

# **Workshop on Capping Design in South Africa**

Plastics SA, Midrand, 29 June 2016

## **CLOSURE AND REHABILITATION OF WASTE DISPOSAL FACILITIES**

**Peter Legg**



# LANDFILL COVERS

- OBJECTIVES OF COVER SYSTEMS
- DESIGN ASPECTS
- COVER COMPONENTS
- STABILITY
- DRAINAGE
- CONCLUDING REMARKS

# Objectives of Capping

- Contain the wastes
- Manage leachate production by controlling the ingress of water into the waste
- Prevent uncontrolled escape of landfill gas and odours or the entry of air into the wastes
- Provide protection for the wastes
- Accommodate environmental control measures such as gas vents, etc.
- Provide physical separation between waste and humans, animals and plants.

(Daniel and Koerner, 1993; United Kingdom Department of the Environment, 1995; Jesionek et al, 1995)

# World Bank / IFC and US EPA

“At final closure of the landfill or upon closure of any cell, cover the landfill or cell with a final cover designed and constructed to:

- Provide long-term minimization of migration of liquids through the closed landfill;
- Function with minimum maintenance;
- Promote drainage and minimize erosion or abrasion of the cover;
- Accommodate settling and subsidence so that the cover's integrity is maintained; and
- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils.”



# Prime Objective

- The prime objective of landfill final cover is generally accepted to be keeping water out of the waste (Daniel and Koerner, 1993).
- Isolate the waste body from the surrounding environment (both air and water environments)







# Design Life

- The cover system must perform these functions for an extended period of time. The design life of a cover depends primarily on the nature of the waste, the site hydrology, and the length of time that the maintenance of the cover will be provided.
- Post-closure Care
  - Post-closure care period typically 30 years
  - Must maintain integrity and effectiveness of cover
  - Must maintain leachate collection
  - Must monitor groundwater
  - Must maintain and operate gas monitoring



# Environmental Risk

- Assess the environmental risk posed by the waste facility
  - Nature of waste (hazardous or general waste)
  - Bottom liner or not (MRs Clause 8.4.7)
  - Groundwater sensitivity
  - Adjacent landusers (neighbours)
- Determine minimum requirements of the Regulator
  - In absence of strong regulations, apply “Duty of Care” principle and international “Best practice”

# Design Aspects

- Landscaping requirements including additional topsoil needs
- Consider final end-use
- Low permeability to minimise gas emission and surface water infiltration
- The relationship between phasing of construction and the landscape design for the after-use
- Recirculation of leachate if required

# Knots Dump before Capping





# Knots Dump after Phase 1 Capping





# Knots Dump during Phase 2 Capping





# Knots Dump after Phase 2 Capping



## Design Aspects (cont.)

- Alterations caused by gas derived from volatile components of the waste or decomposition products
- Robustness against settlement stresses
- Stability on proposed restoration slopes
- Surface water drainage
- Erosion
- The effects of roots and burrowing animals on its integrity
- Deformations caused by earthquakes



# Design Aspects

Because of these site-specific environmental stresses and conditions, the design of a cover system can be very challenging. It is often more difficult to provide an effective hydraulic barrier layer in a cover system than in a liner system because the cover system is challenged by unknown and unquantifiable stresses that do not act on liner systems buried deep beneath the waste.

# Temporary Covers

- Daniel and Koerner (1993) contend that in many cases, it could be preferable to construct a temporary cover for an actively decomposing and deforming body of waste, and then wait until substantial decomposition of the waste body has occurred before attempting to construct a final cover.

# Cover Components

The components of a cover comprise a combination of some or all of the following:

- Surface erosion and vegetation layer
- Protection layer
- Drainage layer
- Barrier layer, and
- Foundation or gas collection layer.

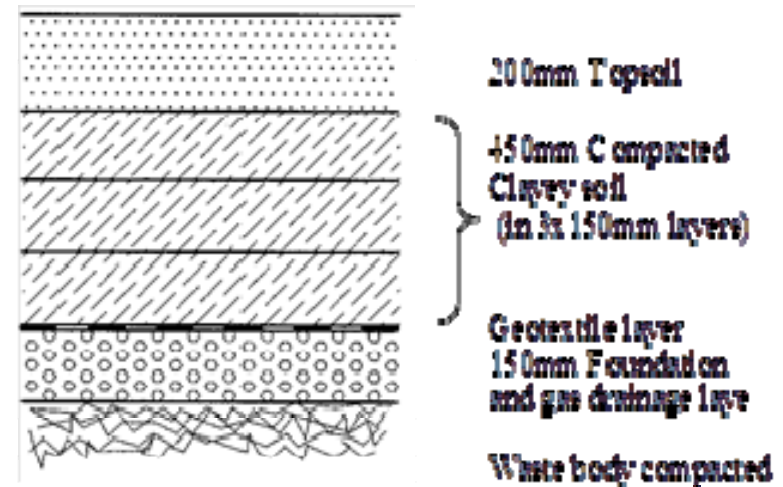


# Capping - General Waste

- Clay Barrier

- PI between 5 and 15
- Particle size < 25mm
- Compacted to 85% Proctor
- $k < 0.5 \text{ m/yr}$  ( $1.6 \times 10^{-6} \text{ cm/s}$ )
- Slopes > 3%

**General Waste Landfills**



- Problems with clay

- Cracking due to differential settlement (clay max strain 0.3%)
- Cracking due to dessication

- GCL alternative

- Requires minimum 600mm cover soil for confining stress
- Be aware of cation exchange
- Roots and animal burrow risks

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**For GSI Members/  
Associate Members  
Review Only**

