CLOSURE AND REHABILITATION OF LANDFILLS

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LANDFILL COVERS

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

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
- 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)

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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)
    - Cap works in conjunction with the liner by limiting long term generation of leachate
  - 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"

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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

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Knots Dump after Phase 1 Capping

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Knots Dump during Phase 2 Capping

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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.

Exposed cover

Temporary cover

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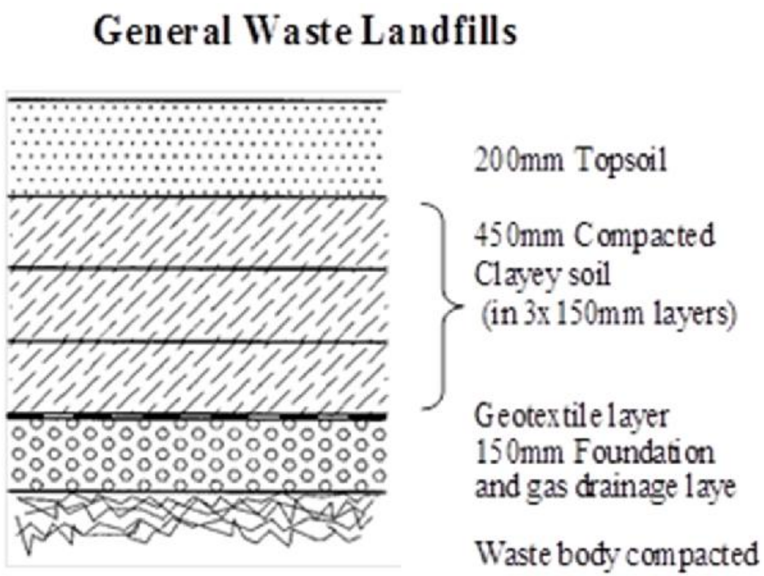
Cover Components

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 m/yr (1.6x10^{-6} cm/s)
  - Slopes > 3%



- 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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DRAFT

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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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A GRI White Paper

on

The Questionable Strategy of Soil-Only Landfill Covers

by

Robert M. Koerner, Ph.D., P.E.
Director and Professor

Geosynthetic Research Institute
475 Kedron Avenue
Folsom, PA 19033-1208

GRI Report #28

August 7, 2002

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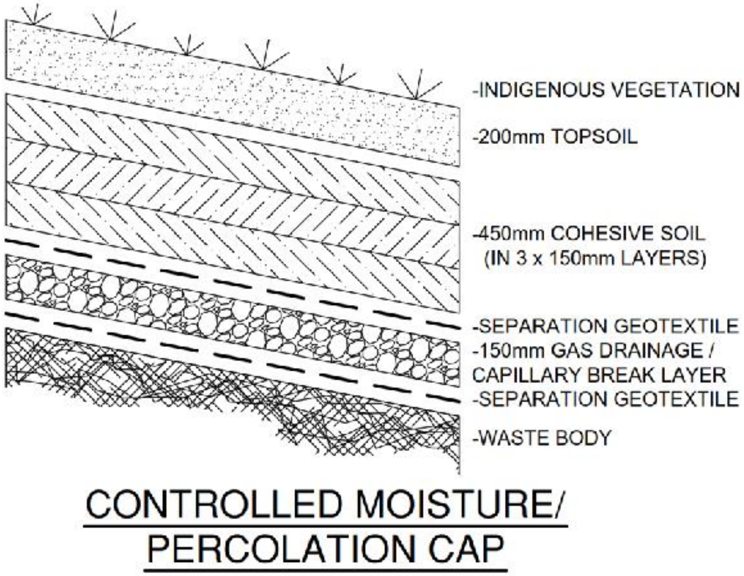
Capping – General Waste

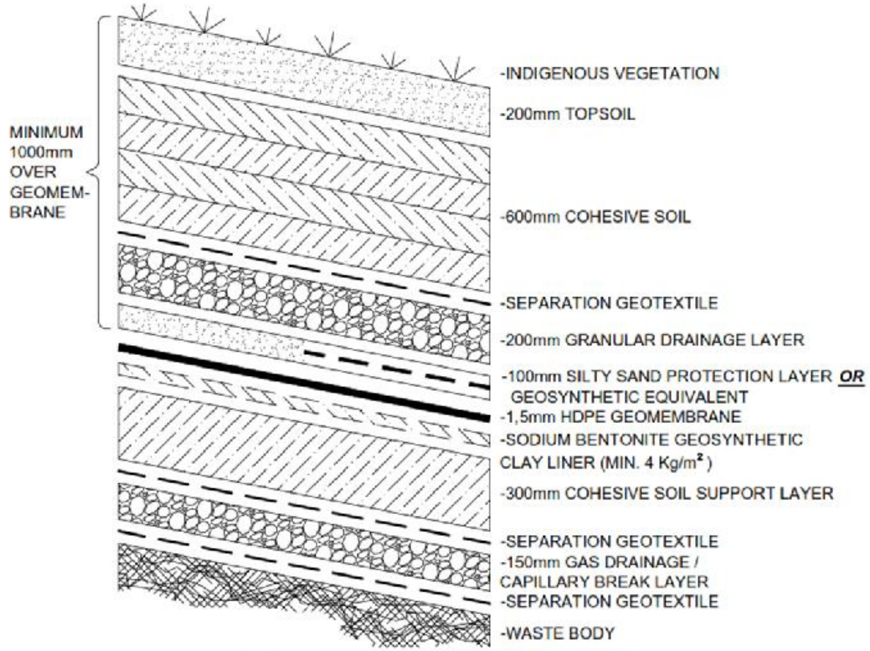
- Current South African proposal
  - Controlled moisture ingress
  - Allows for waste stabilisation
  - Silty soil (less cracking)
  - Assumes no active gas extraction system
  - Suited to drier climates



- If gas active gas management, then require barrier in capping system

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).



