Performance and design features to improve and sustain geomembrane performance

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Observations

- To minimize leakage you need a composite liner

- Data shows that composite liners with a GCL perform **much** better than a composite with a CCL

BUT why is the

- observed leakages 10 to 10,000 times larger than calculated using traditional equations assuming direct contact and a reasonable number of holes/ha

Topics

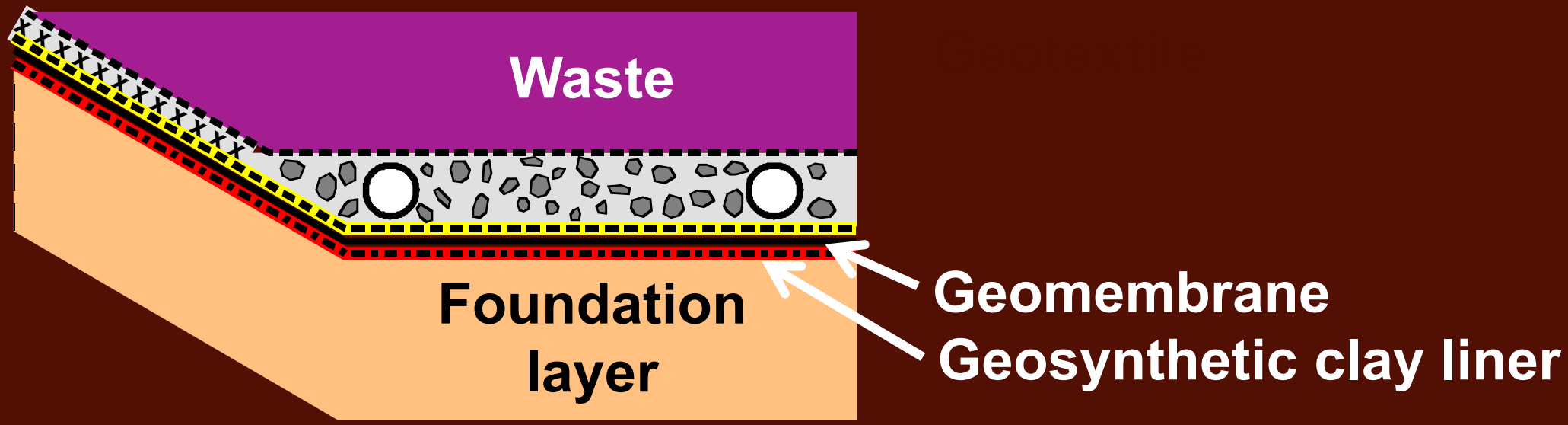
- Holes in geomembranes
- Leakage through geomembrane liners
- Leakage through clay liners
- **Leakage through composite liners**
  - Direct contact
  - Observed leakage
  - **Wrinkles/waves**
  - GCL overlaps/ panel shrinkage
  - GM/CCL interface and desiccation of compacted clay liners (CCL)

GM in Direct Contact with GCL

GM with no wrinkles; cloudy November morning when ambient T = 3 ^{o}C

Rowe et al. (2012)

Single Composite Liner Systems

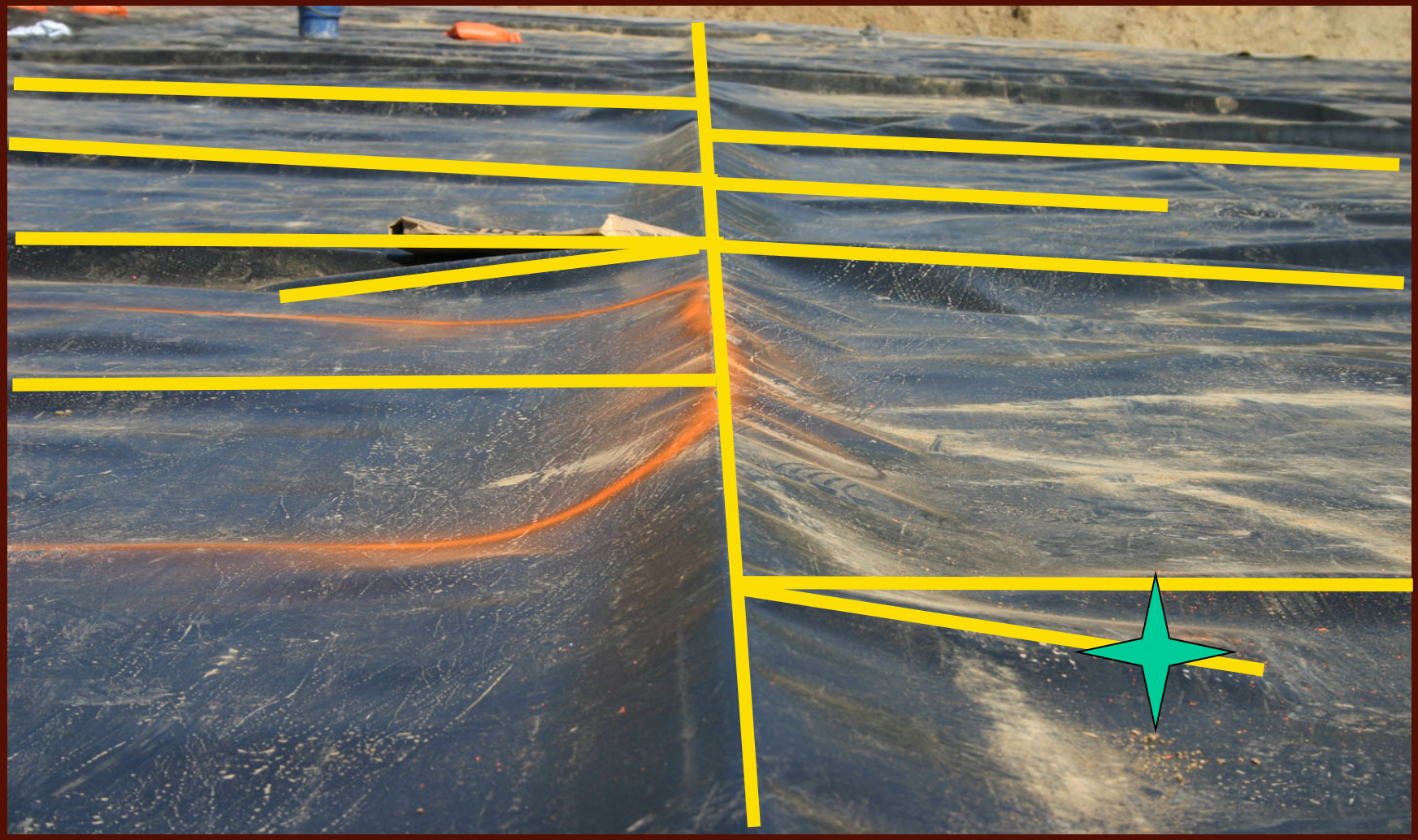


GM Wrinkles

GM with wrinkles; midmorning when ambient T = 17 °C (same location as shown in earlier slide)

Rowe et al. (2012)

