Dispersive Clay in Landfill Liners

"to crumb or not to crumb"
… that is the question



Gary Schmertmann & Adam Muller, WSP Australia, Sydney

Motivation for this presentation

A frequent scenario in liner construction with low-permeability compacted clay layers:

- clay specification has a limit on soil dispersivity
- compliant clay source – unavailable/high cost
- RFI requests designer acceptance of lower Emerson Class, meaning higher dispersivity

CCL – low permeability

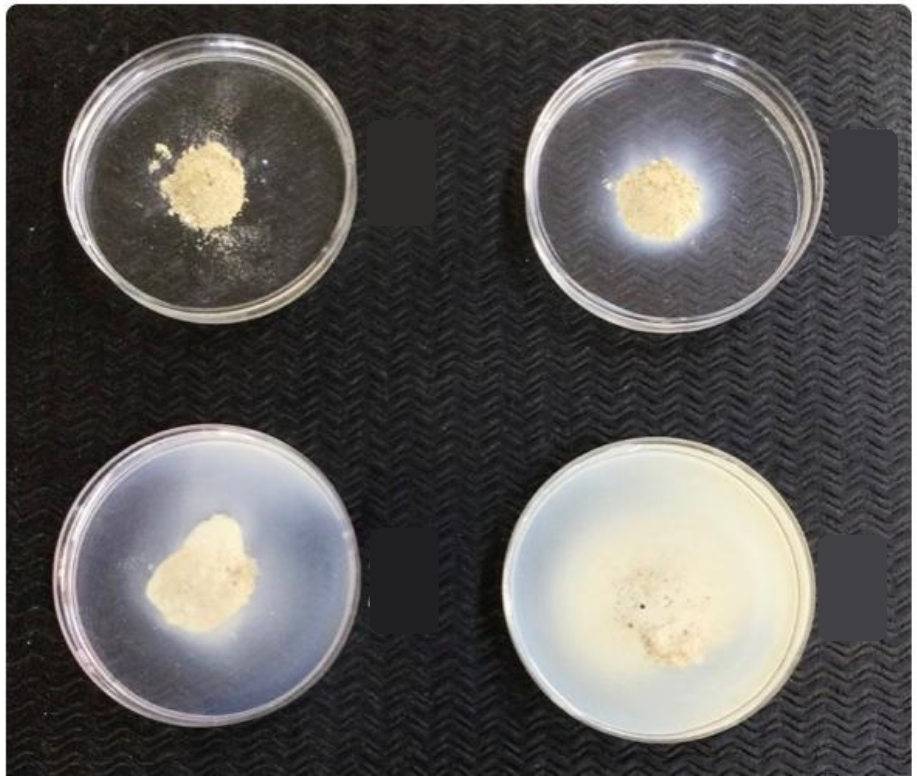
Emerson “Crumb”

RFI

This presentation provides information and a framework for technical assessment

What is a dispersive clay soil?

- Clay particles detach from within soil structure and go into suspension when immersed in still water
- Factors for dispersivity in earthworks
  - soil chemistry: clay minerology, pore water chemistry (Na/Ca/Mg ratios), organic content
  - physical: PSD, plasticity, soil structure (compaction)
  - external: water chemistry, flow velocity
  - definitive test? no
- Dam engineering
  - extensively studied in Australia (Fell et al. text)
  - major risk factor for internal erosion/piping
  - catastrophic dam failures
- Soil science –extensively studied; agricultural applications



from SoilsWest – Western Australia Soil Quality Knowledge Base

⟵ **dam engineering**

Where are they?