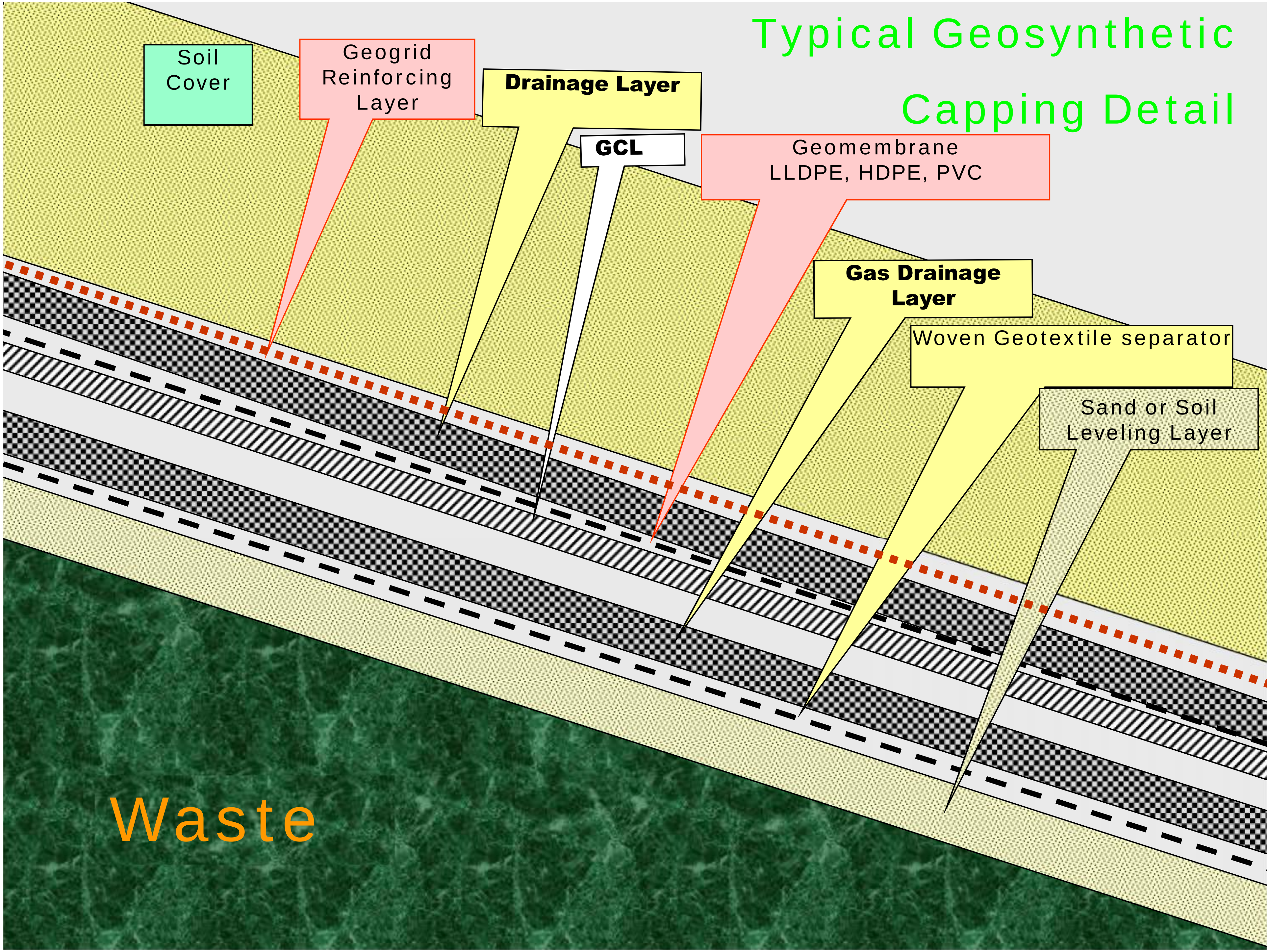
RESTRICTED MOISTURE/
DRY CAP GCL ALTERNATIVE

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
Soil Cover
Geogrid Reinforcing Layer
Drainage Layer
GCL
Geomembrane LLDPE, HDPE, PVC
Gas Drainage Layer
Woven Geotextile separator
Sand or Soil Leveling Layer
Waste

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 = $\dfrac{\text{Shear strength of veneer system}}{\text{Shear stress on the veneer system}}$

