INTEGRATED MINE CLOSURE II

UNIVERSITY OF ALBERTA

"uplifting the whole people"

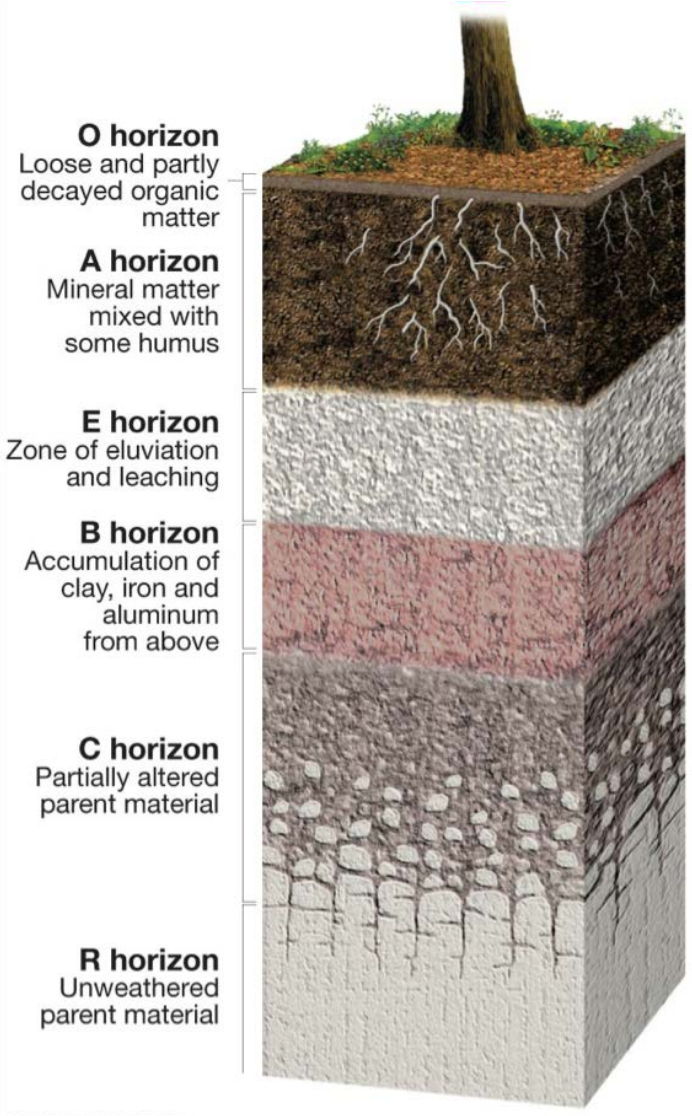
— HENRY MARSHALL TORY, FOUNDING PRESIDENT, 1908