Wrinkle Parallel to Panel



Note Extent and Interconnectedness of Wrinkles

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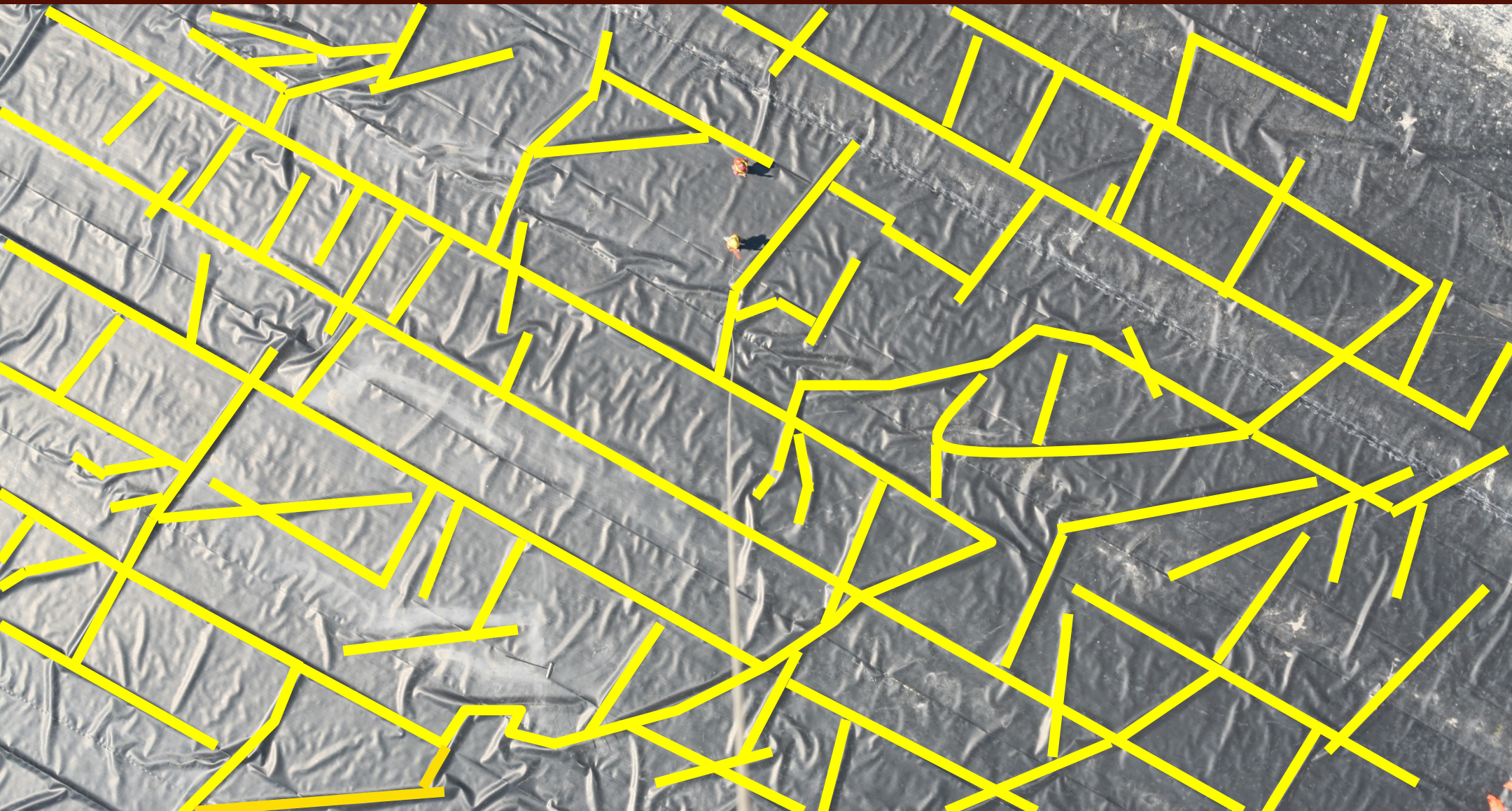
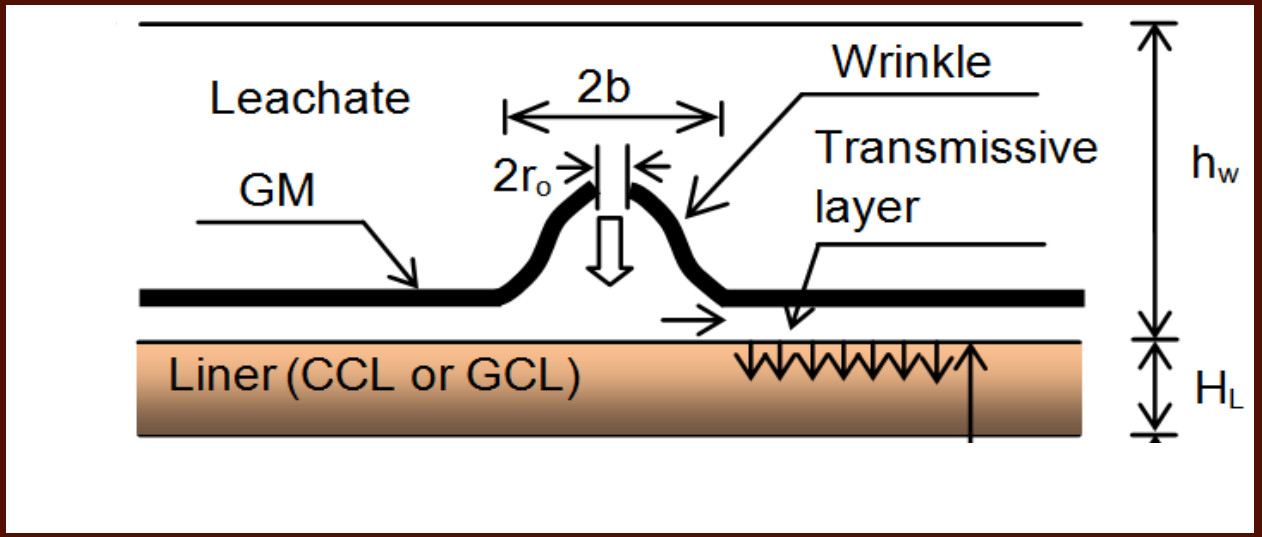


Leakage Calculations

Rowe (1998) equation:

$$Q = L\,[k_s\,2b + 2(k_s\,H_L\,\theta)^{0.5}]\,h_d / H_L$$



Q: flow through GM

L: wrinkle length

k_s: hydraulic conductivity of liner

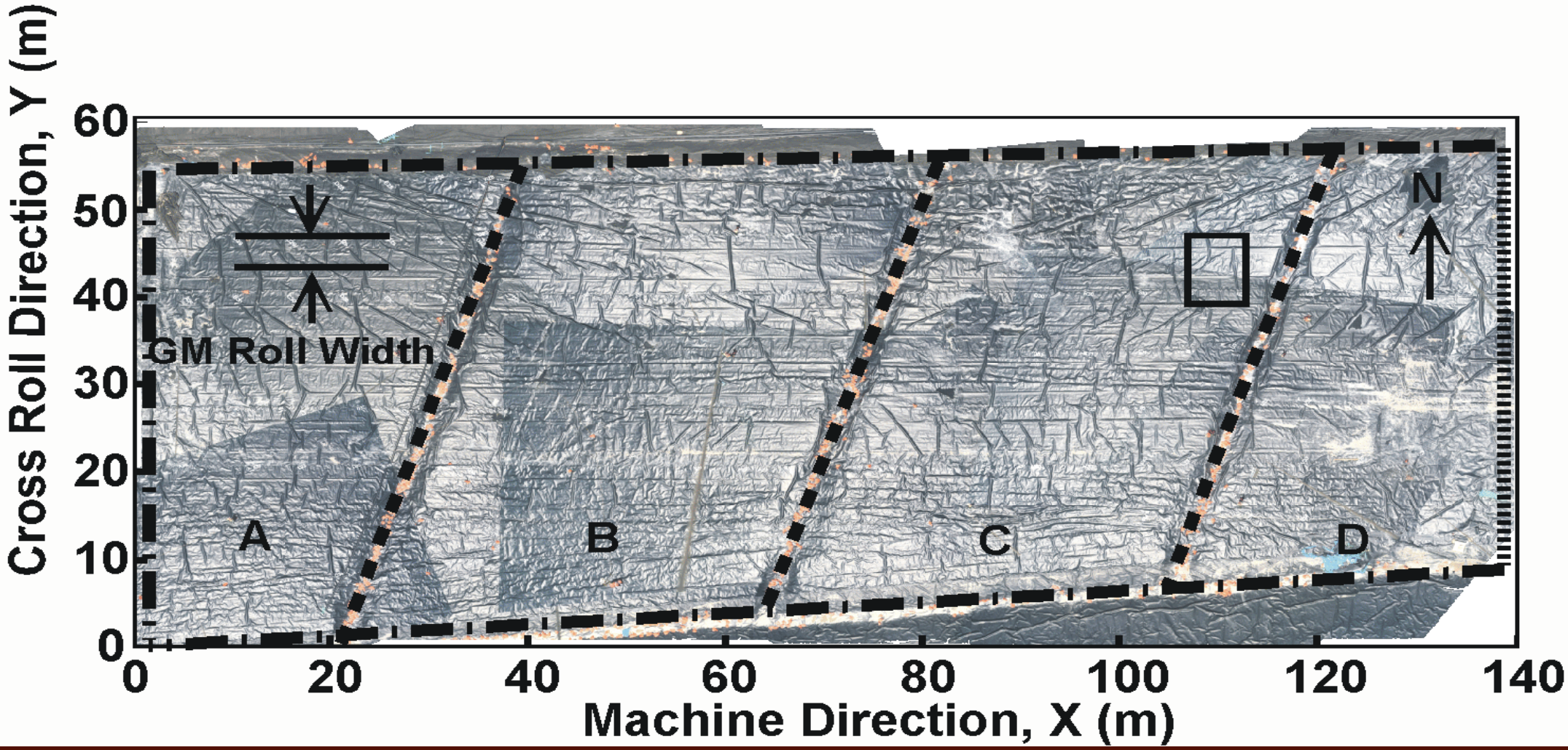
2b: width of wrinkle

H_L: Liner thickness

θ: transmissivity between GM and clay liner

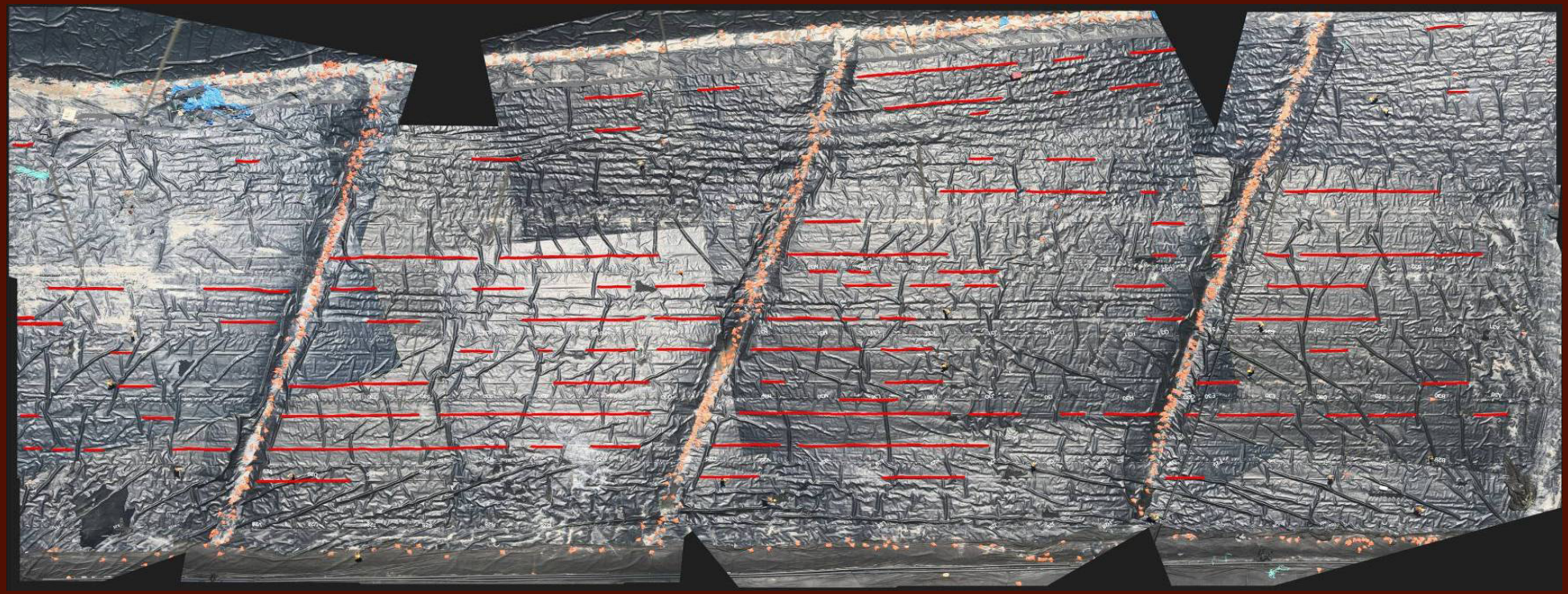
h_d: Head loss ($h_d = h_w + H_L$)

Site in Ontario Latitude 44° 24’ North



Chappel et al. (2012)

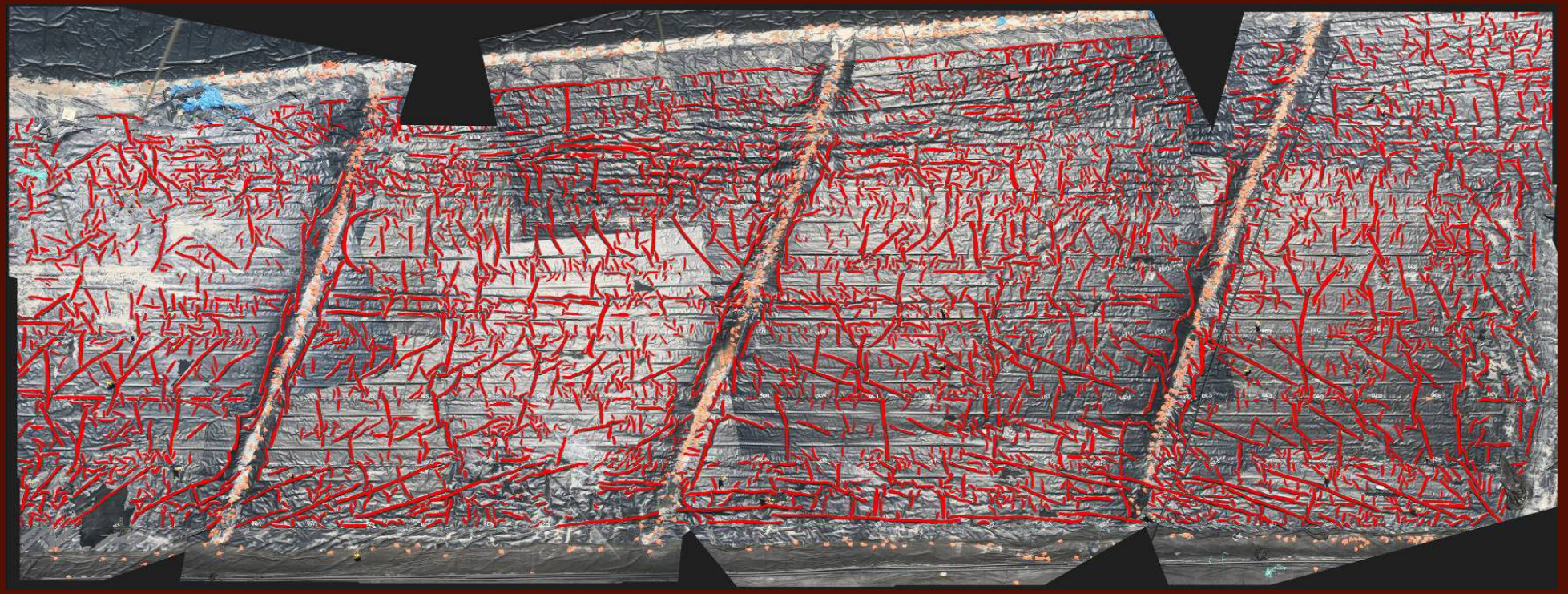
Site in Ontario Latitude 44° 24’ North



Early morning

Chappel et al. (2012)