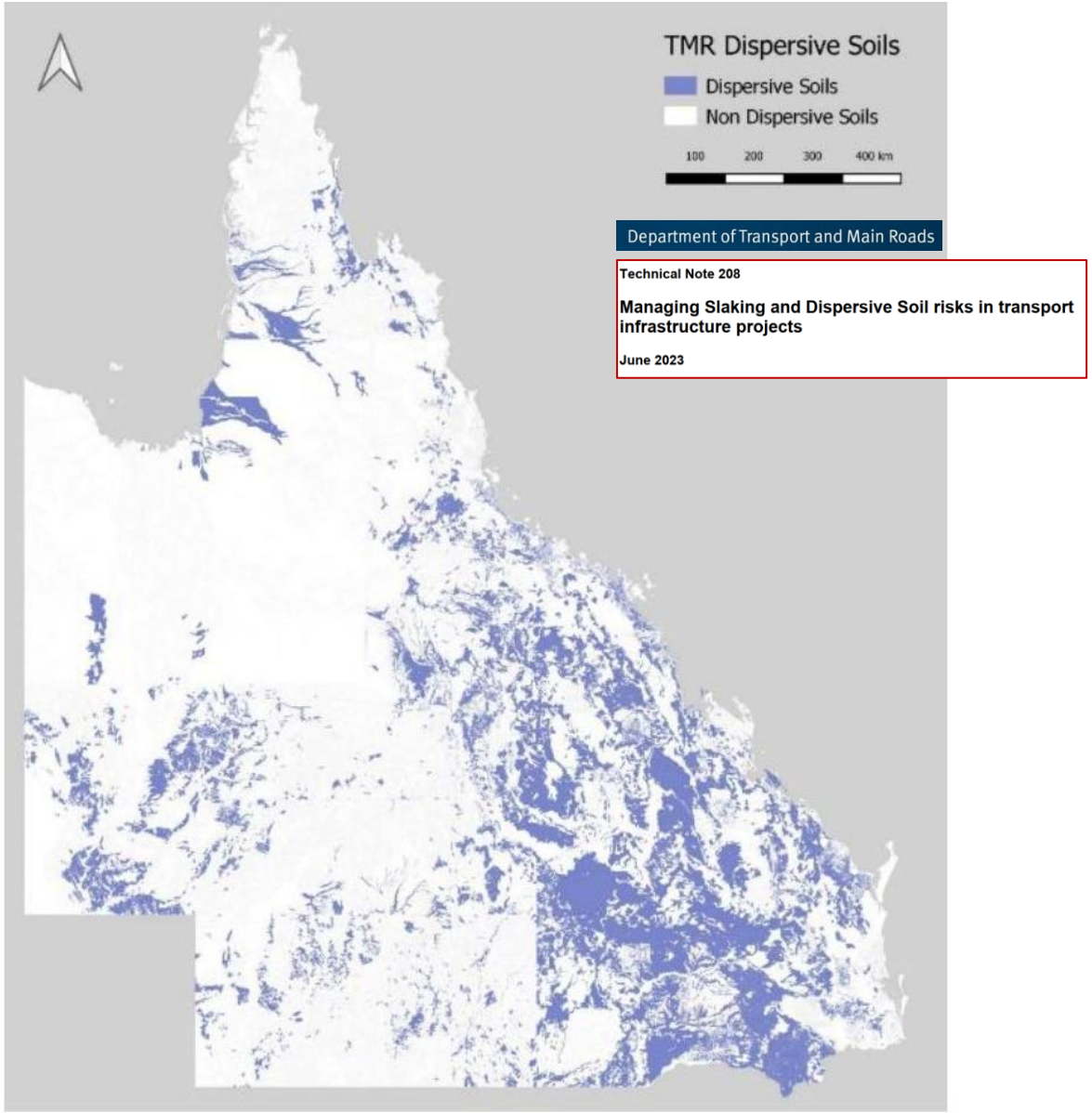
- widespread

Australian Context

Dispersive soils are found across Australia, notably in:

- **NSW**: Hunter Valley, Central West, Riverina
- **QLD**: Darling Downs, Brigalow Belt
- **VIC**: Northern Plains, Murray River zone
- **SA**: Murray Basin, Yorke Peninsula
- **WA**: Wheatbelt region, Swan Coastal Plain

from Civil Engineering Hub Australia



Why is there a dispersivity limit for the clay liner ?

- Liner construction:
  - reduce ESC management risks for large exposed clay areas
  - note: option to manage with a construction EMP
- Liner performance:
  - sustained leachate head on liner (leachate “dam”)
  - potential for internal erosion/piping risk through the layer
  - dispersivity limit to reduce risk of leachate leakage to subgrade
- High impact of any leakage (site-specific)
- Engineering conservatism
- Regulatory requirement in some states

common limit:
Emerson Class ≥ 4
AS 1289.3.8.1

What do regulations say?

