Canadian Nuclear Safety Commission | Commission canadienne de sûreté nucléaire

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Supplementary Information

Renseignements supplémentaires

Presentation from Kerry Rowe

Présentation de Kerry Rowe

In the Matter of the

À l'égard des

Canadian Nuclear Laboratories (CNL)

Laboratoires Nucléaires Canadiens (LNC)

Application from the CNL to amend its Chalk River Laboratories site licence to authorize the construction of a near surface disposal facility

Demande des LNC visant à modifier le permis du site des Laboratoires de Chalk River pour autoriser la construction d'une installation de gestion des déchets près de la surface

Commission Public Hearing
Part 2

Audience publique de la Commission
Partie 2

May 30 to June 3, 2022

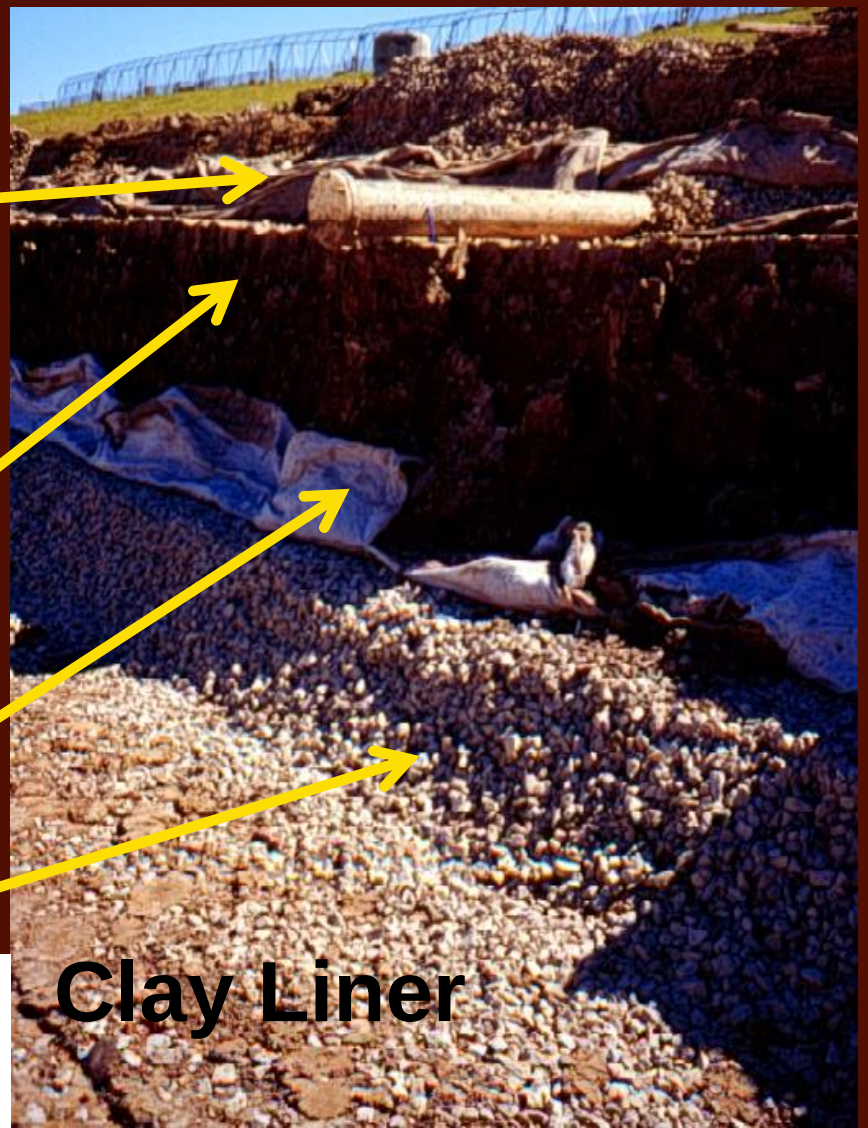
30 mai au 3 juin 2022

Canada

Long-term design and safety of the NSDF Engineered Containment Mound

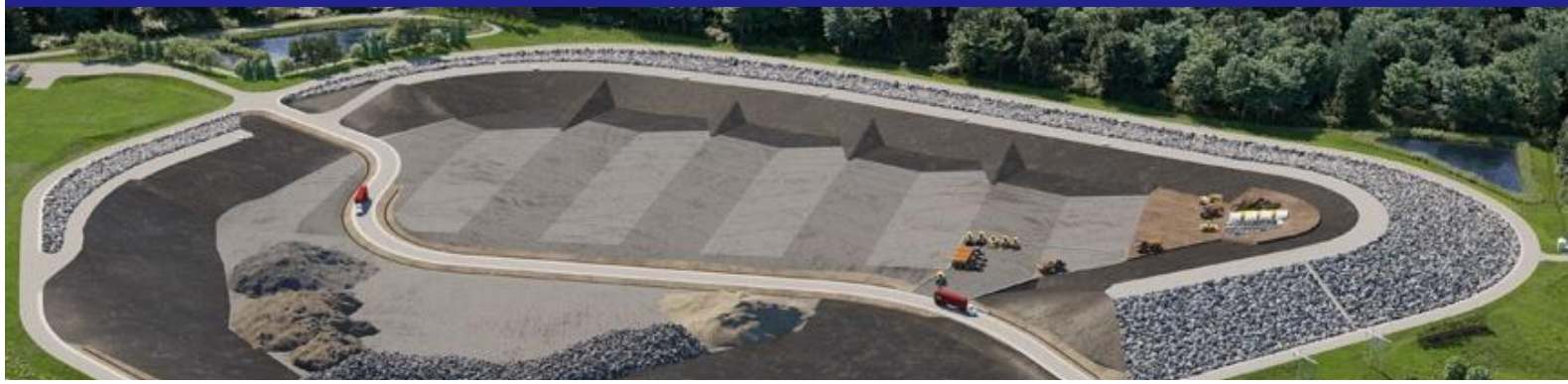
R. Kerry Rowe OC
PhD, FRS, NAE, FRSC

First fully engineered landfill in Ontario Halton Landfill 1991- (a show case)



We have come a long way in 40 years

Canadian Nuclear Laboratories (CNL)
Near Surface Disposal Facility (NSDF)