**GRI White Paper #10**

**The Uselessness of Compacted Clay Liners in the Closure  
(i.e., Capping) of Landfills**

**by**

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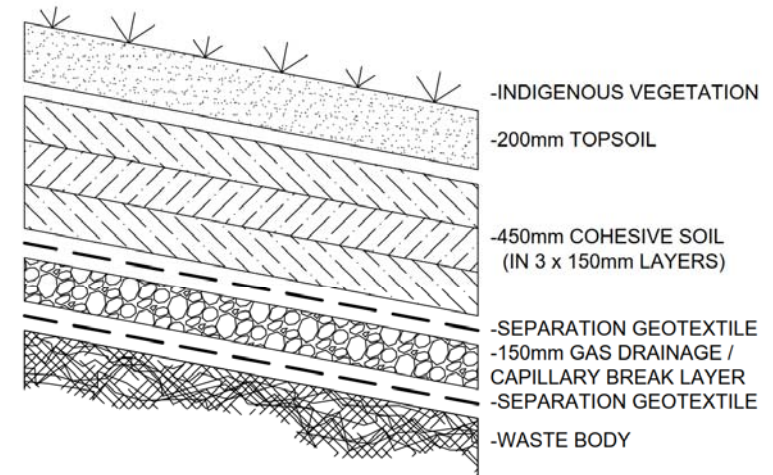


**January 2, 2006**



# Capping – General Waste

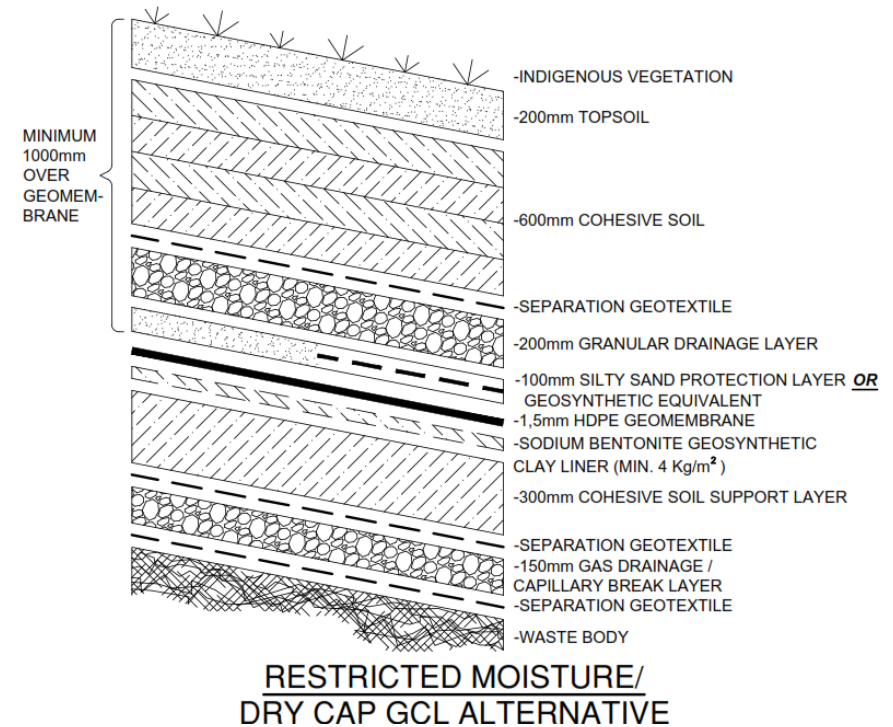
- Current South African proposal
  - Controlled moisture ingress
  - Allows for waste stabilisation
  - Silty soil (less cracking)
  - Assumes no active gas extraction system
  - Suited to drier climates
- If gas active gas management, then require barrier in capping system



CONTROLLED MOISTURE/  
PERCOLATION CAP

# Capping – Dry Cap (restricted moisture)

- Hazardous waste and general waste in wet climates
- Similar to US EPA
  - Surface/protection layer 600 mm thick (vegetated soil or rock);
  - Filter layer (geotextile);
  - Drainage layer (granular or geosynthetic);
  - Geomembrane barrier layer;
  - Low permeability soil barrier; and
  - Foundation layer (coarse material which could also act as a gas venting layer).



# Comments on layers

- Surface layer
  - Thin as possible but sufficient to support vegetation
  - Indigenous vegetation
  - Ensure erosion control, particularly until vegetation has established
- Protection layer
  - Use local soil, with moderate compaction
  - Thickness sufficient for frost penetration and/or GCL confining stress
- Filter layer and drainage layer
  - Use geotextile filter plus stone drainage layer, or geocomposite drain
  - Ensure capacity for drainage of extreme design storms (stability)
  - Install collector pipes
- Barrier layers
  - **Geomembrane** – LLDPE better than HDPE for flexibility during settlement (LLDPE 75% max strain vs HDPE 25% max strain)



