Geomorphic design and landscape evolution modelling for best practice mine rehabilitation

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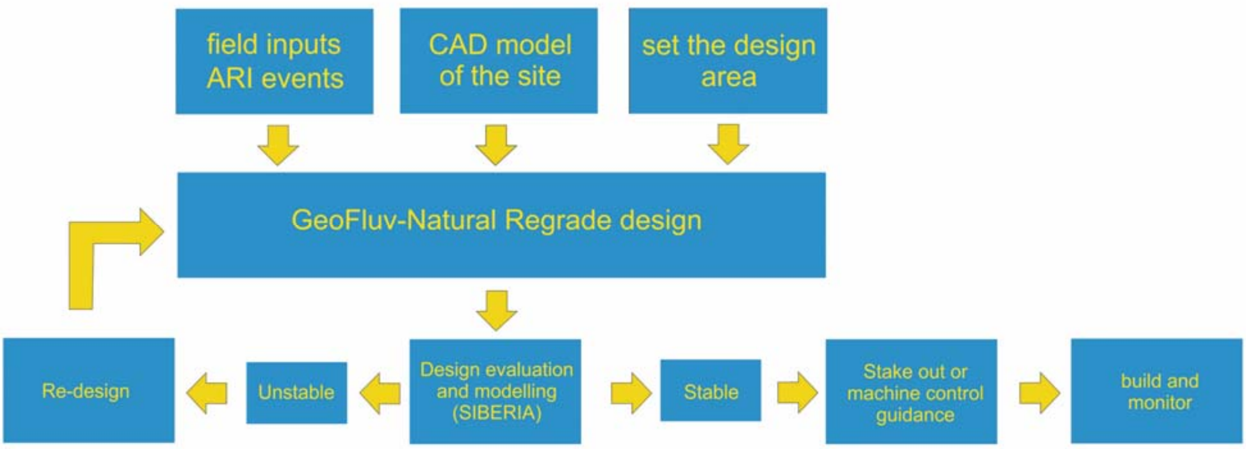
A) GEOMORPHIC DESIGN FOR BEST PRACTICE MINE REHABILITATION. A WHOLE GEOFLUV-NATURAL REGRADE GEOMORPHIC REHABILITATION PROCESS



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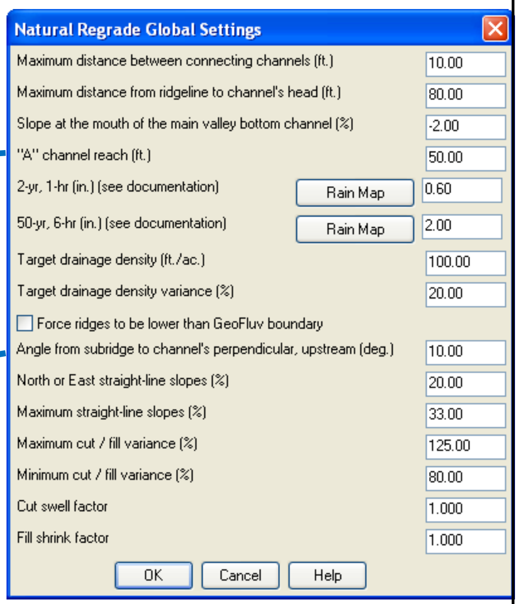
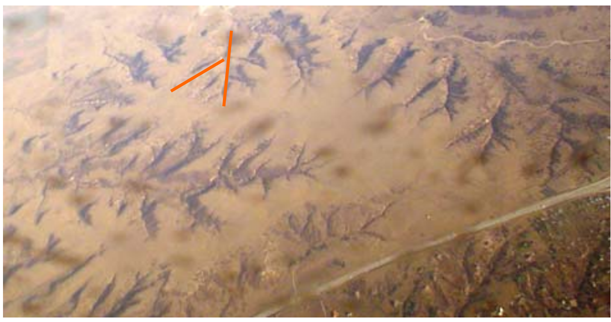
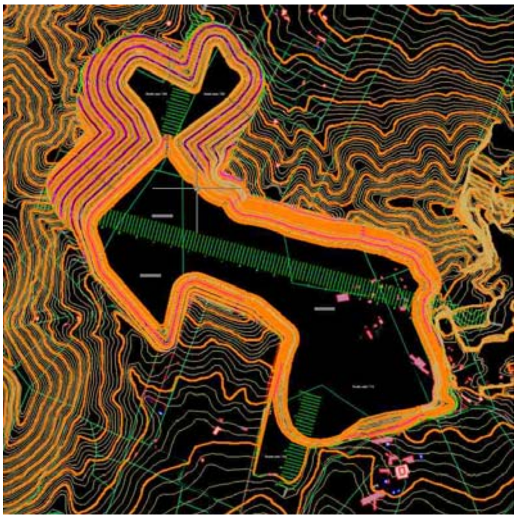
1. Getting field inputs (reference area)

