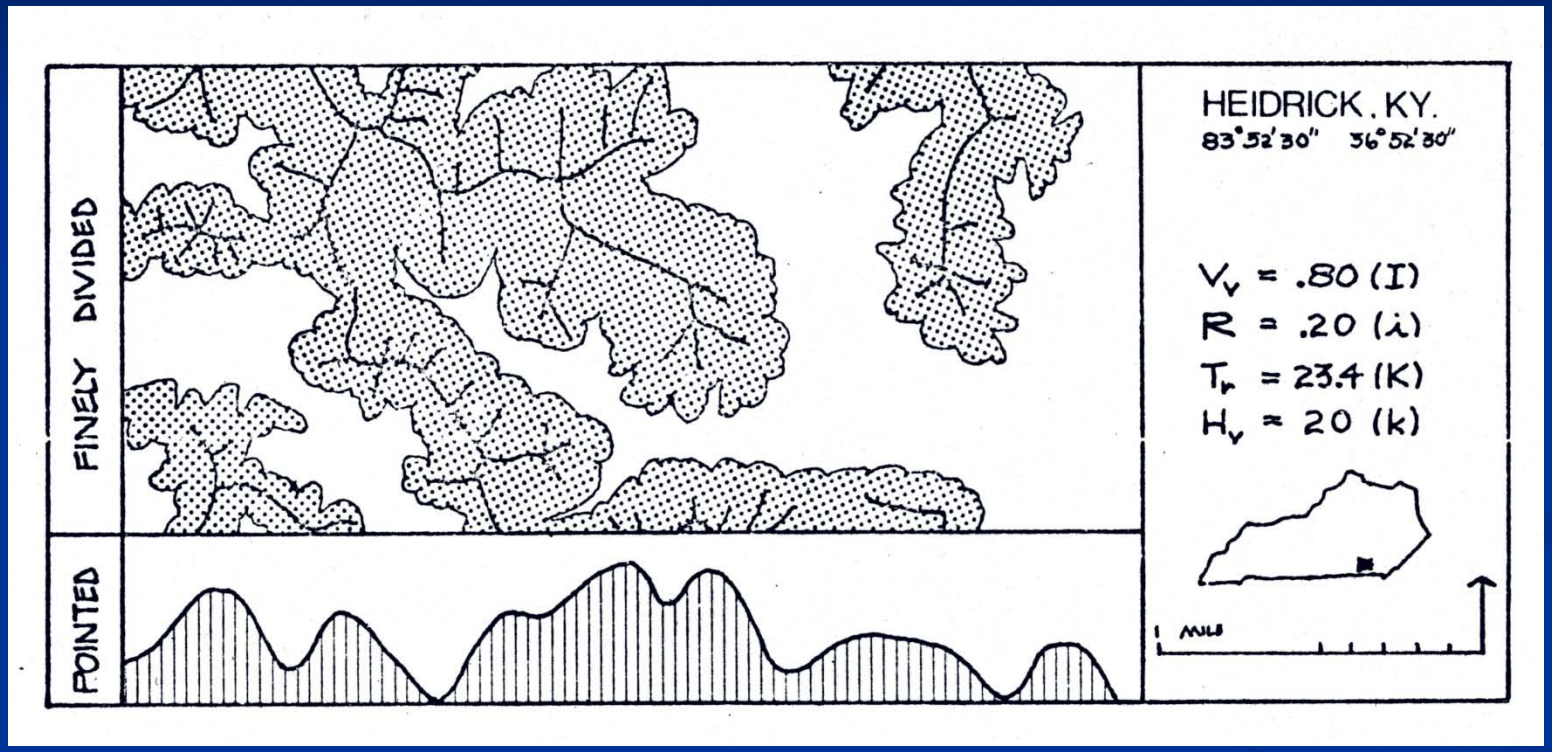
- Mine site within its context scale
  - Elevation, spacing and connectivity of landforms
  - Data, map and field surveys
  - Permit data – if available
- Parameters useful within a mine site
  - Survey and field data collection
  - Permit data – if available
- Detailed site parameters
  - Field survey
  - Historic data
  - Reference landforms
  - Reference reaches

Site context parameters – landform parameters

- Landform texture – e.g. ridgeline length per unit area
- Vertical variation – amplitude of elevation changes on upper slopes
- Reticulation – terrain net patterns
- Horizontal variation – distances to adjacent landscapes at roughly the same elevation

- Parameters measurable from data – DEM, LIDAR, imagery, etc.

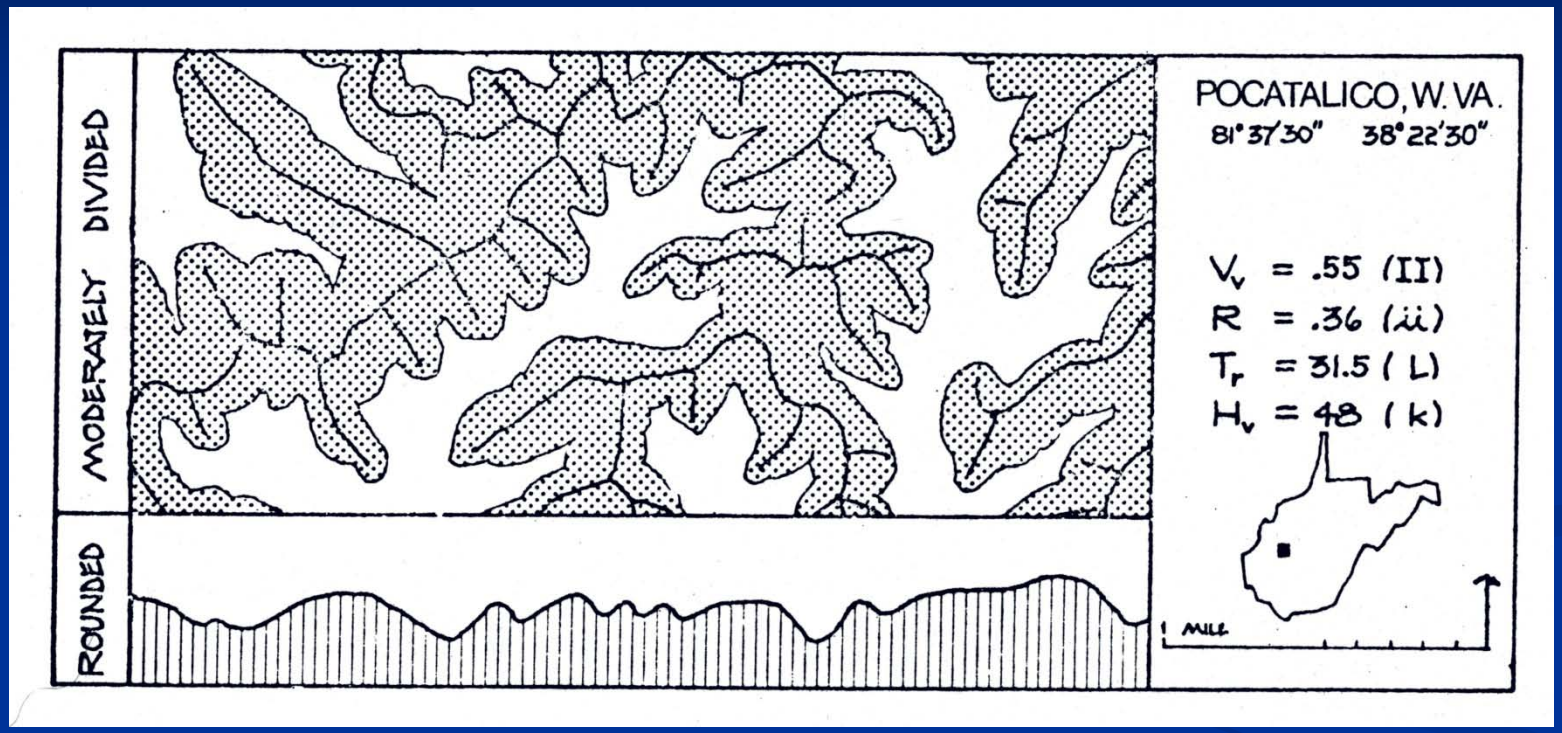
Some examples of the resulting landscapes from this level of classification with results for including landform parameters



Pointed-Finely Divided (Ii)

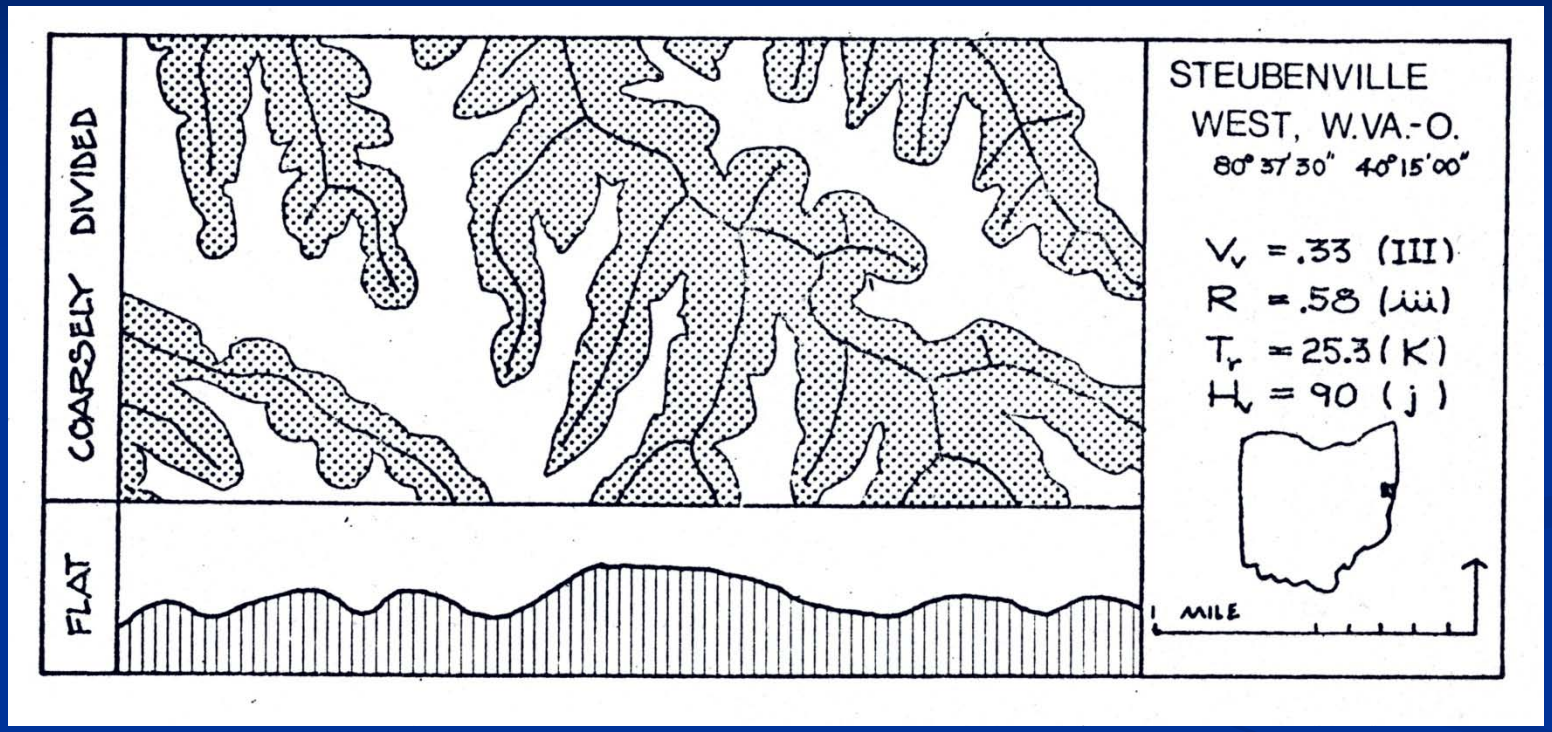
The parameters refer to landform texture, vertical variation, reticulation And horizontal variation

Another landscape within the western Appalachians of West Virginia



Rounded-Moderately Divided (Iiii)

And a third landscape where the Appalachians for flattening out



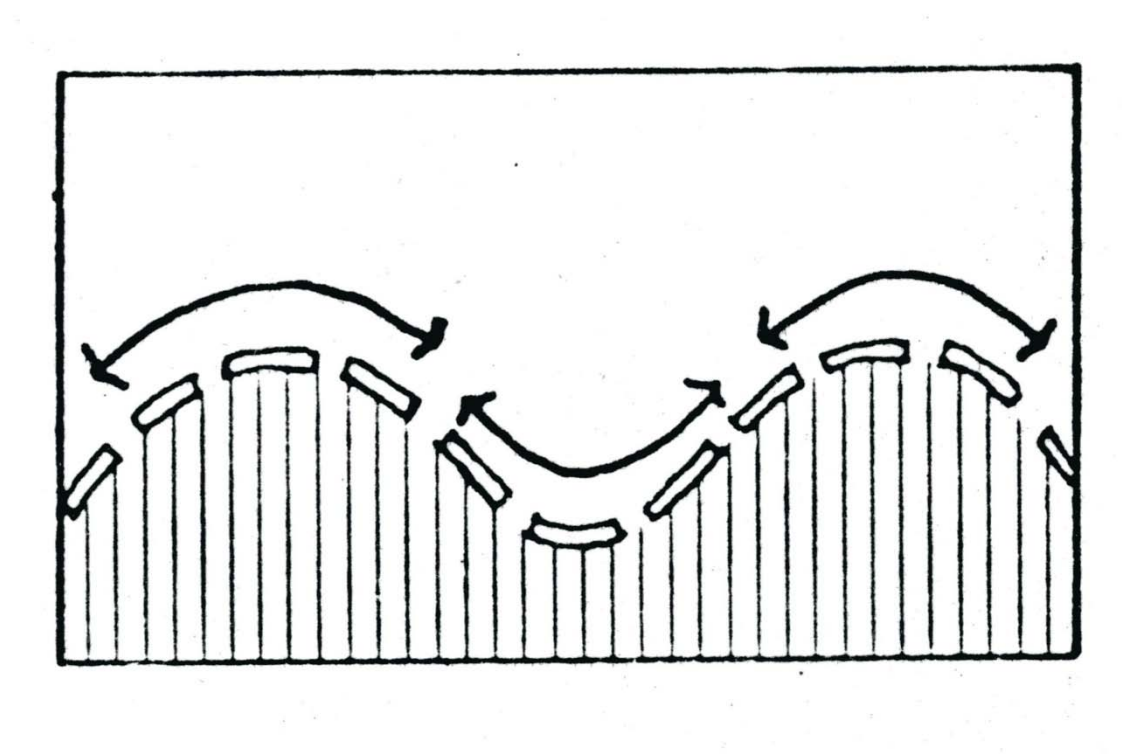
Flat-Coarsely Divided (IIIiii)

The site level – actual details for landforming parameters

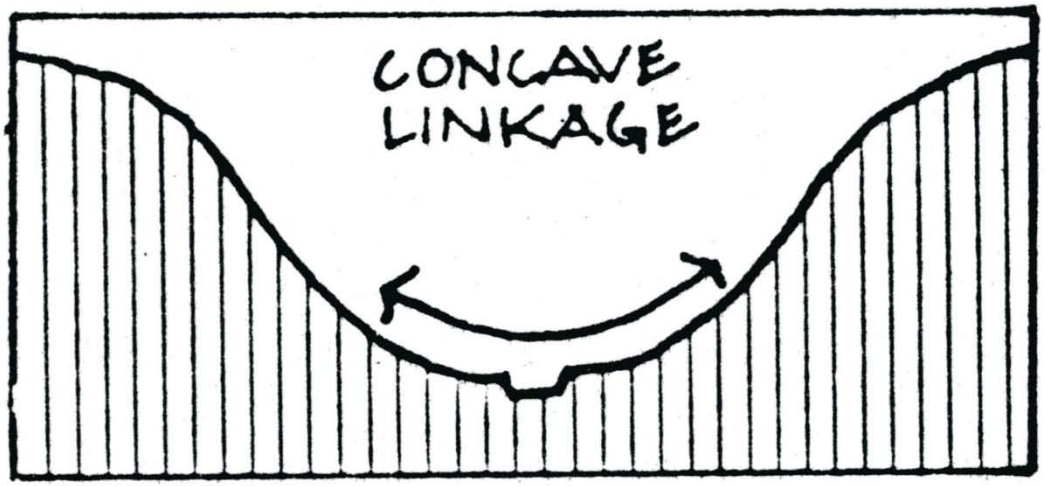
- Crest curvature
- Linkage angles
- Texture – drainage network
- Slope profiles

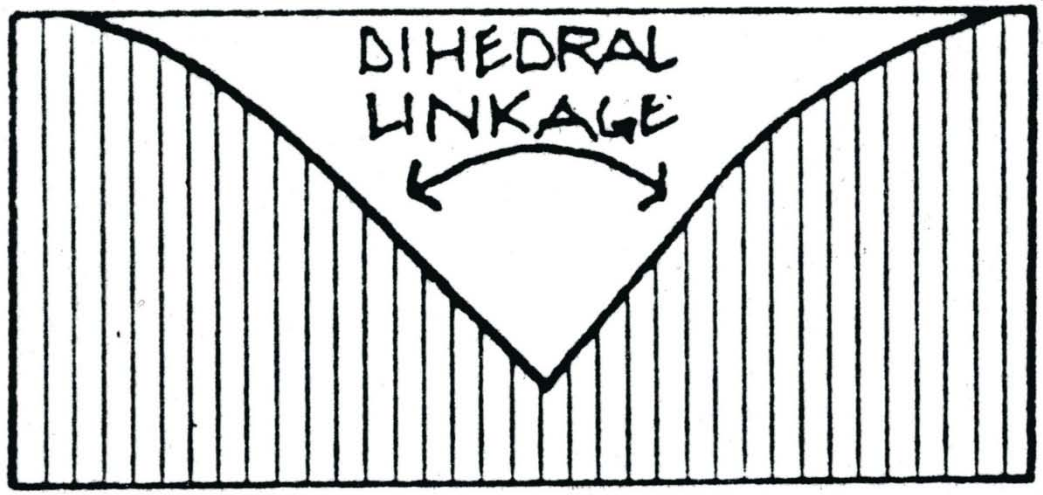
- Field investigations, historic data, reference data