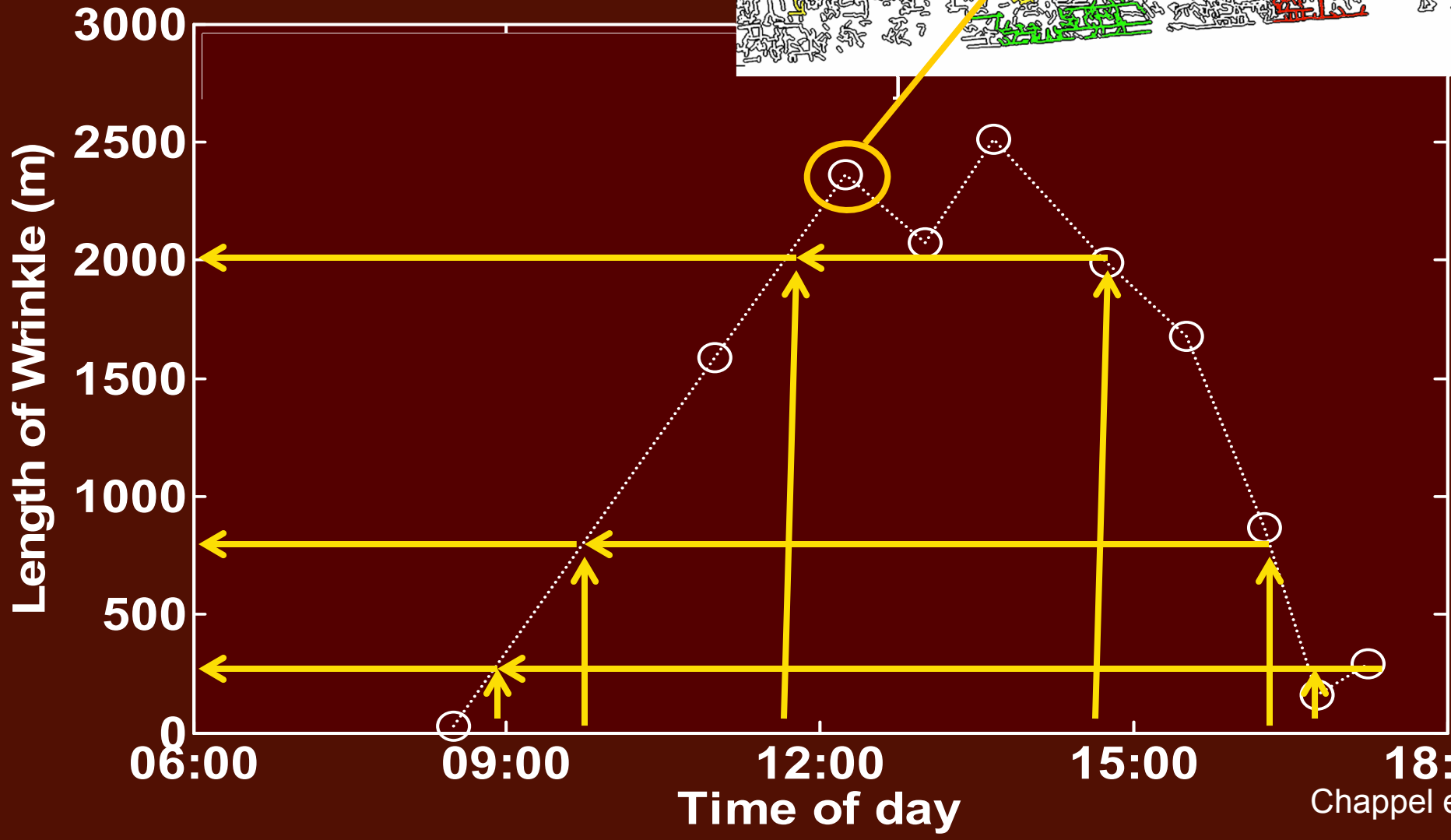
Site in Ontario Latitude 44° 24’ North



Midday

Chappel et al. (2012)

Change in connected wrinkle length over time



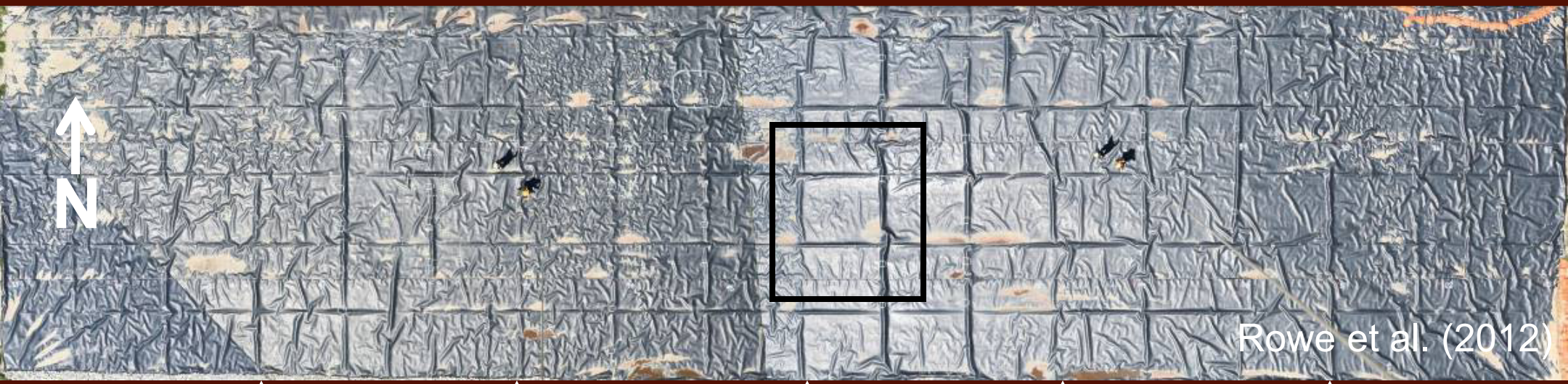
Chappel et al. (2012)

Queen's Experimental Liner Test Site (QUELTS)

- What we are examining:
  - Geomembrane Wrinkles
  - Geosynthetic Clay Liner Shrinkage (GCL)