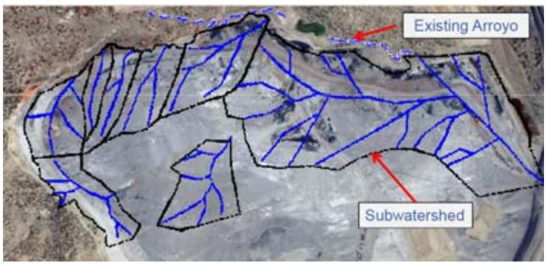




2. CAD model of the site



3. Set the design area



Chevron Mckinley Coal Mine NM, US, Earth and Water Technology

Son Amat, limestone quarry (Majorca, Spain), with permission of Gravillas Son Amat

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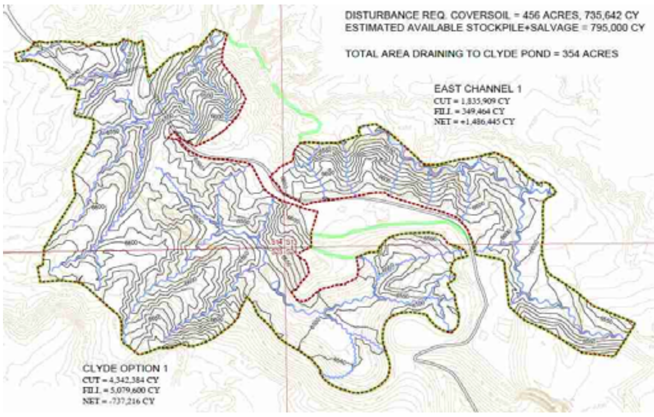
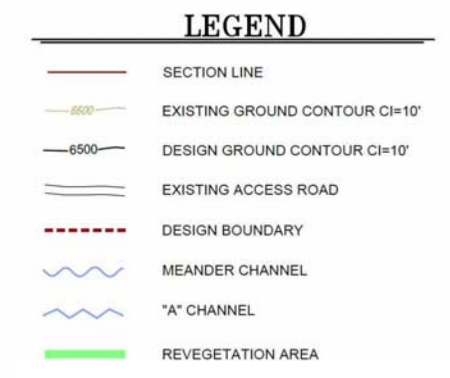
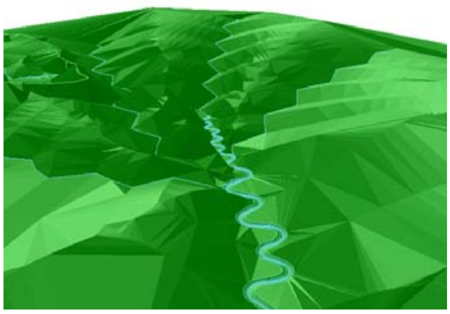
4. GeoFluv – Natural Regrade design



Day Loma reclamation project, AML project 16 G-II, Freemont County, Wyoming. BRS Inc.- Engineering Consultants, Wyoming, USA