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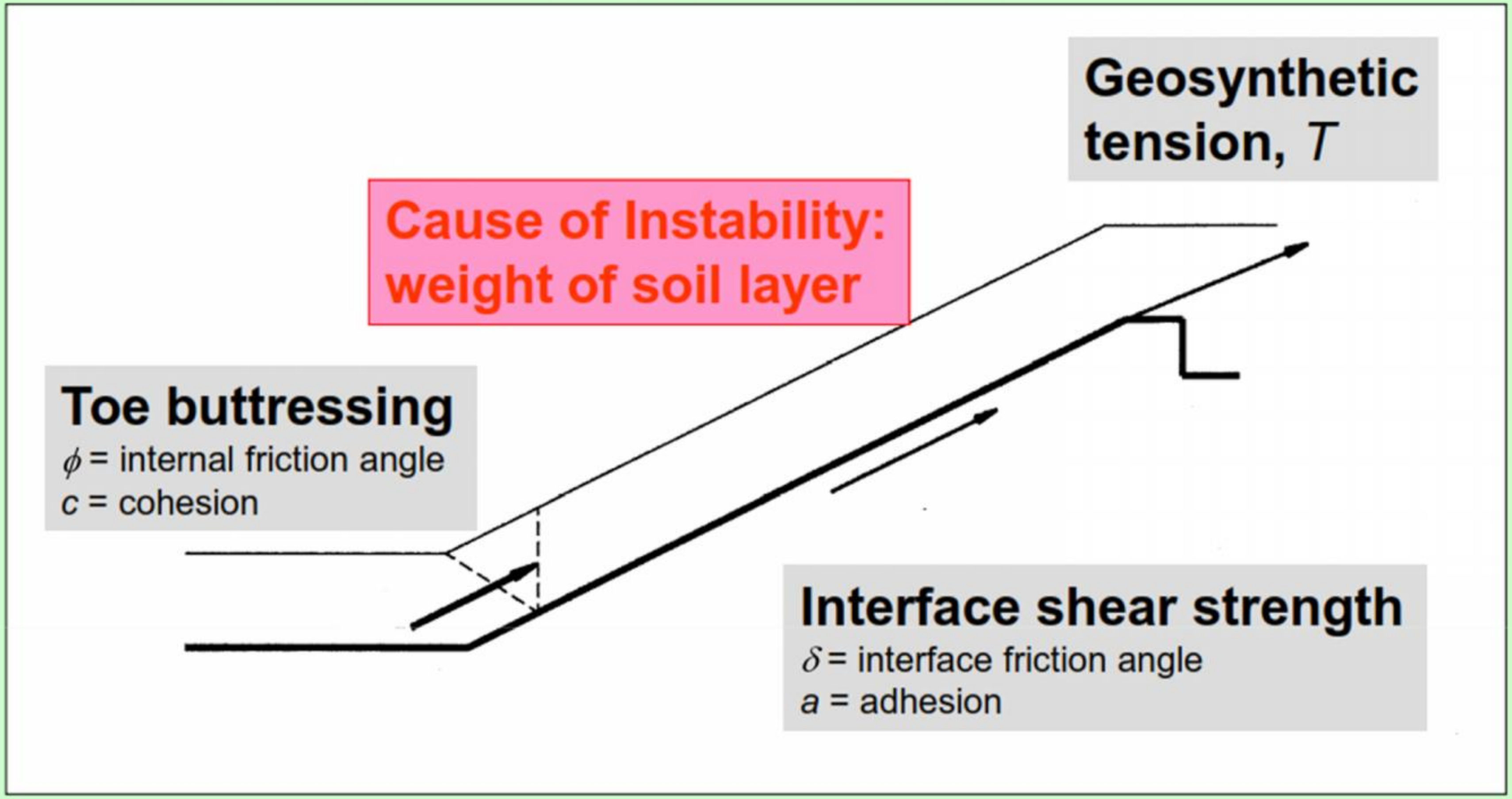
SLOPE STABILITY MECHANISMS



AND DEFINITION OF STABILITY PARAMETERS

Courtesy of J.P. Giroud

Courtesy of Rick Thiel

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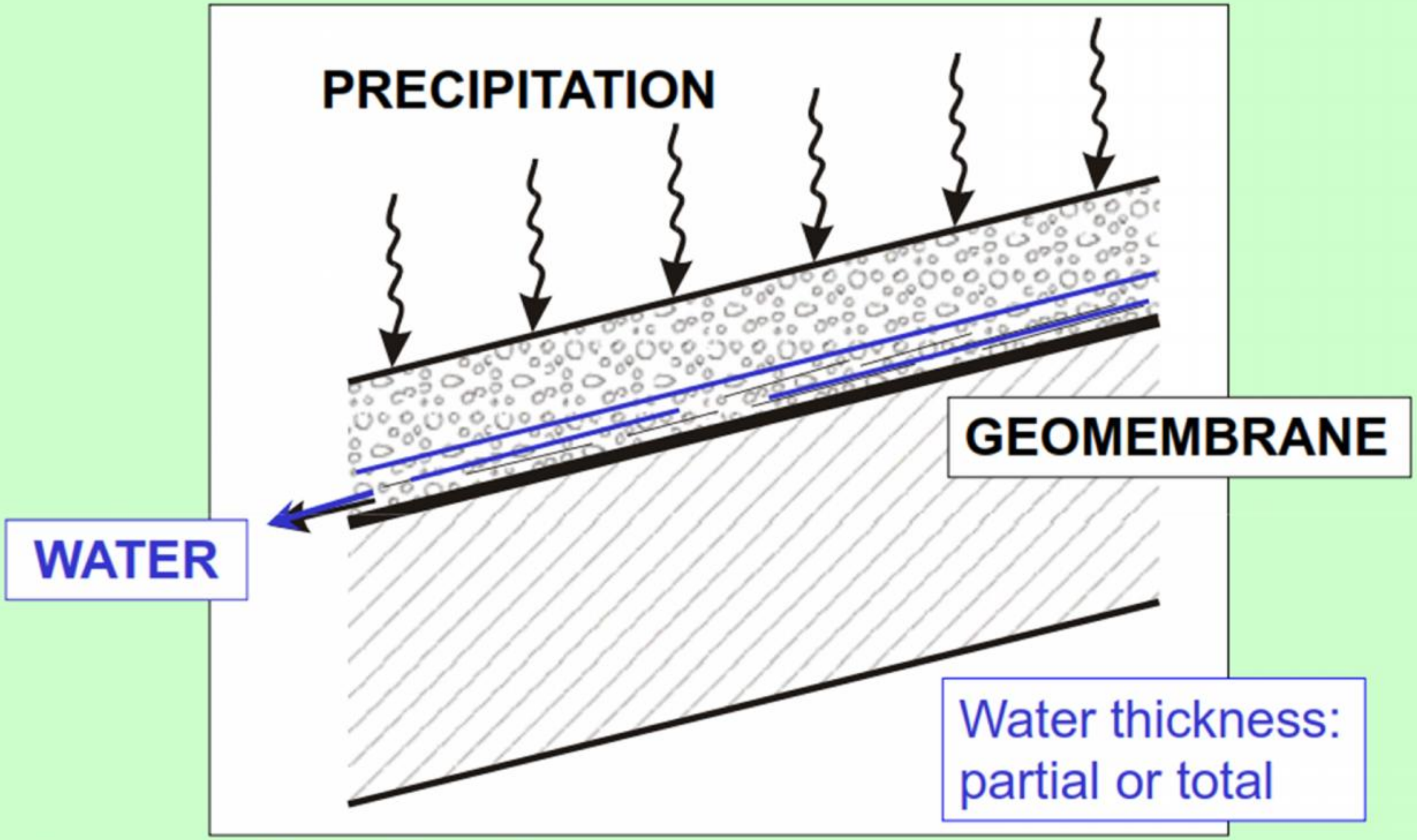
Seepage Forces