We have many decades of research and field experience

LANDFILL STANDARDS

A GUIDELINE ON THE REGULATORY

AND APPROVAL REQUIREMENTS

FOR NEW OR EXPANDING LANDFILLING

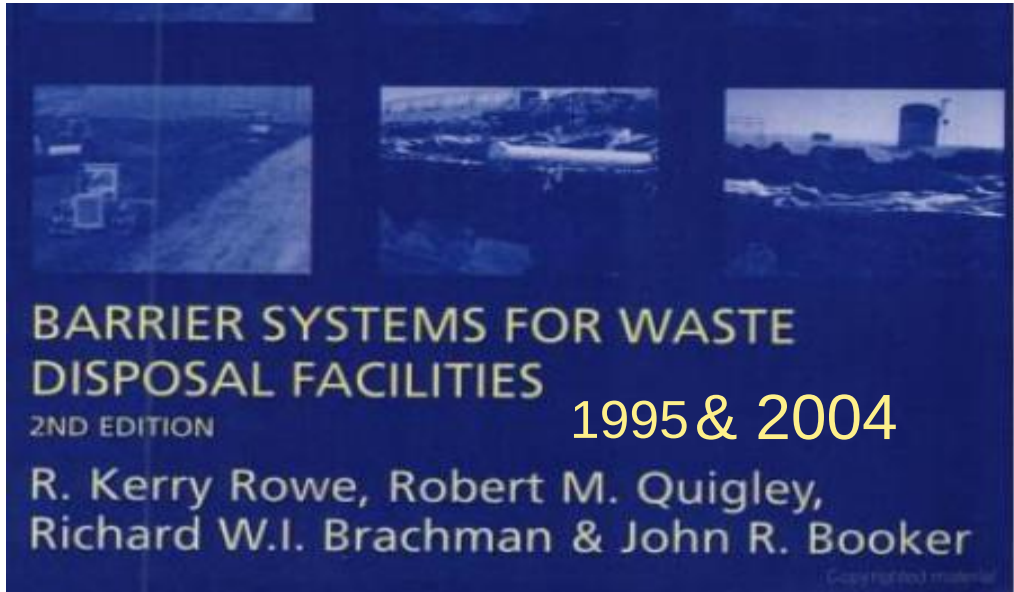
SITES

MAY 1998

Ontario