Crest curvature

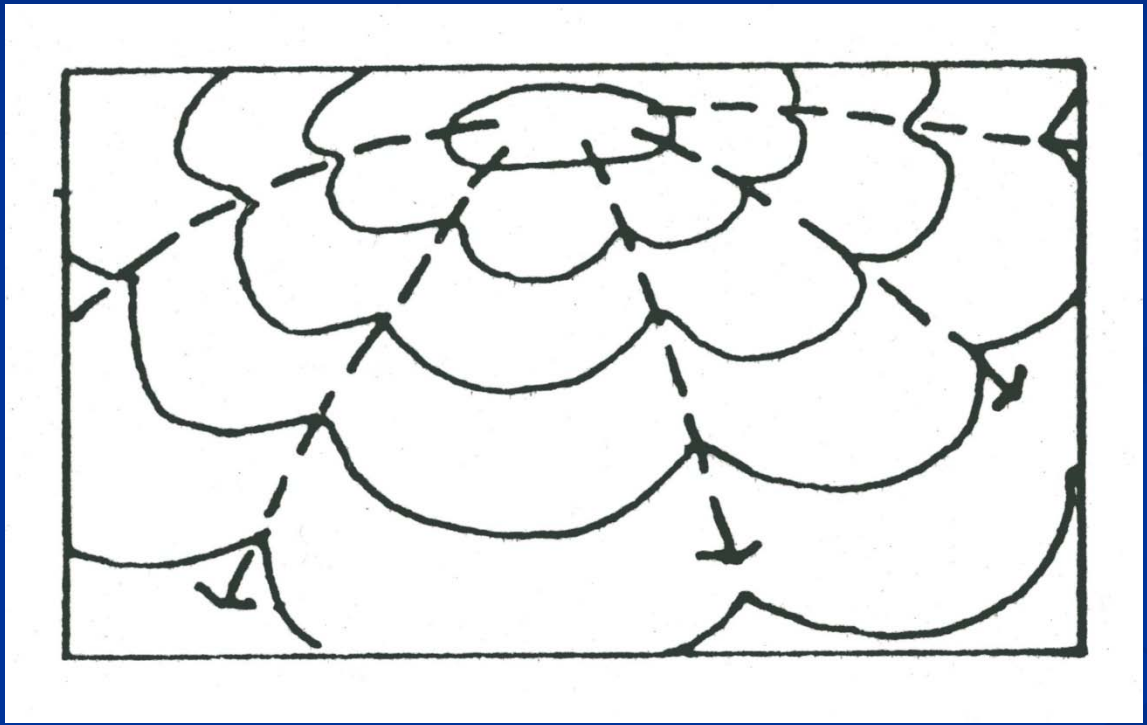


Linkage angle

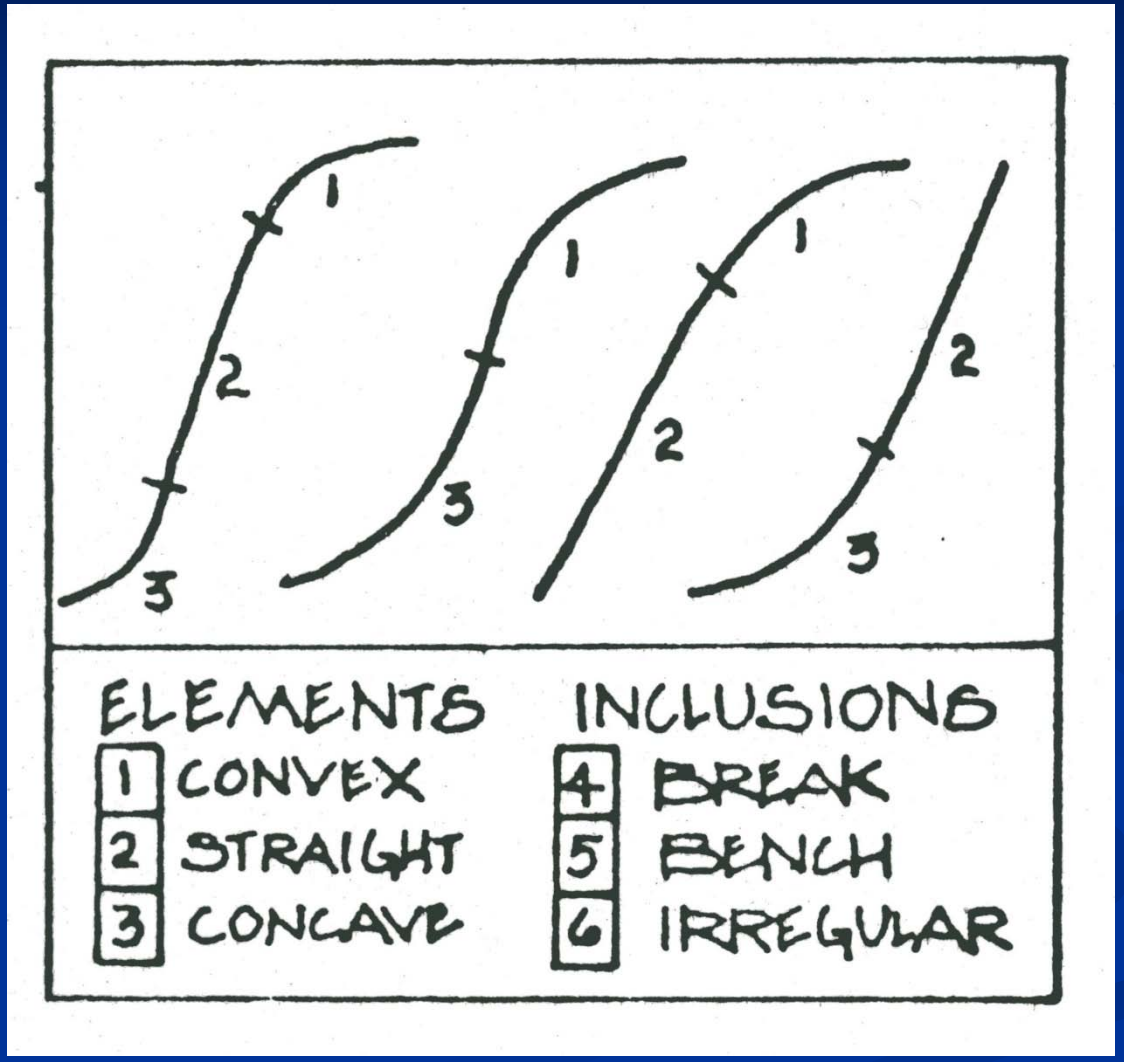




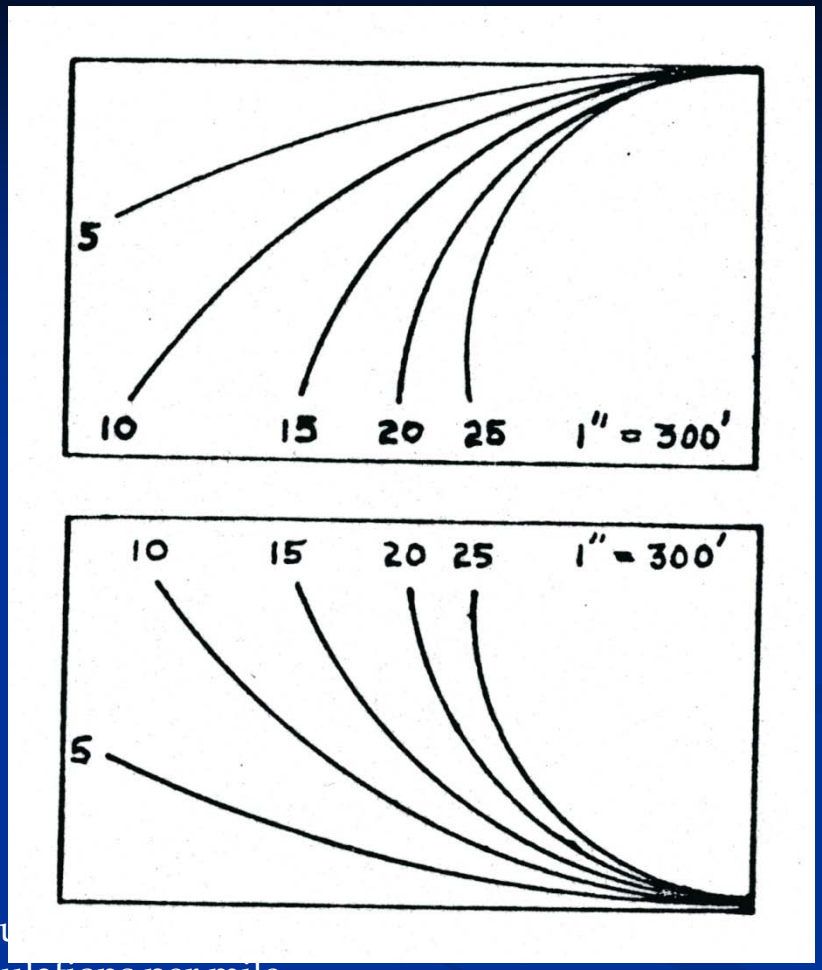
Micro texture / drainage density



Slope profile



	Class	Interval Range
CREST CURVATURE	c1	0° – 5° per 100′
	c2	5° –10° per 100′
	c3	10° – 15° per 100′
	c4	15° – 20° per 100′
	c5	20° – 55° per 100′
	c6	Dihedral Angle
LINKAGE ANGLE	1	0° – 5° per 100′
	2	5° –10° per 100′
	3	10° – 15° per 100′
	4	15° – 20° per 100′
	5	20° – 55° per 100′
	6	Dihedral Angle
MICRO TEXTURE	x1	coarse 5 crenu
	x2	medium 5 - 8 crenulations per mile
	x3	fine 8-11 crenulations per mile
	x4	very fine 11+ crenulations per mile

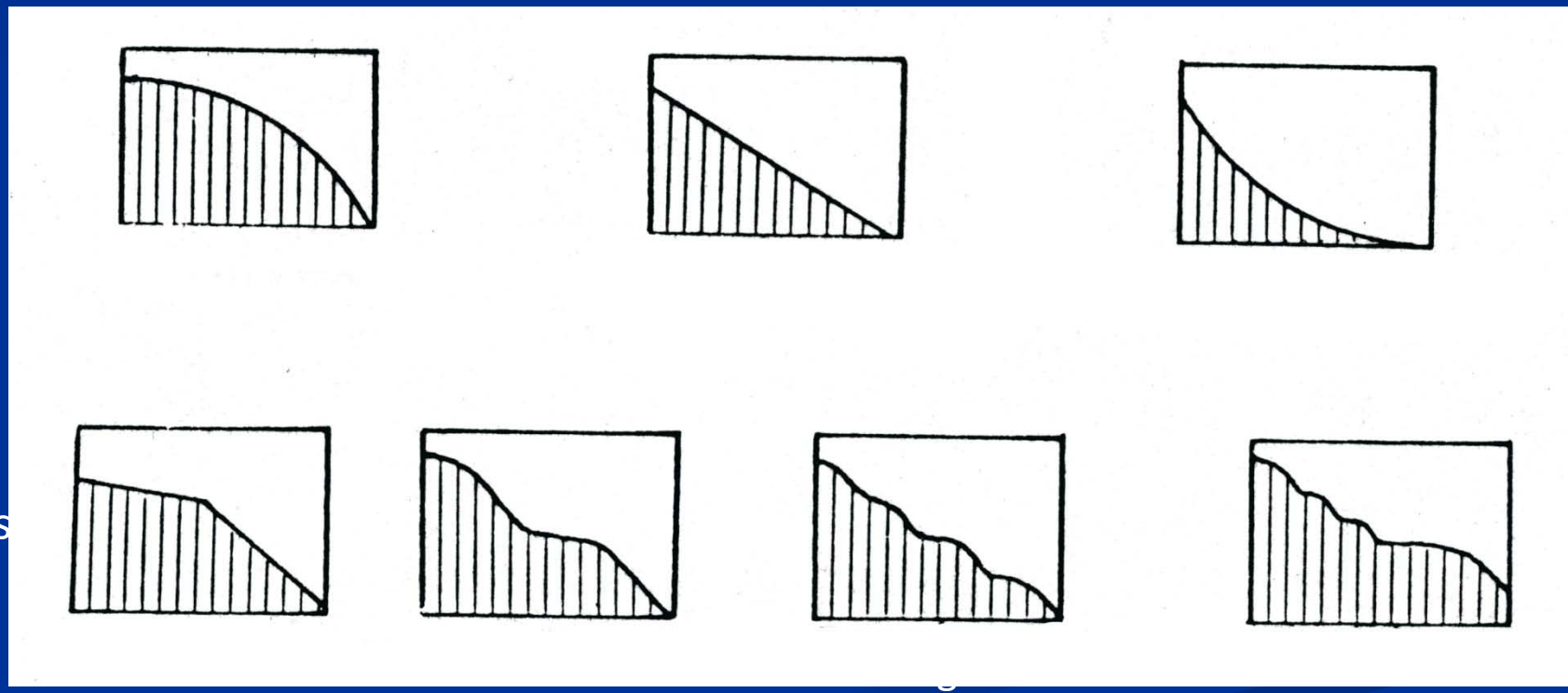


SLOPE PROFILE

Profile is classified by the sequence of curvature elements, codes 1, 2, 3 and by the presence of profile inclusions, codes 4, 5, 6 and 7.

Elements

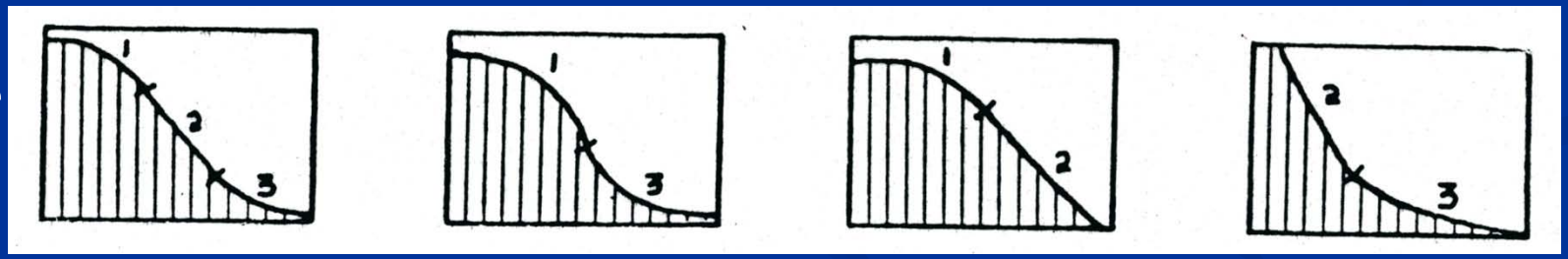
Inclusions



of 4, 5 & 6

Four sequence types, coded A, B, C, and D are designed and described below. By noting the presence of inclusions (e.g., A5, D6, etc.), a fairly sophisticated description and classification of slope profile is possible.

Sequence Types



Type A	Type B	Type C	Type D
1-2-3	1-3	1-2	2-3

Such a system….

- Opportunities for understanding terrain systems using measurable terrain parameters
- A design framework for post mining land shaping
- A system for evaluating alternative plans – qualitatively and quantitatively

- A system based in…
  - Geomorphic descriptions and processes
  - Helps place surface hydrology on the land
  - Language used by engineers, landscape architects and other landforming professionals
  - Uses historic patterns and reference data whenever possible

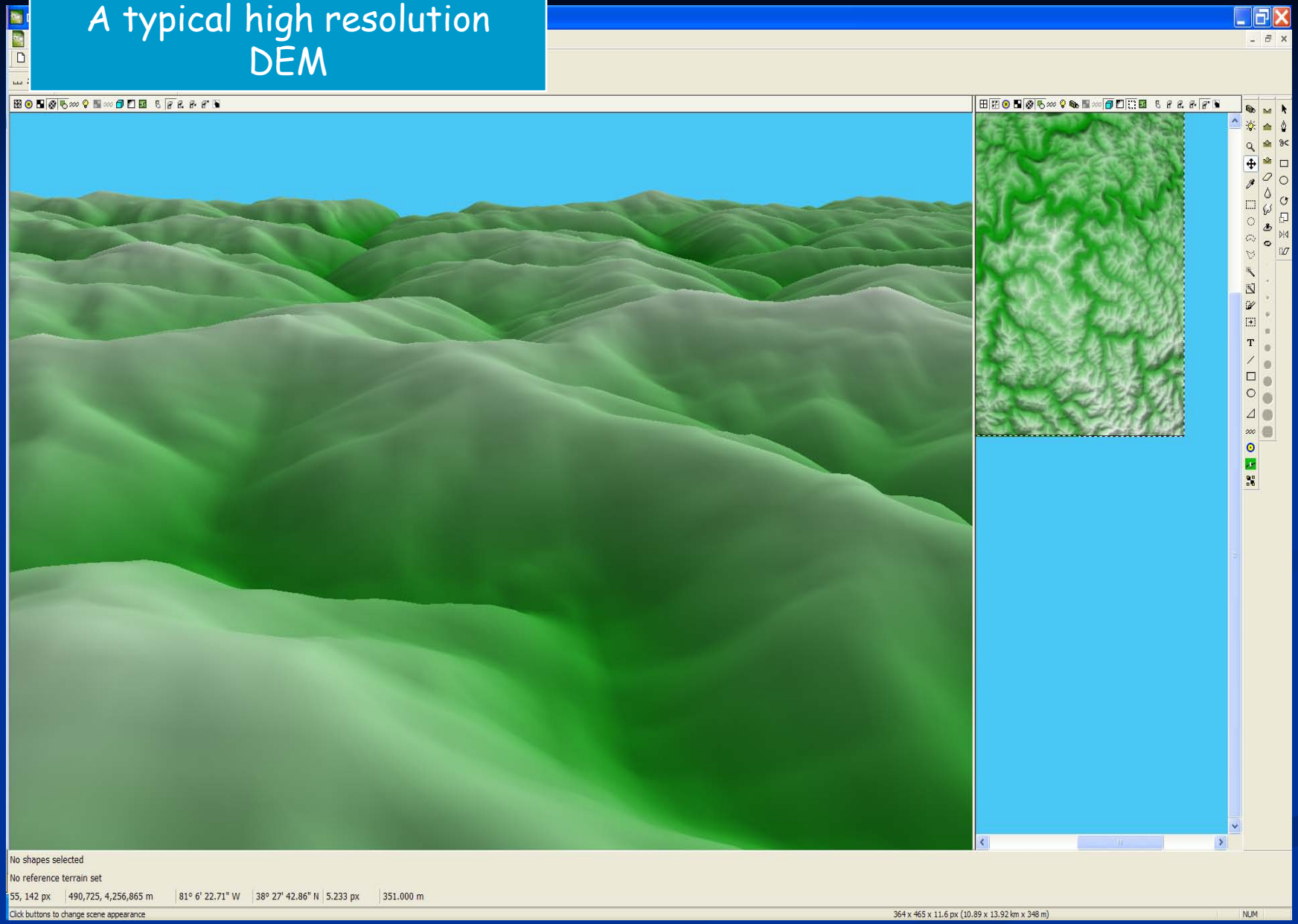
A second component we are interested in exploring