Thickness typically 1mm to 1.5mm

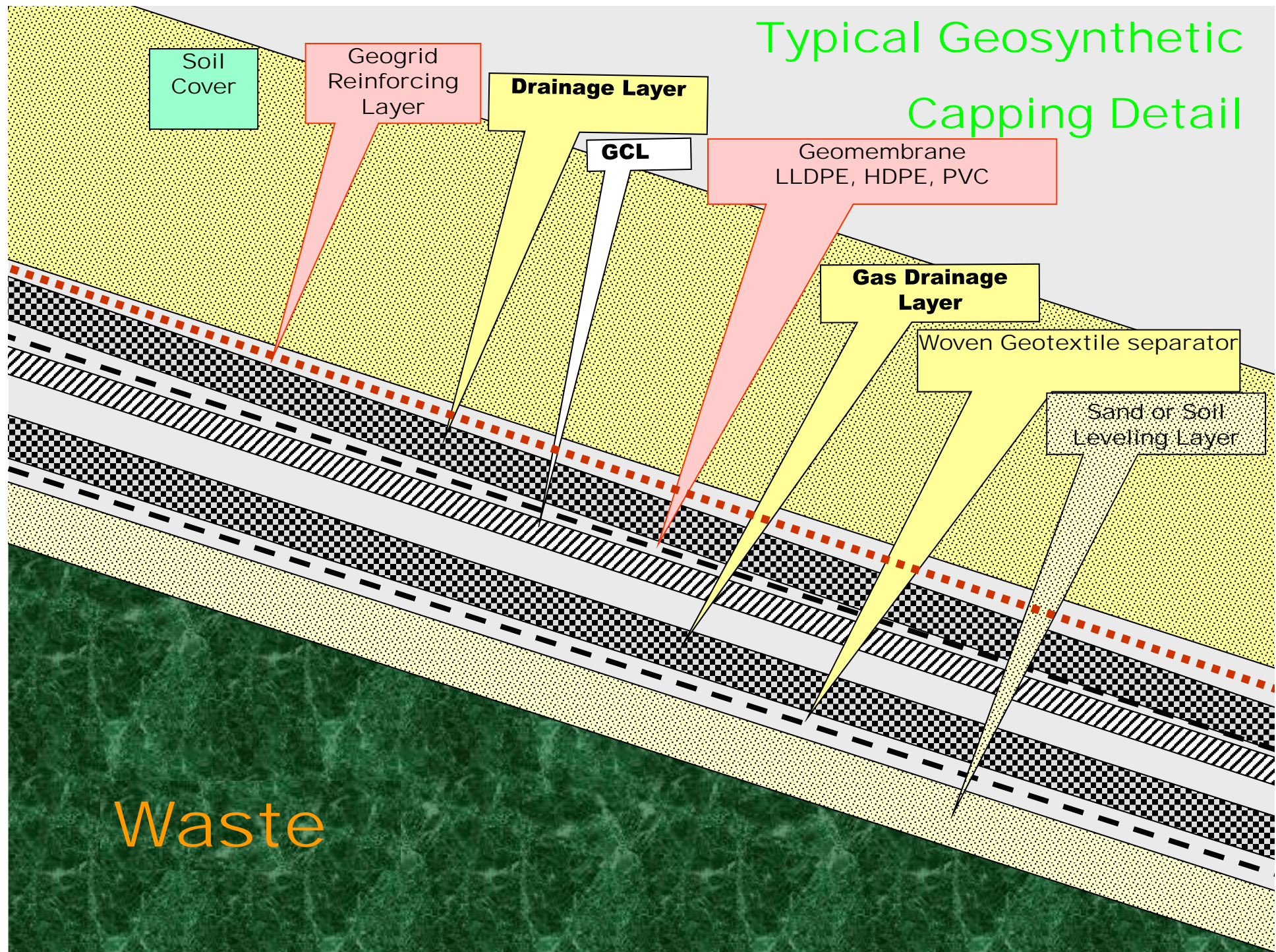




# Comments on layers

- Barrier layers
  - GCL – Can handle 10 to 15% strain before permeability breakthrough, and 15 to 25% strain before tensile failure
  - GCL requires confining stress
  - Check landfill gas and moisture compatibility
  - Dr R Koerner recommends GM plus GCL or GM alone; not GCL alone or CCL alone
- Foundation layer
  - Gas collection layer important to prevent gas buildup and possible instability.
  - Geocomposite drain or heavy geotextile (NW) plus collector pipes and vents
  - Foundation and leveling layer; use locally available granular soil

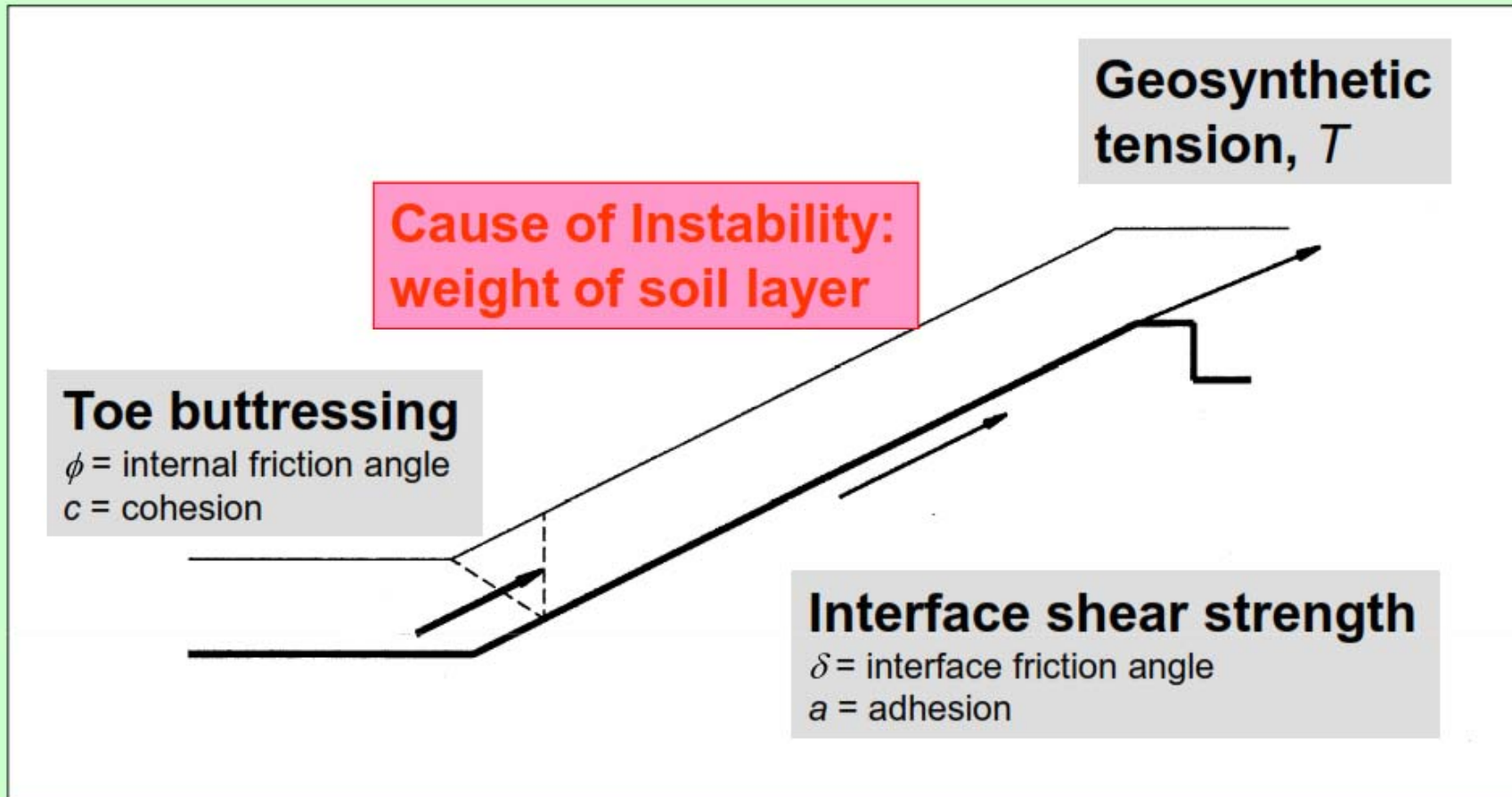
# Typical Geosynthetic Capping Detail



# Cover stability design

- Assess cover veneer stability for dry and saturated conditions
- Determine various liner interface shear strength parameters by means of lab testing using actual materials (soils and geosynthetics)
- Ensure failure plane is above the geomembrane barrier layer so as to protect the barrier
- If necessary, use a geosynthetic reinforcement product above the geomembrane to provide stability of the cover soil.
- Stability FoS =  $\frac{\text{Shear strength of veneer system}}{\text{Shear stress on the veneer system}}$