NSW

- Current guidelines 2016 – no requirement
- Draft guidelines 2025 (not operable)

Emerson Class	>3

SA 2019

- **Dispersion (AS1289 3.8.1)**

  Clay soils should have a low susceptibility to undergo dispersion.

QLD

- Draft guidelines 2023 (not operable)

- Have low susceptibility to undergoing dispersion when tested in accordance with *AS1289 3.8.1.*

Geochemical requirements such as CEC and pH appear in some state guidelines- not for dispersibility

International: dispersibility requirements not apparent in guidance from:

- WasteMINZ (2023)
- USEPA guidance
- EU guidance
- German guidance

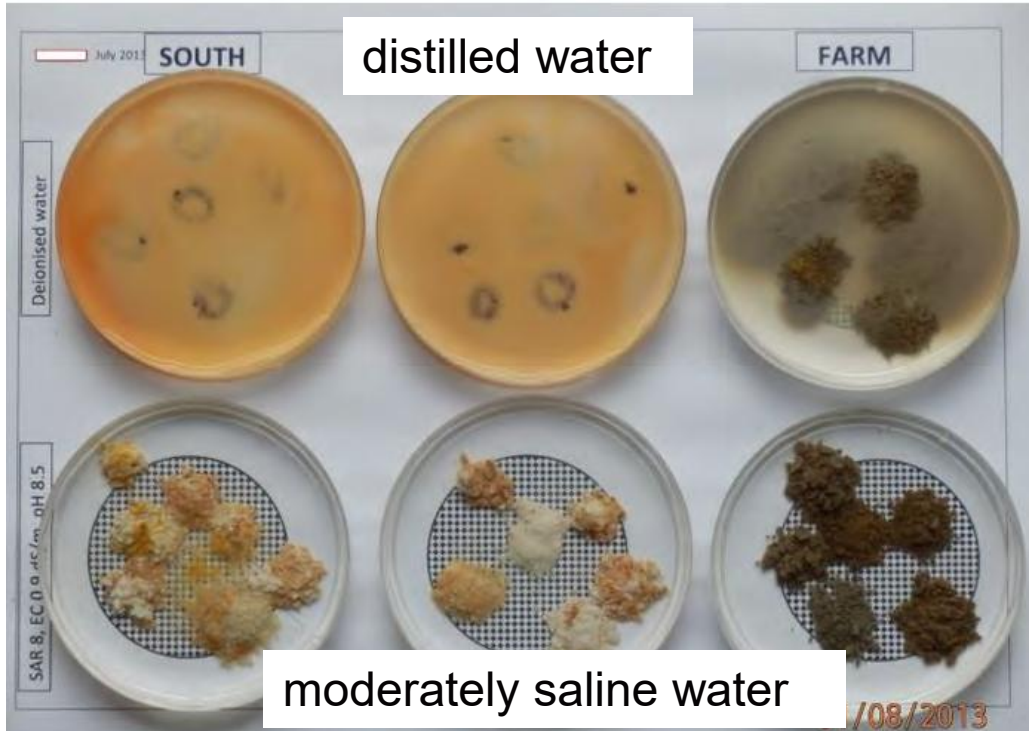
Dispersibility Testing

Test types:

- Index: Emerson Class
- Geochemical: CEC, SAR, ESP
- Performance analog: Pinhole dispersion

Emerson Class

- test specimen – 3 crumbs (3-5 mm size) selected from a 5 g air-dried sample
- place crumbs into beaker of water; distilled water is standard; use other water sources if specified.
- observe for slaking and colloidal dispersion.
  - Classes range from:
    1= most dispersive to 8= least dispersive
  - 4 and higher are non-slaking or exhibit no colloidal dispersion after remolding to 3 mm balls