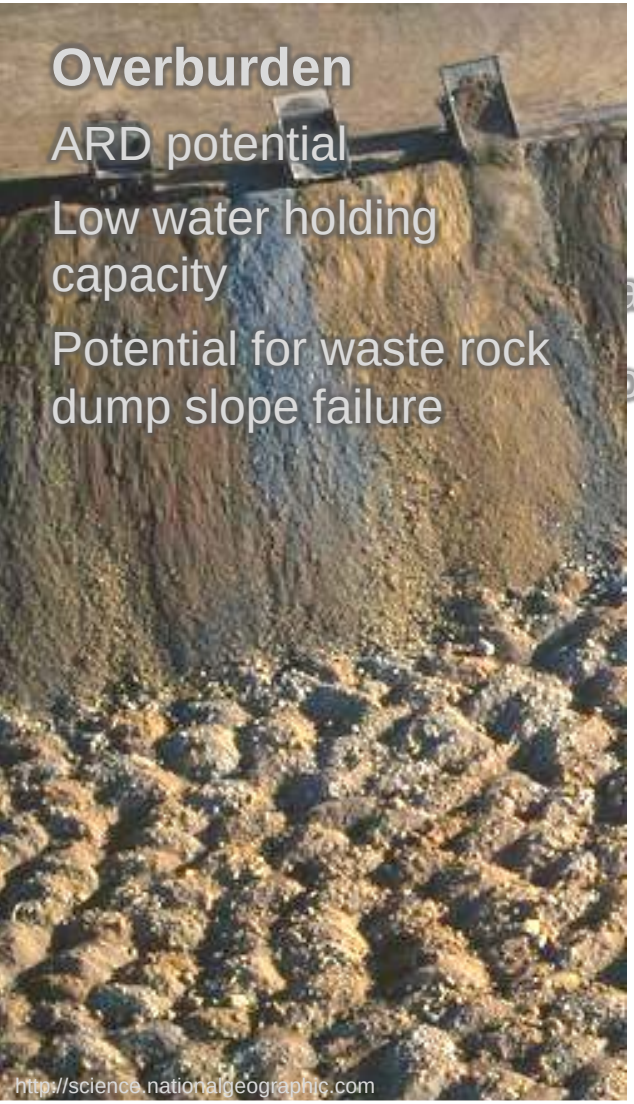
Reclamation: A horizon & above

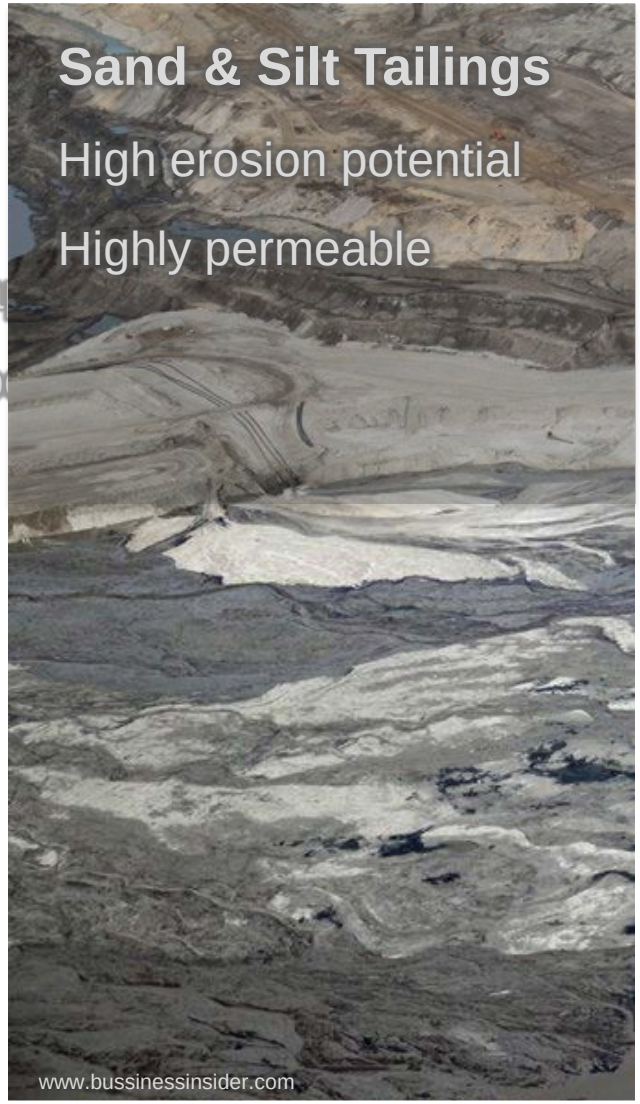
Geotechnical: below A horizon

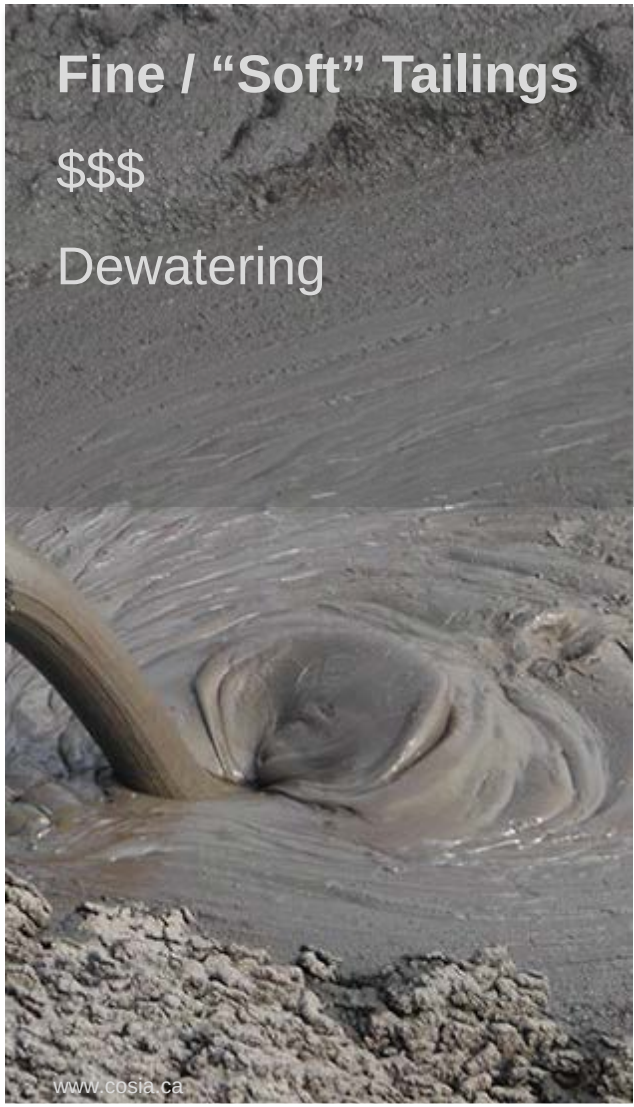
BUT:

The success of the surface landscape is dependent on what lies beneath, and what lies beneath is affected by how the surface is shaped.




Overburden
ARD potential
Low water holding capacity
Potential for waste rock dump slope failure
http://science.nationalgeographic.com


Sand & Silt Tailings
High erosion potential
Highly permeable
www.bussinessinsider.com