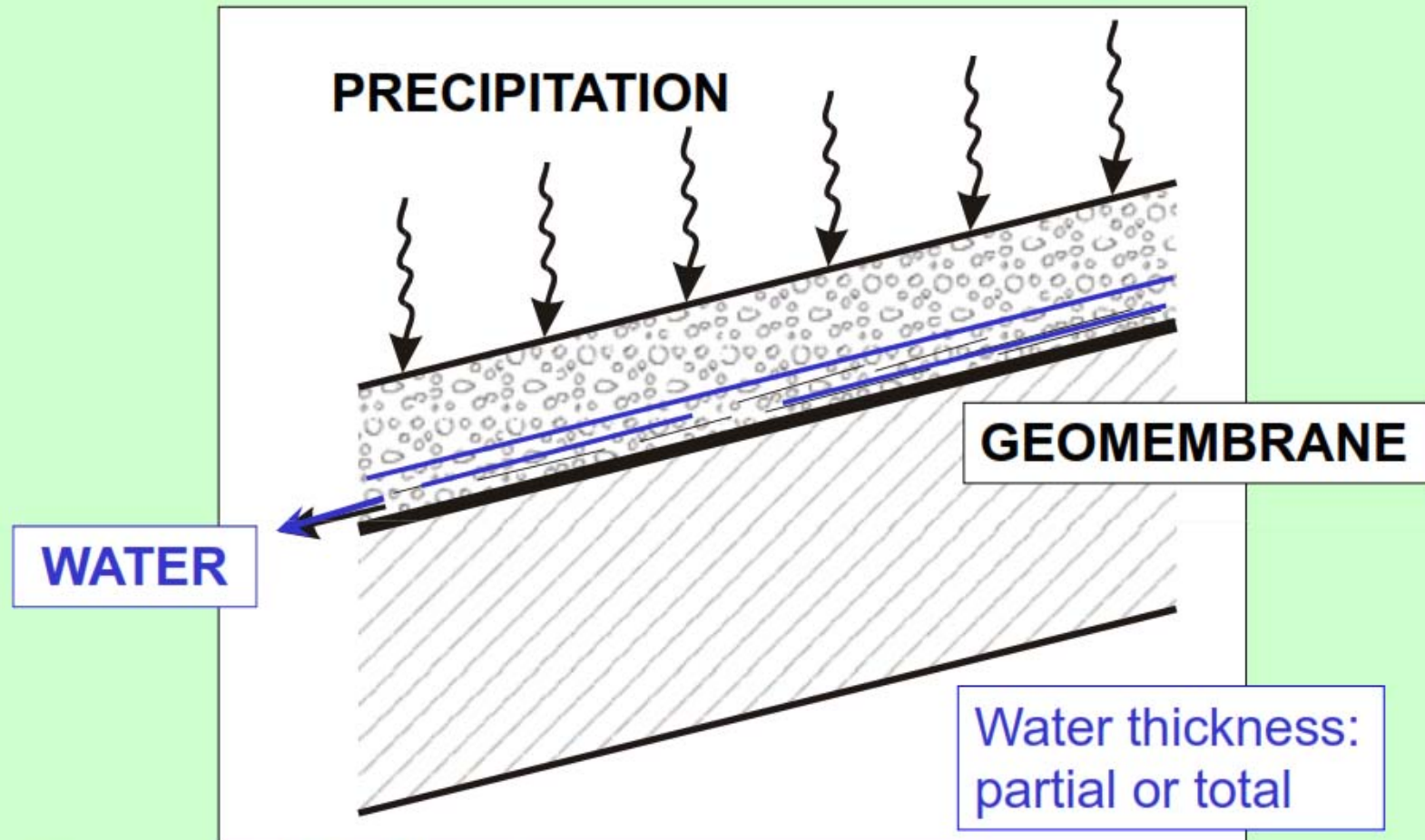
# SLOPE STABILITY MECHANISMS



## AND DEFINITION OF STABILITY PARAMETERS

Courtesy of J.P. Giroud

# Seepage Forces



Courtesy of J.P. Giroud



# Slope Stability Equations

## INFINITE SLOPE WITHOUT WATER

$$FS = \frac{\tan \delta}{\tan \beta}$$

## INFINITE SLOPE WITH WATER

**ABOVE**

$$FS_A = \frac{\gamma_b}{\gamma_{sat}} \frac{\tan \delta_A}{\tan \beta}$$