Source: R. Patterson, Lanfax Laboratories, Armidale, NSW

← **crumbs <1g, visual selection**

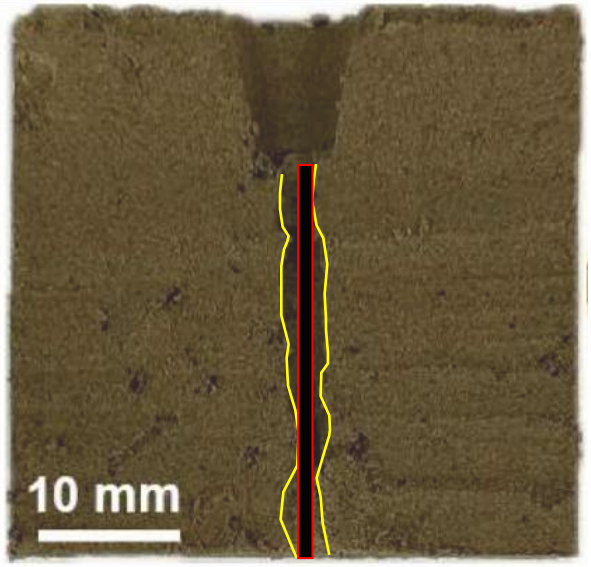
← **dispersion is greatest in distilled water**

← **Class ≥4 : low dispersibility**

Dispersibility Testing:

Geochemical tests

- soil science oriented
- major/complex dam assessment





Pinhole dispersion:

- developed for dam engineering practice
- sample screened to remove gravel and coarse sand; 50-75 g specimen compacted to target moisture/density into small mold
- 1 mm hole created along specimen; water flow induced through hole water at a range of applied heads.
- distilled water is standard; use other water sources if specified
- observe water outflow rate and turbidity, measure hole enlargement; establish test result
  - ND1 or ND2 non-dispersive
  - PD1 or PD2 potentially dispersive
  - D1 or D2 dispersive

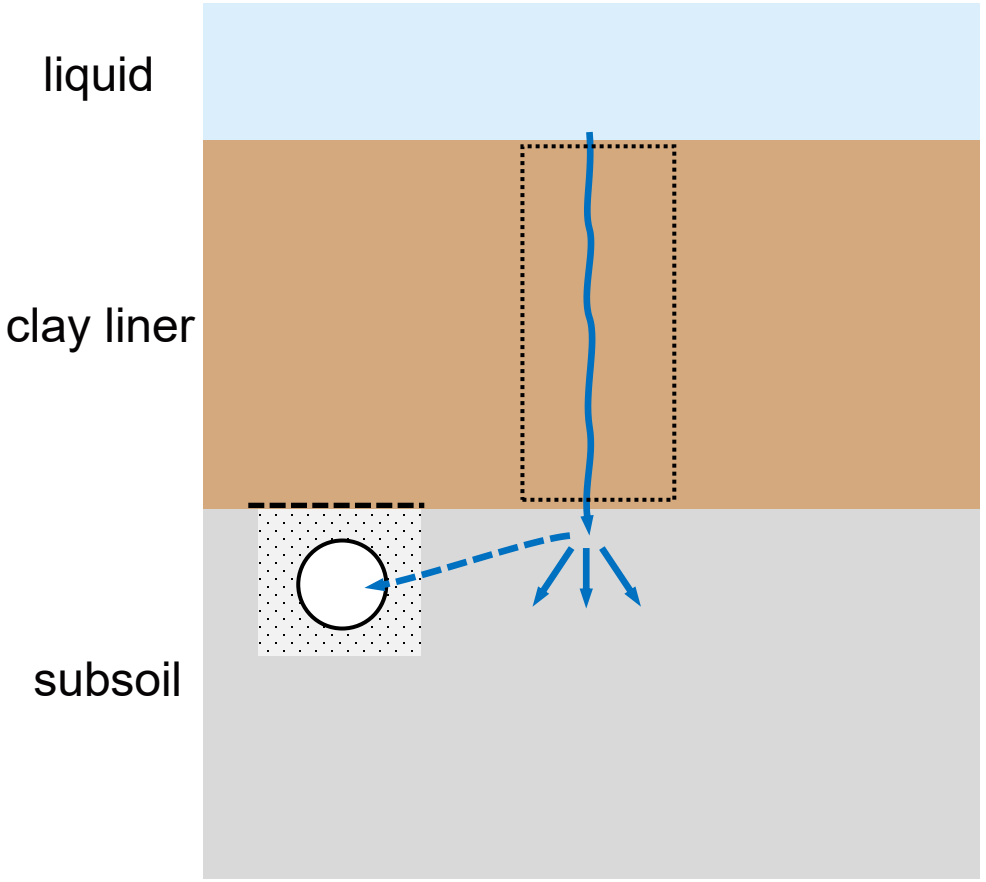
← **sample better represents compacted liner**