- Landforming – design and pre-engineering
- Basic methods derived from evidence that engineering and design that focuses in 2D plan view design is often difficult to visualize during plan development
- 3D methods may present us with pre-engineering opportunities for landforming
- 3D methods can feed traditional engineering documentation development

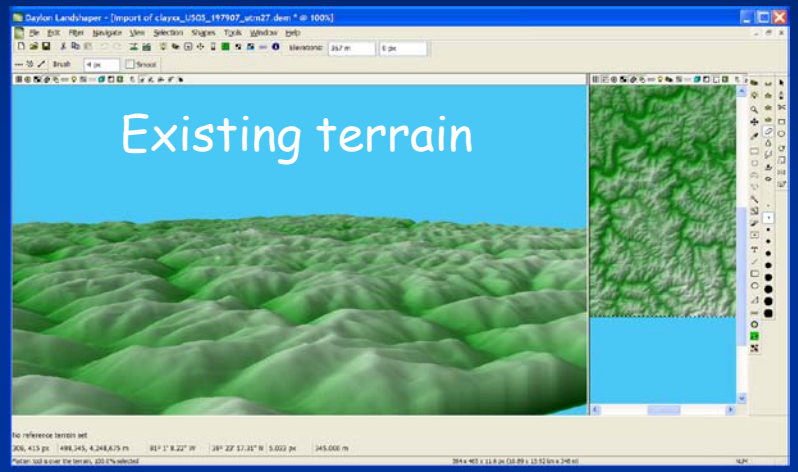
We are working with two approaches

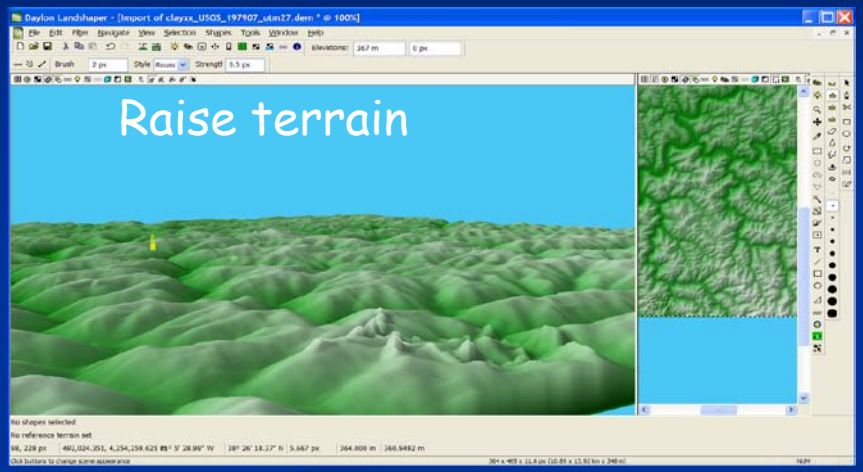
- The earlier on-the-fly landform manipulation tools
- A more controlled set of landform manipulation primitives
  - Currently prototyping a workable mining landforming system with of-the-shelf-software – landshaper sdk – can be standalone or embedded in other applications.

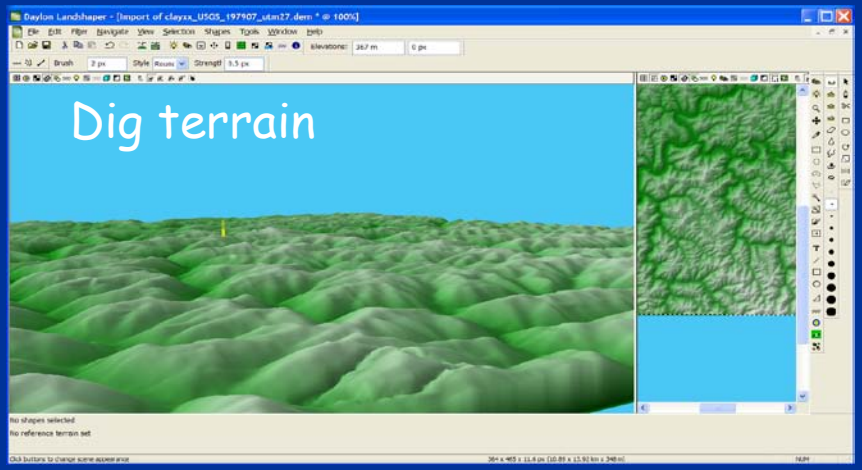
A typical high resolution DEM

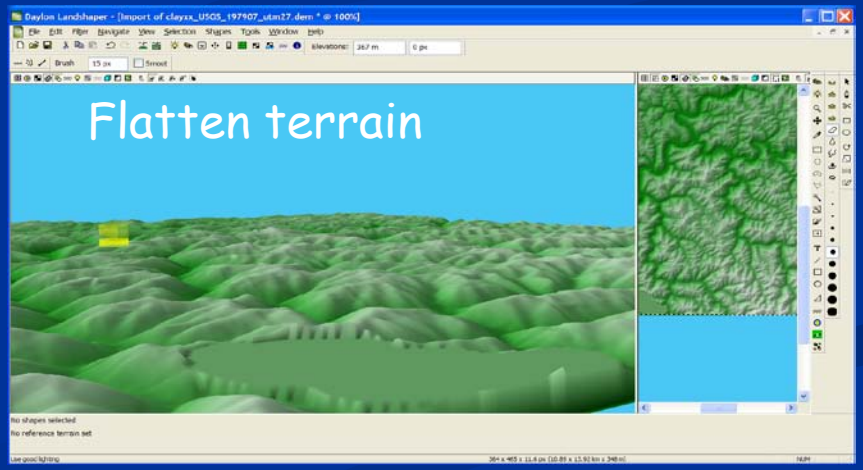


Some terrain modification tools – from a larger toolset



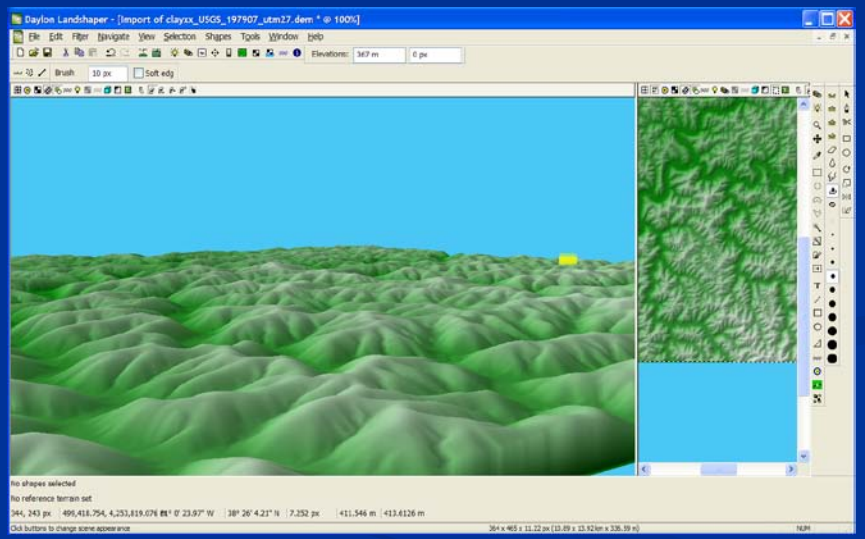






One more to mention…erosion

- This has been linked to the results obtained with the SIBERIA/EAMS erosion model which has utility to long term modeling of erosion potentials in disturbed landscapes.



Terrain / land shaping

- Can then subject all modified terrain to various assessments using GIS or other software
- Can kick alternative landforms back to our visualization functions

- There are over 30 such individual commands. Individual primitive commands can be chained together to form complex landforms such as
  - Fills
  - Backfill / backstack areas
  - Haul roads
  - Stream channels
  - Highwall backfills

A project initiated in the Central Appalachians

- Initial planning for 16,000 acres of a total 45,000 acre area
- Various mining methods over the site over a proposed project period of 20 years
- Intensive land uses are proposed or visualized as a part of the project
- A proposed 20 mile scenic and economic byway is proposed for the area
- Development is emerging as a private / public partnership

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Project Introduction

Mission Statement

Create a visual management plan and improve roadway alignment on a 16.5 mile section of the Clay-Nicholas Economic Corridor. Suggest basic alignment of the roadway to make the drive more desirable and visually pleasing in an extensively mined area of Clay County. Utilize reclamation techniques to buffer and naturalize areas of mining. Implement low impact design practices to encourage long term sustainability and improve water quality within the corridor.

Goals/Objectives

Goal 1:
Enhance the transportation network by producing a faster, safer route between Clay and Summersville that can accommodate the traffic of heavy industry. Yet, emphasizes the area's natural beauty in the overall design scheme to create a scenic, desirable drive.

- Suggest an improved roadway alignment for the Clay Corridor supplemented by an arc and tangent layout.
- Implement sweeping horizontal curves into the roadway for a safe commute.
- Maintain grades of less than 15% for industrial traffic.
- Design roadway layout to optimize the full spectrum of intrinsic qualities.
- Buffer undesirable visual features along the corridor.
- Enhance desirable naturalistic features.
- Utilize points of topographical prominence for possible visual opportunities.
- Preserve the adjacent streams near the corridor when design the road layout.
- Capture natural terrain features to convey scenic drive.

Goal 2:
Site educational, commercial, industrial, and residential facilities while preserving the scenic view for a wide range of residents along the corridor.

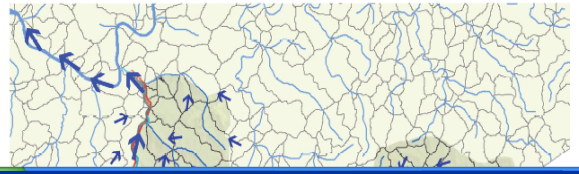
- Propose three land-use plans using variations of educational, commercial, housing, and industrial space.
- Clay County High School and vocational building will be included in the educational area.
- Preserve non-mine areas for future development.
- Preserve the land in the corridor view shed for a naturalistic experience.
- Current valley fill permitted areas will be preserve

Goal 3:
Reduce environmental impact within the corridor by proposing development only on mine permitted areas. Incorporate the area's natural aesthetic features to convey a more naturalistic and visually pleasing drive to residents and other users of the corridor.

- Re-grade surface area affected by mining for a more natural landscape.
- Re-vegetate area with native plants to complement existing vegetation.
- Utilize Landform Grading Principals where applicable
- Implement wildlife corridors along the Clay Corridor.
- Use grass swales where needed.

Area History

Clay County was formed in 1858 from parts of Braxton, Kanawha, and Nicholas Counties and was named in honor of Henry Clay, a Kentucky statesman. We declared our statehood in 1863. Clay County has around 10,120 residents, all of which are located in rural areas. This brings the population density to only thirty people per square mile. In actuality the population has declined from the 1960's and 1970's in Clay. Clay County is made up of about 3,200 county owner-occupied homes and about 900 renter occupied apartments, make about 21% of renters. Clay averages about 2.5 people per household. This figure should be considered when designing housing units. The average rent in Clay in about $250 a month. With an average income of around $27,000 Clay is under the state average at $37,000. Estimated averages of condos in Clay are around $75,000 while detached homes average around $125,000. Clay is predominantly made up of Caucasian Americans (98%) while gender numbers are even at 50% for men and women. The mean annual temperature is 55 degrees and the mean annual snowfall ranges from 22 to 40 inches. The county area is 346.1 square miles, while two thirds of the county lies at elevations of 1000 feet above sea level.



Program Elements

Education
Housing
Business
Recreation
Low Impact Design
Roadway

Program Relationships

Education

- Clay County High School
- Clay County Technical Center
- Arboretum
- Football Field
- Baseball Field
- Fitness Center
- Archery Range
- Driving Range
- Golf Facility

Housing

- Single Family Homes
- Multi-Family Attached Units
- Apartments
- Business
- Business Incubator

Commercial Park

- Industrial Space
- Medical Facility
- Private Practice Physician Space
- Restaurant

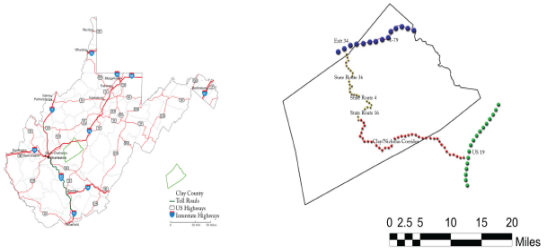
Low Impact Design

- Bioretention areas
- Bio Swales
- Vegetation Buffers
- Native Plants
- Mine Reclamation

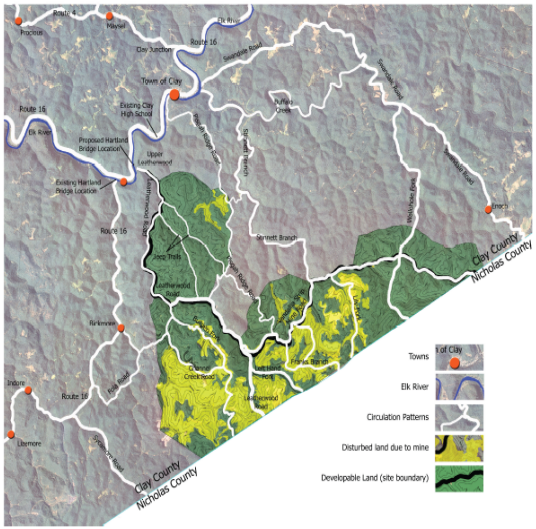
Sheet Flow
Channel Flow
Perennial Stream (Leatherwood Creek)
Sub Watersheds
Proposed Corridor

Location, Climate, and Hydrology

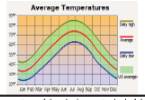
Site Location Maps



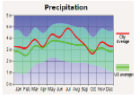
Site Context Map



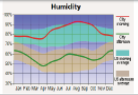
Climate Information



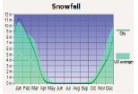
The temperature of the site is very typical of the northeastern part of the country, and enjoys all four seasons evenly throughout the year. In winter months the temperatures can stretch from 20 F to 45 F, while summer averages from around 60 F to 85 F giving the area a balanced seasonal weather pattern.



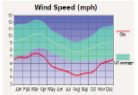
The region's precipitation levels are slightly higher than the rest of the nation. The rainfall is the highest in July, right under five inches. February is the lowest month for precipitation, right about three inches. Due to the average levels of precipitation and slopes within the area the site will need increased stormwater management implementations.



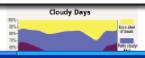
Humidity patterns in this region usually are within the normal range of the rest of the nation. Morning humidity levels are at their highest in September, around 90%, while the lowest humidity level is in April, about 50%. The largest stretch of humidity takes place from May to September.



The past snowfall patterns indicate that the site receives more snow then our nation's average. Average snowfall can reach of eleven inches in January, with the nation's average being just above five inches. Snowfall will be a factor when designing on ridge tops within the site.



The region's average wind speed is below the nation's average throughout the year. Overall wind should not be a major concern for the corridor location; however possible ridge top development locations may provide excessive wind which will need to be accounted for.