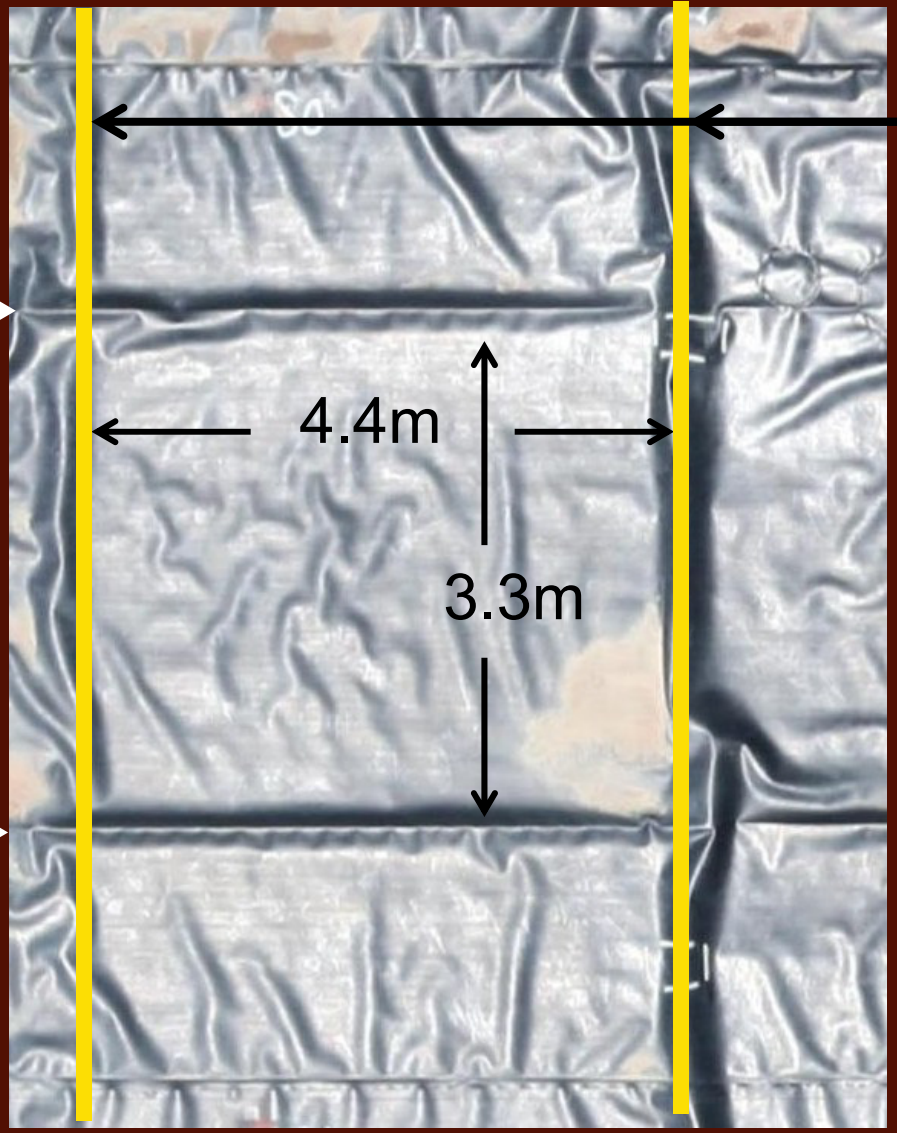
GM Wrinkles on Base QUELTS

28 May 2008 at 13:00 - air temperature=14°C, the geomembrane temperature on the base =54° C, solar radiation = 1050 W/m^2.



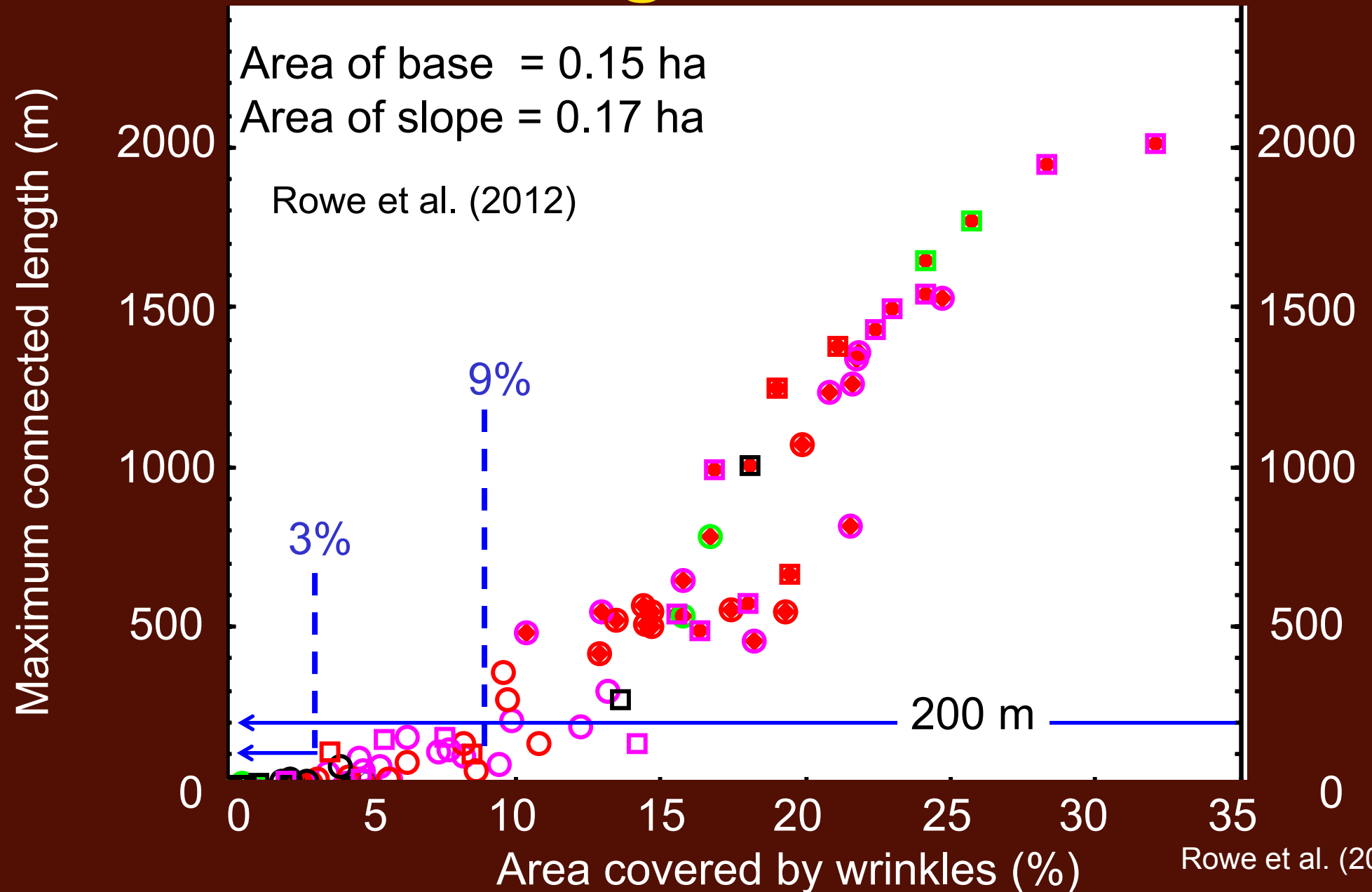
GCL 2 | GCL 3 | GCL 2 | GCL 4 | GCL 1 | GCL 3