National Guidelines
for
Hazardous Waste Landfills

2005



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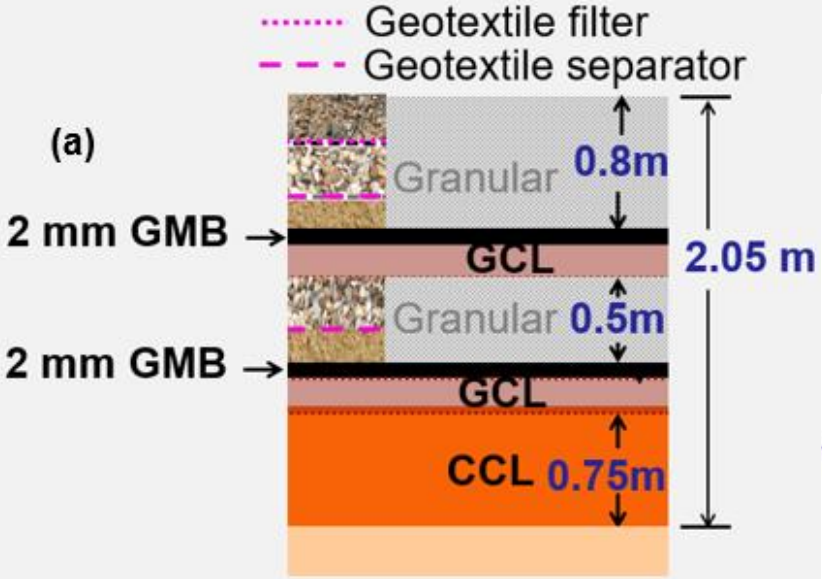
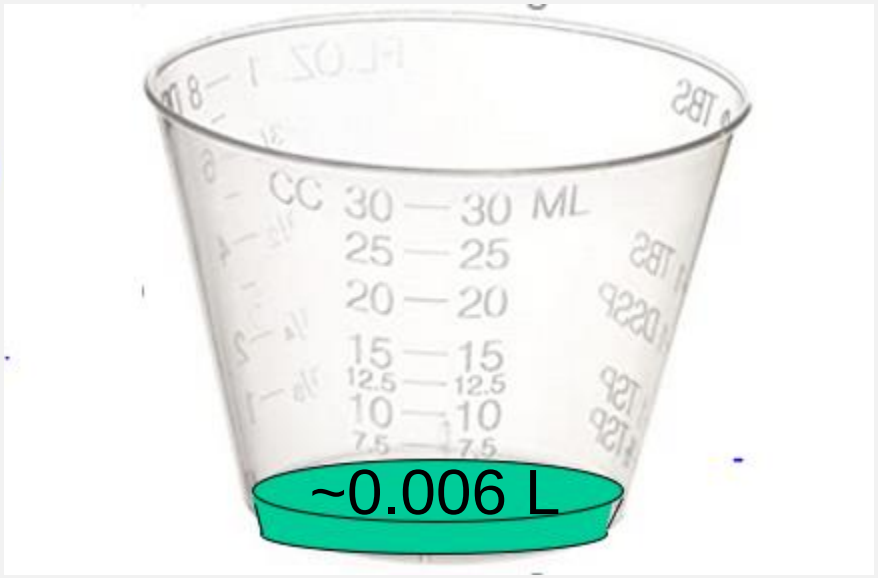
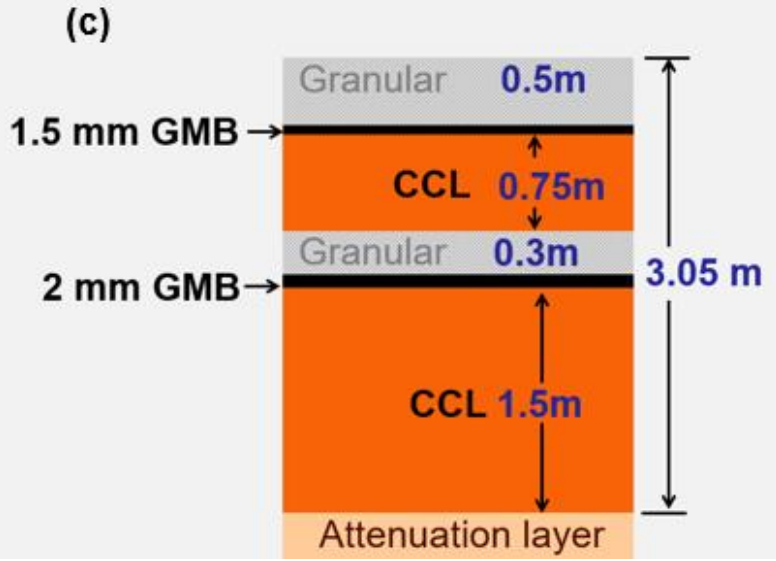