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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

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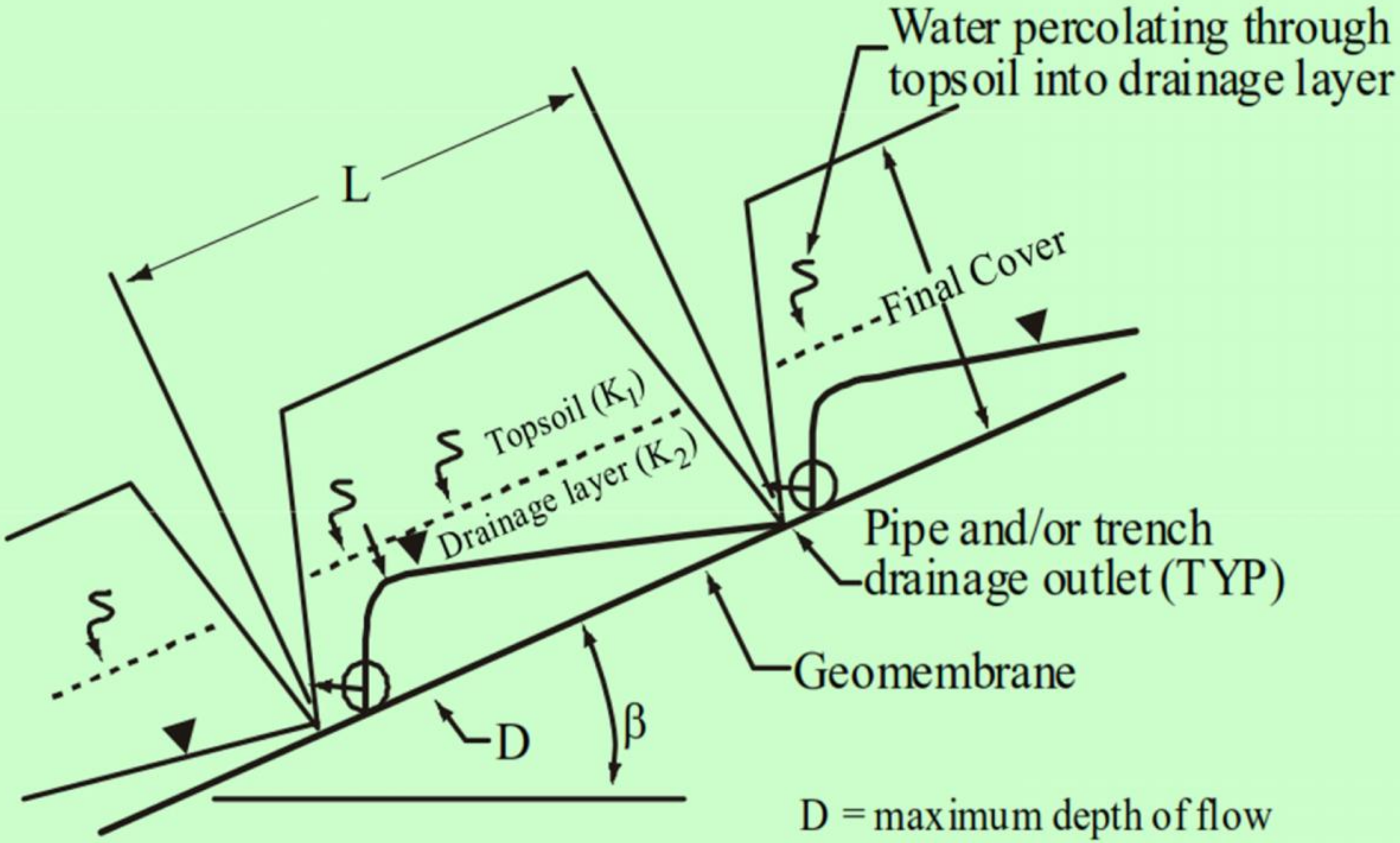
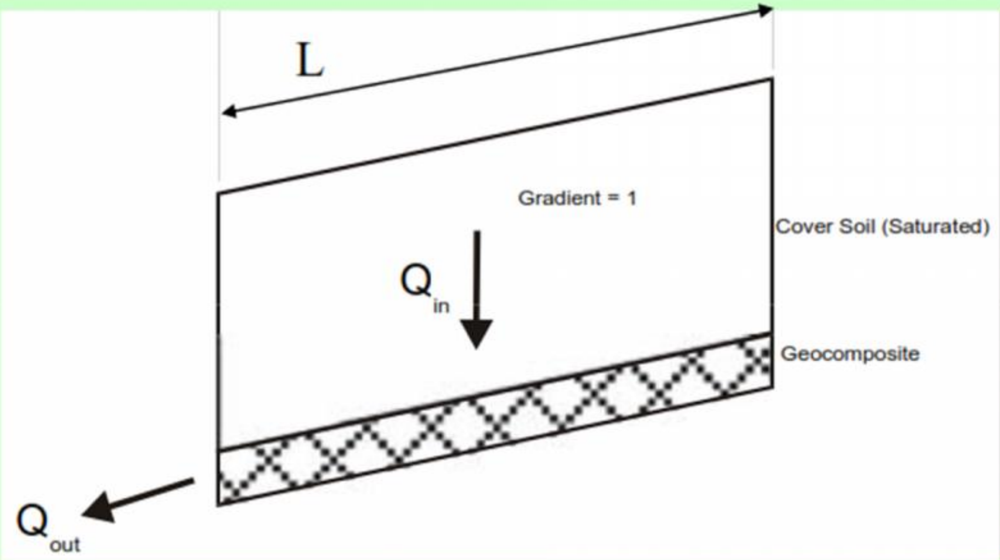
Schematic of Head Buildup in the Drainage Layer (after Thiel & Stewart, 1993, Geo '93, Vancouver BC)