**BELOW**

$$FS_B = \frac{\tan \delta_B}{\tan \beta}$$

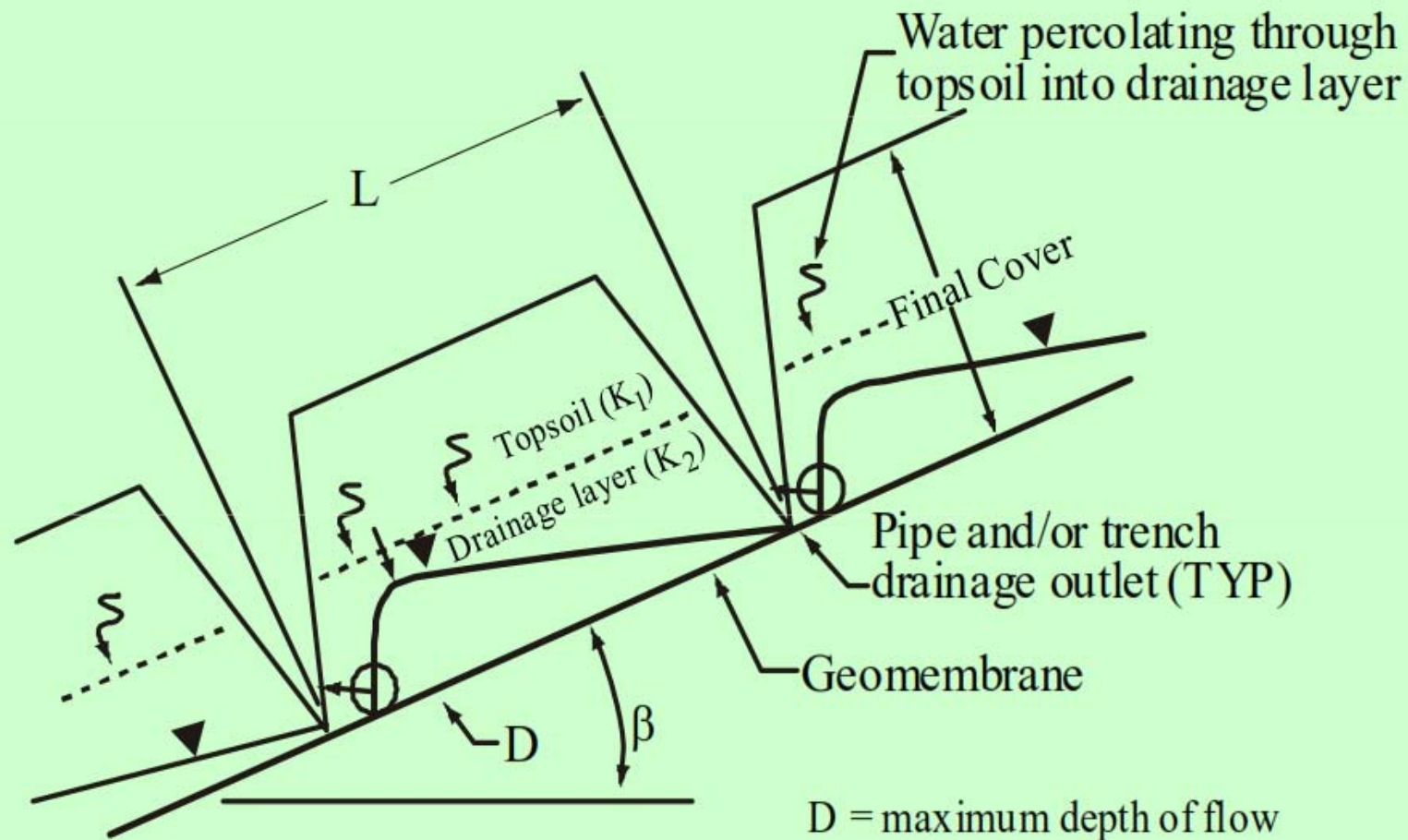
$$\frac{\gamma_b}{\gamma_{sat}} = 0.50 \text{ to } 0.55 \approx 0.5$$

**VERY SIGNIFICANT**

Courtesy of J.P. Giroud

# Schematic of Head Buildup in the Drainage Layer

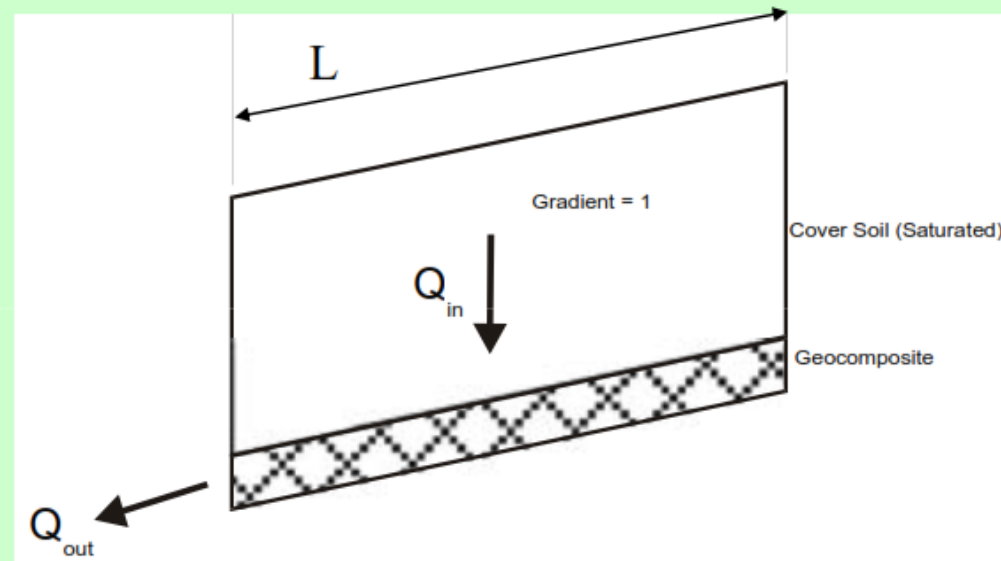
(after Thiel & Stewart, 1993, Geo '93, Vancouver BC)