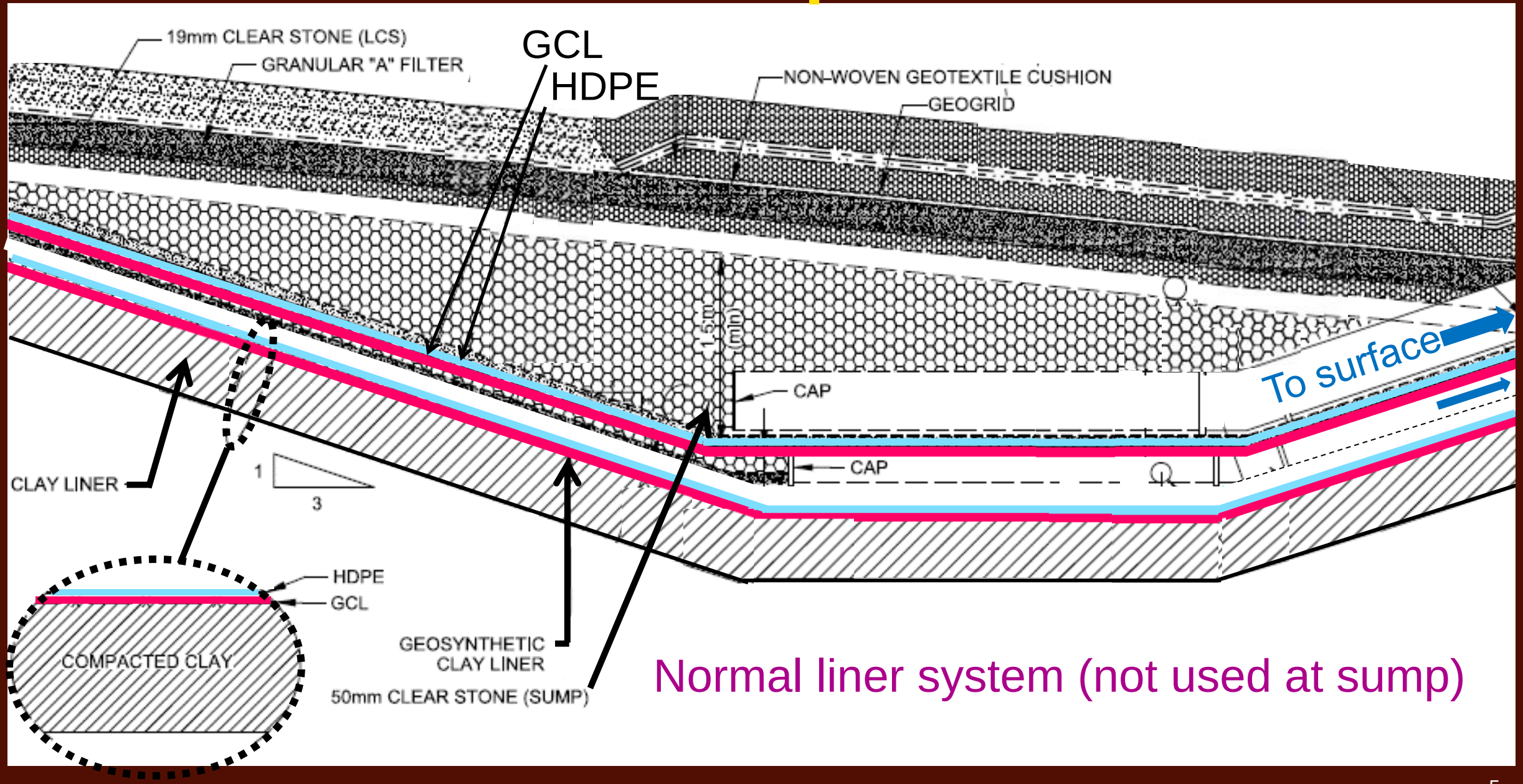
(a) NSDF ECM (b) Ontario Reg. 232/98 Generic Design (c) CCME Hazardous Waste