Circulation Analysis

The route of the proposed corridor is made up for three main roads. The first road, located nearest to the Elk River, is Leatherwood Road. Leatherwood Road runs along the proposed corridor route until mile seven when the Vandellia Strip Mine Road continues the proposed route. The two roads are separated by a stream. Vandellia Strip Mine runs along the corridor until about mile sixteen, into Nicholas County, when it

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Clay Corridor Mine Site

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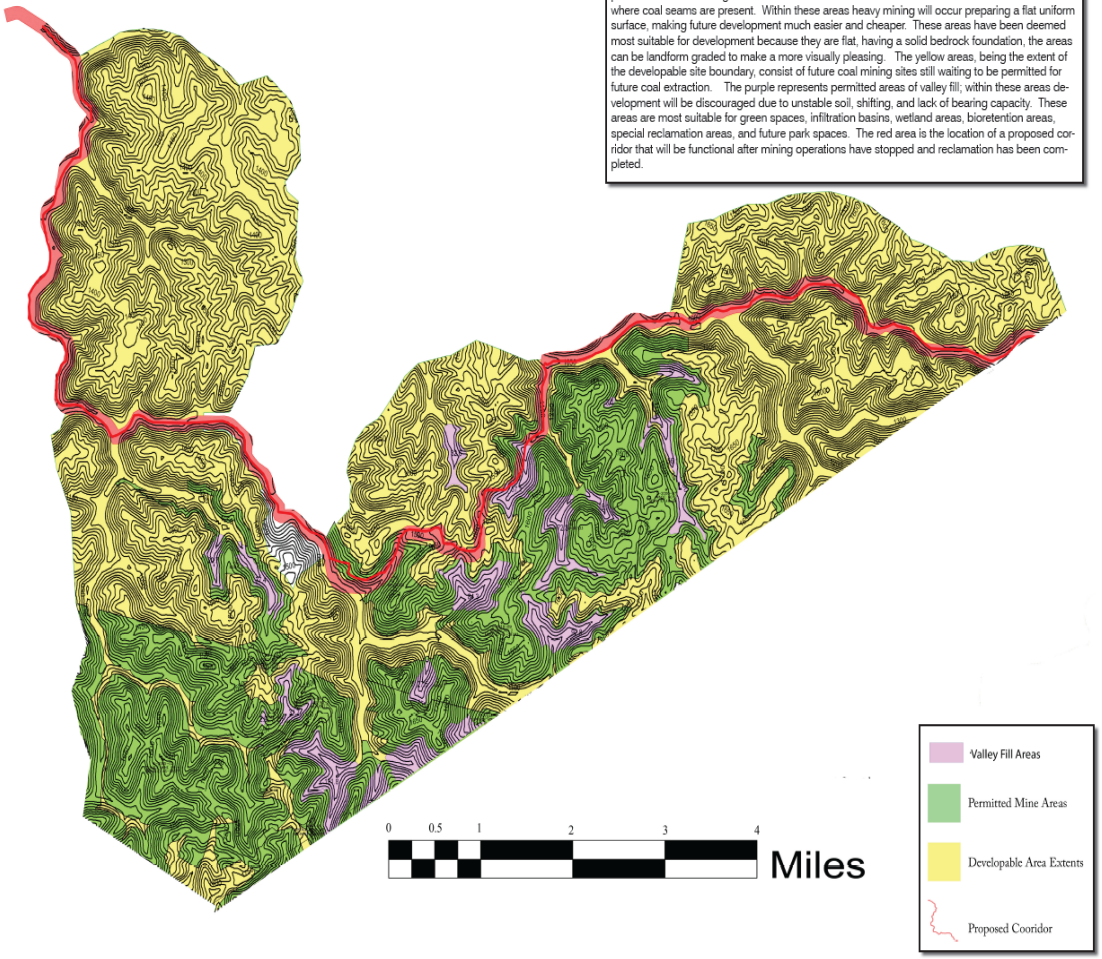
The composite analysis was completed by studying mining permits, contour mining areas, strip mining areas, site boundaries, and permitted valley fill areas. The green areas within the site are permitted surface mining areas that are focused on the 1200 foot and the 1400 foot contour areas where coal seams are present. Within these areas heavy mining will occur preparing a flat uniform surface, making future development much easier and cheaper. These areas have been deemed most suitable for development because they are flat, having a solid bedrock foundation, the areas can be landform graded to make a more visually pleasing. The yellow areas, being the extent of the developable site boundary, consist of future coal mining sites still waiting to be permitted for future coal extraction. The purple represents permitted areas of valley fill; within these areas development will be discouraged due to unstable soil, shifting, and lack of bearing capacity. These areas are most suitable for green spaces, infiltration basins, wetland areas, bioretention areas, special reclamation areas, and future park spaces. The red area is the location of a proposed corridor that will be functional after mining operations have stopped and reclamation has been completed.



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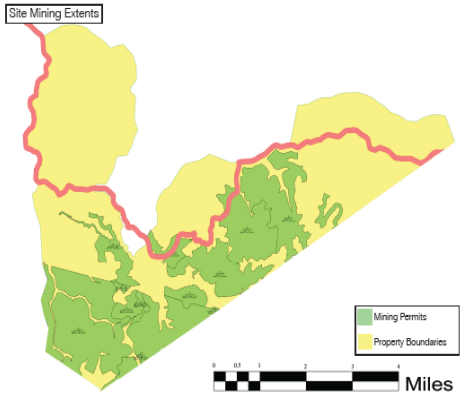
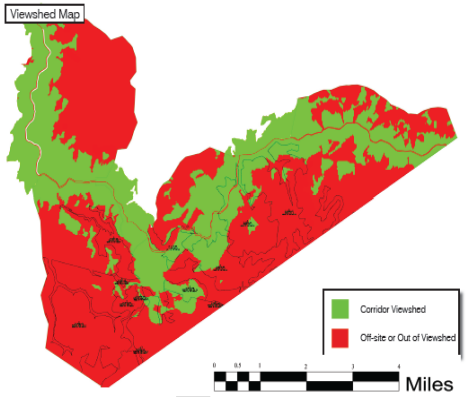
Design Development

Site Mining Extents

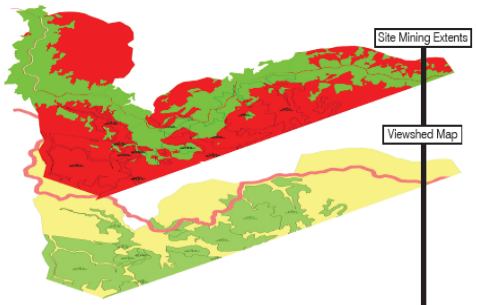


This site map shows the extends and boundaries of the mining permits that are current within the site. When identifying areas that were critical for reclamation, many factors were taken into consideration. Proximity of the mining permit areas to the site development areas, and the corridor had to be understood to begin formulating methods for identifying the key areas for reclamation.

Viewshed Map

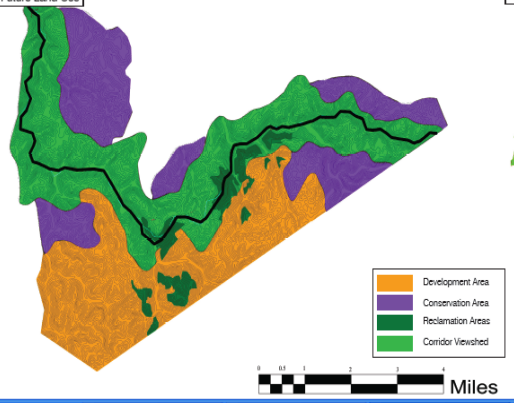


After understanding the mining permit extents and locations, a viewshed analysis was done to give a better understanding of what a passer by driving on the corridor could actually see. From this analysis we were able to conceptually formulate a plan based on viewshed areas and permit areas.

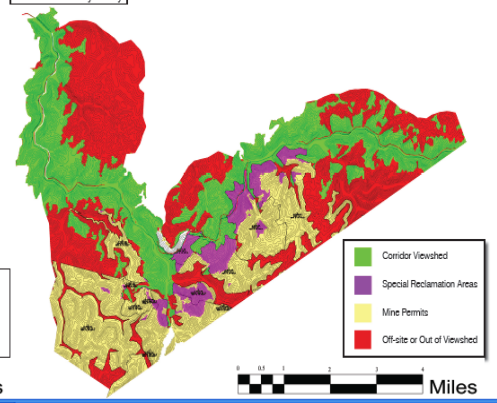


After doing a map over lay of the mining extents map and the viewshed map, the conceptual viewshed map was made to give a general representation of where potential visual impact areas would be. These areas were outlined in purple, and gave a quick representation of where these areas were.

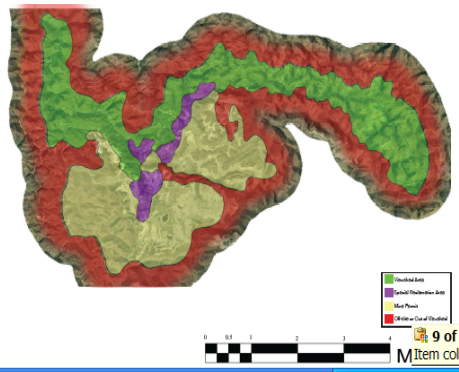
Future Land Use



Visual Sensitivity Study



Conceptual Viewshed Map



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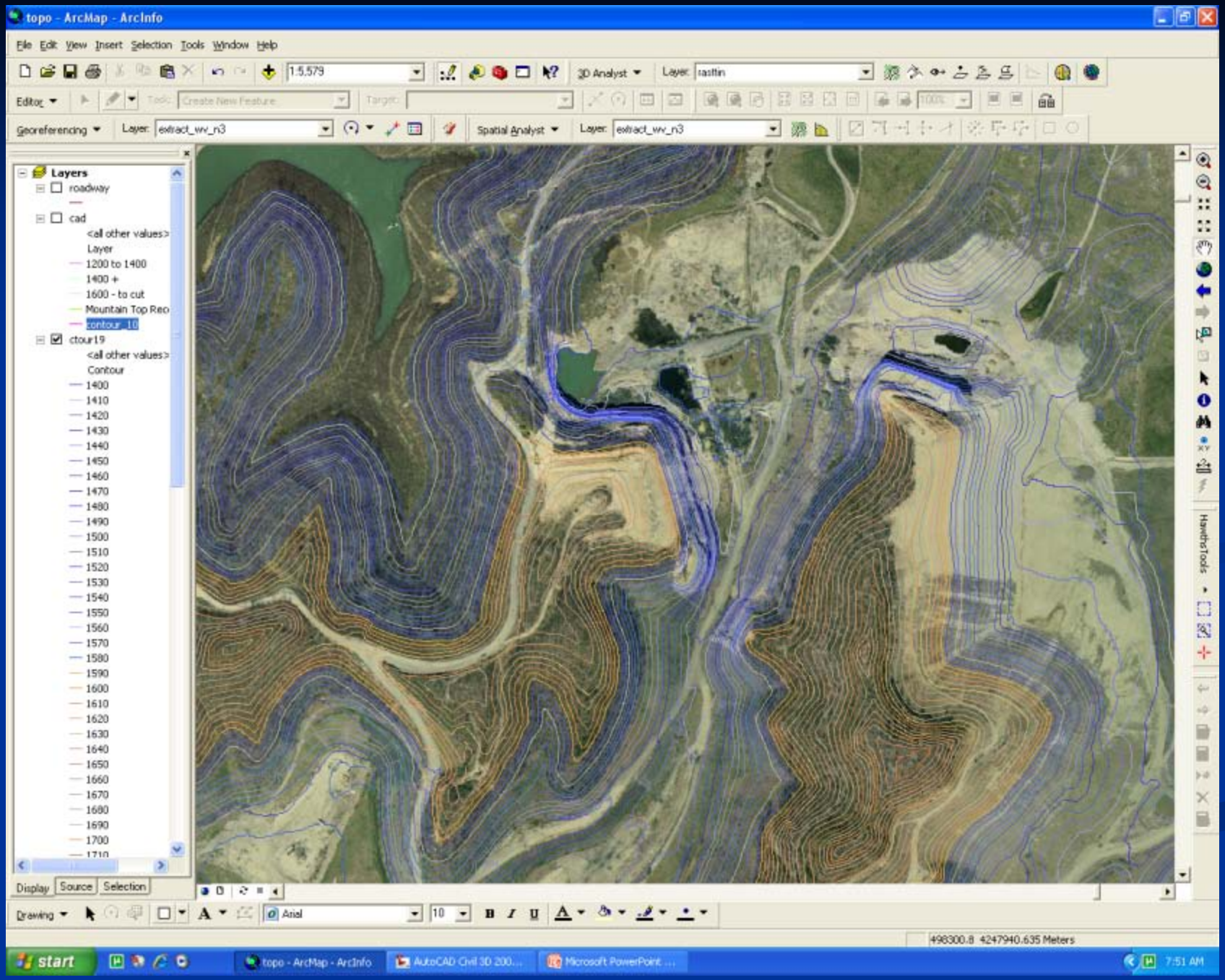
So the project

- Large mine and re-mining areas
- All new mining is being evaluated for some degree of geomorphic reclamation
- Critical areas are being planned with close attention to landforming details

Basic project methods

- Work from past reclamation, current permits and proposed future mining
- Use land use planning and viewshed analysis to establish general landforming goals
- Complete landform analysis using site context and site parameters to quantify current conditions
- Develop preliminary landforming strategies using landforming tools
- Review and finalize preliminary landforming strategies using analysis functions from WCMS and EAMS