Drainage Design For Side Slopes in Landfill Caps

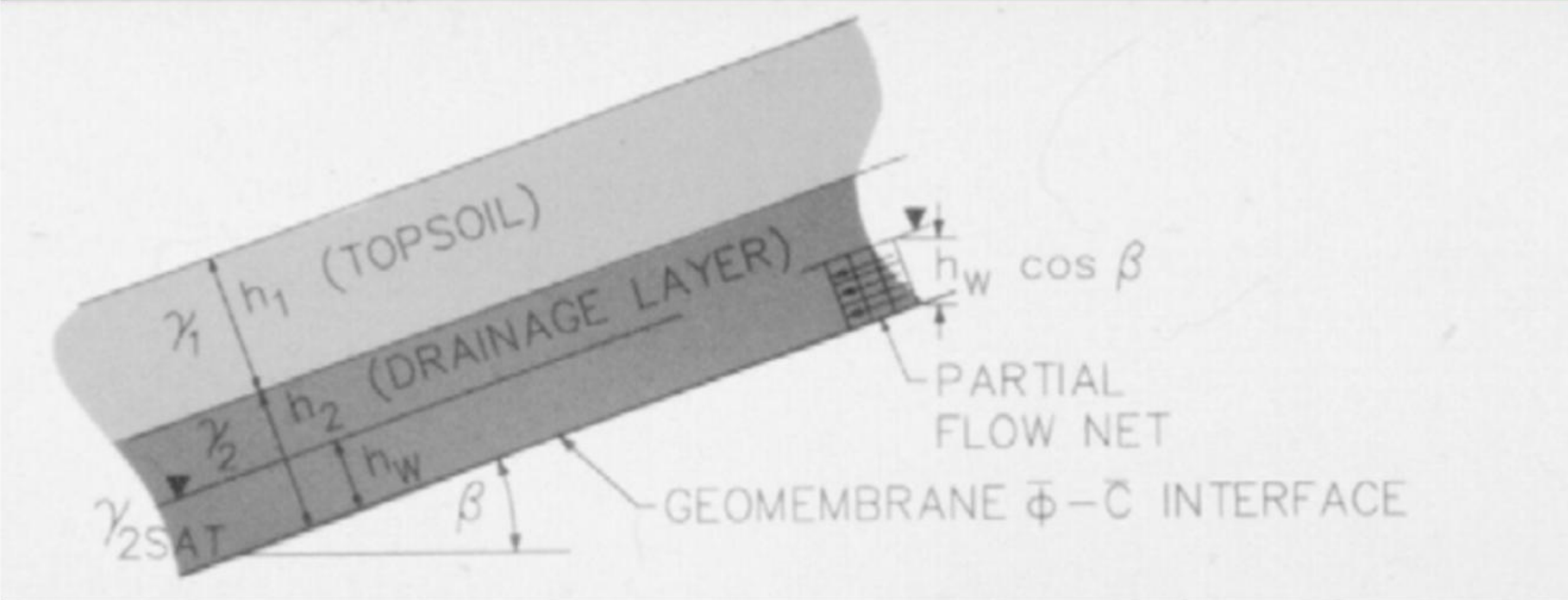
- $Q_{in} = k_{veg} * L * 1$
- $Q_{out} = k_g * i * A = (k_g * t) * i = \theta * i$

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



Courtesy of Rick Thiel

Infinite slope eqn with seepage



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

Thiel and Stewart, 1993

Courtesy of Rick Thiel

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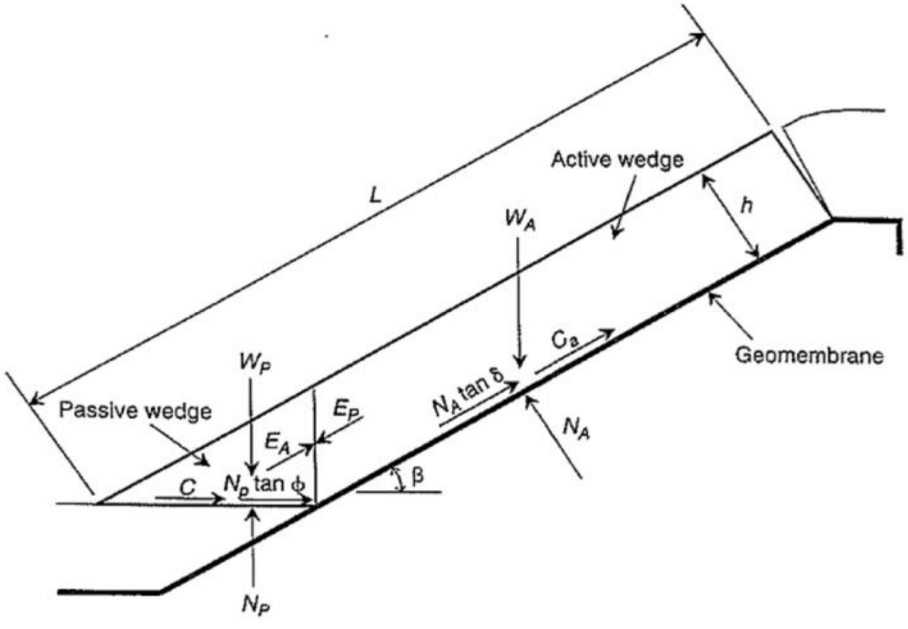
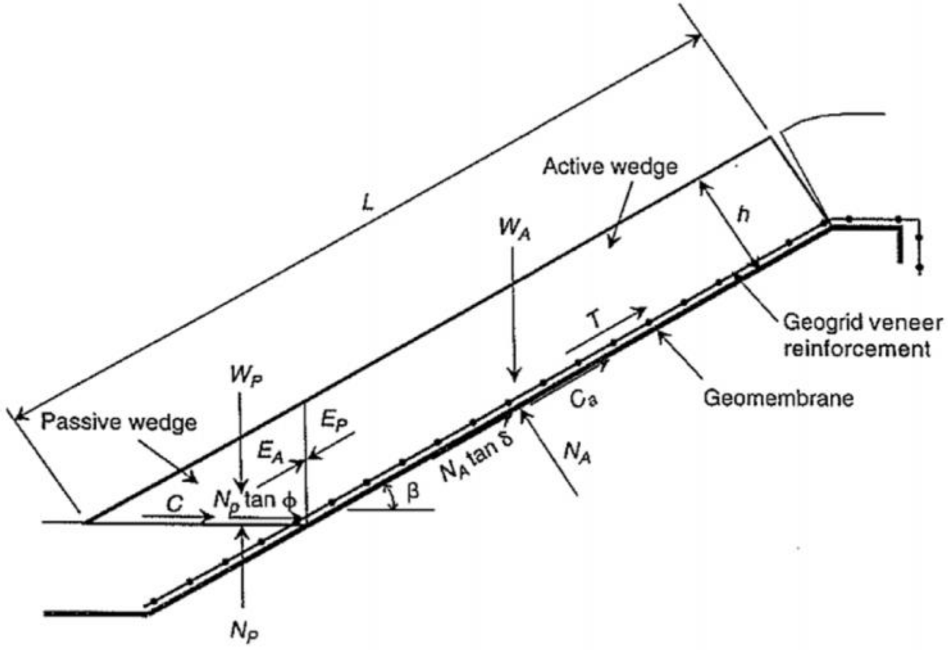
Cover Stability Design