← **piping risk analog**

← **dispersion is greatest in distilled water**

← **Classes ND1 and ND2 low dispersibility**

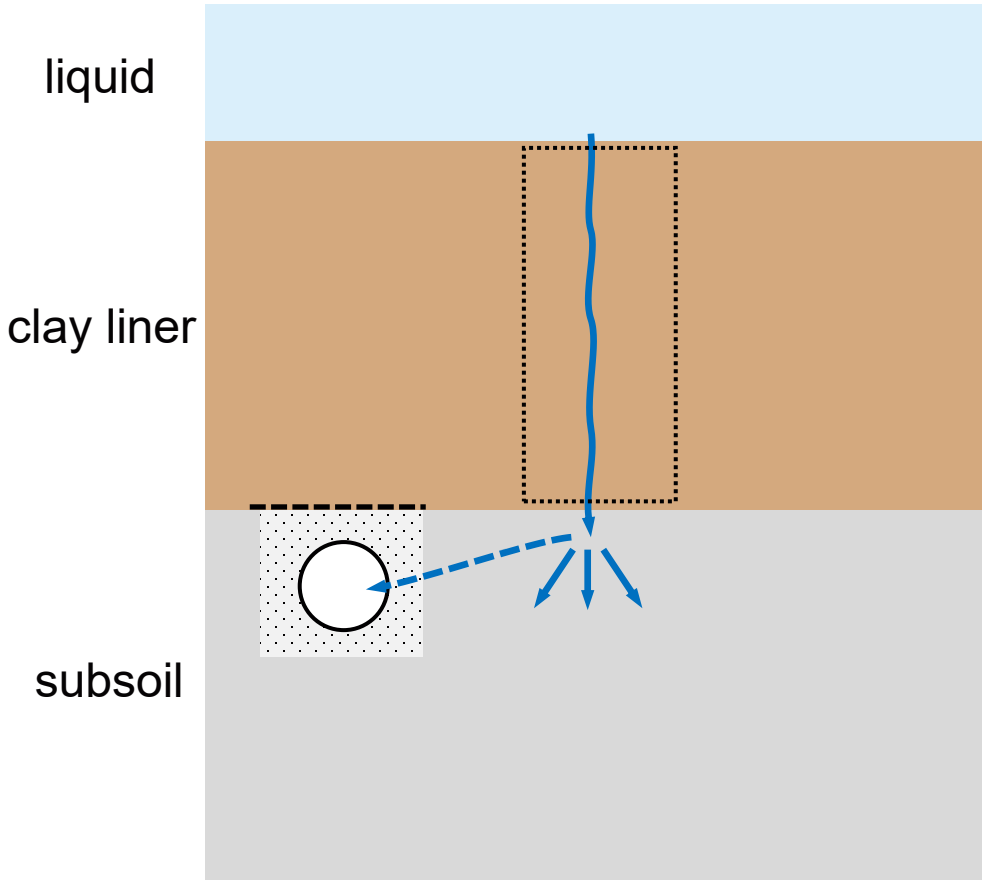
Technical Framework – mechanism



Internal erosion leading to pipe formation

1. seepage flow through clay under hydraulic gradient from liquid source
2. clay particles disperse and are transported in seepage flow to a subsoil receptor
3. clay soil structure loosens, flow velocity increases, and larger particles are transported
4. process advances to full pipe