Primary composite liner 100 mm^2 slit/ha leakage for 12 ha

0.006 L/day 0.55 L/day 0.55 L/day

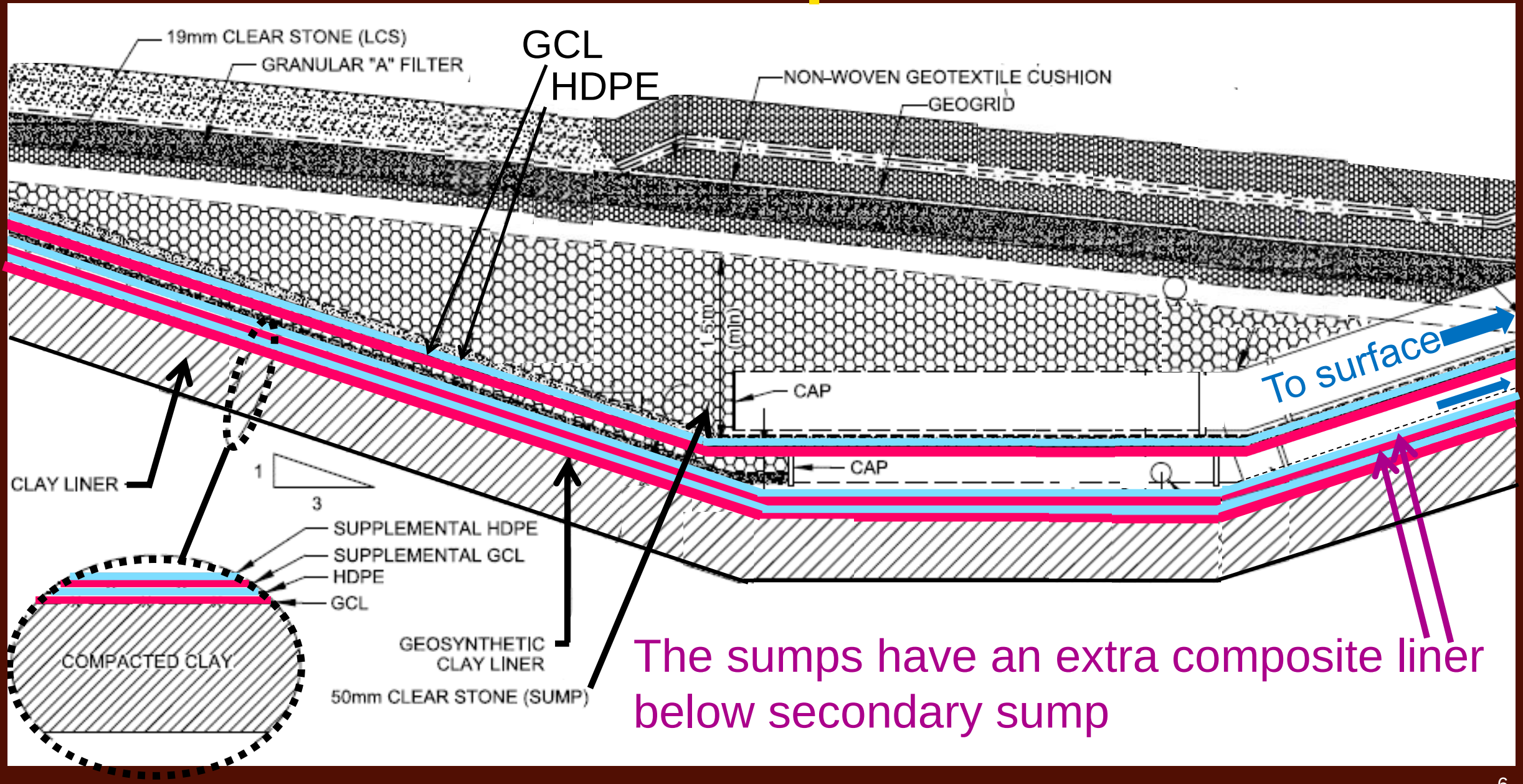
Probability of 0.0008 L/day leakage though a similar slit in secondary liner (except at a sump) less than 0.0006 (1 in 1570)