(a) Without reinforcement



(b) With the use of geogrid veneer reinforcement

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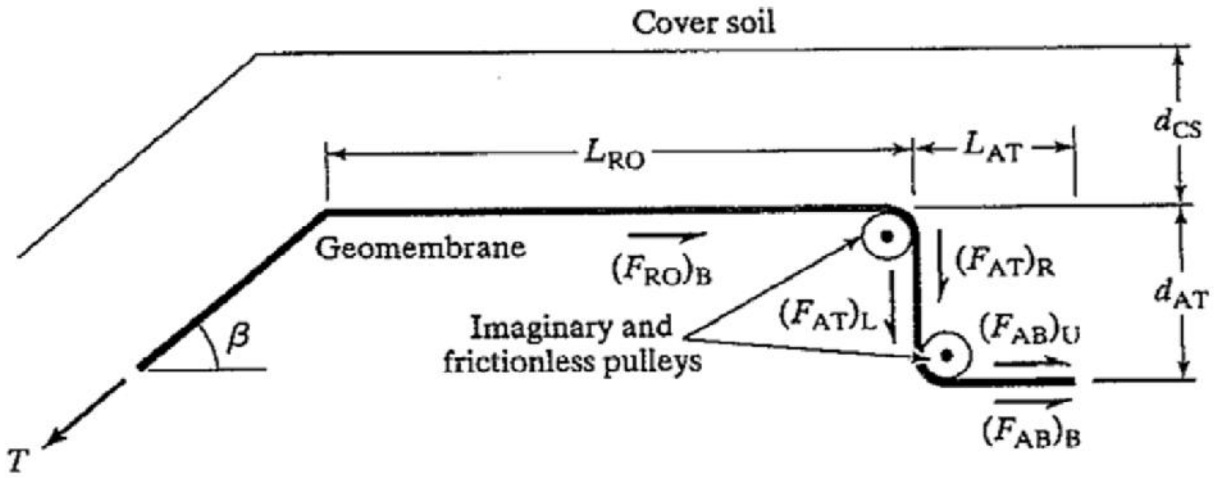
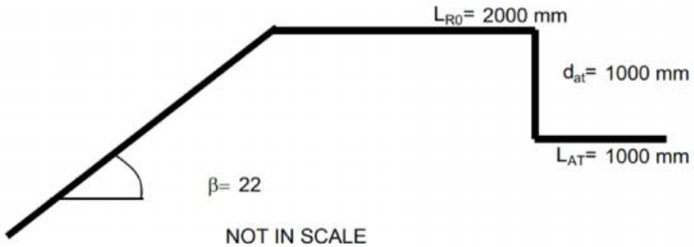
Anchorage design