- MAJOR ISSUES – integrating new reclamation with recent reclamation and with land use goals.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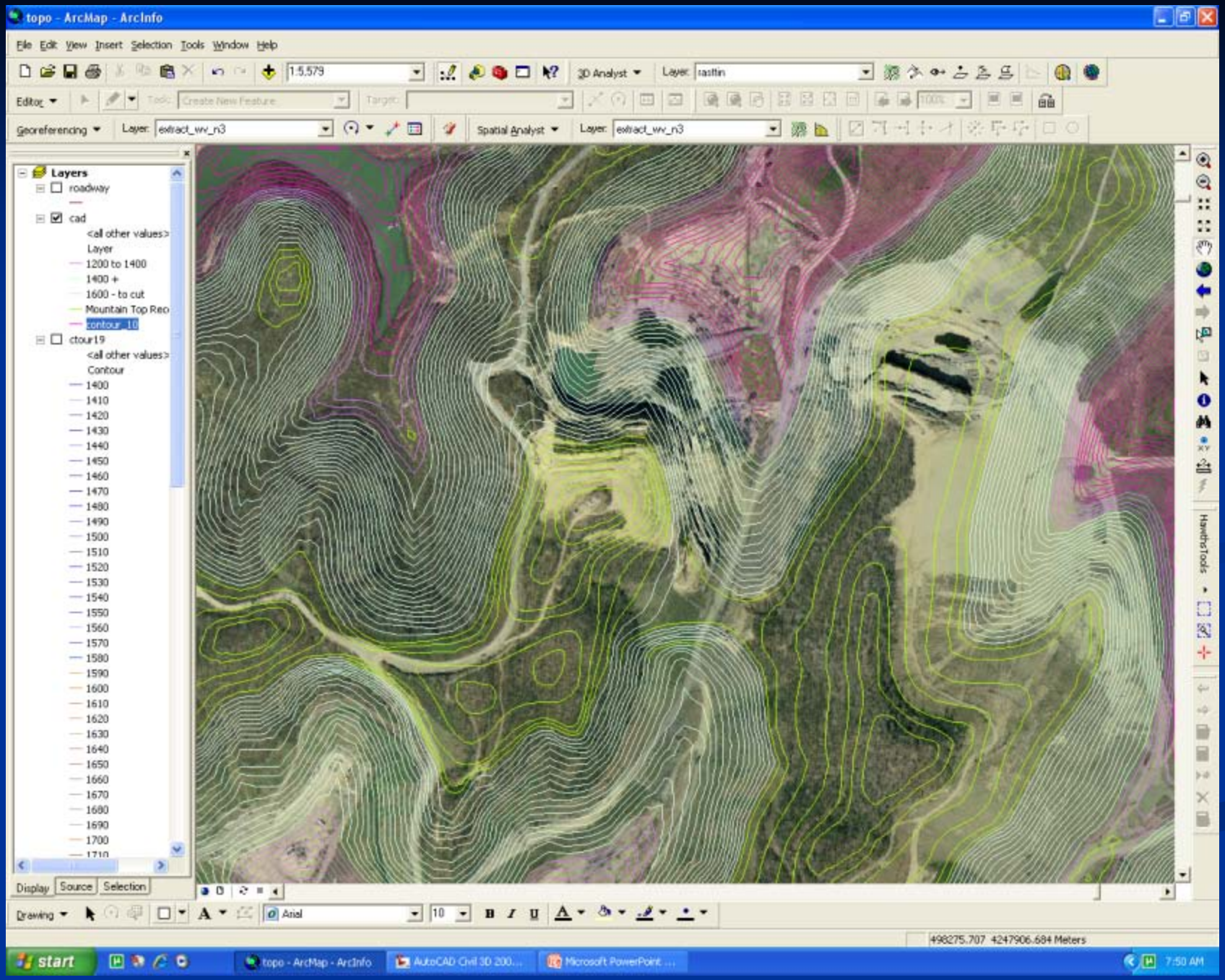
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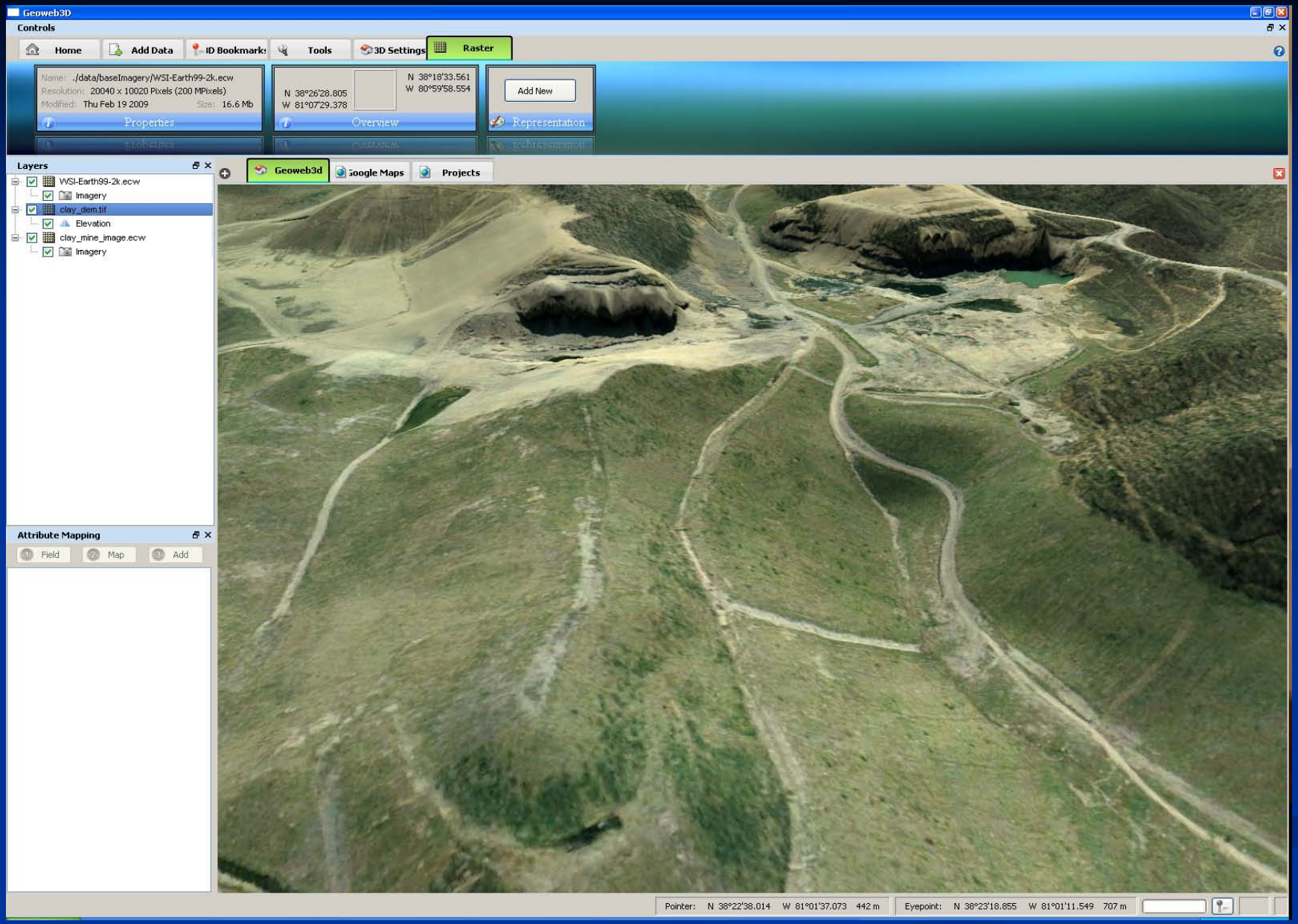
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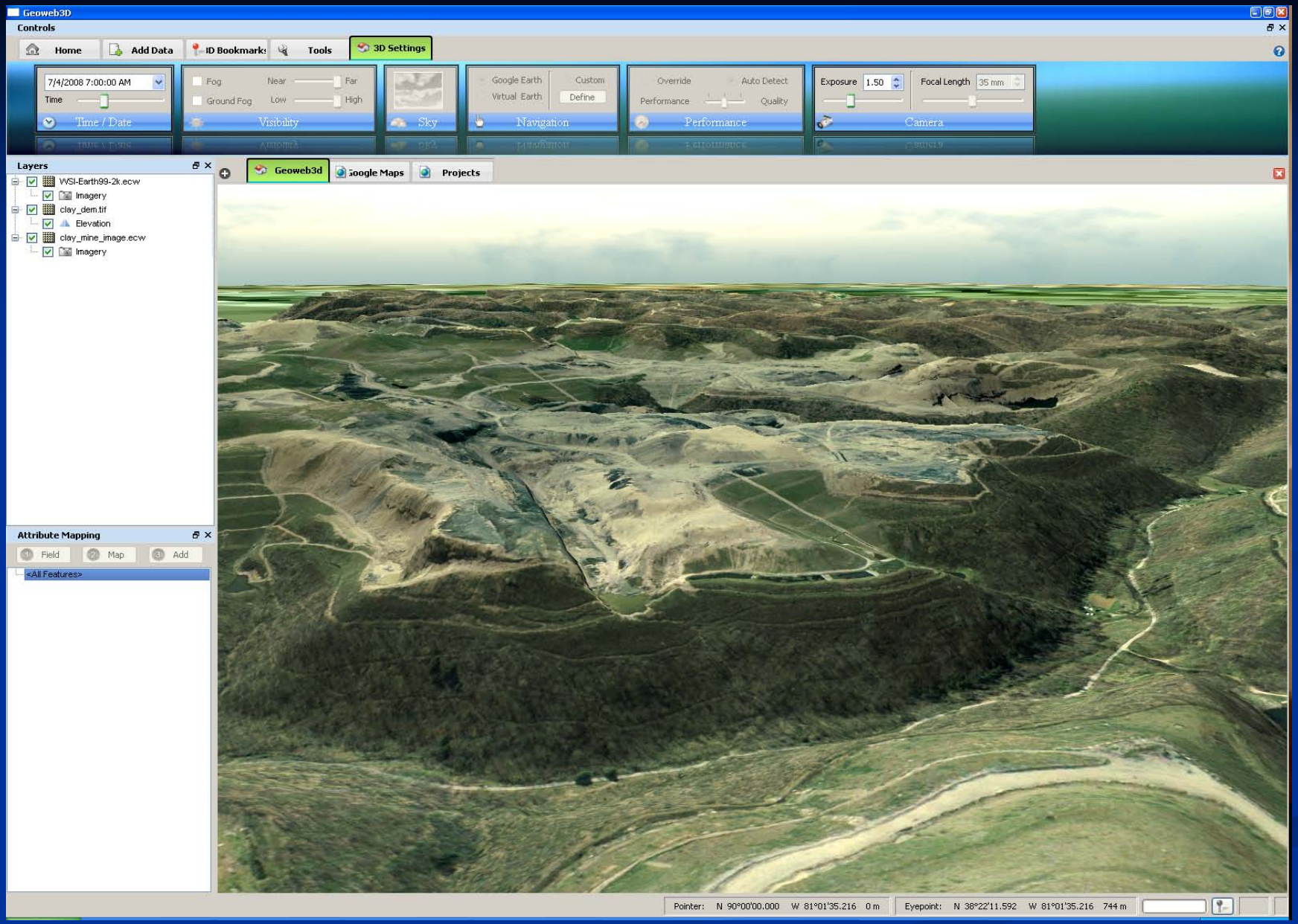
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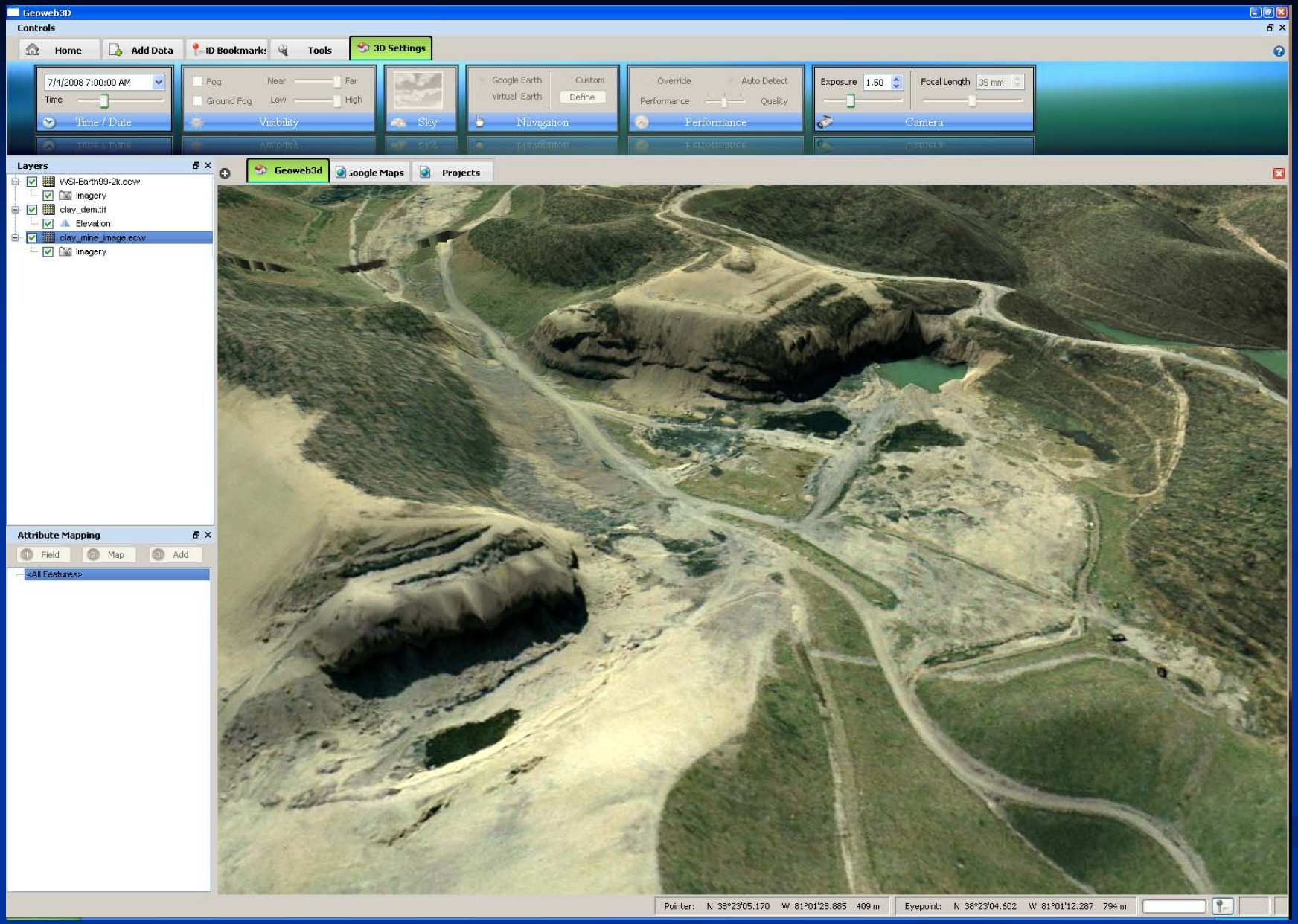
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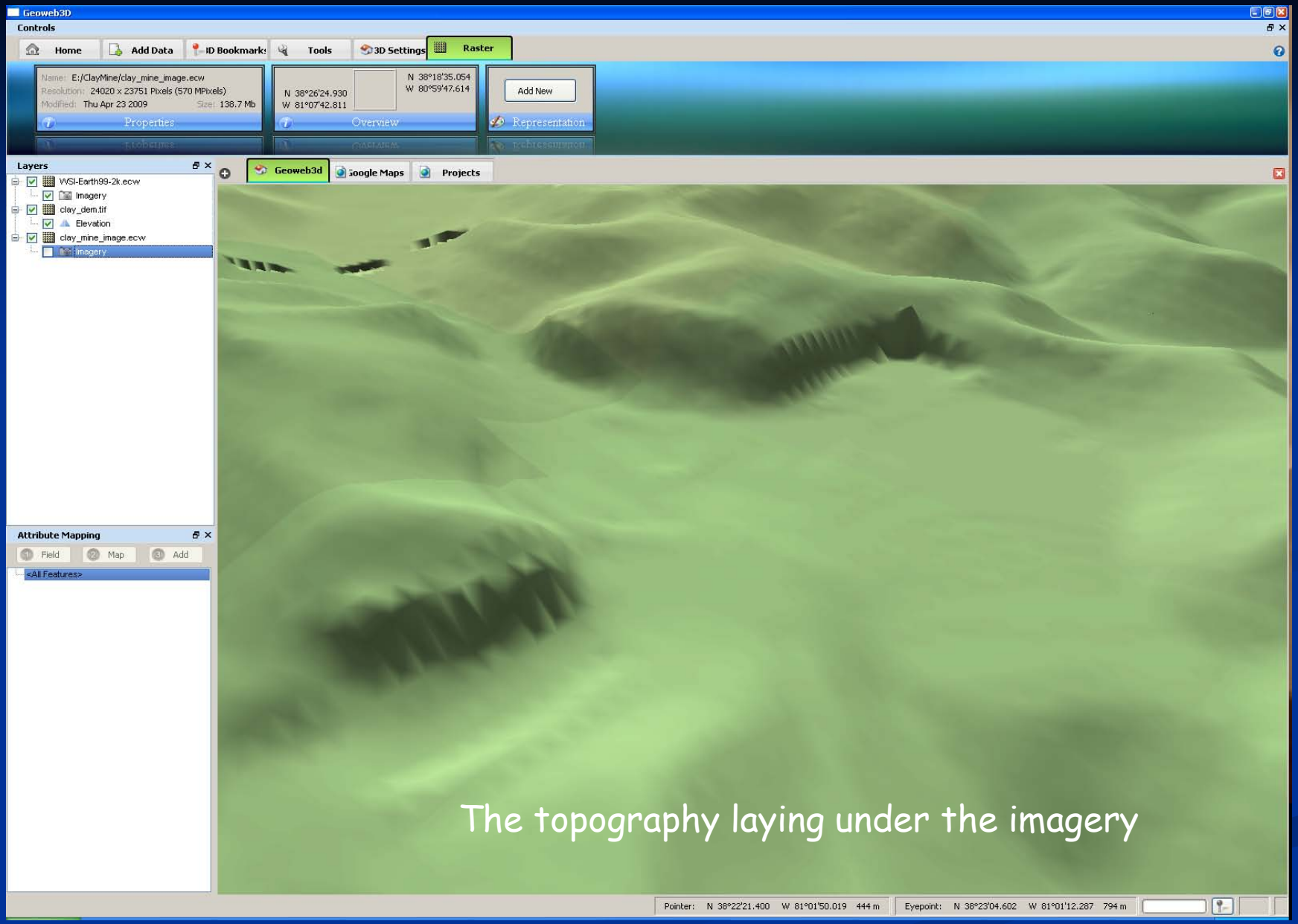
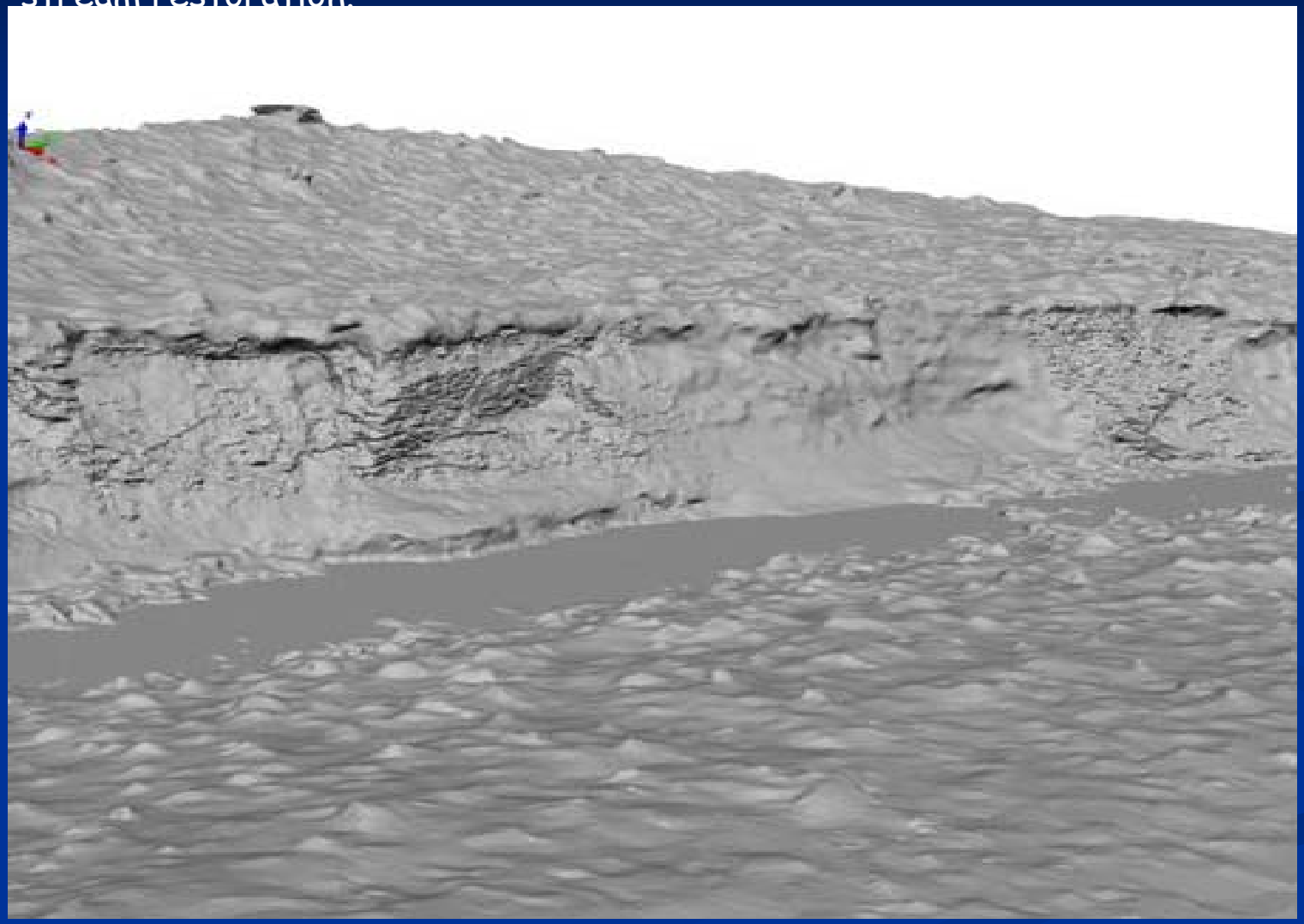
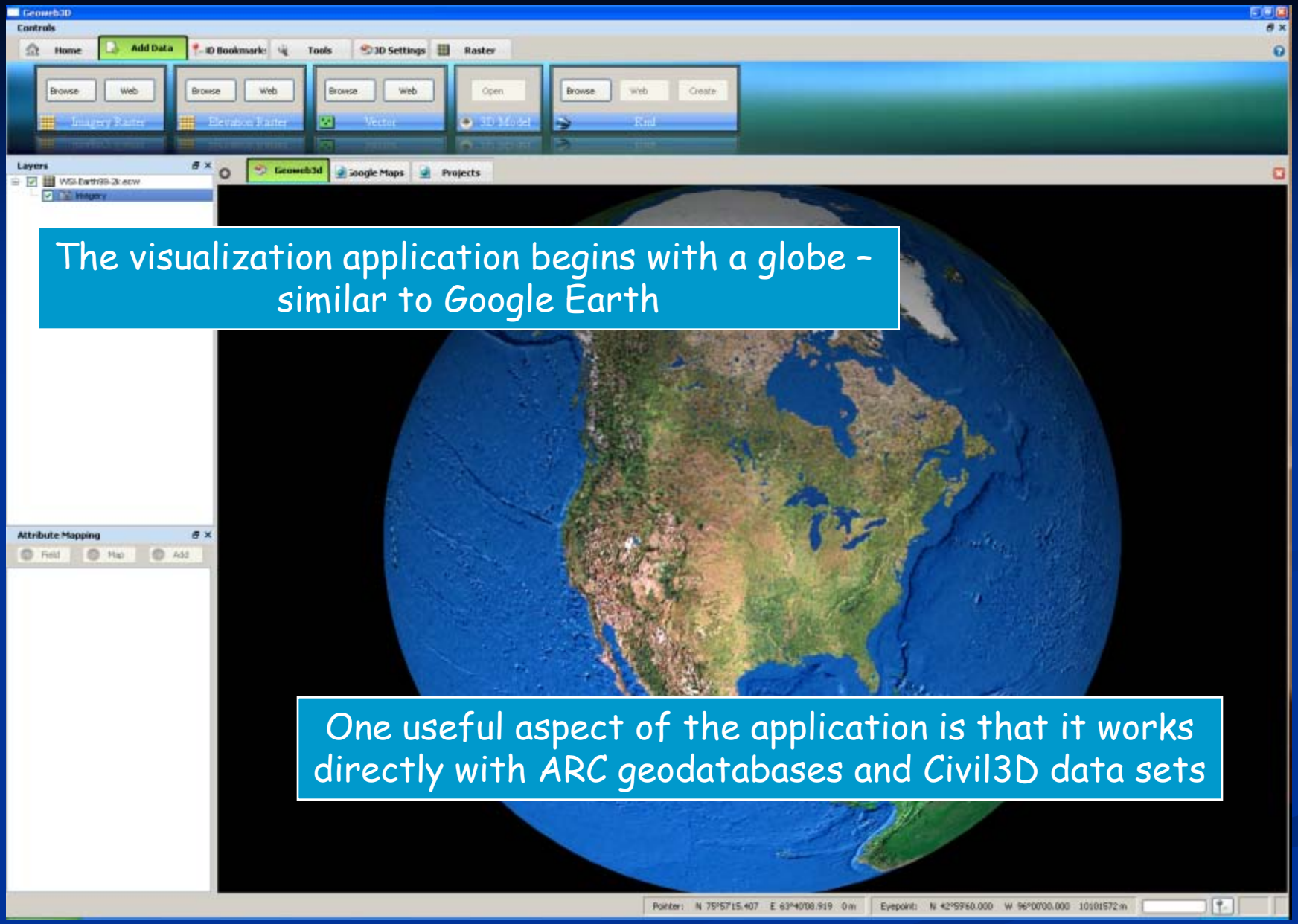