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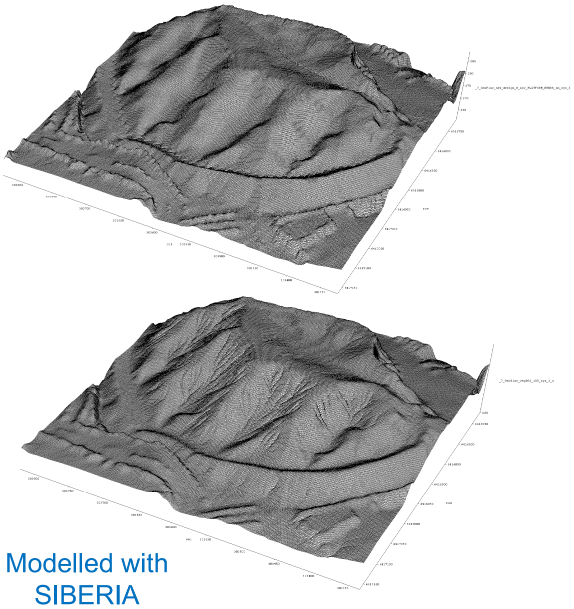
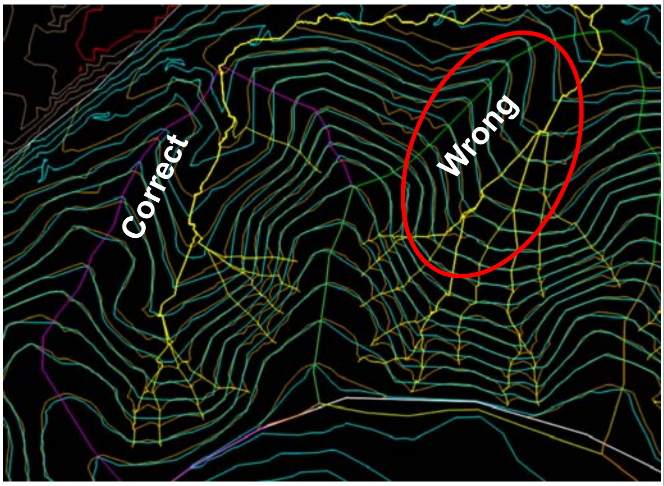
5. Checking the design

Hancock GR, Martín Duque JF, Willgoose GR. Geomorphic design and modelling at catchment scale for best mine rehabilitation – the Drayton mine example (New South Wales, Australia). Submitted to *Environmental Modelling and Software*

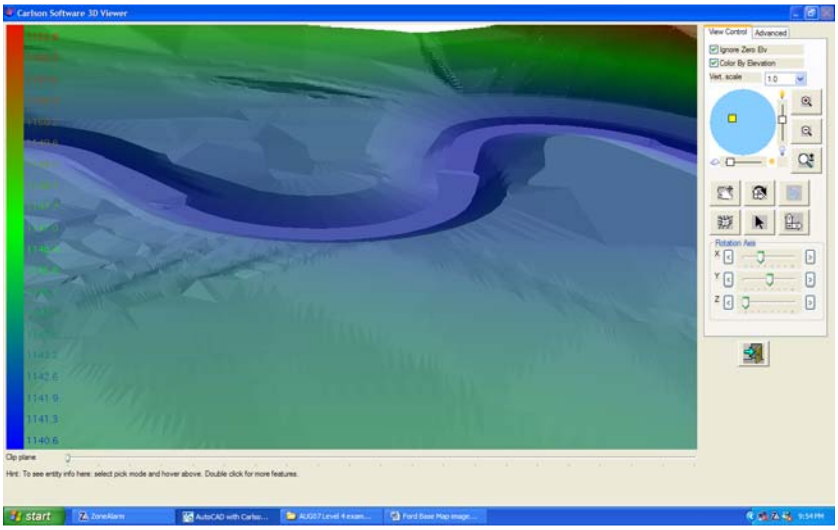


Modelled with SIBERIA



6. Building the design

How these 'natural' landforms are built?



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Conventional earth movement in mine planning and rehabilitation

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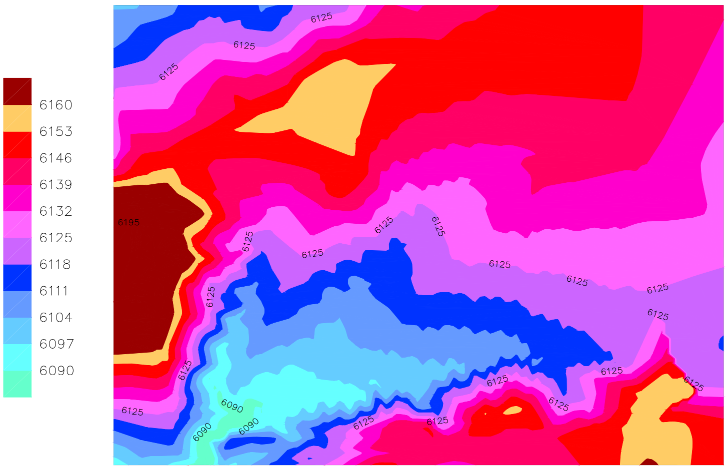
Map for guiding the download of waste (lifts) for GeoFluv-Natural Regrade restorations



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How if the first time that we move the mine wastes…

. . . we move them according to the rehabilitation plan (geomorphic design)?