Sump



Normal liner system (not used at sump)

Sump



The sumps have an extra composite liner below secondary sump

Base Barrier US LLW vs NSDF ECM

Clive, UT	Oak Ridge EMWF, TN	Hanford ERDF, WA	CERCLA DF, ID	Fernald OSDF, OH	Proposed NSDF ECM	
Crushed rock Granular filter	Soil layer Geotextile	Soil layer			Granular filter Geotextile	Primary system
LCS	LCS	LCS	LCS	LCS	LCS	
Geotextile	Geotextile	Geotextile			Geotextile Sand protection	
GMB/CCL	GMB	GMB	GMB/GCL	GMB/GCL	GMB/GCL	

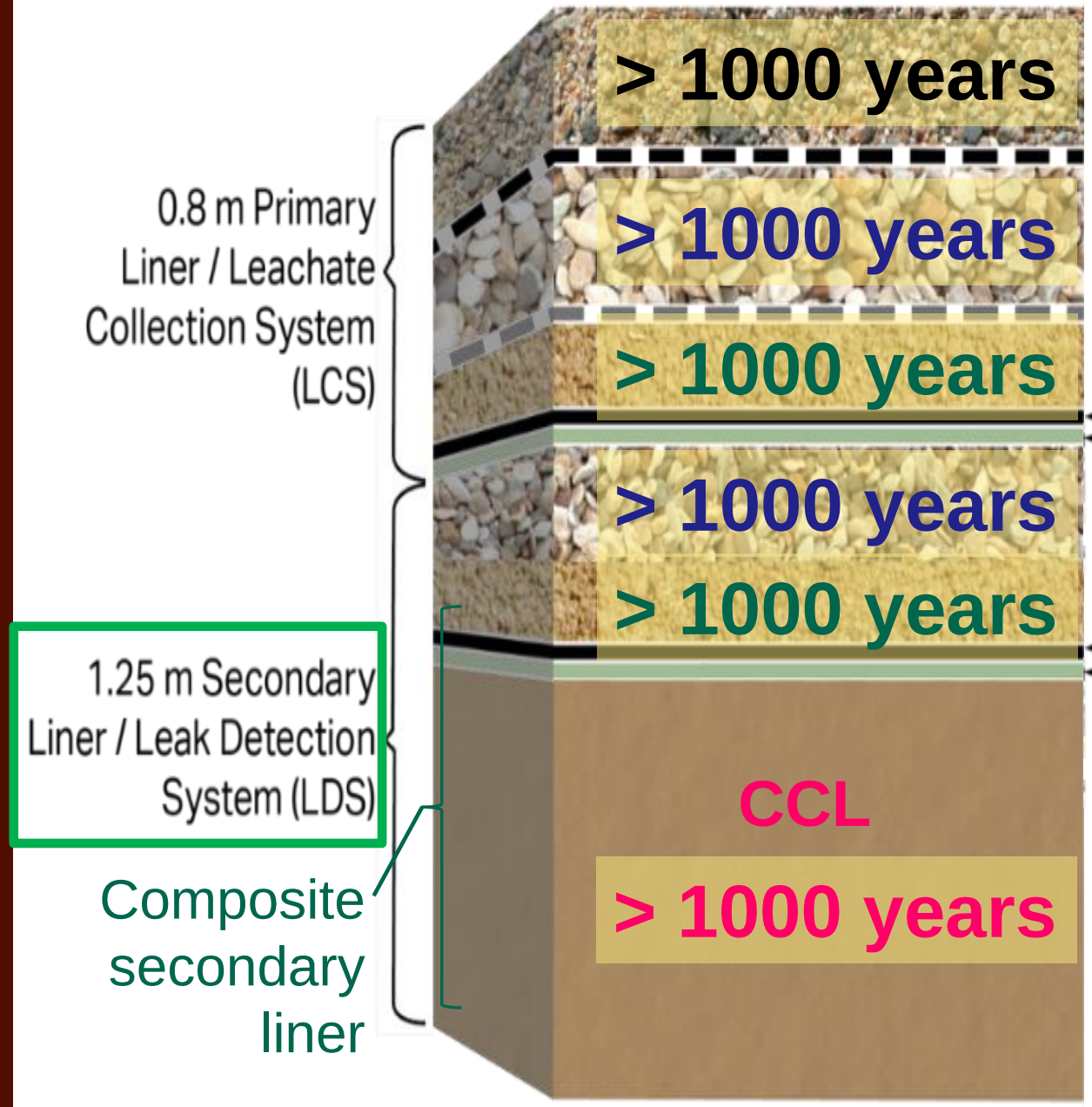
Base Barrier US LLW vs NSDF ECM

Clive, UT	Oak Ridge EMWF, TN	Hanford ERDF, WA	CERCLA DF, ID	Fernald OSDF, OH	Proposed NSDF ECM	
Crushed rock Granular filter	Soil layer Geotextile	Soil layer			Granular filter Geotextile	Primary system
LCS	LCS	LCS	LCS	LCS	LCS	
Geotextile	Geotextile	Geotextile			Geotextile Sand protection	
GMB/CCL	GMB	GMB	GMB/GCL	GMB/GCL	GMB/GCL	