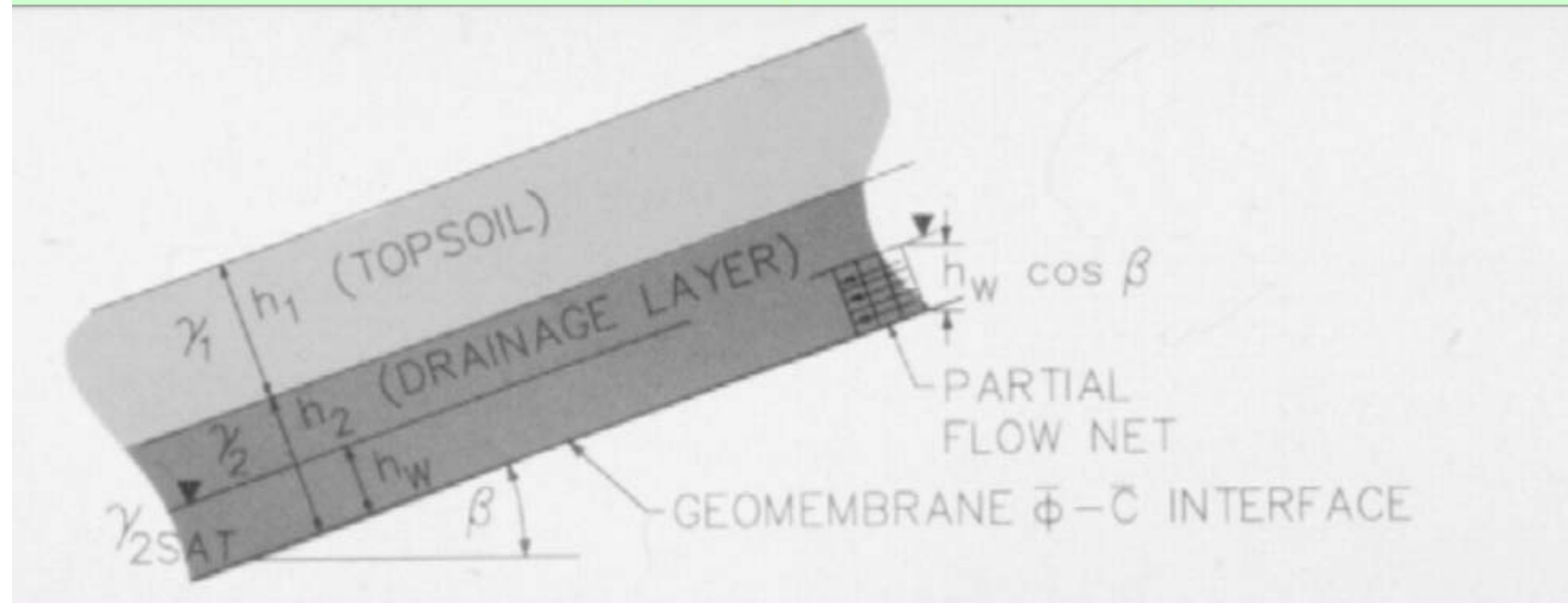
# Drainage Design For Side Slopes in Landfill Caps

- $Q_{in} = k_{veg} * L * 1$
- $Q_{out} = k_g * i * A = (k_g * t) * i = \theta * i$

$$\theta_{req} = \frac{K_{veg} * L}{i}$$



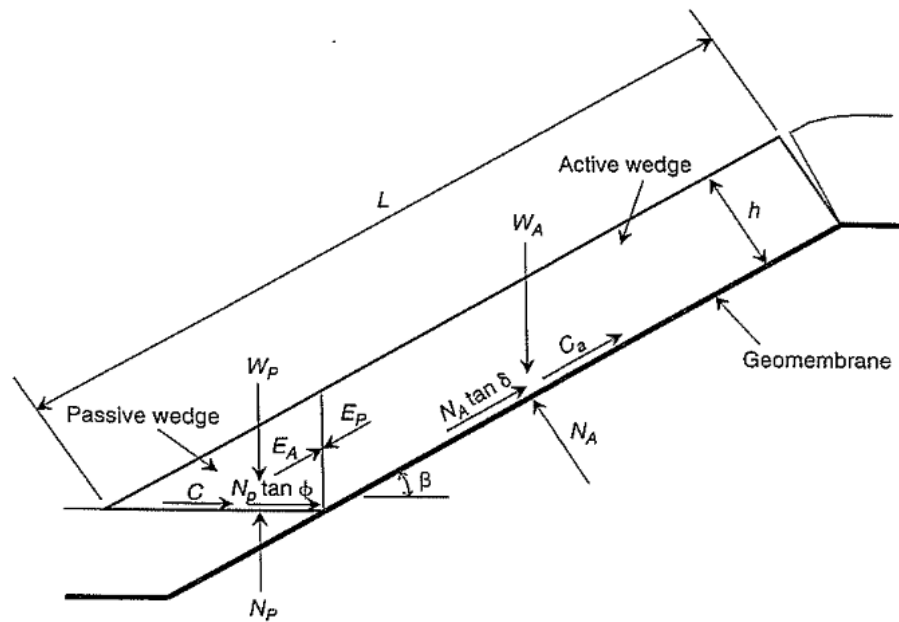
# Infinite slope eqn with seepage



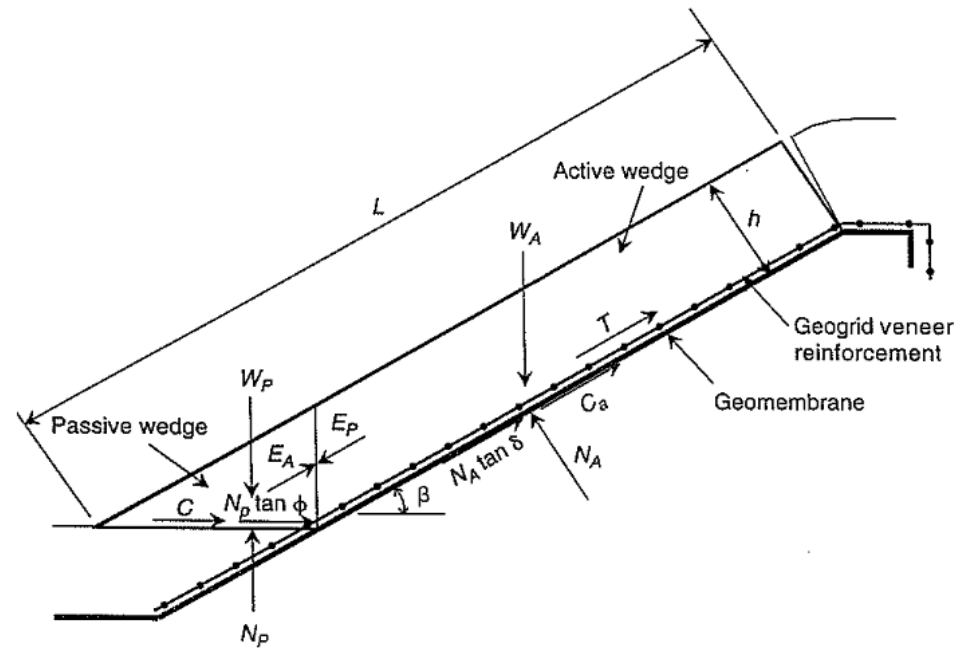
$$FS = \frac{c + [h_1\gamma_1 + (h_2 - h_w)\gamma_2 + h_w\gamma_{2SAT} - h_w\gamma_w] \tan \phi \cos \beta}{[h_1\gamma_1 + (h_2 - h_w)\gamma_2 + h_w\gamma_{2SAT}] \sin \beta}$$