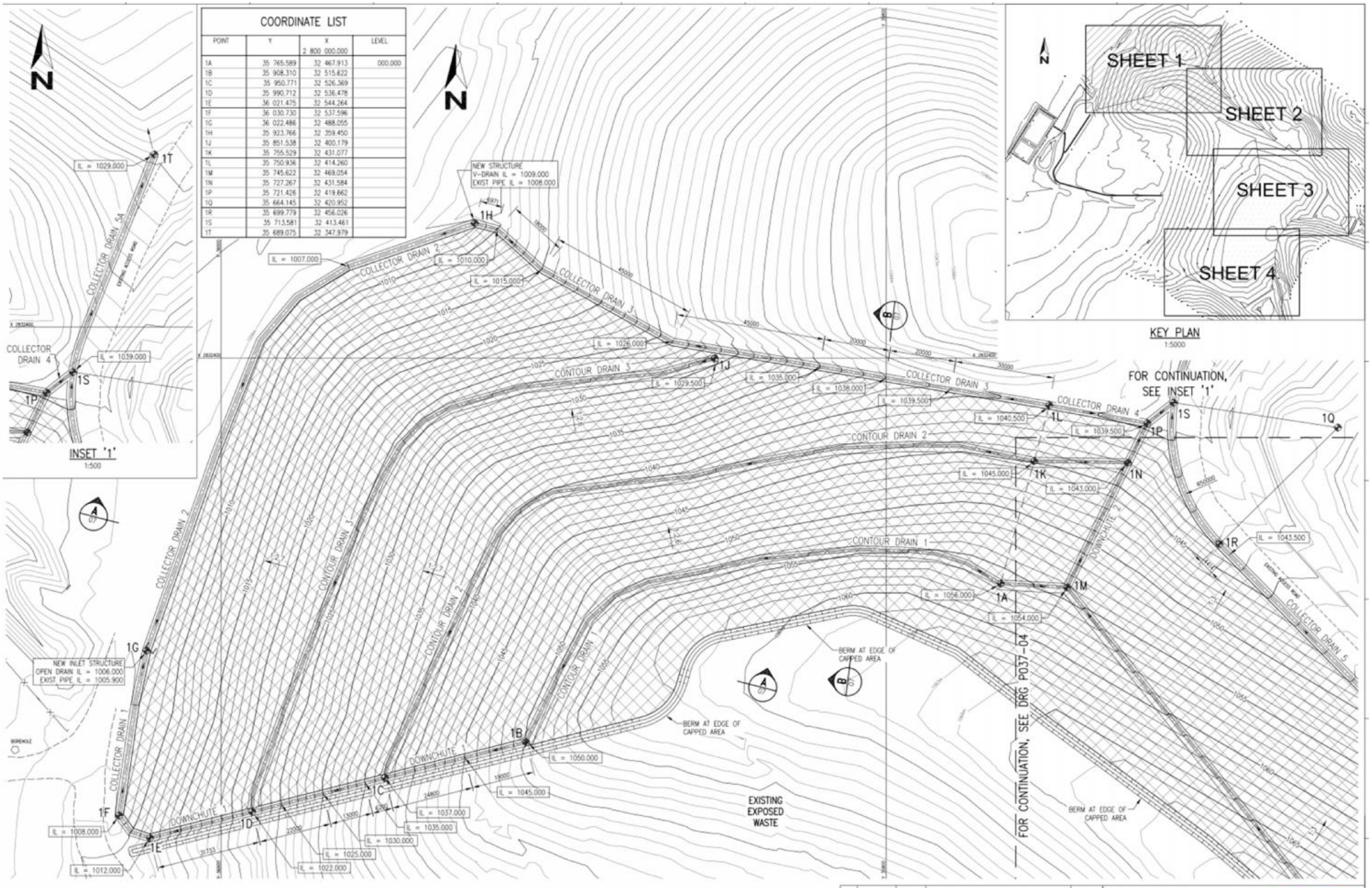
RESULTS			
SYMBOL	VALUE	UNIT	DESCRIPTION
$(F_{RO})_B$	14.03	KN/m	friction force beneath runout geosynthetics
$(F_{AT})_R$	4.04	KN/m	friction force between the right side of the geosynthetic and the side wall of anchor trench
$(F_{AT})_L$	4.04	KN/m	friction force between the left side of the geosynthetic 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 botton 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 botton of anchor trench
T_{MAX}	55.51	KN/m	geosynthetic tensile force developed by the anchor trench

FoS	1.39



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



COORDINATE LIST

POINT	Y	X 2 800 000.000	LEVEL
1A	35 765.589	32 467.913	000.000
1B	35 908.310	32 515.622	
1C	35 950.771	32 526.369	
1D	35 990.712	32 536.478	
1E	36 021.475	32 544.264	
1F	36 030.730	32 537.596	
1G	36 022.486	32 488.055	
1H	35 923.766	32 359.450	
1J	35 851.538	32 400.179	
1K	35 755.529	32 431.077	
1L	35 750.936	32 414.260	
1M	35 745.622	32 469.054	
1N	35 727.267	32 431.584	
1P	35 721.426	32 419.662	
1Q	35 664.145	32 420.952	
1R	35 699.779	32 456.026	
1S	35 713.581	32 413.461	
1T	35 689.075	32 347.979	