GM Wrinkles on Base QUELTS



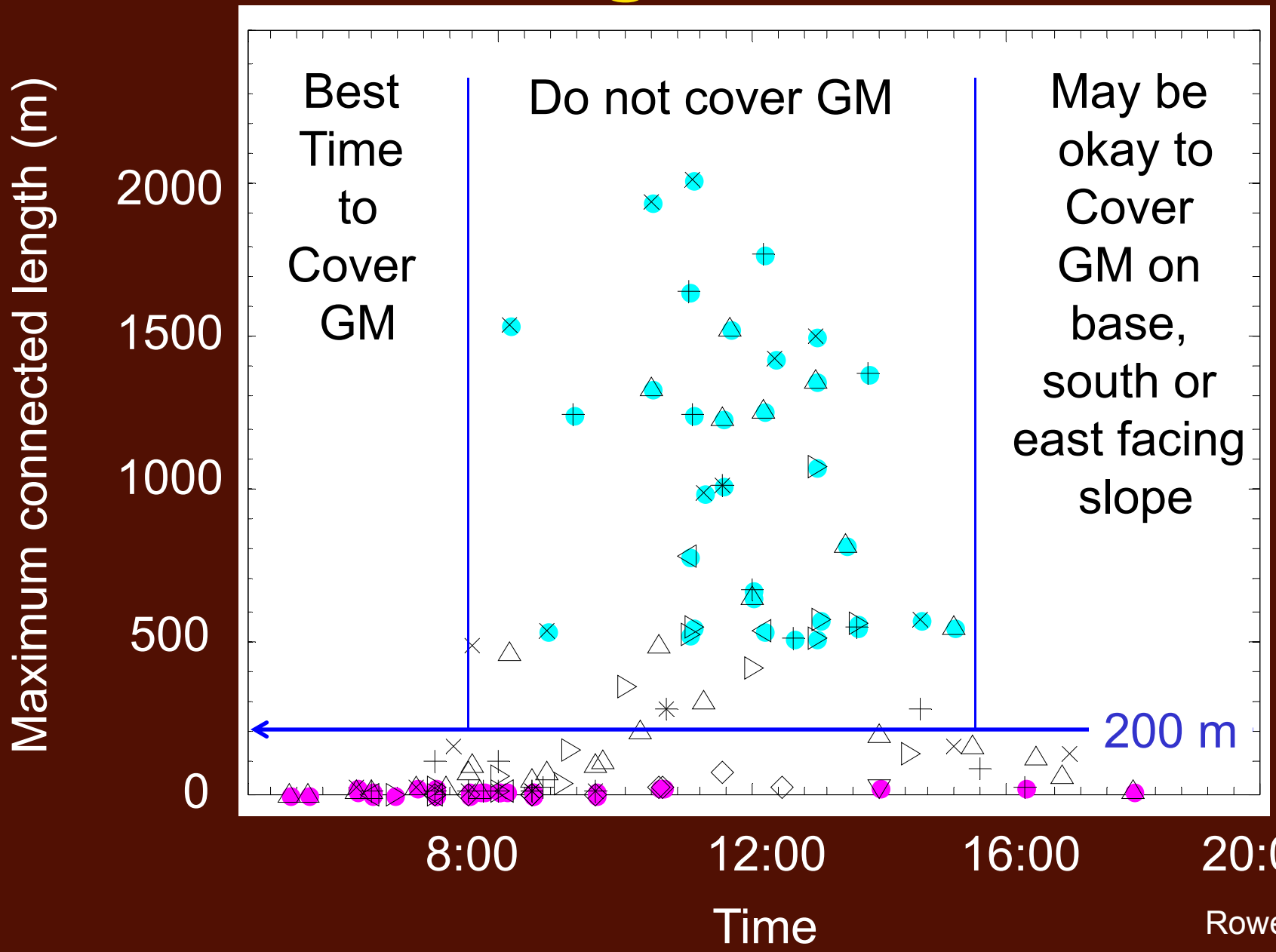
Rowe et al. (2012)

Wrinkle Length at QUELTS



Rowe et al. (2012)

Wrinkle Length at QUELTS



Rowe et al. (2012)

Wrinkle Summary

- Wrinkling related to solar radiation and GM temperature (may be 20-40^{o}C > ambient)
- Typical wrinkle width about 0.2 - 0.3 m
- Typical wrinkle height about 0.06m
- Wrinkles could range from a few % to more than 30% depending on time GM is covered
- Even on a “small” area (0.15-0.17 ha), wrinkle length exceeded 200m once more than about 8-9% of area was wrinkles

Winkle length (with hole) need to explain observed leakage

	Wrinkle length (m/ha)
Typical leakage	10 - 210

Rowe (2012)

Winkle length (with hole) need to explain observed leakage

	Wrinkle length (m/ha)
Typical leakage	10 - 210
High end leakage	800 -1300

Rowe (2012)

Calculated leakage through a primary liner

Liner	L (m/ha)	Leakage (lphd)
GM	-	63,000
GCL	-	1,300
CCL	-	1,300

GCL k_L = 5x10^{-11}m/s, H_L = 0.01m, θ = 3x10^{-11}m^2/s; CCL k_L = 1x10^{-9} m/s, H_L = 0.6m, θ = 1.6x10^{-8} m^2/s; GM 5 holes/ha, r_o = 5.6mm, h_w = 0.3m

Rowe (2012)

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GM/GCL	100	5

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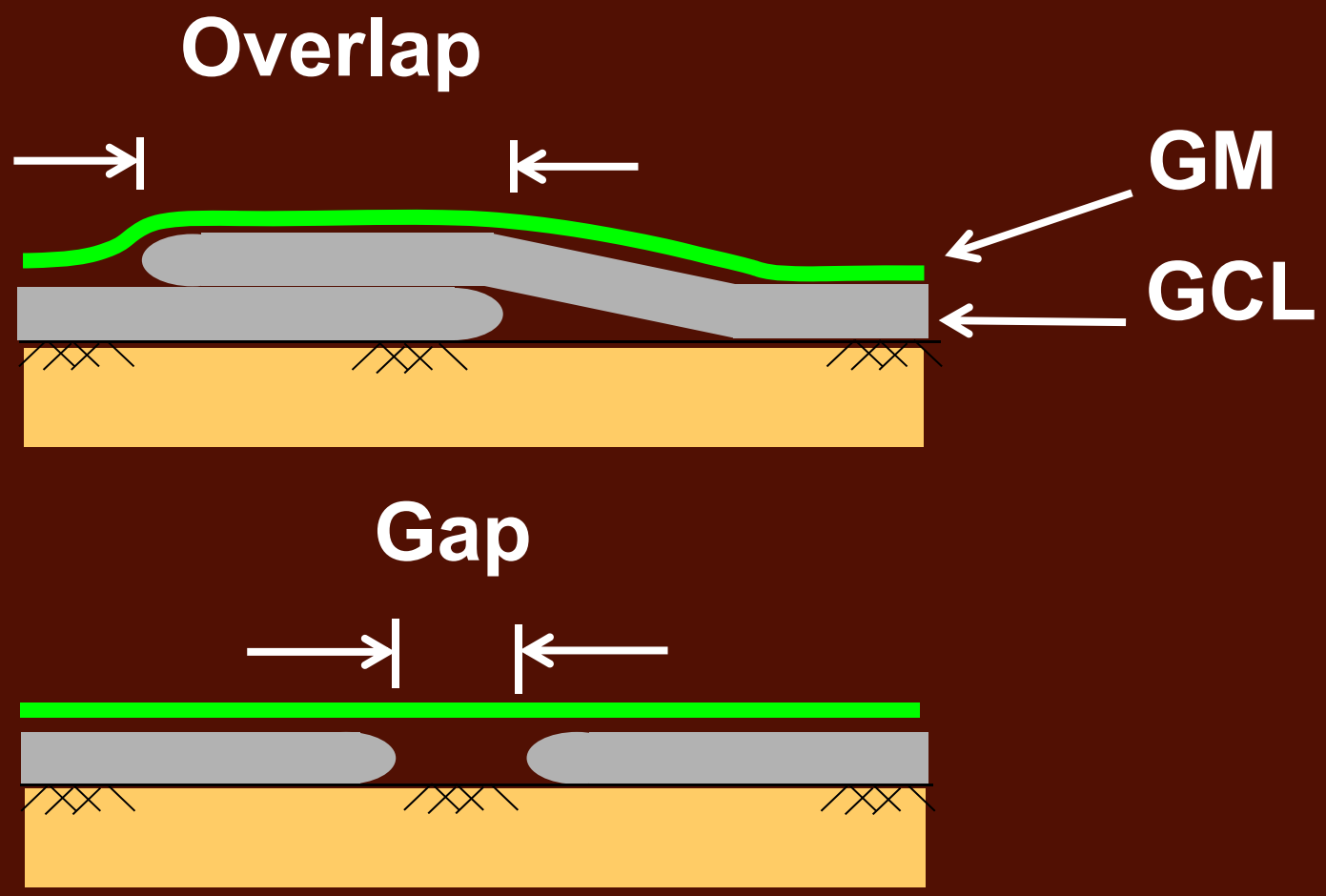
Rowe (2012)