Fine / “Soft” Tailings
$$$
Dewatering
www.cosia.ca

Performance Issues

Surface & groundwater quality

Ground settlement

Consolidation

Degassing / vegetation die-off

Built Structures

Tailings impoundments

Water treatment facilities

Armoured channels…

www.grist.files.wordpress.com

INTEGRATED MINE CLOSURE II - THE “CLOSURE-FIRST” PRINCIPLE

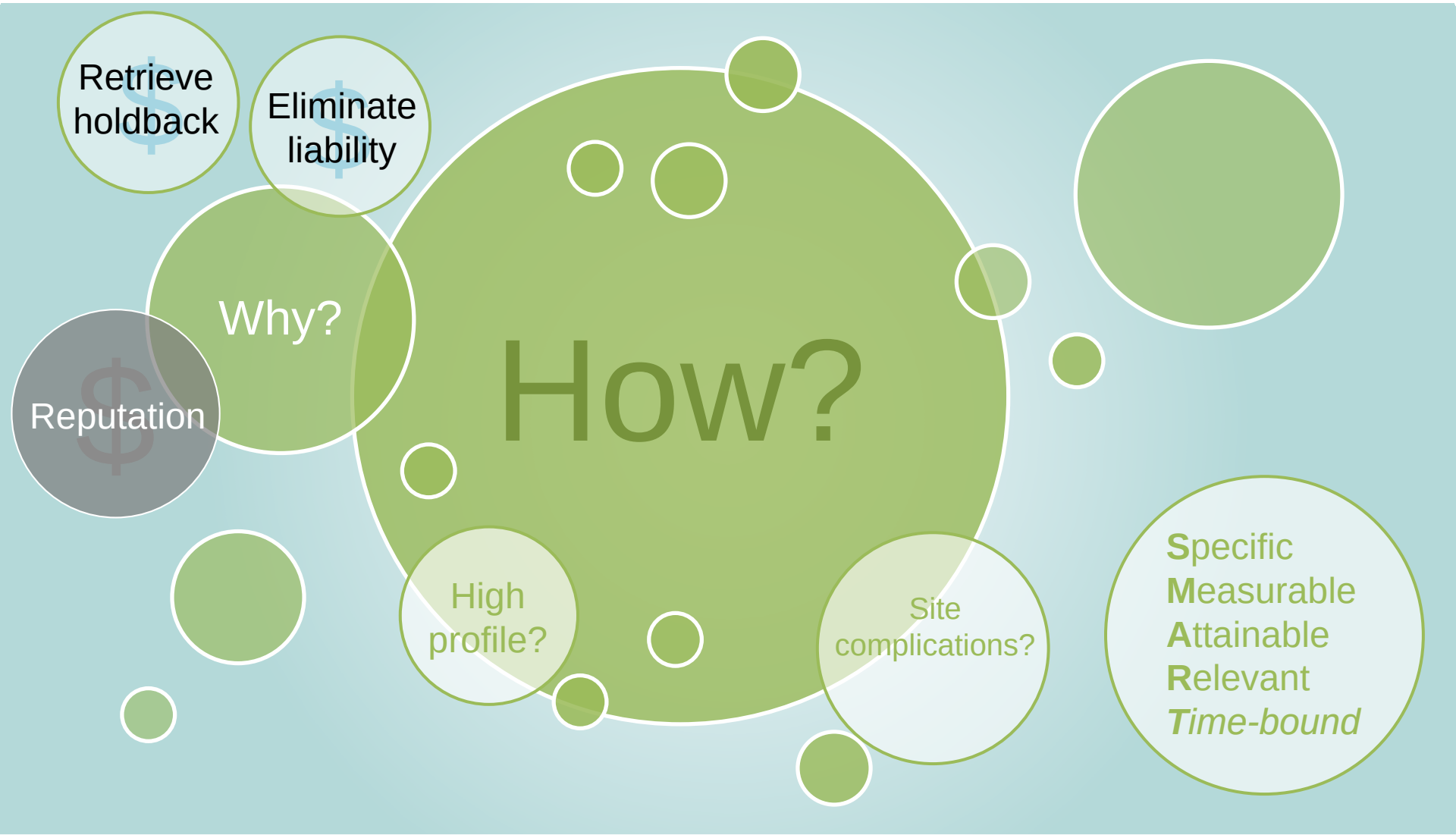
INTEGRATED MINE CLOSURE II - MATERIALS

"Wicked problems are ill-defined, ambiguous and associated with strong moral, political and professional issues. Since they are strongly stakeholder dependent, there is often little consensus about what the problem is, let alone how to deal with it. Above all, wicked problems won't keep still: they are sets of complex, interacting issues evolving in a dynamic social context. Often, new forms of wicked problems emerge as a result of trying to understand and treat one of them."

- Ritchey, 2013
(on Rittel & Webber's 1973 Theory)

TEN CRITERIA FOR WICKED PROBLEMS:

1. There is no definite formulation of a wicked problem.
2. Wicked problems have no stopping rules.
3. Solutions to wicked problems are not true-or-false, but better or worse.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
6. Wicked problems do not have an enumerable (or an exhaustively describable)set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another [wicked] problem.
9. The causes of a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. **[With wicked problems] the planner has no right to be wrong.**


Retrieve holdback
Eliminate liability
Why?
Reputation
How?
High profile?
Site complications?
Specific
Measurable
Attainable
Relevant
Time-bound

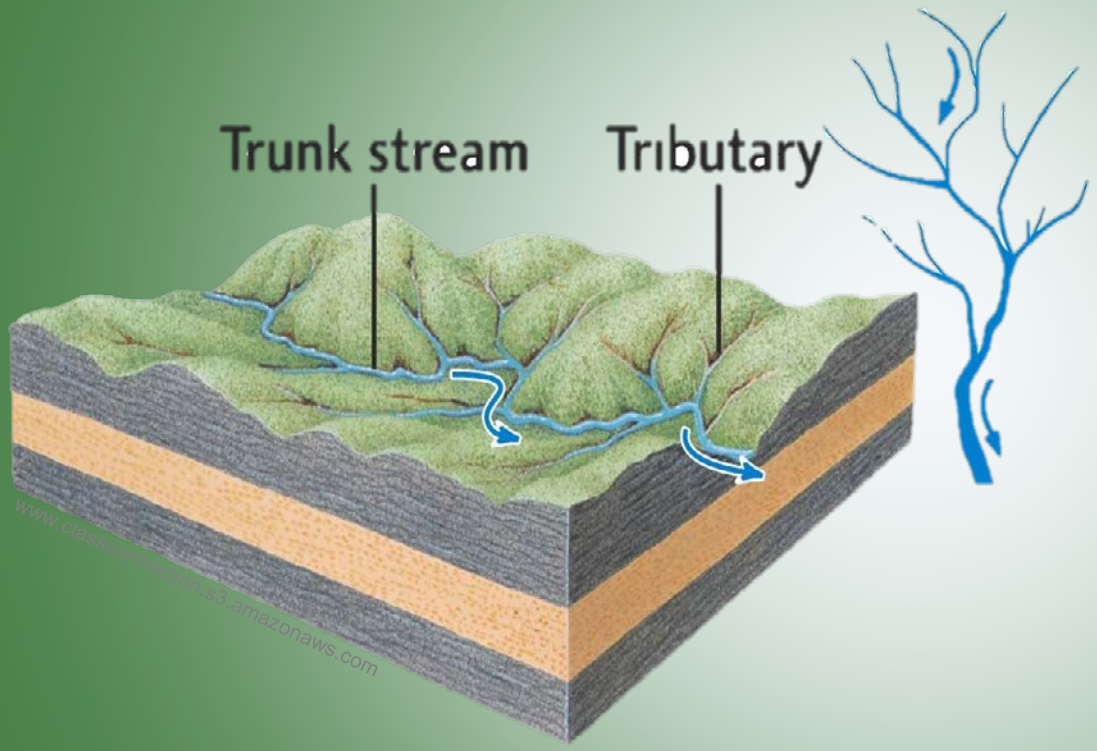

Construction Ends
t = 0

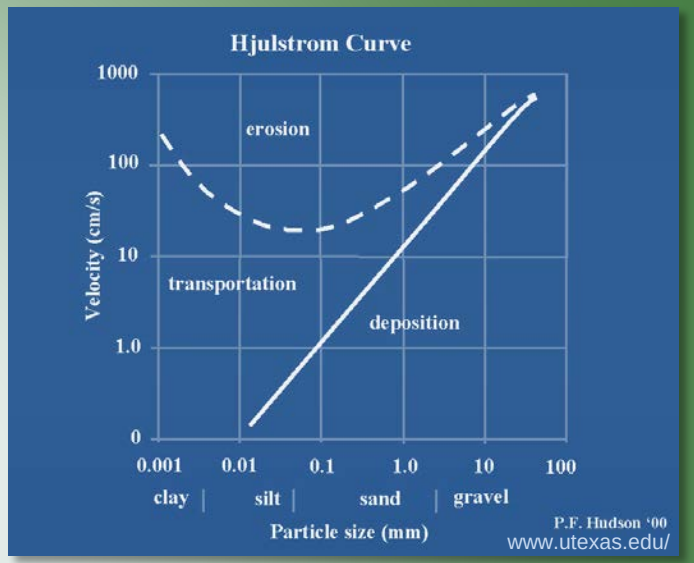
http://www.uu.nl/node/499/research/earth-surface-hydrology