Technical Framework – internal erosion scenario

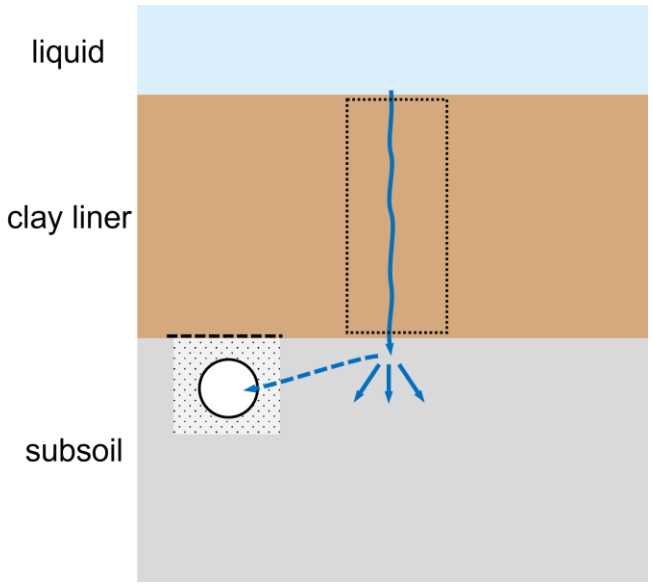


liquid source:
- leachate within LCS
- beneath interconnected Gmb wrinkles
- sustained long enough for piping to develop

- initial preferential seepage pathway:
  desiccation cracking, lift interface or other feature
- dispersive in the seeping liquid:
  capable of developing and sustaining pipe

Receptor for liquid and transported particle:
- more permeable than clay
- allows entry of transported particles, i.e. does not filter particles - coarser than fine sand
- sufficient pore space to accept particles
- consider liner underdrain as a potential receptor

Technical Framework – alignment
could all elements be present at one location?



Liquid – possibly present at all locations

- clay liner (no overlying Gmb):
  - base: entire area
  - side slope: less frequent/sustained
- composite liner: at Gmb holes and interconnected wrinkles (rule out with CQA? generally no)

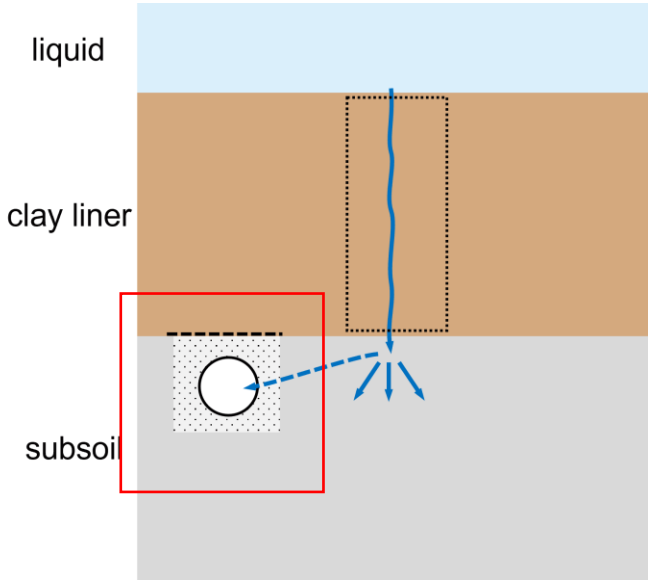
Clay – clay crack/flaw could be present at any location (rule out with clay CQA? generally no)

Internal erosion receptor

- subsoil – present at all locations
- underdrain - only at specific locations

Overall, cannot rule out presence and alignment of all elements; lower likelihood for composite liner and for underdrain receptor