Moving the earth only once is efficient

In these images, a competitive company is building a GeoFluv rehabilitation

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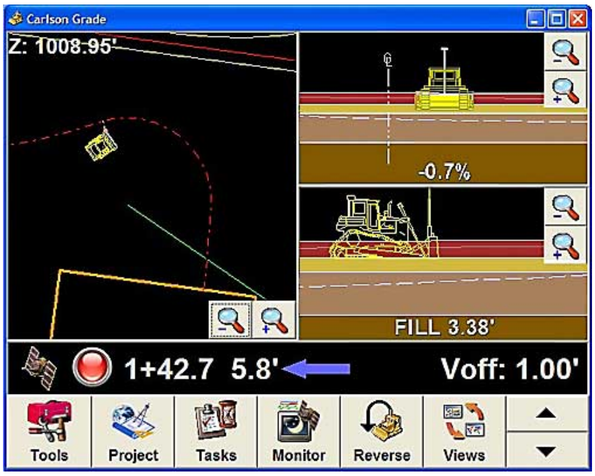
The machinery that regrades the land has this screen



ENGINEERING TECHNOLOGY

RESTORING EROSIONAL FEATURES IN THE DESERT

New Landform Design Software and Automated Machine Guidance Combine in Award-Winning Reclamation Project

Using specially developed software and GPS guidance systems on dozers, BHP Billiton's La Plata mine restored mined desert lands efficiently and cost-effectively.

The focus of any mining operation is recovery of the mineral reserve, whether coal or other deposit, but often the greatest cost of mining is associated with moving, storing and replacing overburden – functions that produce no revenue for the mine. When that material is replaced during reclamation, it will have to meet many newly developed technologies for topographic (modeling) design and automated machine control to achieve dramatic results in productivity in its award-winning reclamation project at La Plata, N.M.

RECLAMATION CHALLENGE AT LA PLATA

en to eight years, using the conventional methods available at the time, and BHP Billiton began looking for ways to speed up the work to minimize this liability period.

The La Plata reclamation program faced a number of challenges. The swell factor of the material dictated an additional out-of-pit waste dump because the swelled material could not fit back into the mine pits.

Because of the unique topography, the company was not satisfied with the gradient terrace and down-drain design for slope reclamation that was the conventional practice. The terraces and down-drains were expensive to build, and expensive to maintain because sediment accumulation on the terraces or animals burrowing through them could cause slope washouts. If the slope damage required major repair work, the bond liability period could be restarted from the repair date.

Also, the constant-gradient slope faces associated with the then-conventional design led to great slope areas facing the same direction (aspect) and very uniform water retention across the slope faces. These factors combined to

Coal Age, March 2006

D9 dozer equipped with machine control GPS shaping "A" channel

Abandoned Mine Lands Project 16 N-3 rehabilitated with GeoFluv – Natural Regrade. Images from Harold Hutson, Project Engineer, BRS Inc.- Engineering Consultants, Wyoming, US

D9 dozer equipped with machine control GPS shaping "A" channel

Abandoned Mine Lands Project 17 H-2B (Wyoming, US) rehabilitated with GeoFluv – Natural Regrade. Images from Harold Hutson, Project Engineer, BRS Inc.- Engineering Consultants, Wyoming, US

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Abandoned Mine Lands Project Lionkol (Wyoming, US) rehabilitated with GeoFluv – Natural Regrade. Images from Harold Hutson, Project Engineer, BRS Inc.- Engineering Consultants, Wyoming, US

Machinery regrading GeoFluv – Natural Regrade rehabilitations

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Soil replacement and seeding complete GeoFluv – Natural Regrade rehabilitations

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7. Monitoring

Experiment preparation for sediment yield monitoring

Earth dams construction at La Plata, New México.