Geomorphology
Topography &
Erosion control

Water →

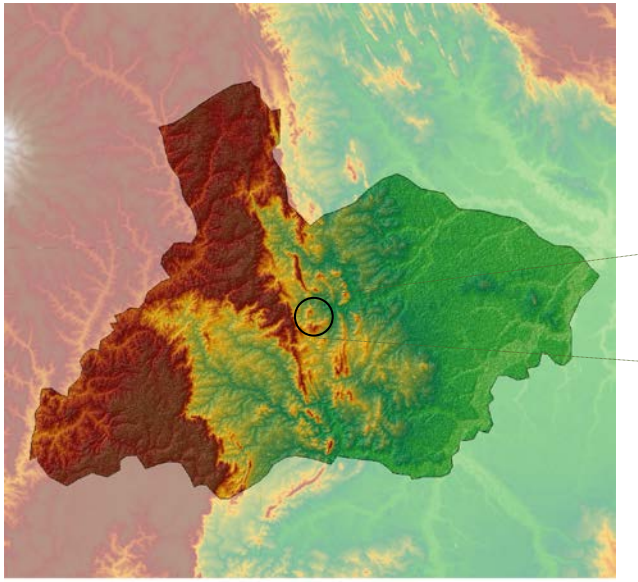
Vegetation
& topsoil
evolution

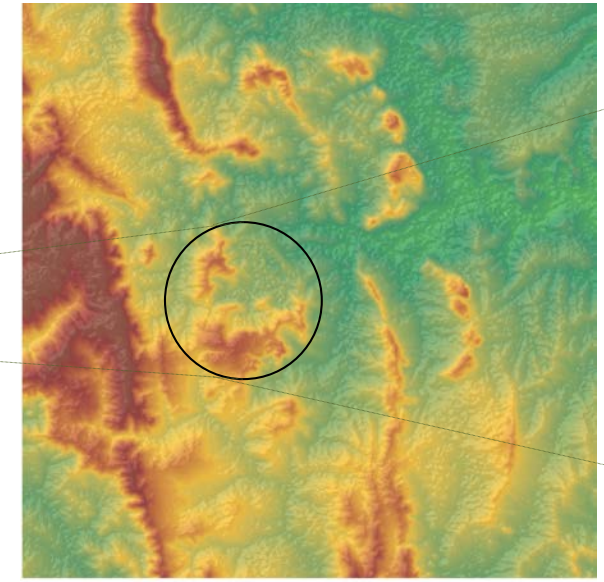


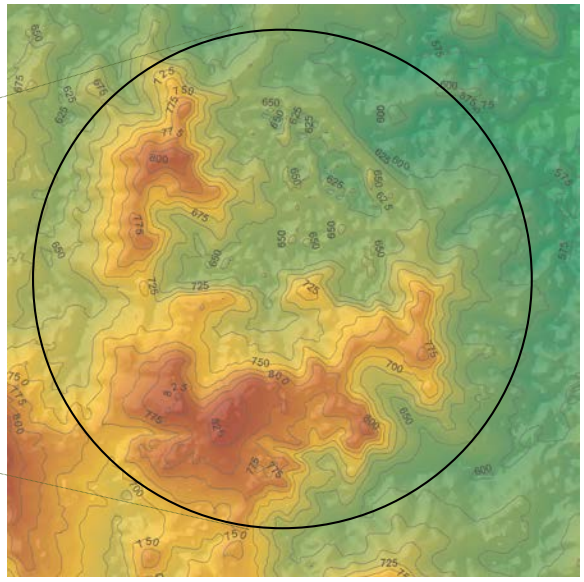


www.tnepsc.org

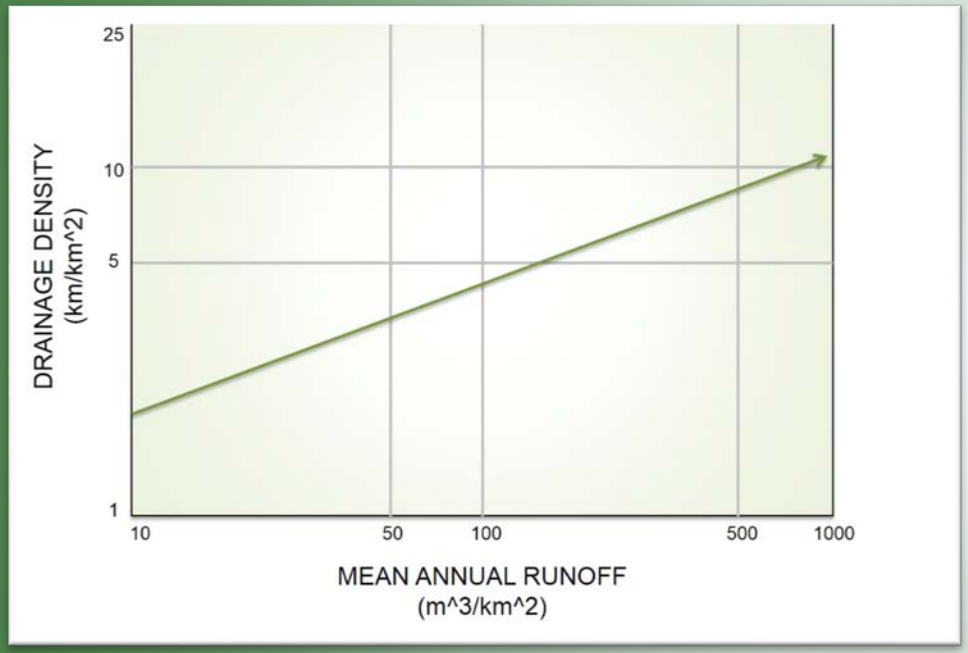
INTEGRATED MINE CLOSURE II - GEOMORPHOLOGY