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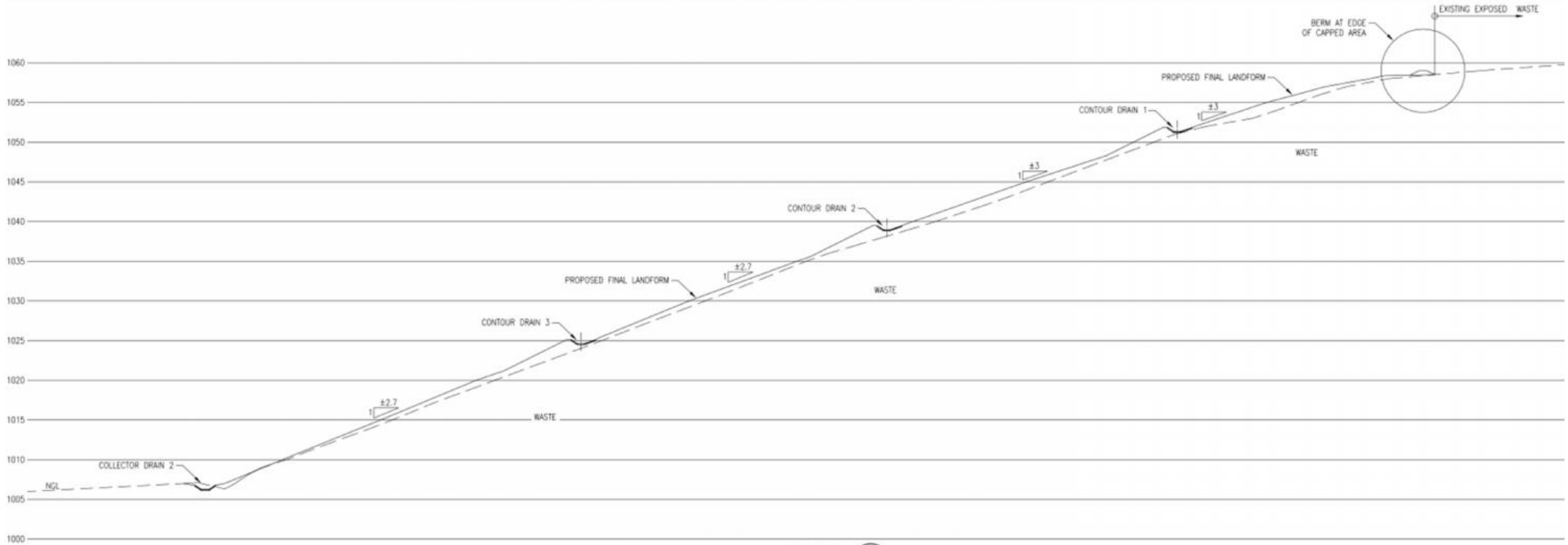
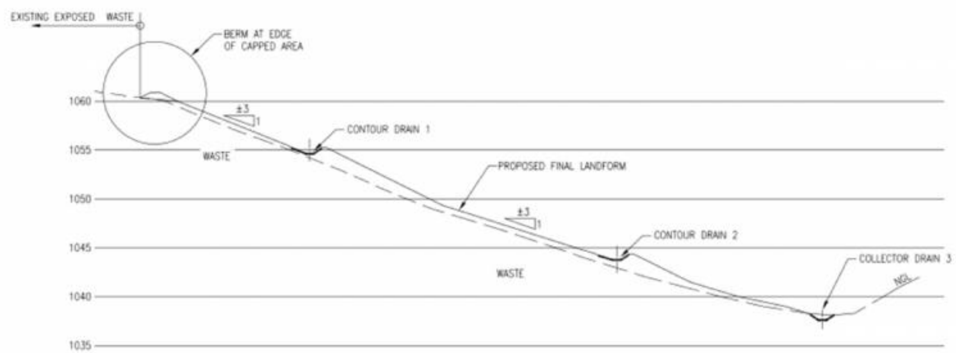


SECTION A 03
SCALE 1:250



SECTION B 03
SCALE 1:250

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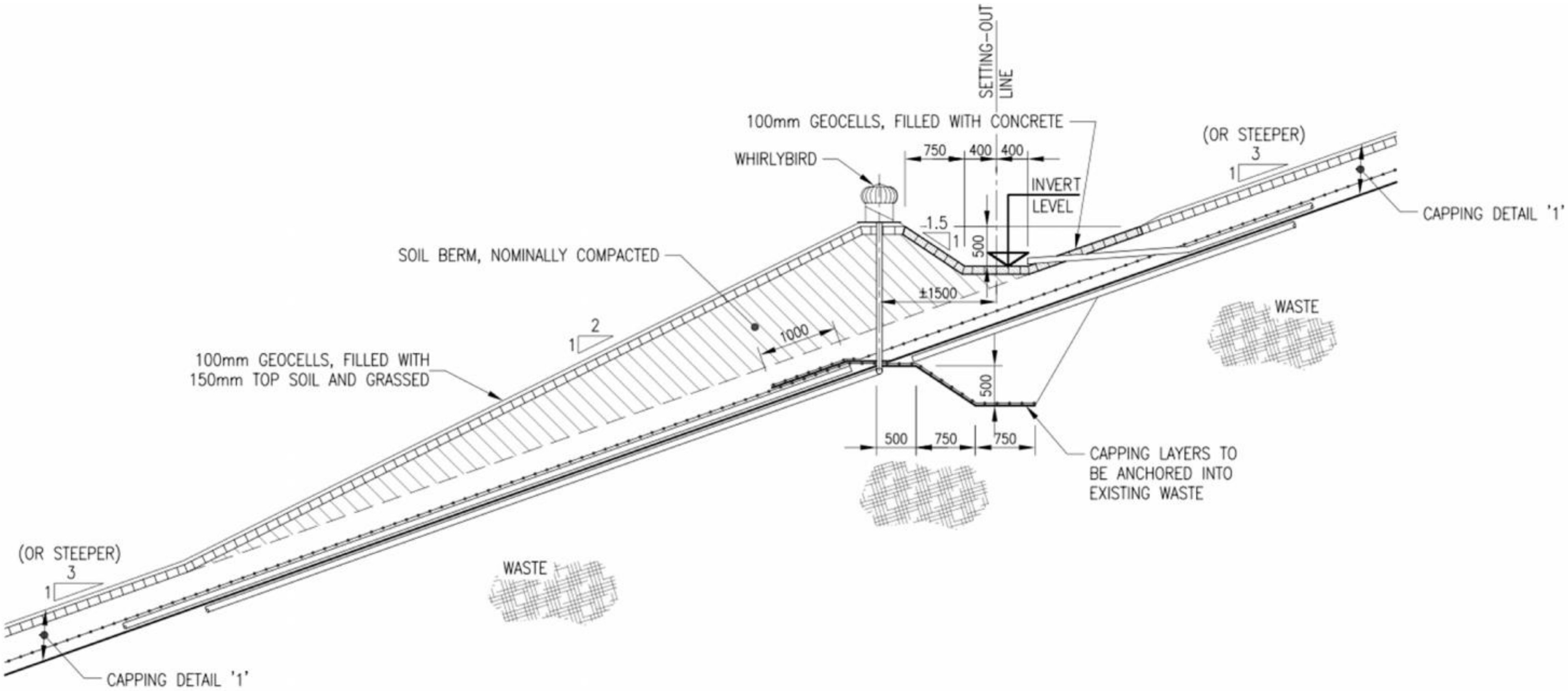
Typical contour drain with geogrid reinforcement



TYPICAL CONTOUR DRAIN ON 1:3 AND STEEPER SLOPES

SCALE 1:50

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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 for your attention

Any questions

Logo to be

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