Photos by Edward Epp and Nicholas Bugosh

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B) GEOFLUV – NATURAL REGRADE BASED MINE REHABILITATION EXAMPLES ALL OVER THE WORLD. BASIS FOR DISCUSSION

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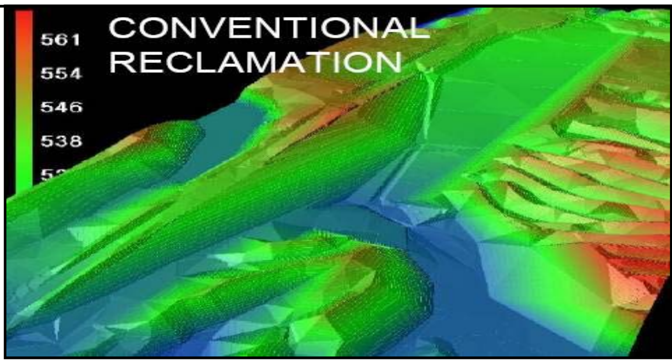
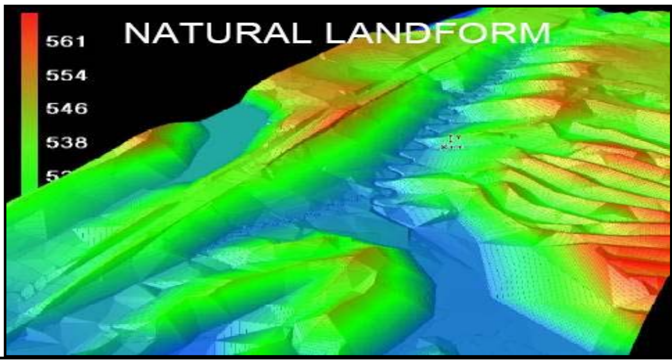
1. EXAMPLES IN THE US



Example of the AML coal mine (Indiana, US)



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Tijeras limestone quarry (New Mexico, US)

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

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La Plata mine, New Mexico, US

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La Plata mine, New Mexico, US

La Plata mine, New Mexico, US

La Plata mine, New Mexico, US

La Plata mine, New Mexico, US

La Plata mine, New Mexico, US

GeoFluv rehabilitations at La Plata
5.65 - 8.25 t/ha/yr

Neighbour undisturbed native site
9.53 t/ha/yr

Bugosh and Epp (submitted to CATENA)

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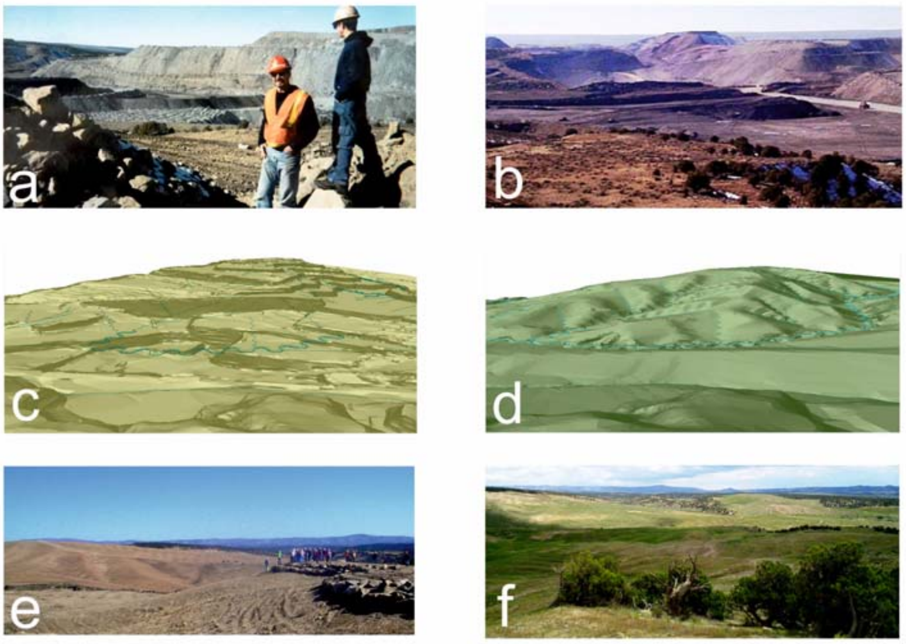

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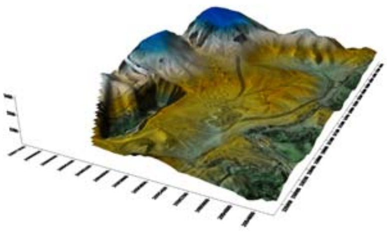
San Juan mine, New Mexico, USA



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2004 “Best of the Best” award, mine reclamation, USA