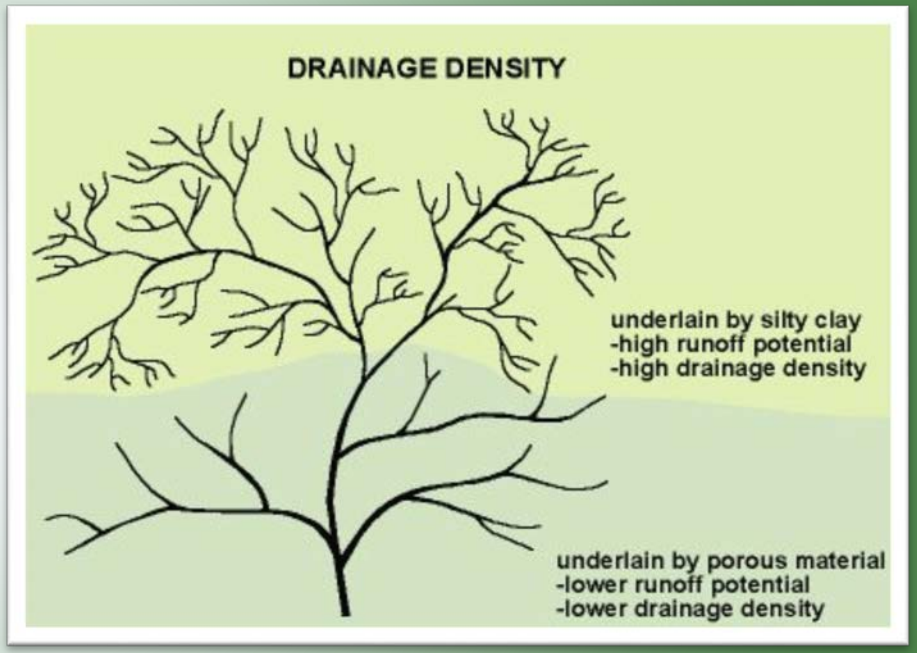






SCALE: Small / Regional Medium / Local Large / Site

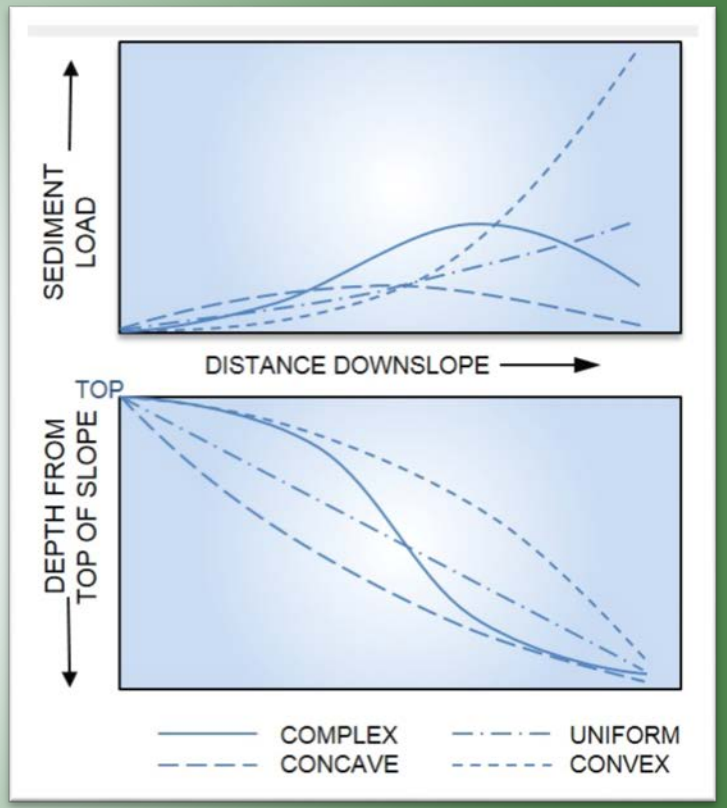




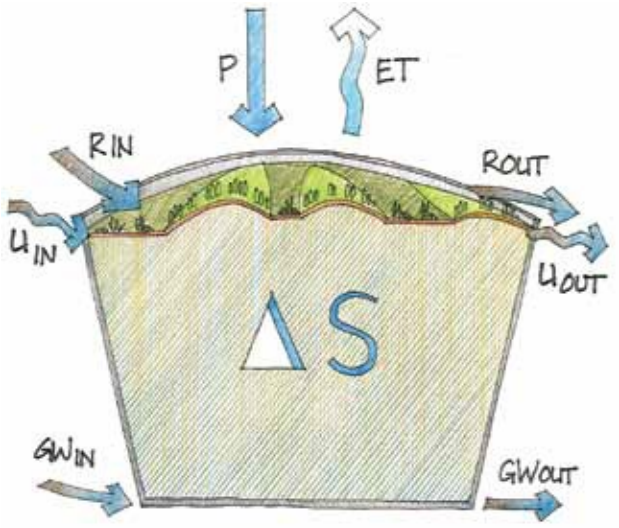
*approximate values. Adapted from Toy & Hadley, 1987.

www.geology.isu.edu

http://www.fs.usda.gov/Internet/FSE_MEDIA/stelprdb5361417.jpg



*approximate values. Adapted from Toy & Hadley, 1987.