Thiel and Stewart, 1993

# Cover Stability Design



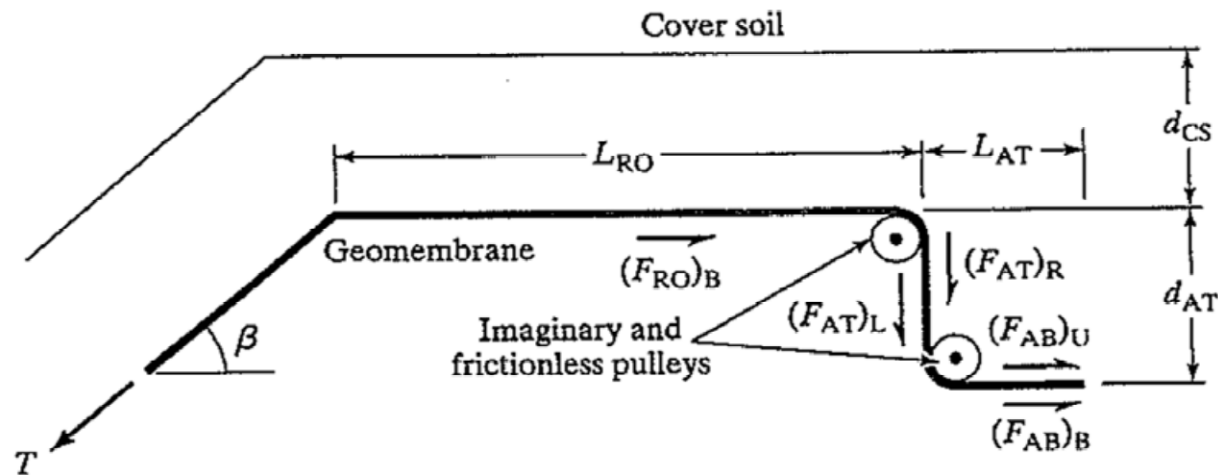
(a) Without reinforcement



(b) With the use of geogrid veneer reinforcement



# Anchorage design



RESULTS			
SYMBOL	VALUE	UNIT	DESCRIPTION
$(F_{RO})_B$	14.03	KN/m	friction force beneath runout geosynthetics
$(F_{AT})_R$	4.04	KN/m	friction force between the right side of the geosynthetic and the side wall of anchor trench
$(F_{AT})_L$	4.04	KN/m	friction force between the left side of the geosynthetic and the side wall of anchor trench
$(F_{AB})_B$	13.13	KN/m	friction force between the right side of the geosynthetics and the underlying soil at the bottom of anchor trench
$(F_{AB})_U$	13.13	KN/m	friction force between the right side of the geosynthetics and the overlying soil at the bottom of anchor trench
$T_{MAX}$	55.51	KN/m	geosynthetic tensile force developed by the anchor trench
		<b>FoS</b>	<b>1.39</b>

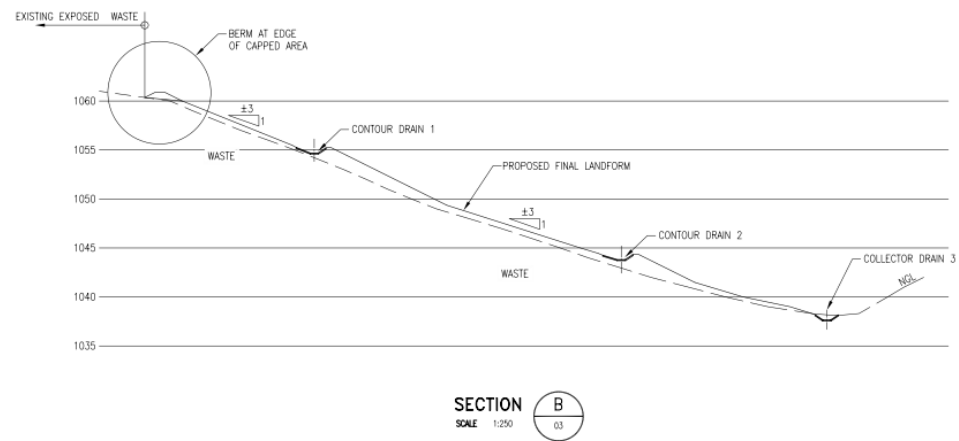
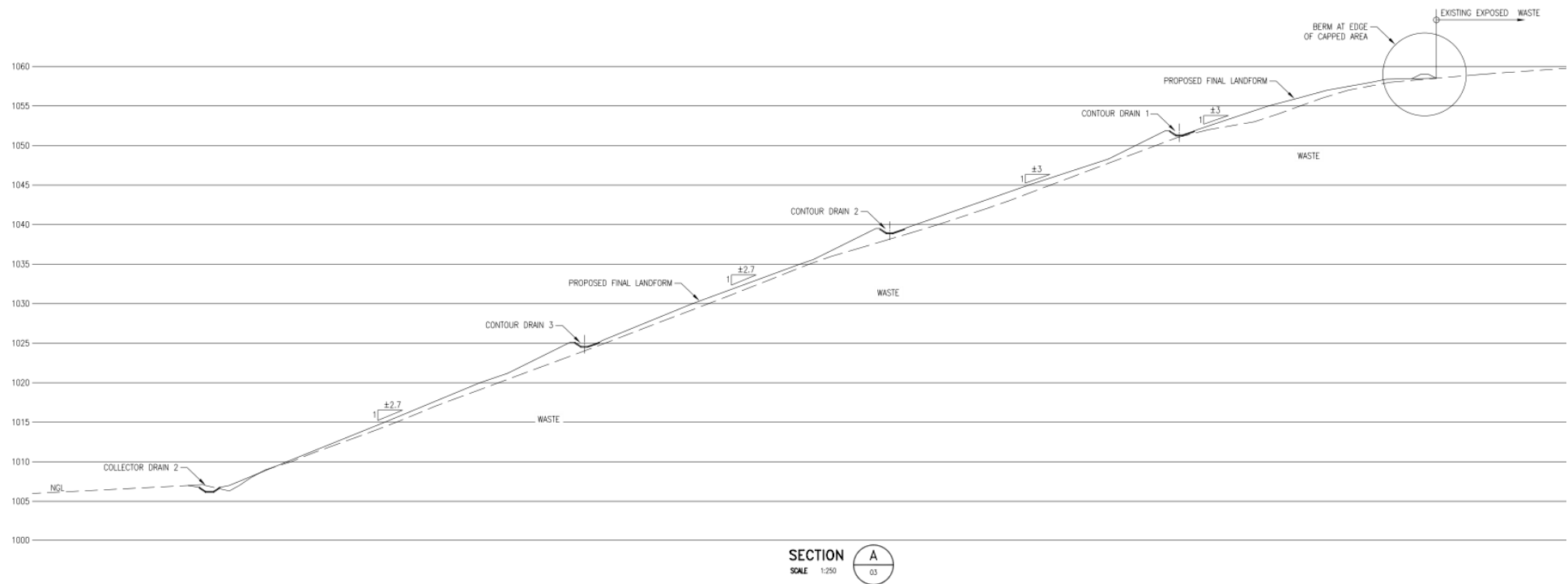