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Sands Mine in Wisconsin (US) in humid, temperate environment

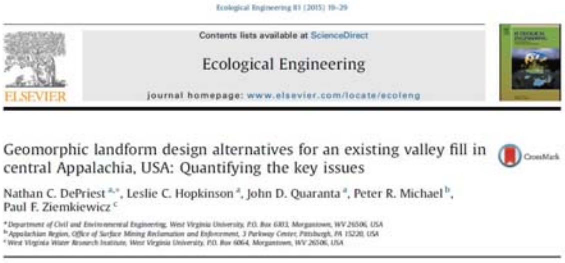
This sand mine in northern Wisconsin has erodible sands that for many years led to maintenance and repair of traditional slope reclamation. The earth material properties, clean and loose sand particles made very difficult to reclaim with stability against erosion using traditional reclamation methods. GeoFluv – Natural Regrade designs have passed heavy storms without requiring repair. The reclamation designed also blends into the surroundings providing additional benefit at no additional cost.

Coal slurry stabilization (Indiana, US) in a humid temperate environment (Minnehaha Mine, Sullivan county)

Example of physical and chemical stabilization

Información adicional en: www.osmre.gov/programs/awards/2015AMLWinners.shtm

Proposals for valley fills at the Appalachian mountains


Ecological Engineering 81 (2015) 19–29

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journal homepage: www.elsevier.com/locate/ecoleng

Geomorphic landform design alternatives for an existing valley fill in central Appalachia, USA: Quantifying the key issues

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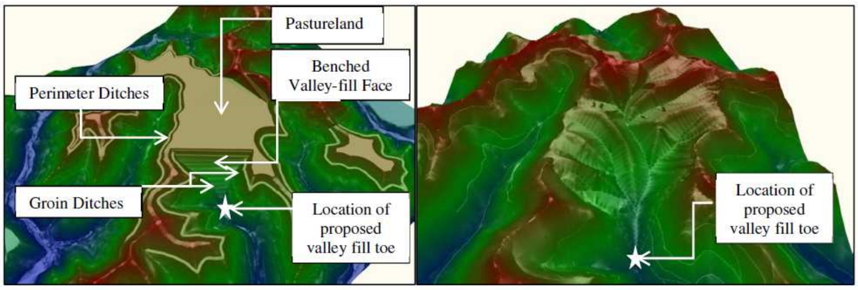
[b] Appalachian Region, Office of Surface Mining Reclamation and Enforcement, 3 Parkway Center, Pittsburgh, PA 15220, USA
[c] West Virginia Water Research Institute, West Virginia University, P.O. Box 6064, Morgantown, WV 26506, USA



Russell, H., DePriest, N., Quaranta, J.D., 2014. Stability analysis comparison of conventional valley-fill to geomorphic landform designs. Trans. Soc. Min. Metall. Explor. 336, 414–420.

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3. EXAMPLES IN SOUTH AMERICA

Coal mine geomorphic (GeoFluv) rehabilitation in a tropical environment with grazing land uses (Bijao mine, SATOR, Argos Group, Colombia)

Puerto Libertador, Córdoba

- High precipitation (>1,000 mm/yr)
- Ecologically and visually sensitive landscape

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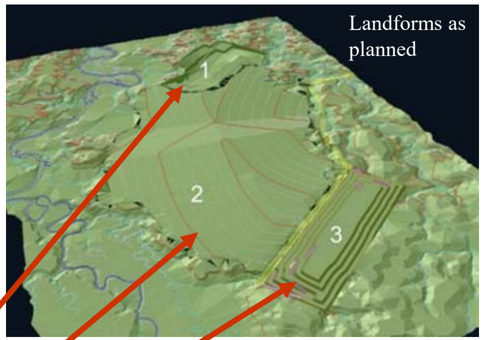

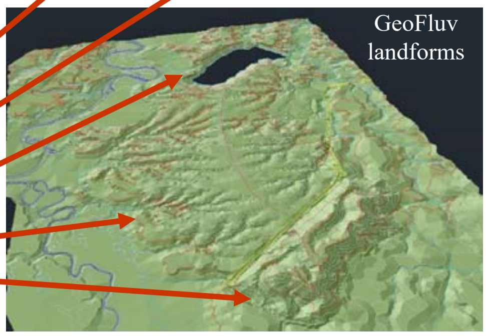

The Traditional reclamation landform has three main features:

- •Final Void-Pit to Lake
- •Regraded overburden (backfilling)
- •Out-of-Pit Waste Dump

- •GeoFluv alternative designs

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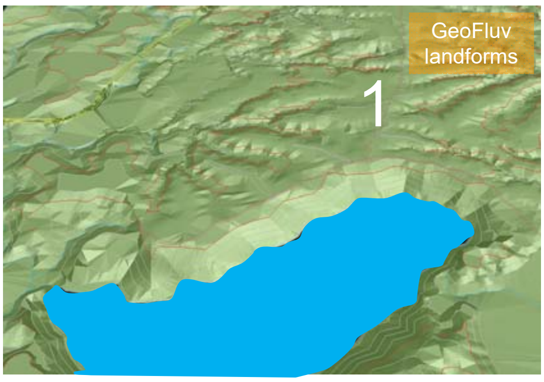
(1) Steeply sloping, uniform gradient banks to the final void would limit its safe access by humans, livestock, and wildlife.

(1) The GeoFluv alternative allows for naturally functioning slopes leading to the pond that provide safe access to the void, while minimizing erosion



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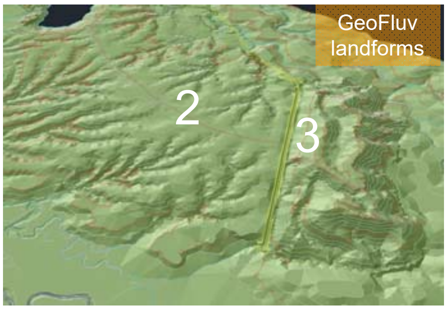
(2) The backfill grading buries the natural drainage pattern, losing hydrologic connectivity.

(3) The out-of-pit waste dump has a minimized disturbance footprint, but it is very unstable against erosion, provides minimal reclamation land use benefit, and is an <u>unsightly</u> monolith on the landscape.

(2) Establishing a fully functioning hydrologic system for the storm runoff, and restoring hydrologic connectivity was possible without extending the toe limits.

(3) The waste dump geomorphic rehabilitation has benefitted by extending its toe as needed to accommodate the volume of waste material, to convey storm water runoff without the accelerated erosion



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Mina Invierno, Isla Riesco, Magallanes Region, Chile

mina invierno

Magallanes Region
Chilean Patagonia

Climate: semiarid, moderate oceanic
Low temperature
Strong winds (130 km/h)

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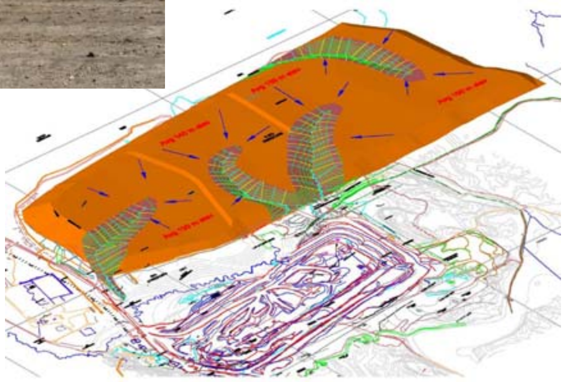
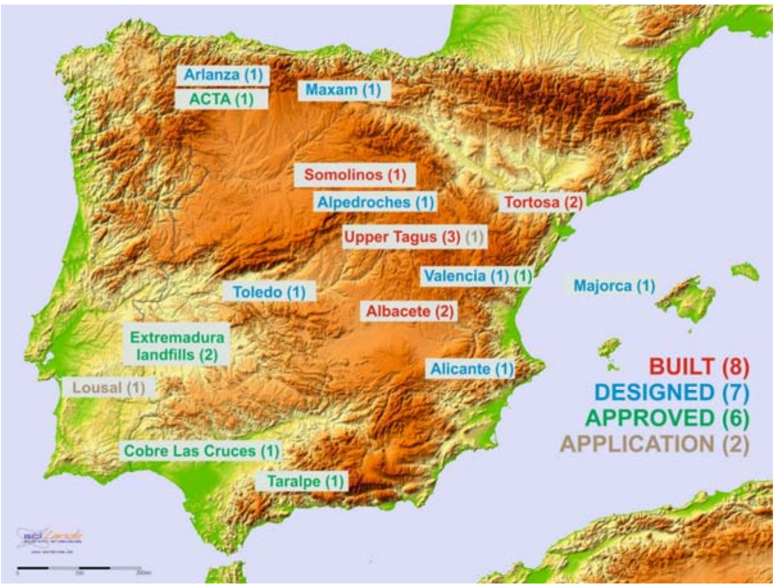
Out-of-pit (external) waste dump