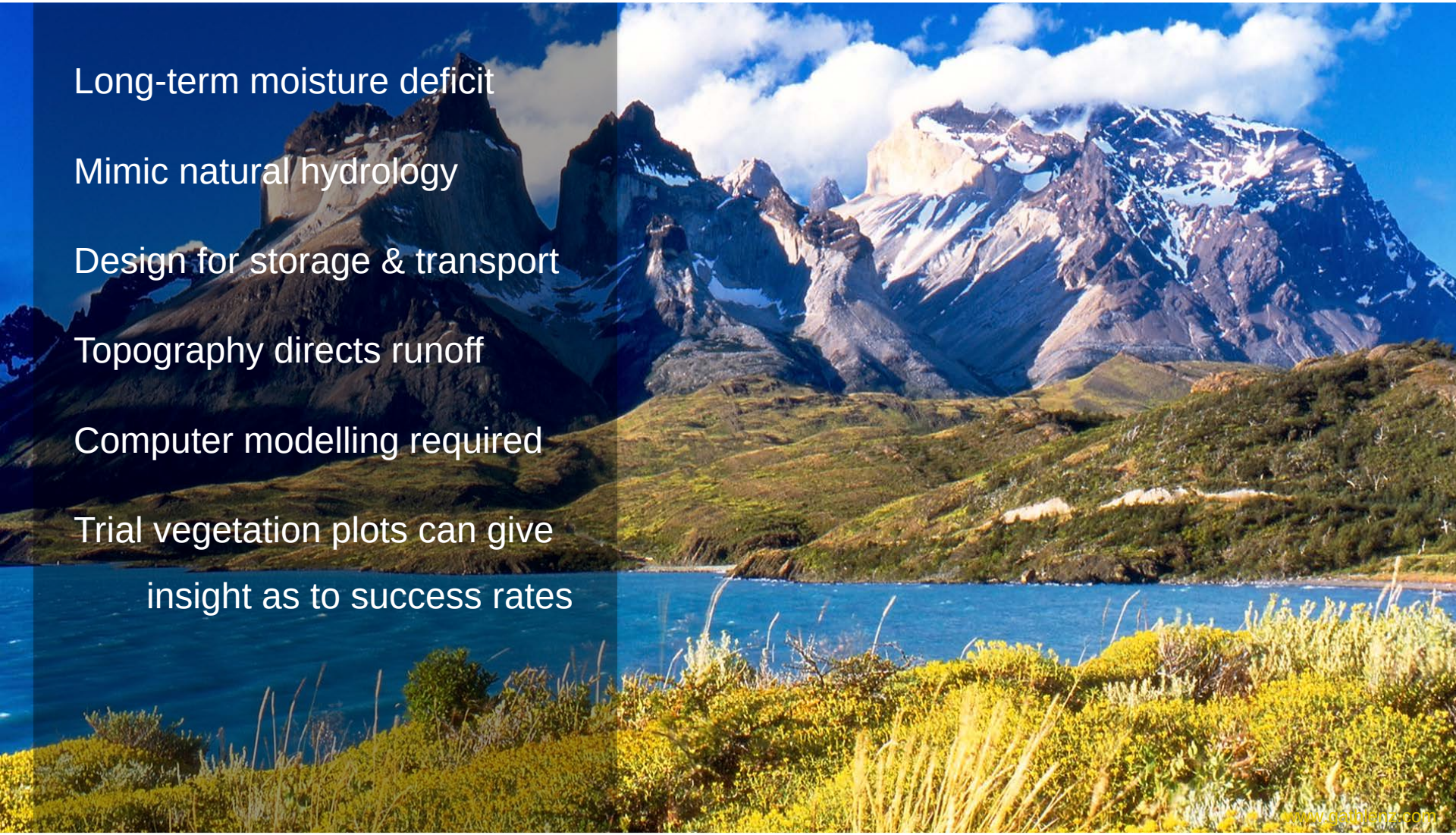


LEGEND:

- ΔS = storage flux
- P = precipitation
- ET = evapotranspiration
- R = runoff (flowing in and out of system)
- GW = groundwater (in & out of system)
- U = uplift (in & out of system via root networks and vegetation)

$$\Delta S = P - ET + (R_{IN} - R_{OUT}) + (GW_{IN} - GW_{OUT}) + (U_{IN} - U_{OUT})$$

Illustration by Derrill Shuttleworth



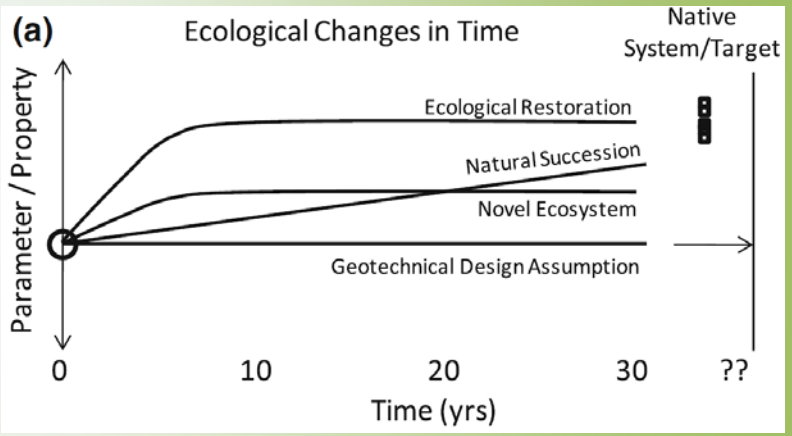
- Long-term moisture deficit
- Mimic natural hydrology
- Design for storage & transport
- Topography directs runoff
- Computer modelling required
- Trial vegetation plots can give insight as to success rates

GEOTECHNICAL DESIGN:

- Assumptions valid over short term
- Properties do not change over time or when they do, (i.e. consolidation) it occurs predictably
- As-built properties used to predict performance
- Service life is typically extended

BUT:

- Few inspections post-mining over long term
- Subject to climate, vegetation, geochemistry, microbes, animals



CLIMATE

- Erosion can be a problem if it is too dry (wind) or too wet (rain)
- Affects vegetation success

VEGETATION

- Increases stability against slope failures
- Increased water holding capacity
- Can create preferential pathways

ANIMALS

- Burrowing,
- Blocking waterways
- Bioturbation

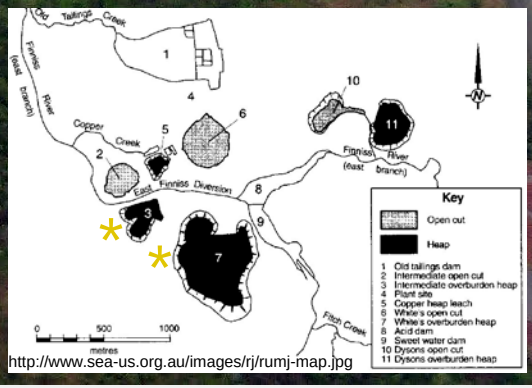
GEOCHEMISTRY

- Acidity can erode rock and create inhospitable conditions for wildlife
- Soil can fuse or reduce permeability

MICROBES

- Increased fertility

- 1950 – 1971 owned by Australian Atomic Energy Authority
- Underground and open-pit with heap leach & ion exchange extraction
- “Promised land” during dry season, depression era
- Tailings often overflowed: 1 million L/day deposited in ponds at pH 1.5
- 1983: $16.2M on metal removal, tailings neutralization
- 1990: $1.8M on south waste dumps