# Drainage Design

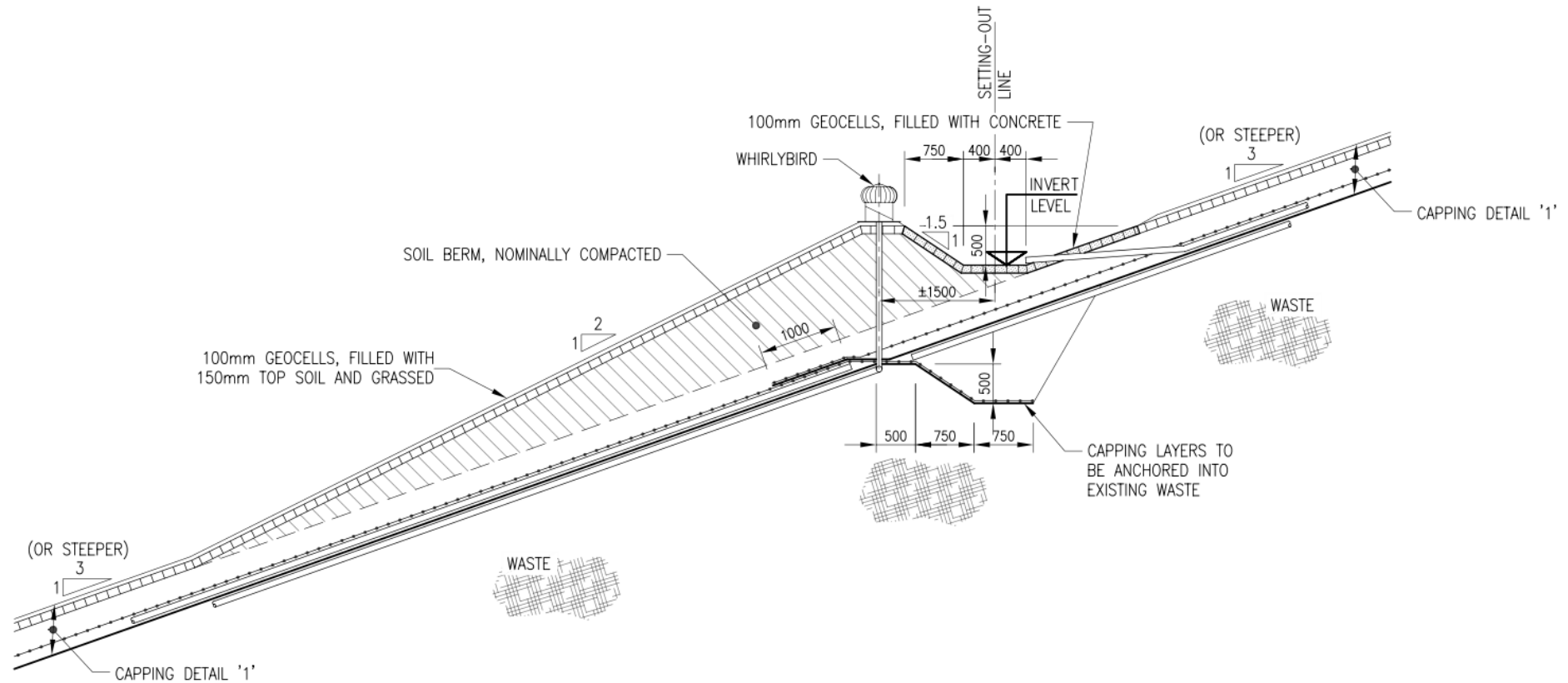
- Surface water drainage design is critical to prevent erosion and instability of the cover system
- Restrict free slope runoff by means of contour drains at calculated intervals (typically 30 to 50m)
- Drain cover seepage into contour drains
- Size drains for 1 in 20 year rain event, plus freeboard to handle the 1 in 50 year rain event
- Design downchute drains to handle high velocities (supercritical flow). Provide energy dissipators
- Design drains as flexible structures with adequate slopes to handle landfill settlement







# Typical contour drain with geogrid reinforcement



TYPICAL CONTOUR DRAIN ON 1:3 AND STEEPER SLOPES

SCALE 1:50

# Concluding Remarks

- The primary objective of closure design is to isolate the waste body from the environment
- Assess environmental risk based on status quo
- Consider practical aspects such as final landform, end-use and phased closure
- Determine required cover system that mitigates the environmental risks
- Ensure stability of the installed cover system in extreme rainfall events
- Design surface water drainage system to protect the installed cover

# THANK YOU

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