The topography laying under the imagery

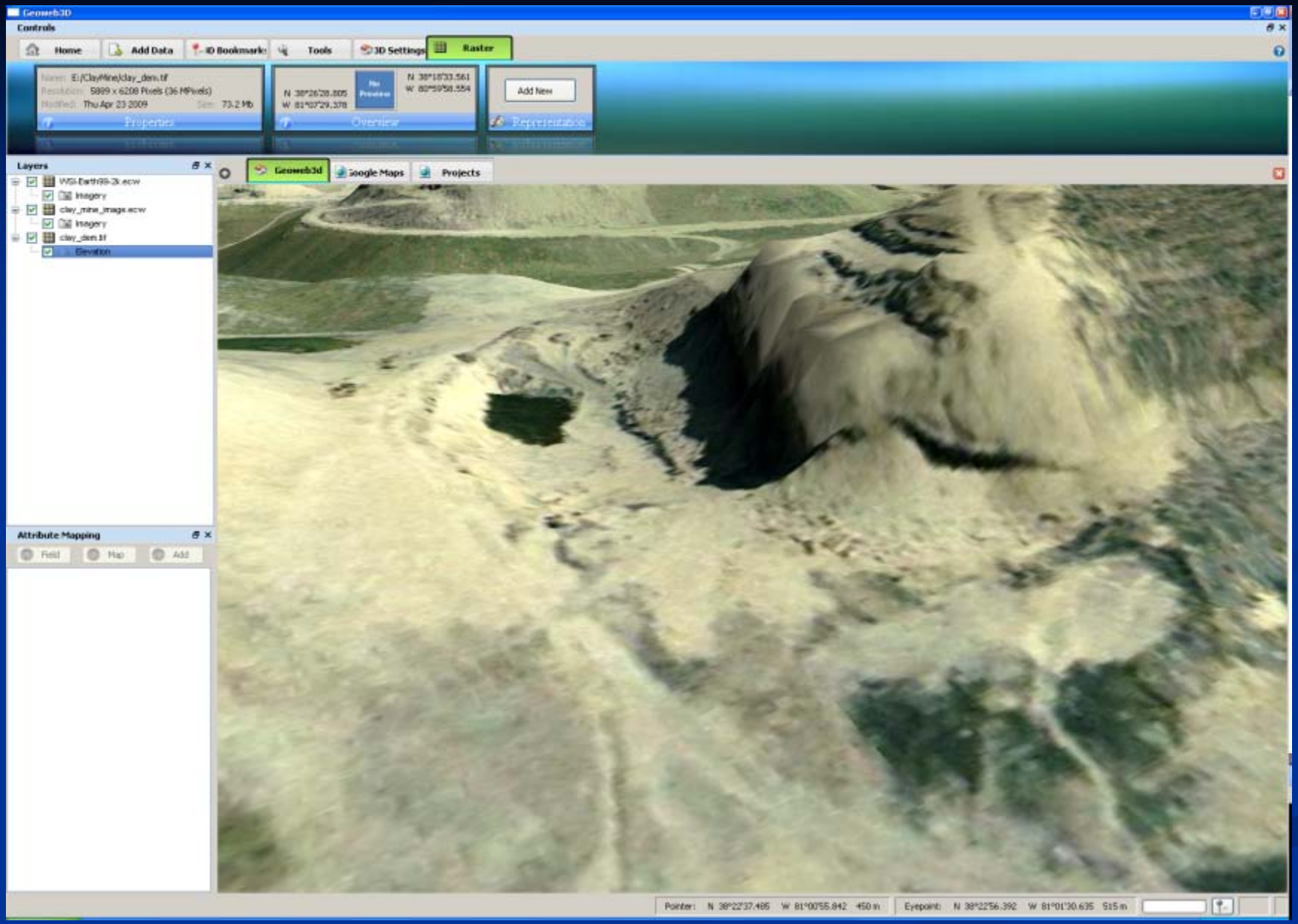
One tool that shows promise for capturing terrain is ground based LIDAR - in particularly critical portions of the sites – for both landforming and stream restoration.





The visualization application begins with a globe – similar to Google Earth

One useful aspect of the application is that it works directly with ARC geodatabases and Civil3D data sets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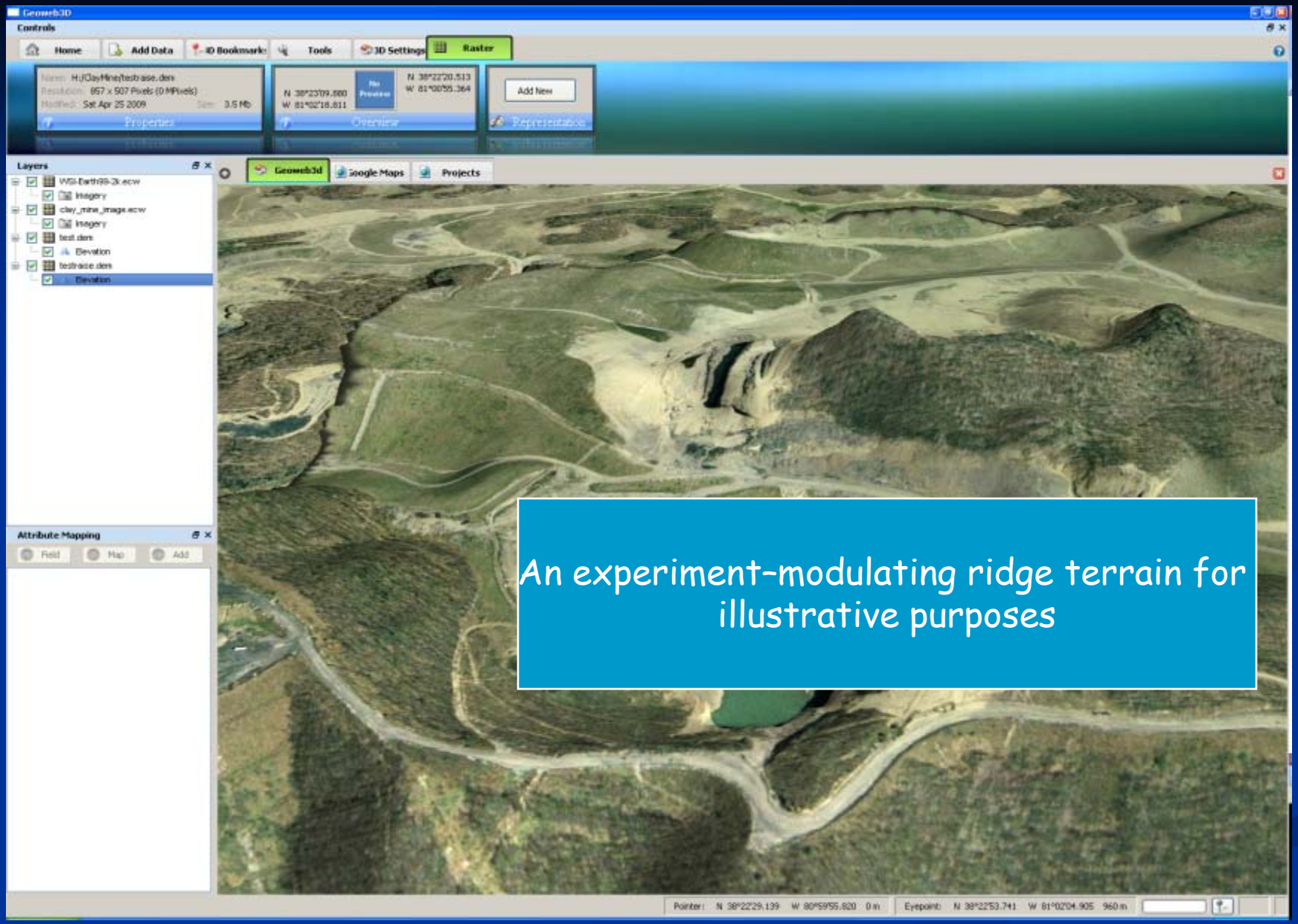
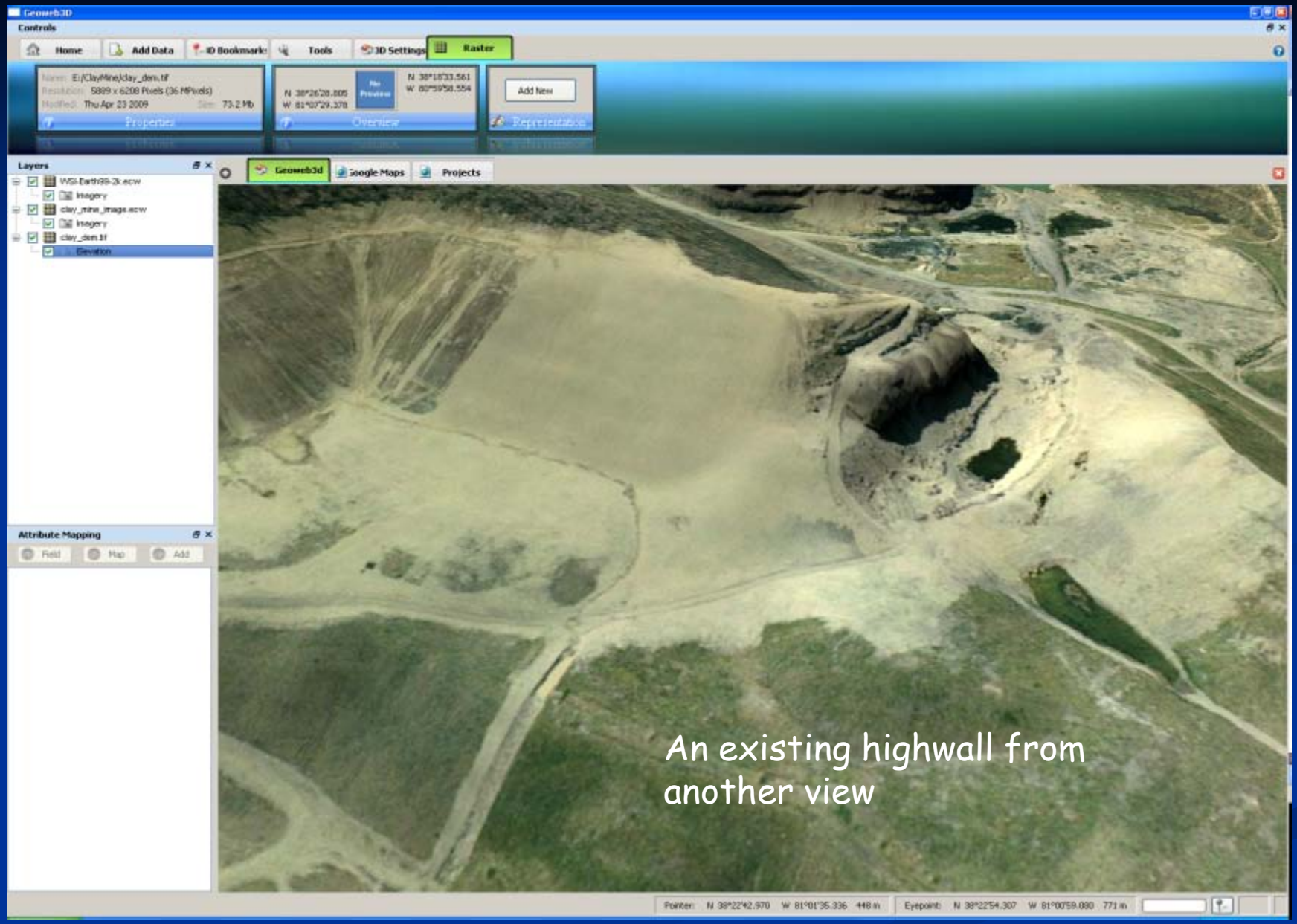
3D Bookmarks
Tools
3D Settings
Raster
Name: E:/ClayMine/clay_dem.tif
Resolution: 5889 x 6208 Pixels (36 MPixels)
Modified: Thu Apr 23 2009
Size: 73.2 Mb
Properties
No Preview
N 38°26'28.805
W 81°03'29.378
N 38°18'33.561
W 80°59'58.554
Overview
Add New
Representation
Layers
WSI-Earth98-2k.ecw
Imagery
clay_mine_image.ecw
Imagery
clay_dem.tif
Elevation
Attribute Mapping
Field
Map
Add
Geoweb3d
Google Maps
Projects
Pointer: N 38°22'37.485 W 81°00'55.842 450 m
Eyepoint: N 38°22'56.392 W 81°01'30.635 515 m

Here is the resulting edge of the ridge landform merging with previously mined areas and areas planned for future development



An experiment–modulating ridge terrain for illustrative purposes

Or a sharper less modulating ridge to define the viewshed from the proposed road


Geoweb3D
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Google Maps
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Imagery
Elevation
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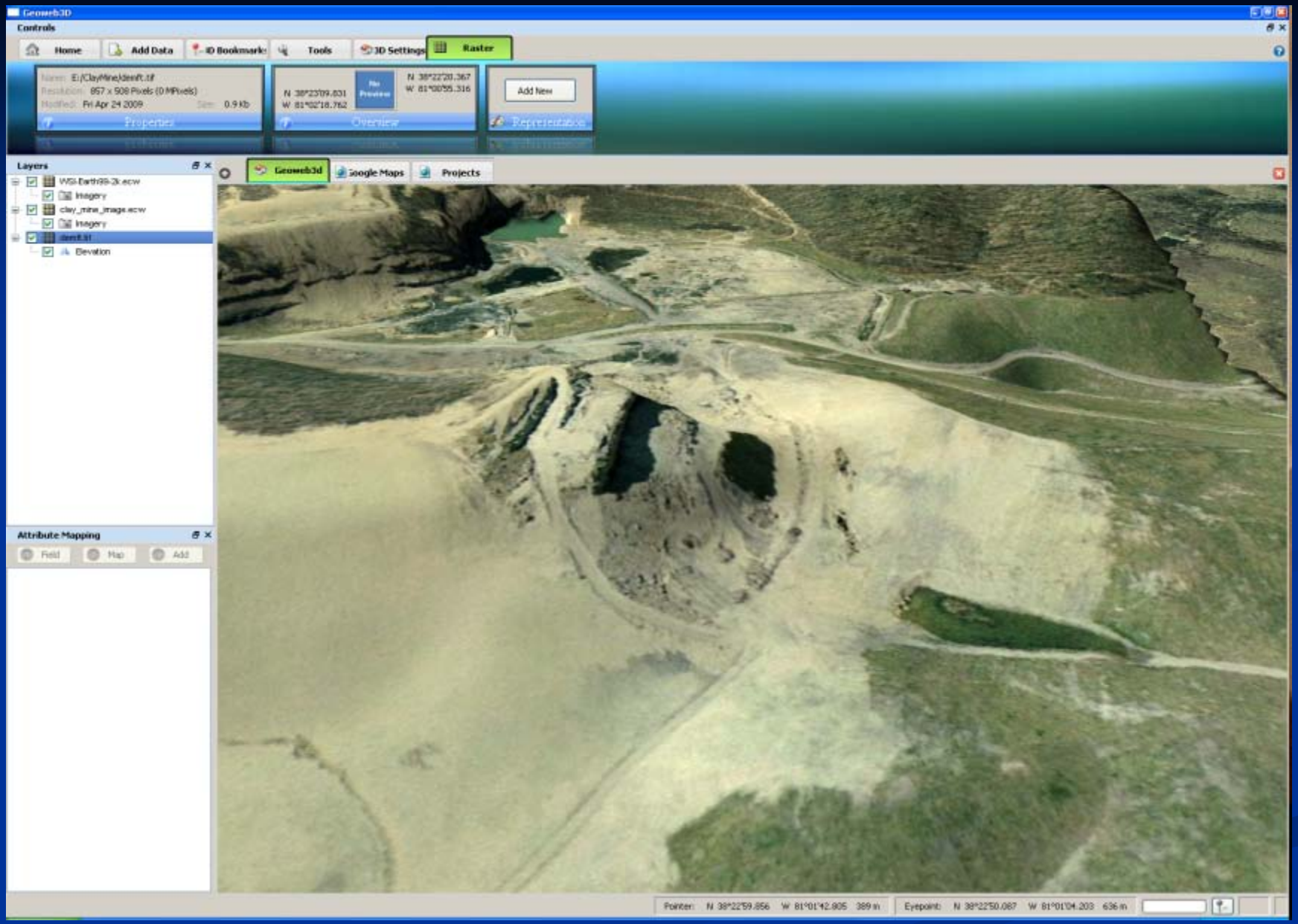
Add
An existing highwall from another view