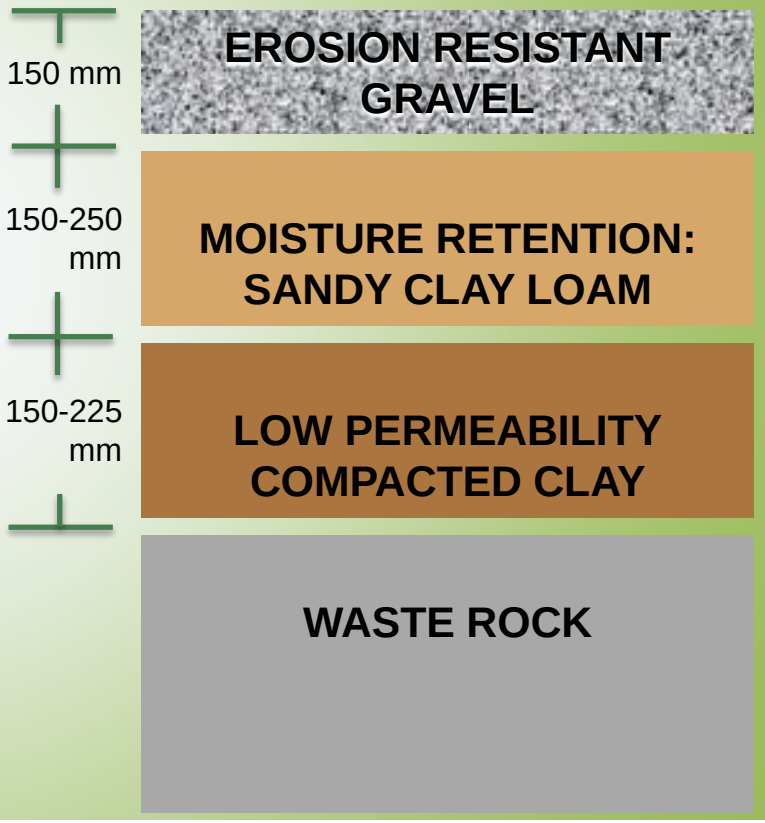


http://www.sea-us.org.au/images/rj/rumj-map.jpg

Home to the only crocodile-free water body in the Darwin Region.

https://www.flickr.com/photos/iaea_imagebank/4770231545/in/photostream/

- 1984/85: three waste rock dumps covered
- Most advanced engineered cover system in the world at the time
- 3-layer cover system
- Limit percolation into waste rock to < 5% of annual precipitation
- Nine lysimeters installed
- Monitored for 18 years



- Layers were too thin
- Performed for first 9 years
- Percolation after 9 years was 8-10% of annual rainfall
- Hydraulic conductivity raised by 1-3 orders of magnitude in all layers
- Field investigation found:
  - Vegetation dieback
  - Termite & ant galleries
  - Root development in all layers
  - Desiccation / drying of clay
  - Acidification of cover soils from capillary action upwards.

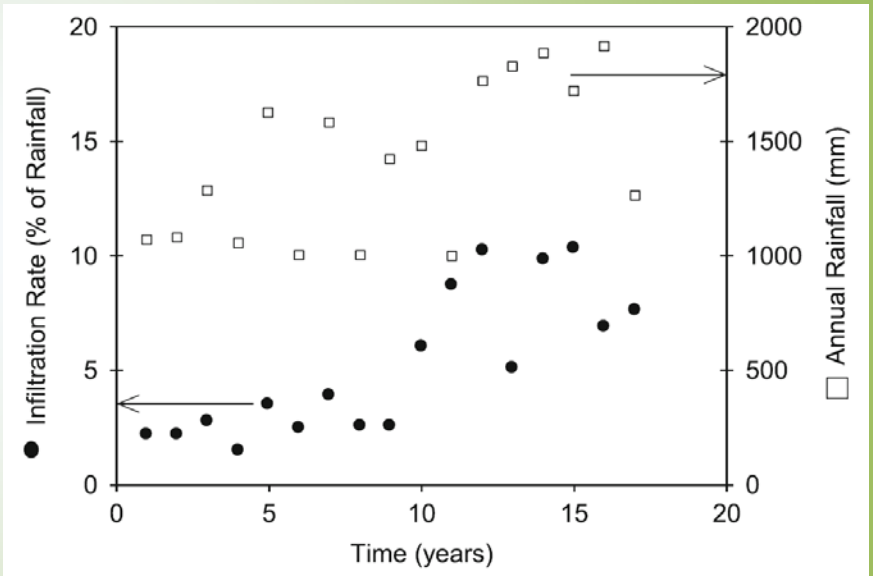
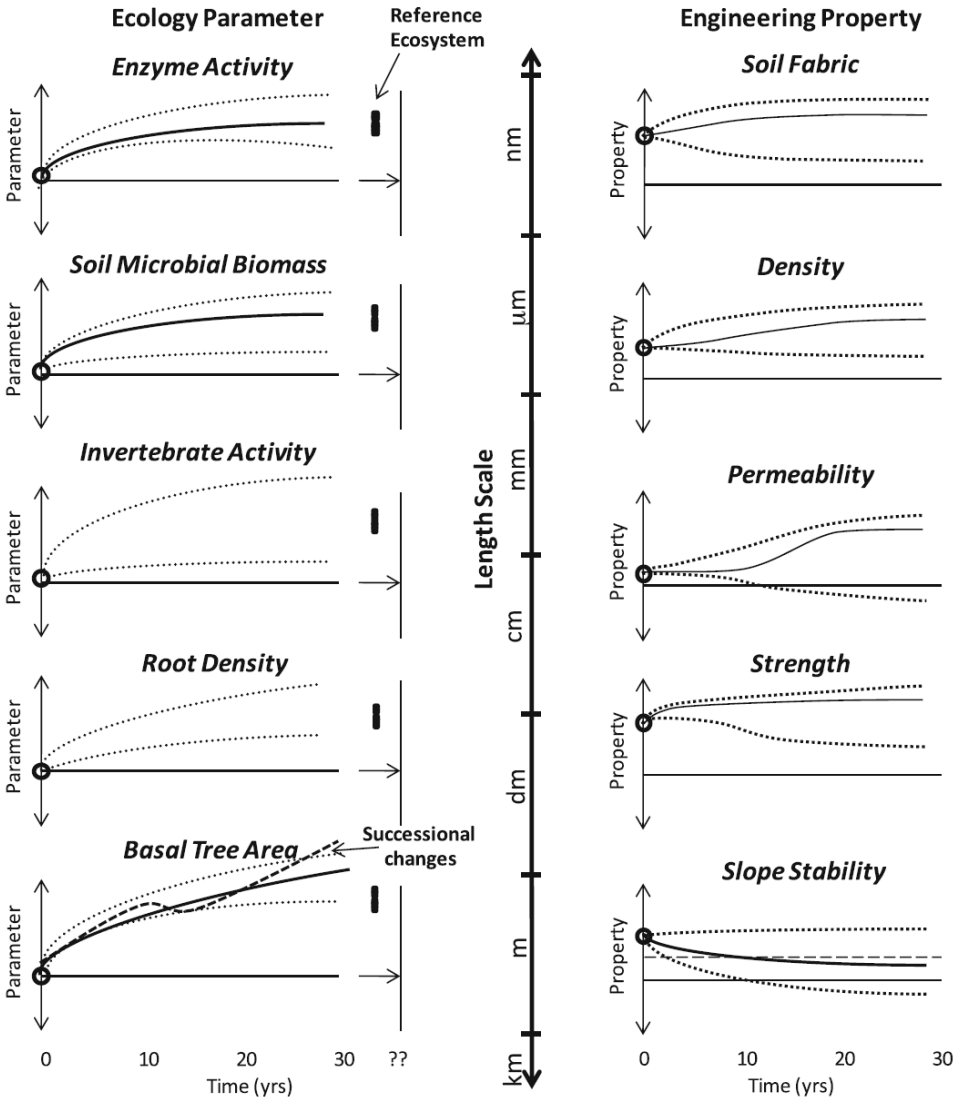