	LDS/LCS	LDS/LCS	LDS/LCS	LDS/LCS	LDS/LCS	Secondary
		Geotextile		Geotextile	Geotextile Sand protection	
	GMB/CCL	GMB/CCL	GMB/CCL	GMB/GCL	GMB/GCL/CCL	

Base Barrier US LLW vs NSDF ECM

Clive, UT	Oak Ridge EMWF, TN	Hanford ERDF, WA	CERCLA DF, ID	Fernald OSDF, OH	Proposed NSDF ECM	
Crushed rock Granular filter	Soil layer Geotextile	Soil layer			Granular filter Geotextile	Primary system
LCS	LCS	LCS	LCS	LCS	LCS	
Geotextile	Geotextile	Geotextile			Geotextile Sand protection	
GMB/CCL	GMB	GMB	GMB/GCL	GMB/GCL	GMB/GCL	
	LDS/LCS	LDS/LCS	LDS/LCS	LDS/LCS	LDS/LCS	Secondary
		Geotextile		Geotextile	Geotextile Sand protection	
	GMB/CCL	GMB/CCL	GMB/CCL	GMB/GCL	GMB/GCL/CCL	
OK	**Good**	**Good**	**Very good**	**Very good**	**Best by far**	

So, how long will it last (years)?



Geomembrane:
the ONLY part of the system of long-term significance that does not have a history of survival that can be traced for > 10,000 years.