Geoweb3D
Controls
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Properties
Overview
Add New
Representation
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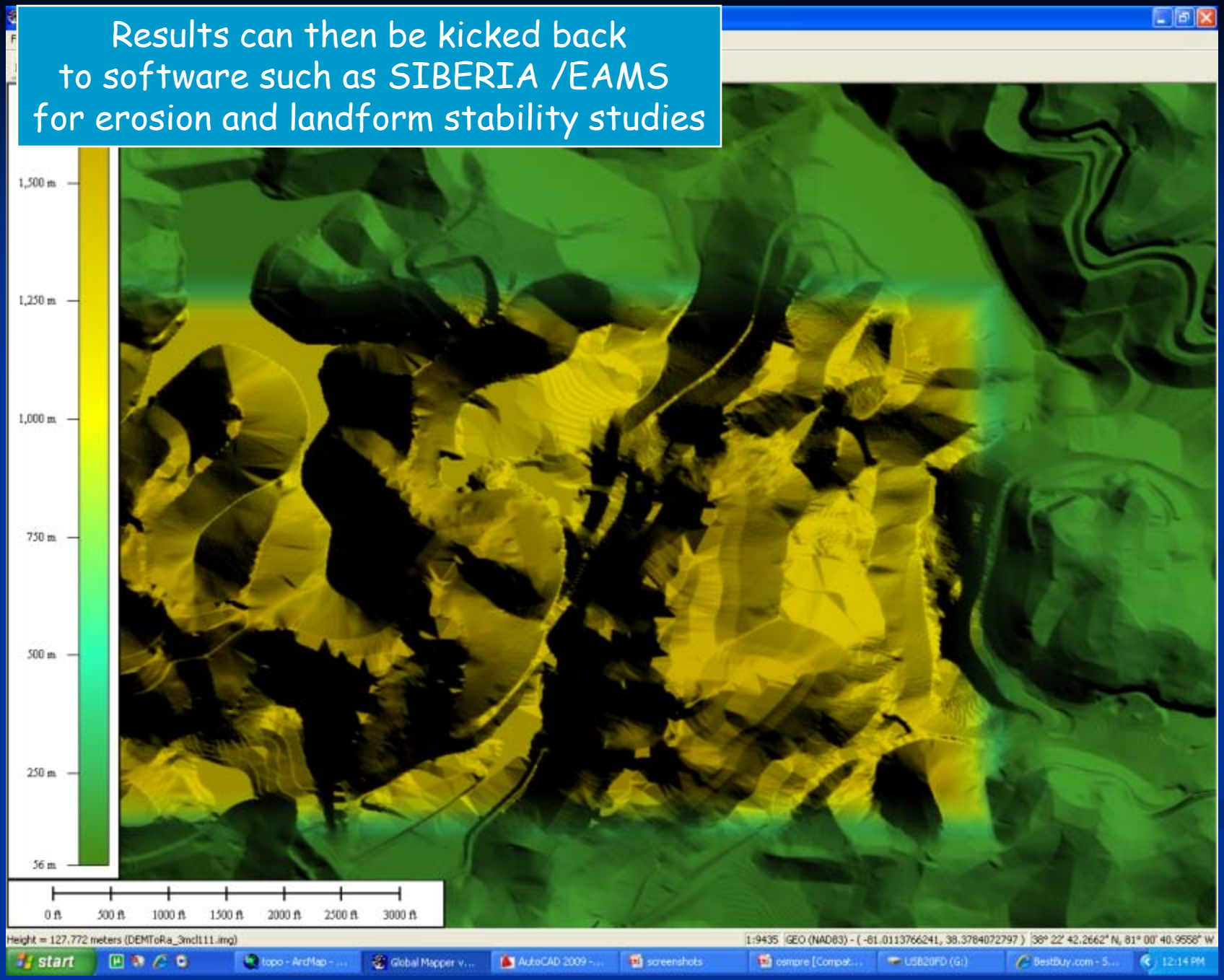
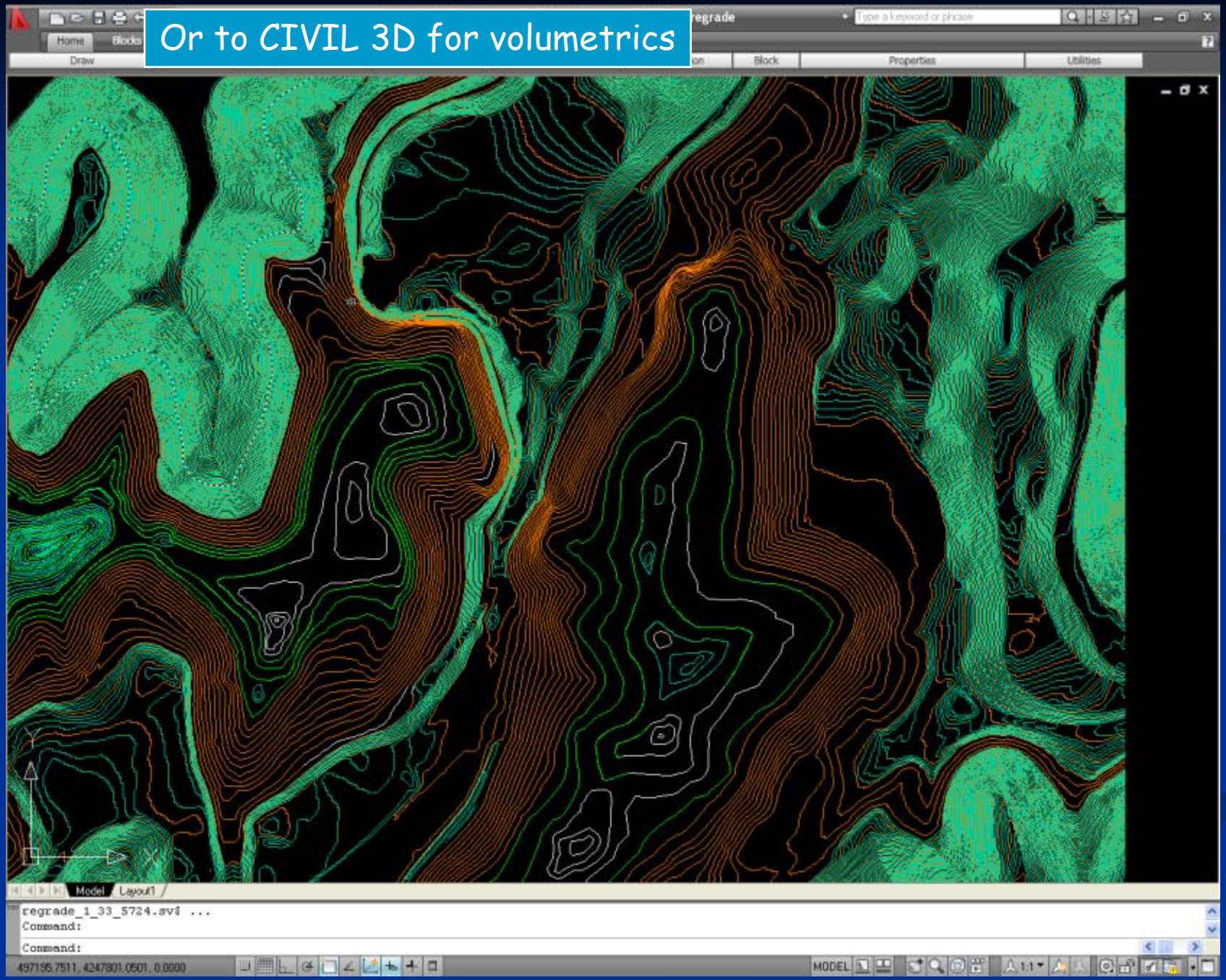
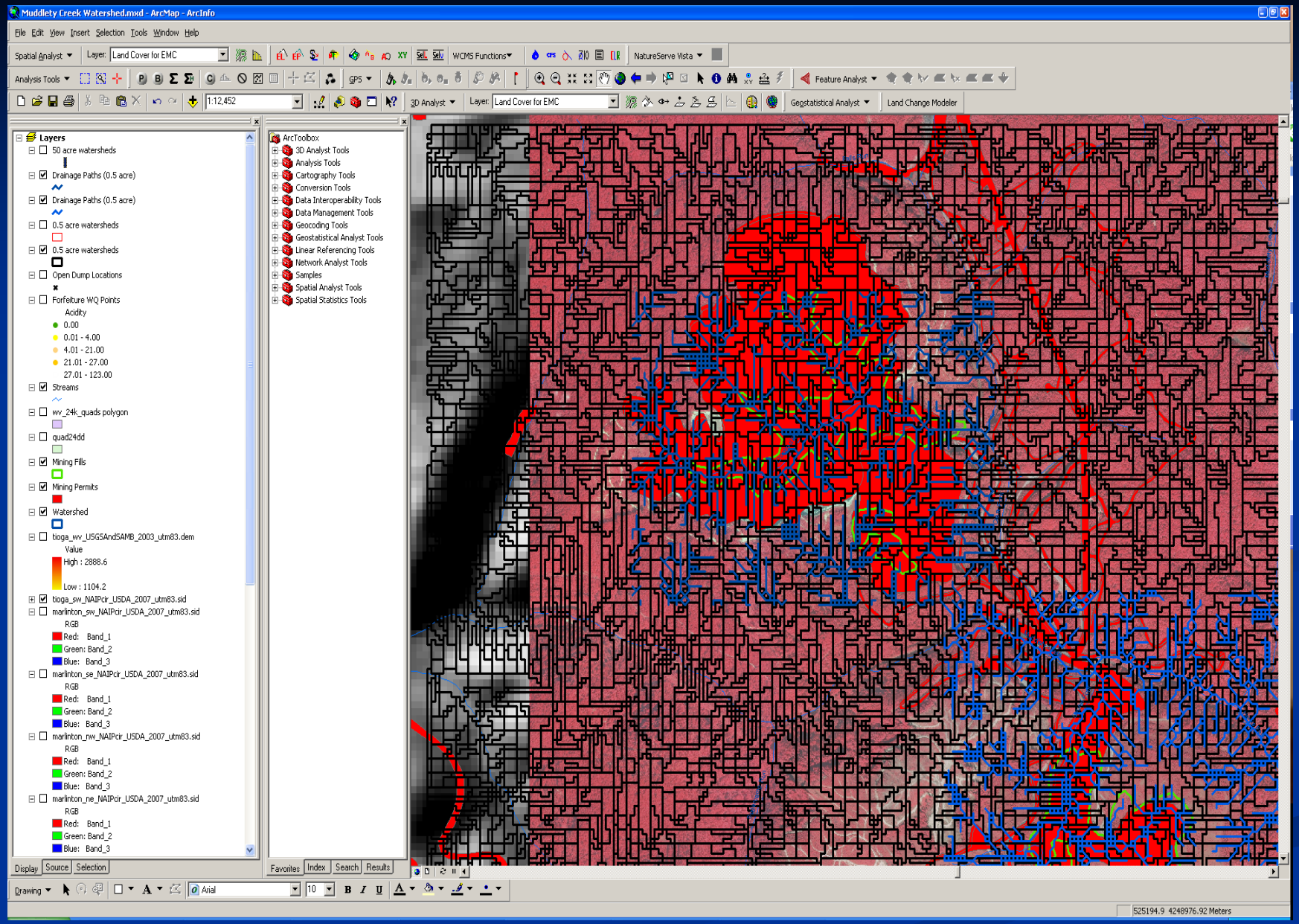
Geoweb3d
Google Maps
Projects
Imagery
Imagery
Elevation
Attribute Mapping
Field
Map
Add
Pointer: N 38°22'59.856 W 81°01'42.805 389 m
Eyepoint: N 38°22'50.087 W 81°01'04.203 636 m

Results can then be kicked back
to software such as SIBERIA /EAMS
for erosion and landform stability studies



Or to CIVIL 3D for volumetrics





Or to WCMS in ARC-GIS. Average watershed size – pre-mining conditions and proposed reclamation conditions