Topics

- Holes in geomembranes
- Leakage through geomembrane liners
- Leakage through clay liners
- **Leakage through composite liners**
  - Direct contact
  - Observed leakage
  - Wrinkles/waves
  - **GCL overlaps / panel shrinkage**
  - GM/CCL interface and desiccation of compacted clay liners (CCL)

Overlap loss due to shrinkage



Observed Field Shrinkage

(Thiel et al. 2006)

GCL Cover/ Carrier GT	Slope	Maximum gap (mm)	Exposure period (months)
W / W	22°	300	60
NW / W	18°	200	15
NW / W	4°	300	2
NW / NW	34°	1200	36
NW / NW	18°	300	5
NW / NW	4°	450	2

NW= Nonwoven geotextile; W = woven geotextile

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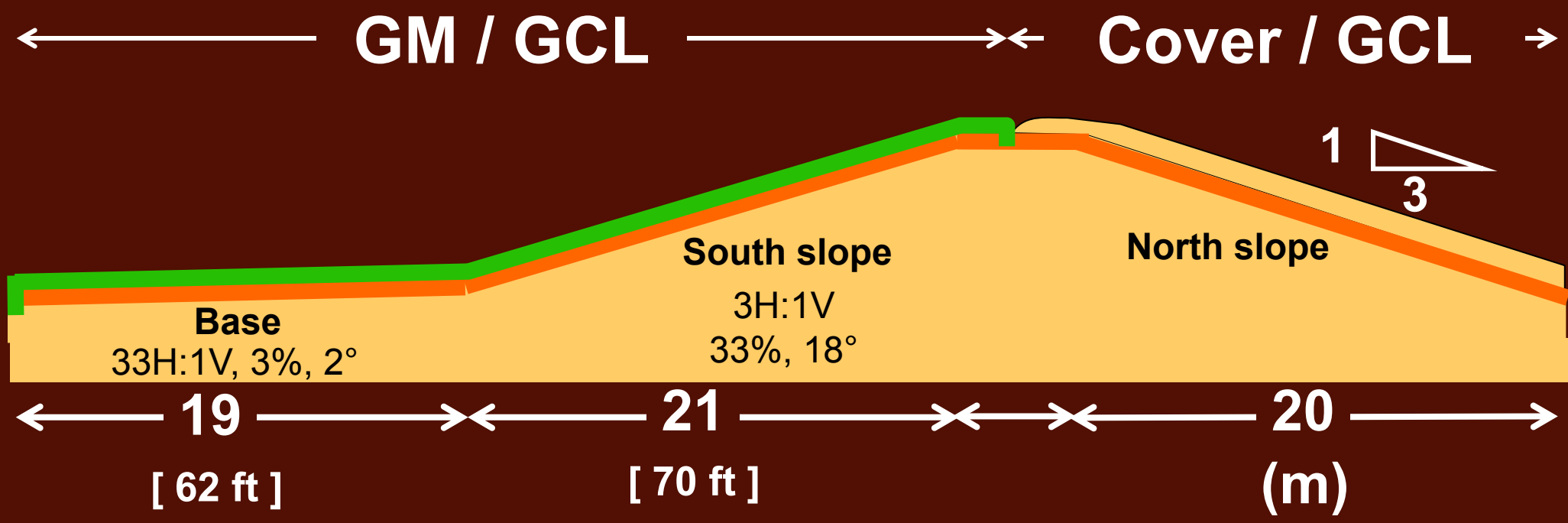
Queen's Experimental Liner Test Site (QUELTS)

- What we are examining:
  - Geomembrane Wrinkles
  - Geosynthetic Clay Liner Shrinkage (GCL)

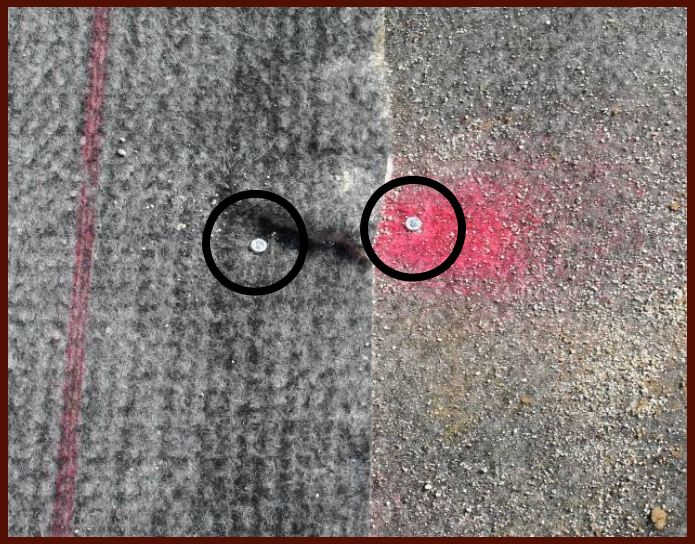
Queen's Experimental Liner Test Site (QUELTS)

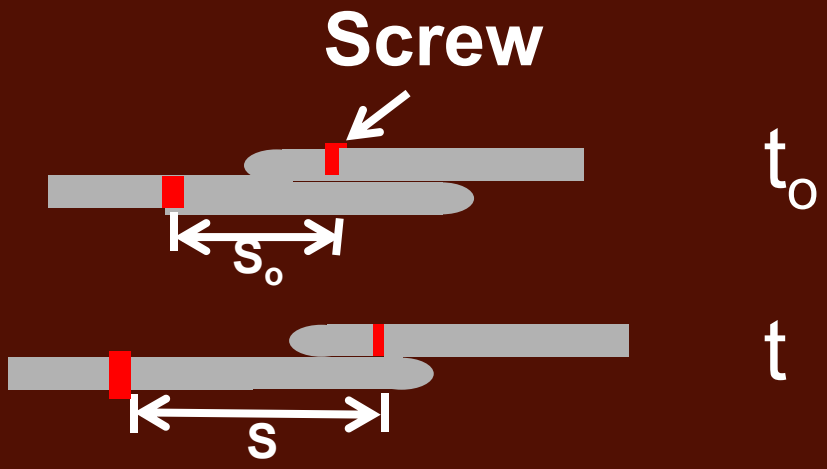
Brachman et al. (2007)

Cross section



Overlap Measurement





Screws at overlap

Shrinkage = Measured change in distance ($s-s_o$)