Technical Framework – underdrain



Consider underdrain system as potential internal erosion receptor

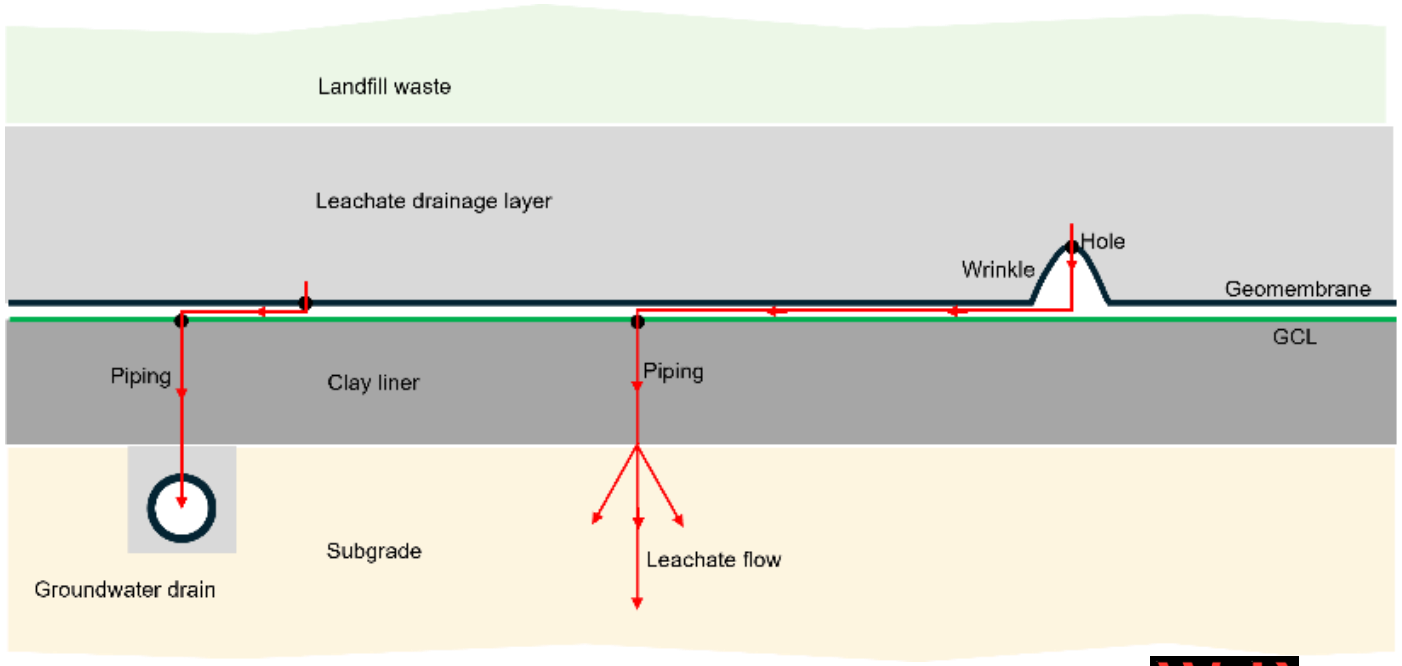
- underdrain will be highly permeable and porous
- Can transported particles enter? Consider covering or full surround nonwoven geotextile
  - covering geotextile only – not an effective filter for lateral seepage flow
  - full surround geotextile – may be an effective filter depending on AOS, note that dam engineering practice often disallows geotextile-only filtration for internal erosion protection
- intended underdrain operation- short or long-term?;
- will leachate seepage into underdrain be contained?

Technical Framework – key questions

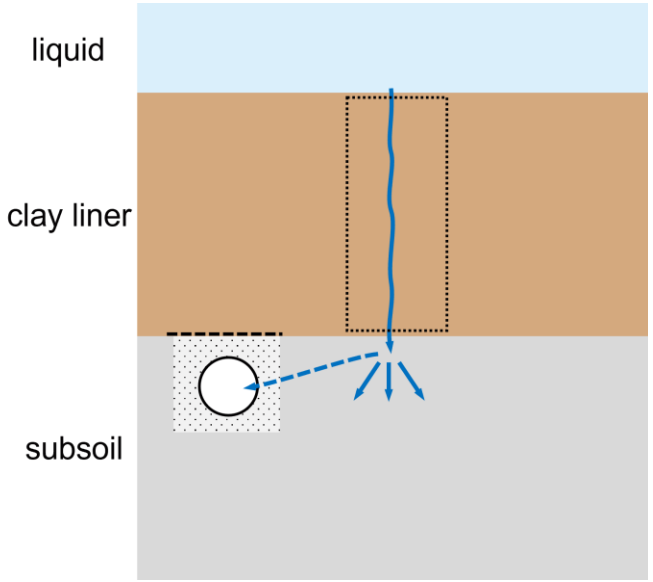
1. Is there a viable internal erosion receptor?
   - will the subsoil allow passage of transported particle (i.e. no filter)?; or
   - is there an underdrain receptor risk?
2. Is alignment of elements sufficiently likely?
3. Is the environmental risk of increased leachate seepage unacceptable?