Geomorphic Reclamation through GeoFluv – Natural Regrade was an alternative, but failed to be implemented

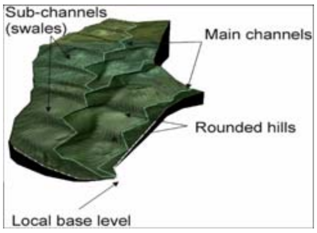


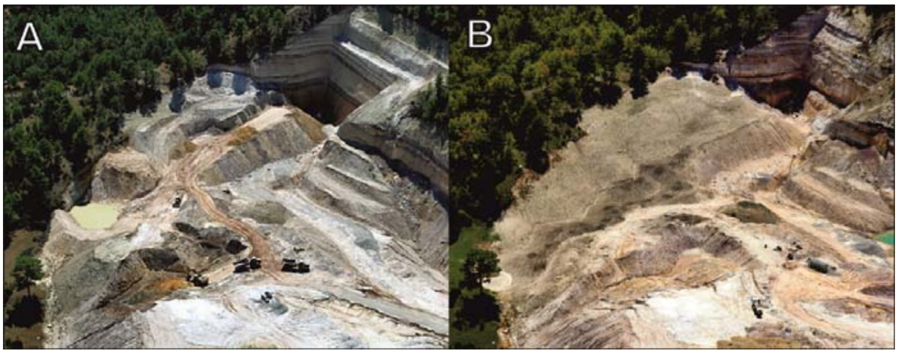
4. EXAMPLES IN SPAIN AND PORTUGAL



BASE MAP SOURCE:
https://www.pinterest.com.au/pin/510877151466792348/

GeoFluv – Natural Regrade at El Machorro mine (Alto Tajo)





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Not possible (because of the altered earth material), to restore the original slope or drainage pattern, but we can make a functional topography for the new earth material

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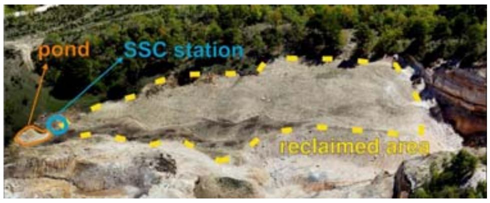
Sediment yield monitoring
for 5 years (2012-2017)

4.02 t/ha/yr



Zapico et al. (2018). *Ecological Engineering* 111: 100-116

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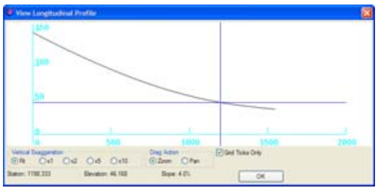
GeoFluv-Natural Regrade
at Maria Jose mine (Alto Tajo)




Why is important to be precise (both at designing and at building)



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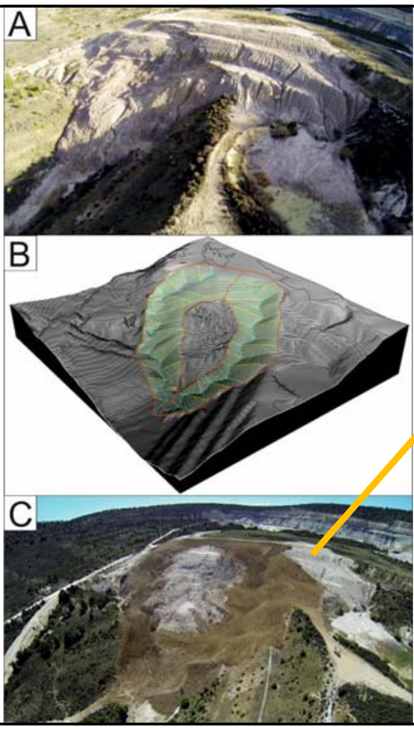
GeoFluv Natural Regrade for the Alto Tajo abandoned mines

https://www.youtube.com/watch?v=rYDQoGGd4l0



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Sand quarry (Somolinos, Guadalajara)

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