Fig. 4 Variation of mean infiltration rate (*solid symbols*) for lysimeters installed in the Rum Jungle cover system and corresponding annual rainfall (*open symbols*) versus years after installation

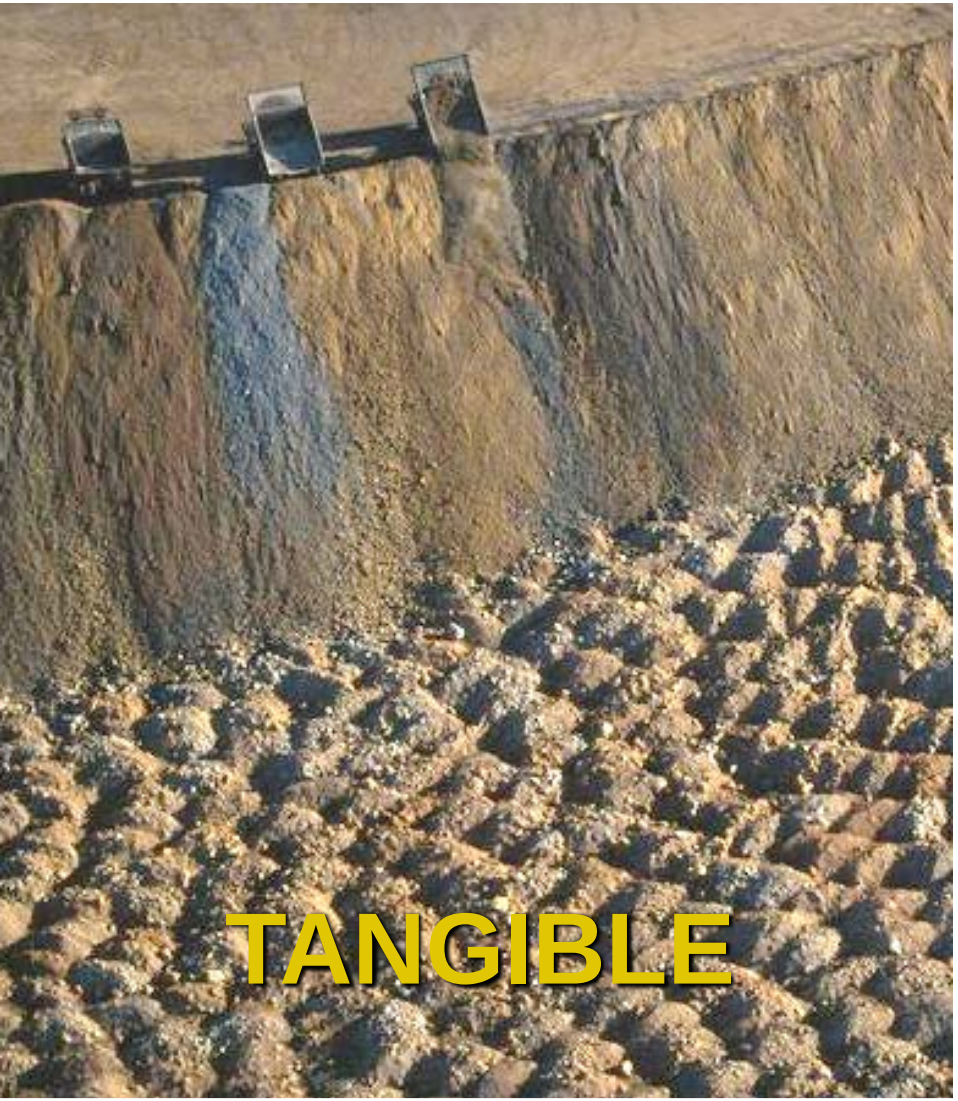


From DeJong, Tibbett, Fourie (2015)

CASE STUDY 2: EROSION CONTROL

WAVE KING | New York State, USA

http://openspacesfengshui.com/


TANGIBLE


INTANGIBLE

LADY OF THE NORTH | Cramlington, UK


£140 million
Predicted injection into economy
100,000
visitors in first year
£3 million
additional costs to Banks
20 ha
public open space
Proven Reputation
Unanimous local government approval for Ferneybeds mine
www.northumberlandia.com

Table 2. Types of after-use for mines located below (wet bottoms) or above (dry bottoms) the water table. [#=sand and gravel pit; *=hard rock quarry]

Land use	Wet site	Dry site
Conservation:	Fish spawning #	Native plant revegetation * #
	Passive lakes	Wildlife habitat * #
	Aquatic habitat * #	Historical *
	Waterfowl habitat * #	Nature center * #
	Riparian habitat #	Threatened/endangered species * #
	Wetland habitat * #	
	Beach restoration #	
	Stream restoration #	
	Threatened/endangered species #	
Recreation:	Active lakes	Botanical garden * #
	Waterslide resort #	Golf course *#
	Swimming * #	Casino #
	Water-skiing #	Hiking, bicycle and horse trails #
	Fishing * #	Motorcycle track #
	Boating and sailing #	Theme amusement park #
		Public parks # *
		Hunting, camping #
		Soccer, football, and baseball fields #
Public facilities:	Harbor *	College campus #
	Tidal pool *	Hospital #
	Sculptural #	Restaurant #
		Amphitheater * #
		City hall *
		Sculptural * #
		Permanent easement for utilities and highways * #
Commercial/ Industrial:	Academic research * #	Academic research * #
	Ferry terminal *	Light manufacturing #
		Office #
		Shopping center * #
Residential:	Sewage treatment #	Housing * #
	Water quality improvement #	
Recycling:	Ground water recharge #	Pasture * #
	Wastewater treatment *	Cropland * #
		Forestry * #
		Composting #
		Methane production *
Storage:	Water supply * #	Livestock shelter *
	Flood control #	Equipment *
	Inert fill material #	Food *
		Trains (city transit) #
		Cemetery *
		Sanitary landfill * #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