If YES to all, then clay that is dispersive <u>in leachate</u> cannot be accepted.

If NO to any, then dispersive clay can be accepted with proper construction erosion management.



Technical Framework – next steps



If concluding that dispersive clay cannot be accepted:

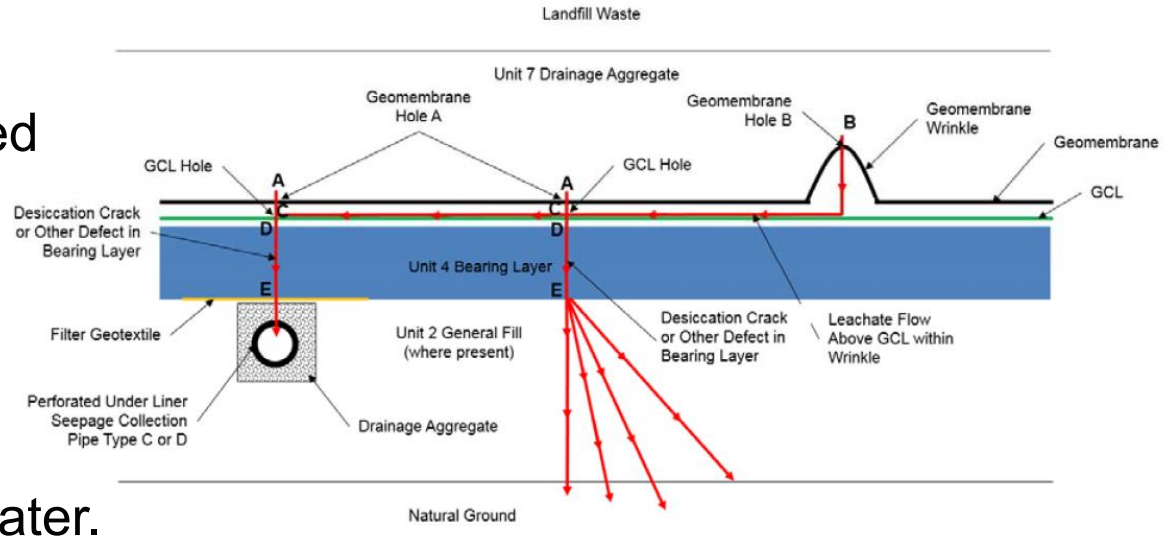
1. Perform additional dispersion tests to evaluate dispersibility
   - Include pinhole test – generally more representative than crumb
   - Replace distilled water:
     - tap water
     - water with dissolved salts to simulate leachate salinity
     - actual leachate – limitations for lab safety and test interpretation due to dark colour
2. If still testing as dispersive, assess treatment with lime or gypsum to reduce dispersivity (consider effects on clay and GCL permeability)

Project Case

Emerson Class test on candidate clay returned non-compliant Class 2/3 results in standard test with distilled water.

Further assessment to assess material and risk.

1) Expanded Testing Program. Emerson and Pinhole Dispersion. Tap water used in addition to distilled water.
   → concerns regarding dispersion risk remained.
2) Credible mechanisms and design risk areas reviewed.
   → construction zoned into areas based on presence of credible piping mechanism; consider sumps.
3) Treatment approaches using lime and gypsum reviewed.
   → cost and liner performance implications.
4) Dispersion testing with simulated leachate
   → clay tested with simulated leachate (NaCl, KCl)
   → results non-dispersive



Outcome

Proposed clay soil accepted with minor design alterations to reduce risk in specific areas.

Closing comments

Hopefully, we have shed some light on clay liner dispersivity assessment.

Dispersive clays can be accepted in many project circumstances based on subgrade assessment and supplementary testing (beyond the crumb).

The technical framework can be adapted for assessment of pond liners and landfill capping. Pond liners are generally higher risk for use of dispersive clay.

Thank you for listening.