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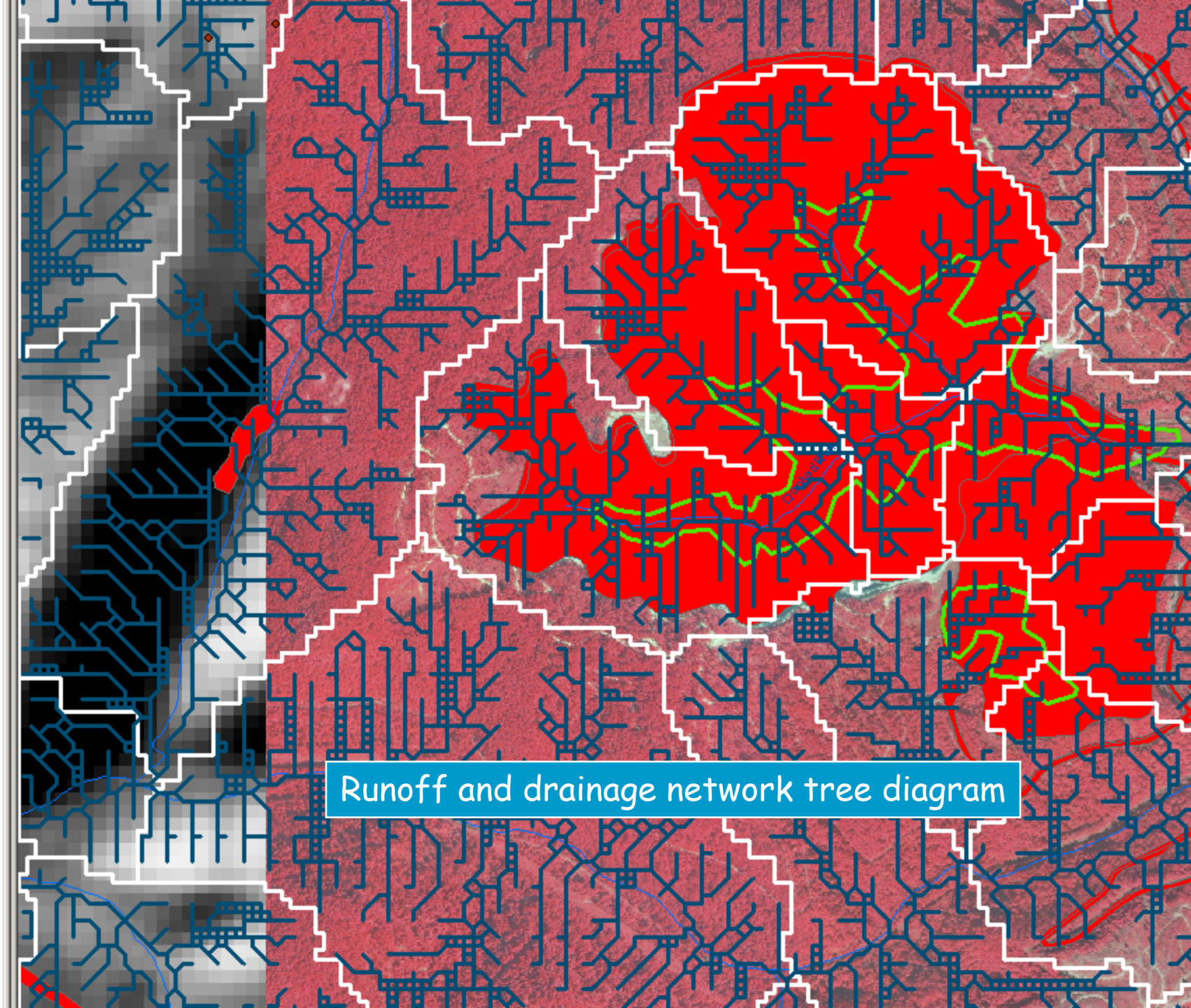
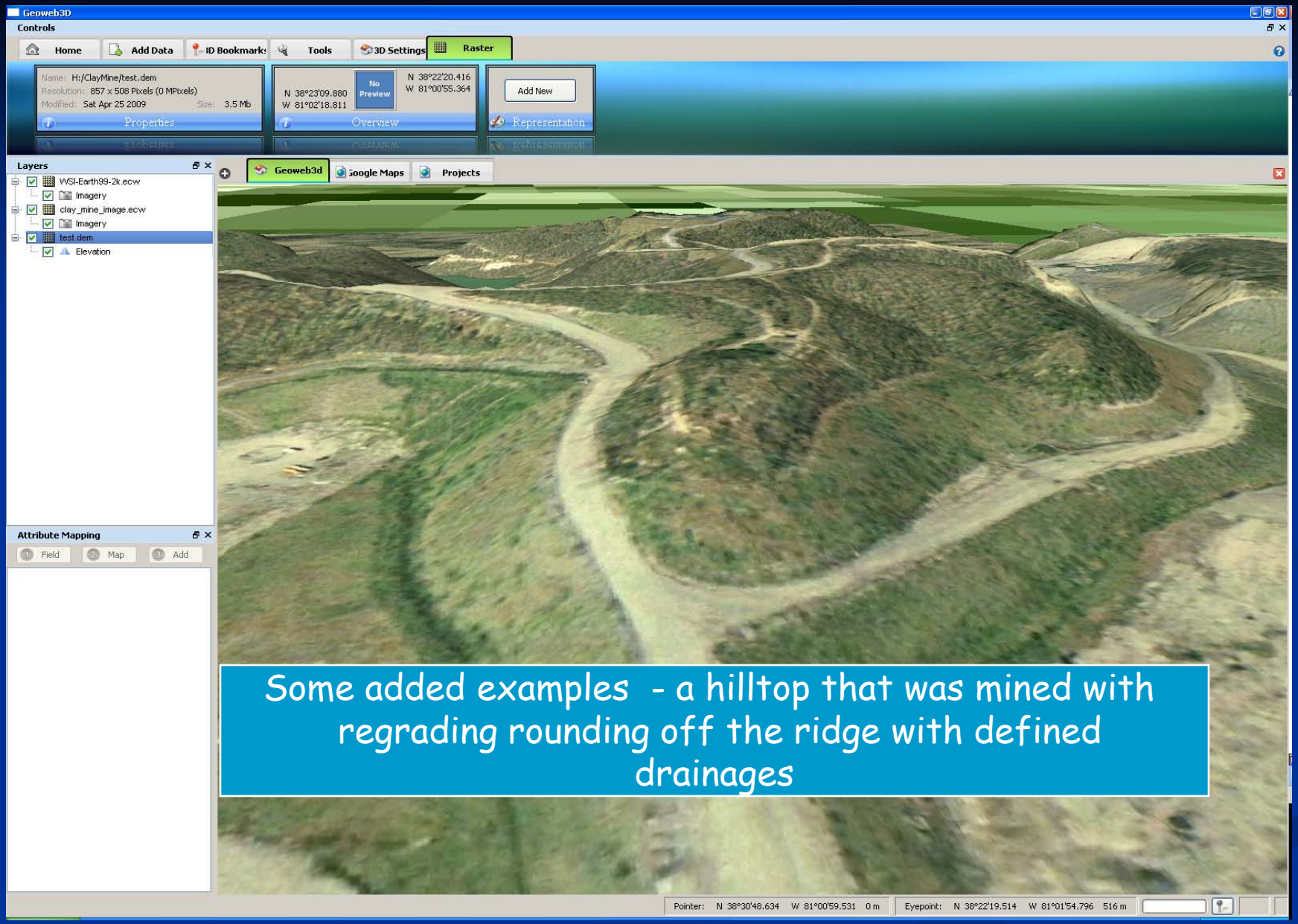
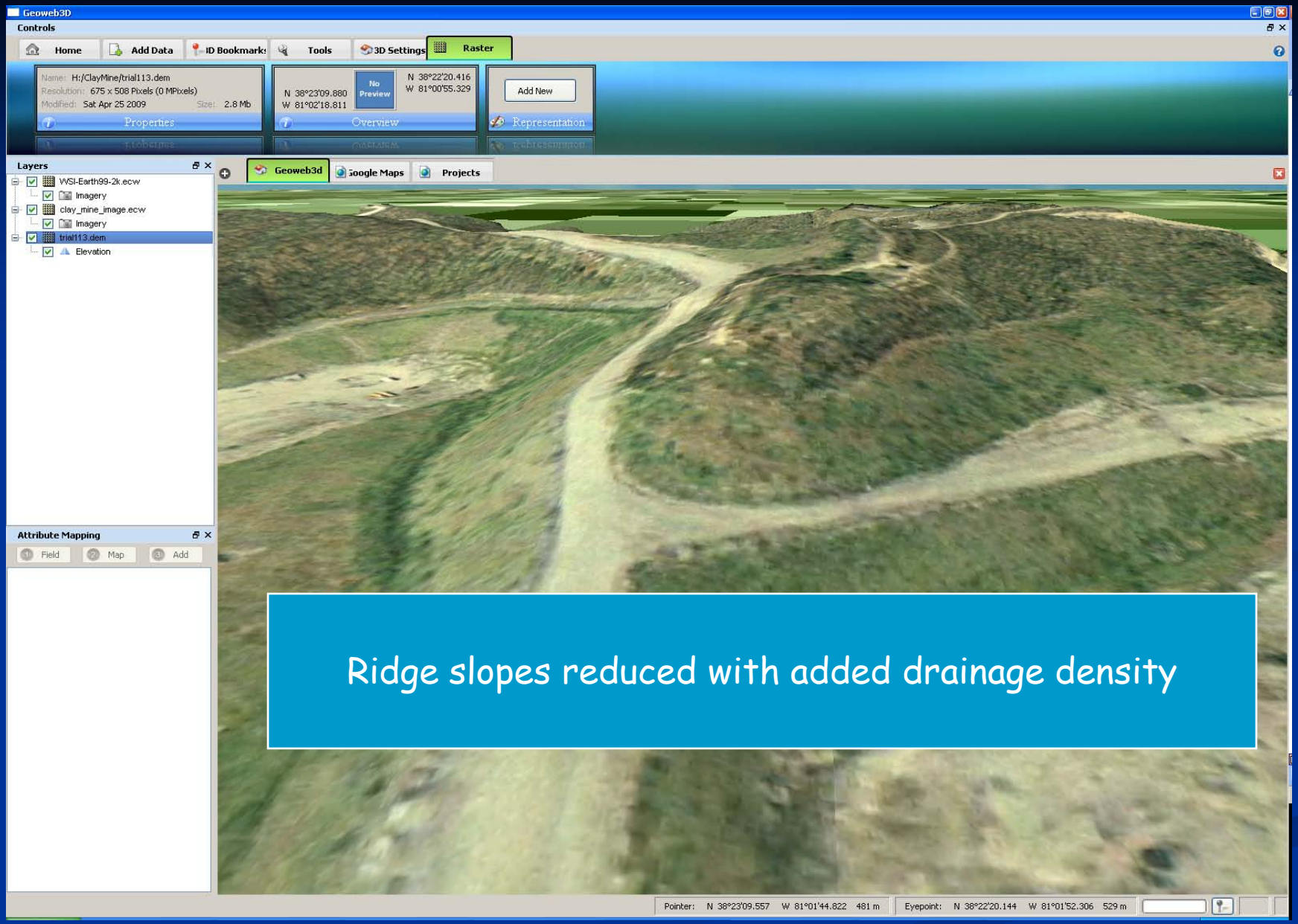
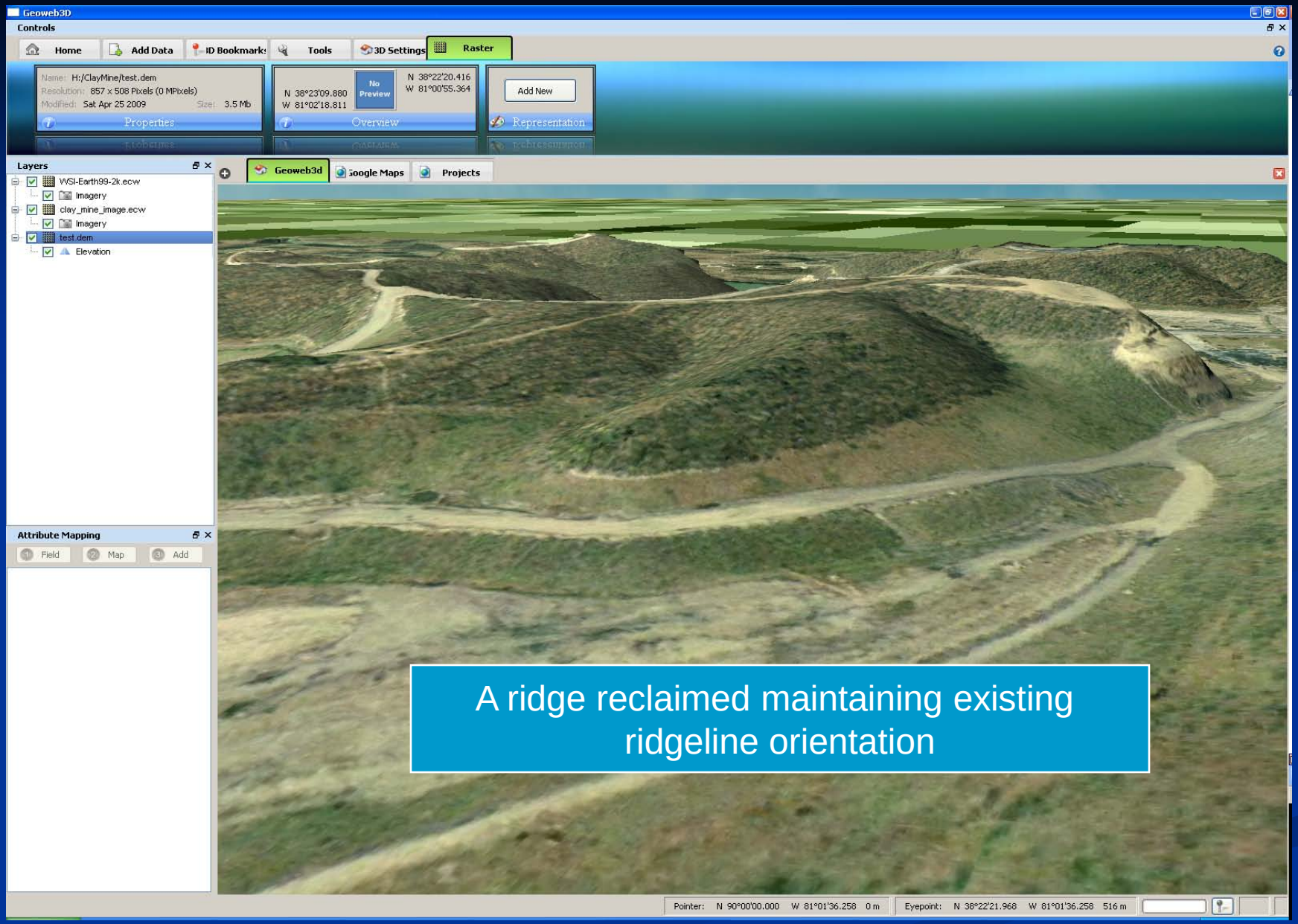




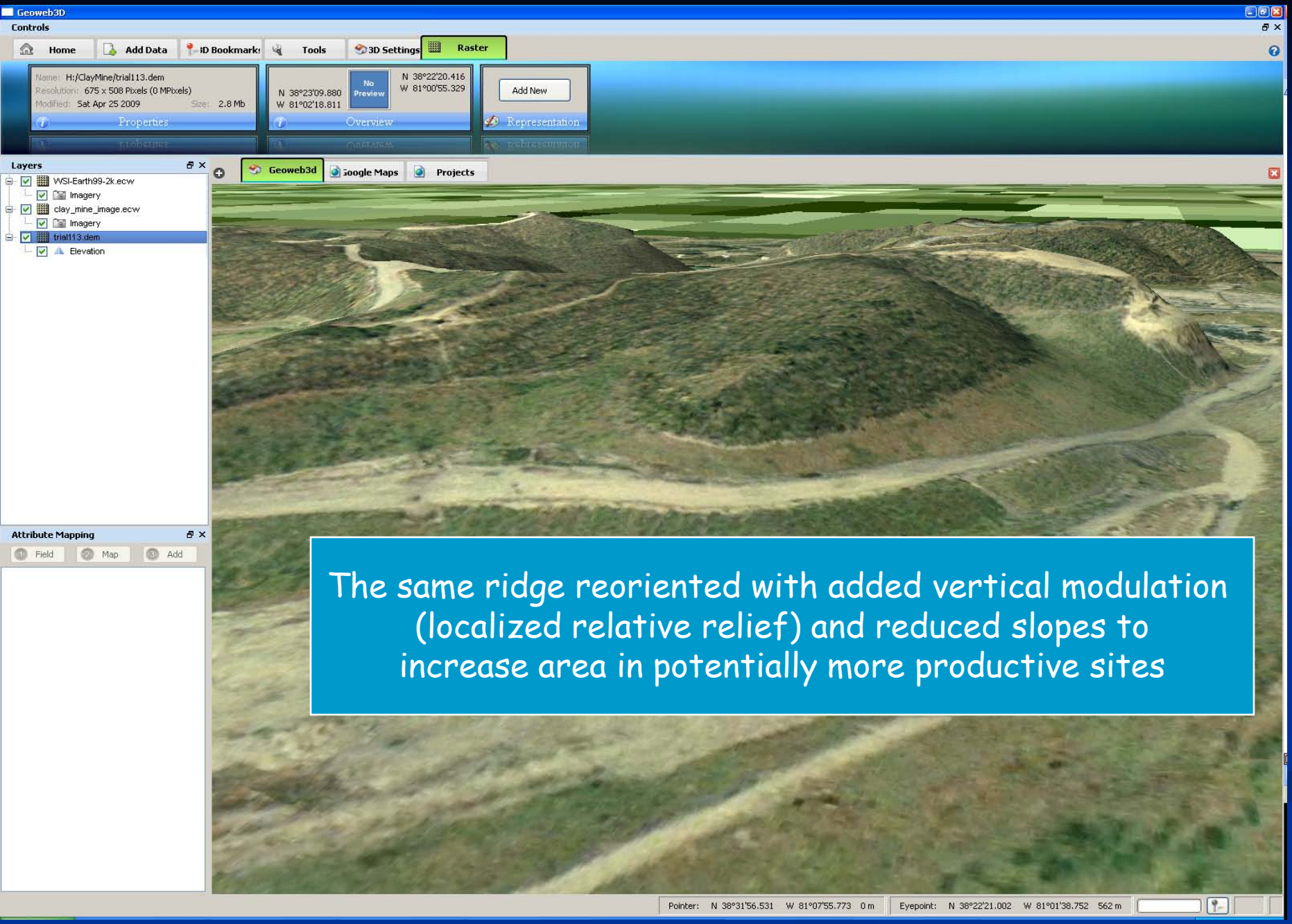
Some added examples - a hilltop that was mined with regrading rounding off the ridge with defined drainages



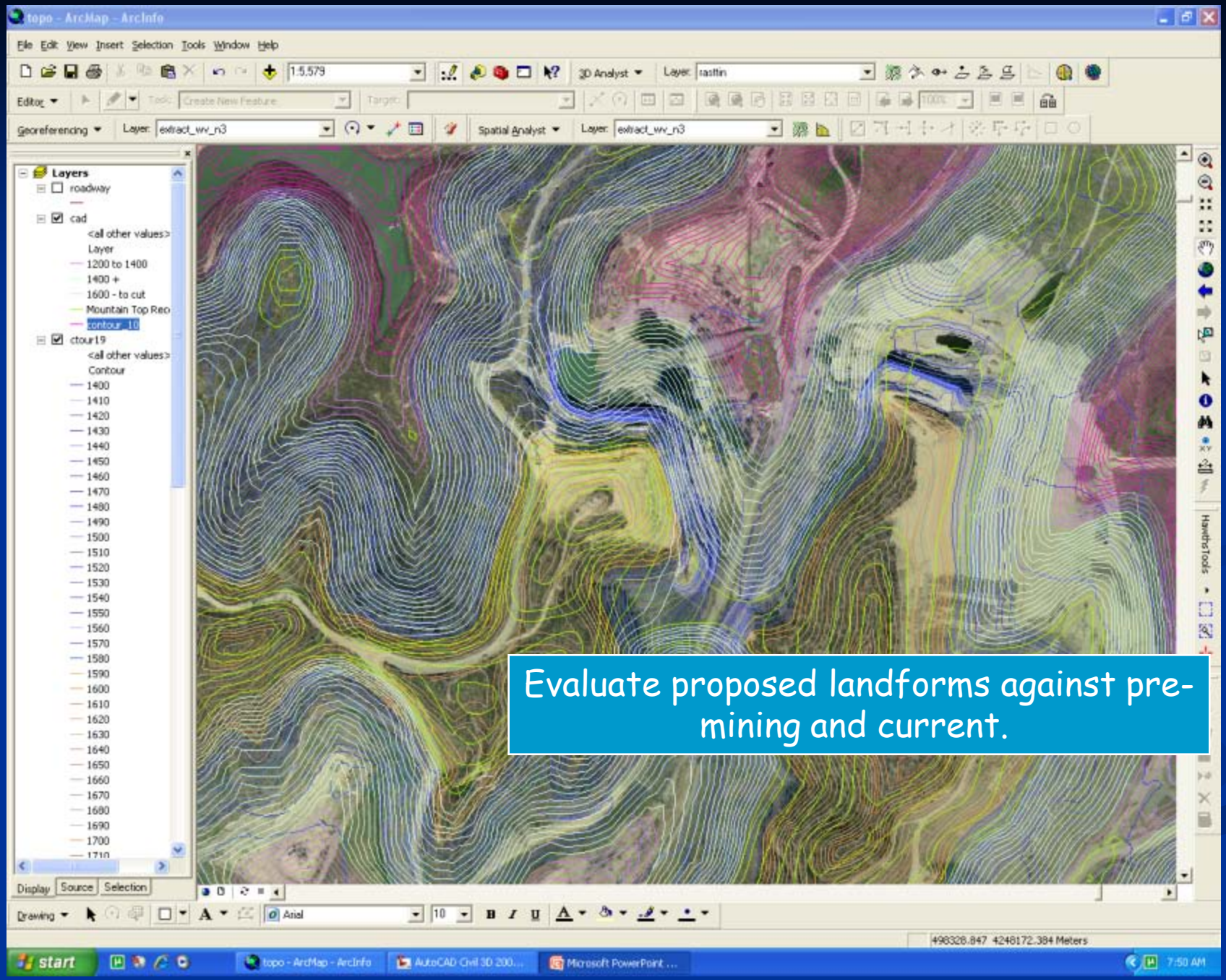
Ridge slopes reduced with added drainage density



A ridge reclaimed maintaining existing ridgeline orientation



The same ridge reoriented with added vertical modulation (localized relative relief) and reduced slopes to increase area in potentially more productive sites



Evaluate proposed landforms against pre-mining and current.

So what we tried to do was…

- Illustrate landforming methods to evaluate and redesign the landforming tools
- Develop a planning approach that..
  - Increases stability and drainage definition in 0 order and adjacent areas by redesigning up-slope drainage networks
  - Increases future site utility
  - Reduces slopes while maintaining natural appearance
    - Increasing areas in more productive slope orientations
    - Minimizes level areas
    - Slightly decreasing slopes in those areas to increase management and planting options but mixing with appropriate steeper areas for……
      - Forest management
      - Managed timberlands – forest / slope protection for critical slopes
      - Sites for potential biofuels production

thanks