GCL Movement

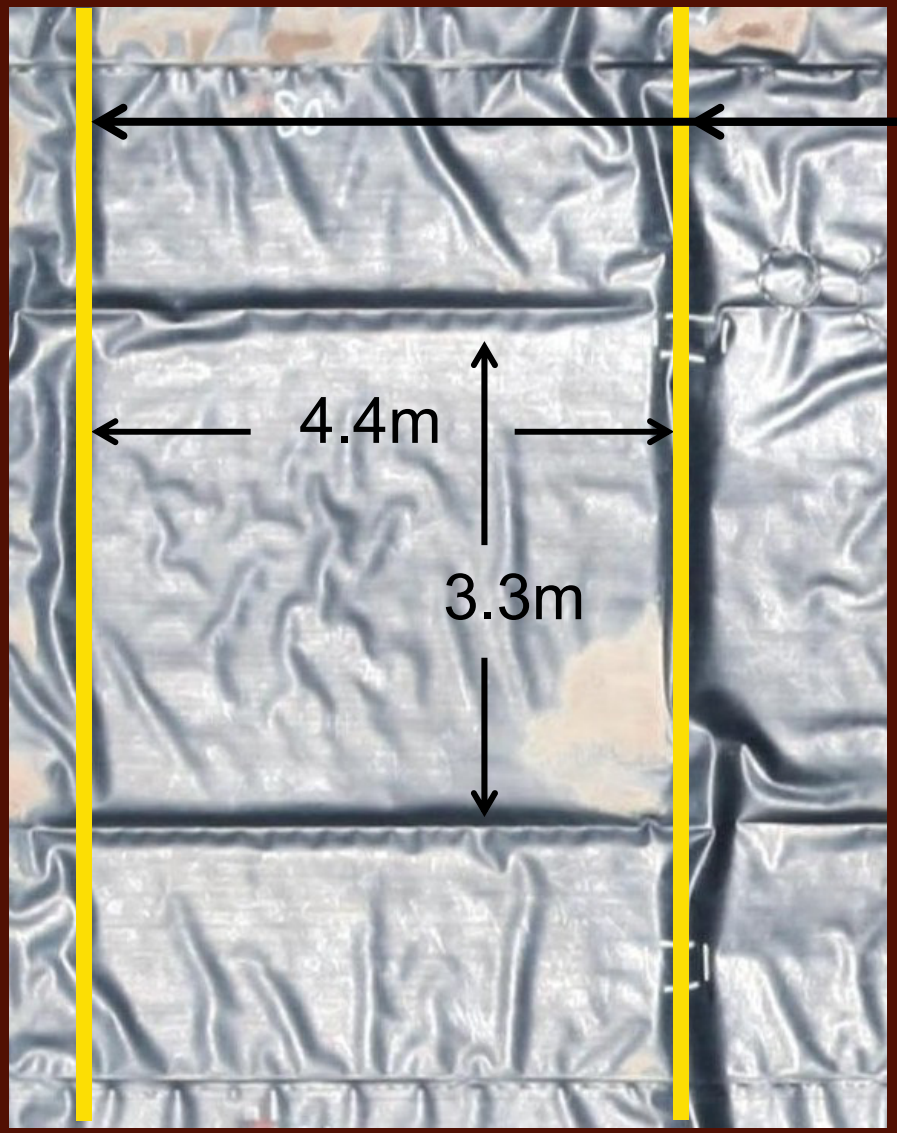
Summary of Observations from QUELTS

GCL panel overlap after 4.8 years:

- GCL 2 (SRNW-NW+T) ≤ 30 mm (1.2 in.) max measured shrinkage
- other three GCLs had significant shrinkage (up to 660 mm)

Loss of 300mm overlap occurred at location of wrinkles

GM Wrinkles on Base QUELTS



Rowe et al. (2012)

Preliminary Observations

- Shrinkage appears to depend on:
  - method of GCL manufacture; and
  - local site conditions
- Effects can be minimized by:
  - **covering as quickly as possible**
  - selecting a GCL with the best performance
  - ensuring 300mm overlap at seams
  - heat tacking seam
  - **covering as quickly as possible**

Topics

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  - GCL overlaps/ panel shrinkage
  - **GM/CCL interface and desiccation of compacted clay liners**

To ensure a good composite liner

CCLs must have a well prepared surface in contact with GM

Not good

To ensure a good composite liner

CCLs must have a well prepared surface in contact with GM

Really bad

Loss of composite liner action

- CCLs desiccate when left without suitable cover; so cover all composite liners quickly

Photo: P. Davies

Calculated leakage through a primary liner

	h_w =	0.3m
Liner	L (m)	Leakage (lphd)
GM/CCL	1000	830
GM/CCL	100	83
GM/DCCL*	-	1,300

* DCCL = CCL with severe desiccation just below GM

CCL H_L = 0.6m, h_a=0, k_L = 1x10^{-9} m/s, θ = 1.6x10^{-8} m^2/s except for DCCL, h_w = 0.3,

Rowe (2012)

Topics

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Conclusions

- Intact GM is essentially impermeable to water
- Leakage occurs through holes in GM
- Composite (GM/CL) liners perform MUCH better than single GM or clay liners.
- Composite liners with a GCL generally perform MUCH better than a composite liner with a CCL

Conclusions

- Need an appropriate design for the local conditions
- Manufacturers produce MANY different GCLs and GMs – choose wisely!
- Good construction is critical to good performance (ignore manufacturers guidelines at your peril)

Conclusions

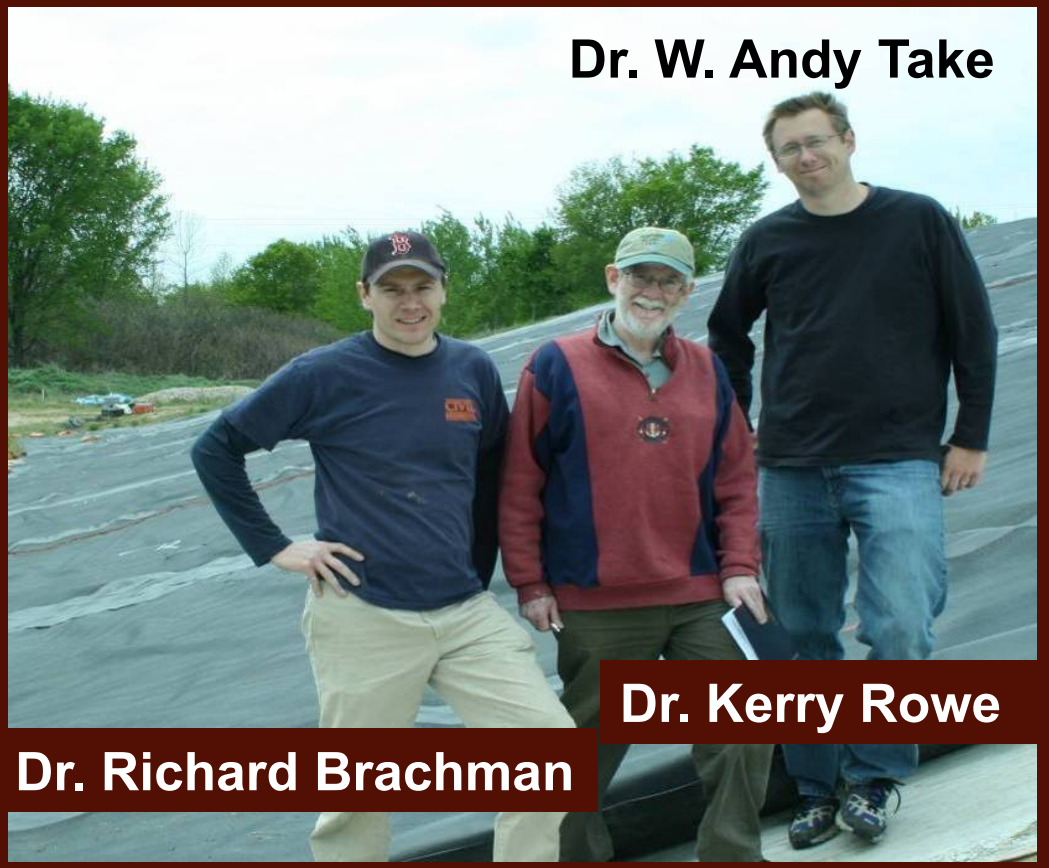
Leakage depends (*inter alia*) on:

- length of connected wrinkles with, or adjacent to, a hole
- contact conditions between GM and clay liner (interface transmissivity)
- desiccation of clay liner or loss of panel overlap
- operational hydraulic conductivity of the clay liner

QUELTS Team

Naidu Arnepalli Melissa Chappel

Laura Bostwick Ryley Beddoe



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Terrafix Environmental (GM/GCL Installation)

Solmax International (Geomembrane)

Cruickshank Construction (Earthworks)





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Terrafix Geosynthetics

Terrafix Environmental

Solmax International

Cruickshank Construction

Golder Associates

AMEC Earth & Environmental

AECOM

Groupe CTT Group

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Limitations

The information contained in this talk has been prepared solely for the guidance of those attending the workshop. It is not to be regarded as complete in itself and should not therefore be used without reading the cited references and independent examination and verification of its suitability for any particular project. Anyone making use of the information or material contained herein does so at their own risk and assumes any and all liability from such use.

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Questions?

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