Textured geomembrane

GCL **> 1000 years**

Textured geomembrane

GCL **> 1000 years**

Priyanto et al. (2019)

How long will a geomembrane last?

depends on

- GMB used – (polymer and antioxidant/stabilizers)
  - 5 Candidate GMBs from 3 manufacturing plants examined
- The exposure conditions
  - Chemical composition of fluid in contact with GMB
  - Temperature (Test at 85, 75, 65, and 55^{o}C)
    - Annual average temperature at Chalk River, Ontario: 5.6^{o}C (1981-2010)
    - Design temperature is 10^{o}C

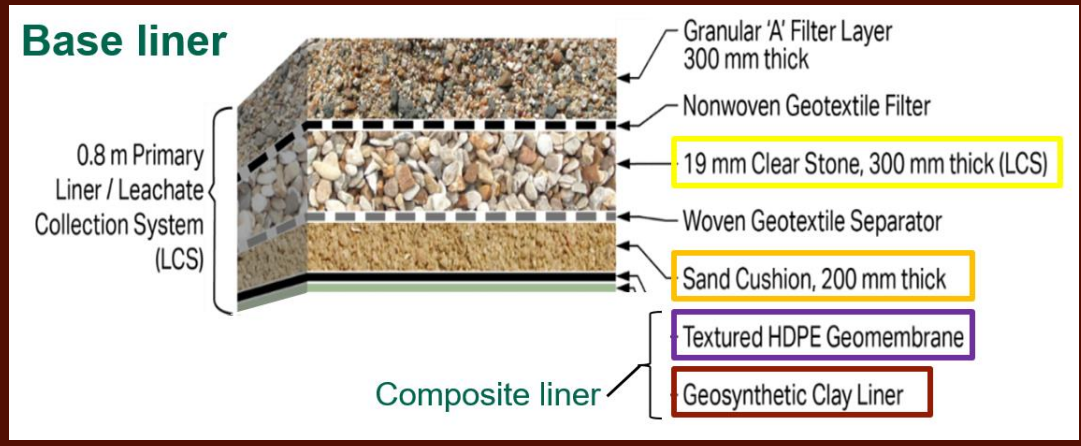
Deduced Service-life of GMBs (years)

t_{SL} = *service life = time until it no longer limits leakage to design value*

t_{SL} *(exp) = expected (most likely) service life*

t_{SL} *(WC) = worst case (most conservative) service life*

xTD and yTB: Eliminated



Deduced Service-life of GMBs (years)

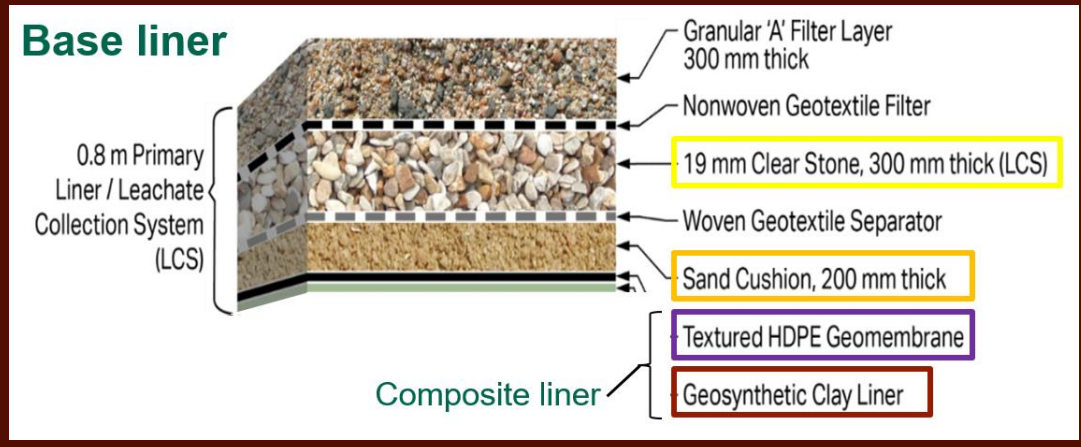
Evaluation	✓		✓✓		⊘	
NSDF GMB	xTB		yTA		zTA	
T (°C)	$t_{SL(exp)}$	$t_{SL(WC)}$	$t_{SL(exp)}$	$t_{SL(WC)}$	$t_{SL(exp)}$	$t_{SL(WC)}$
5	>2000	1400	>2000	>2000	>2000	910
10	**>2000**	**1100**	**>2000**	**>2000**	**>2000**	**670**
15	>2000	710	>2000	1700	>2000	440
Stress Crack	Good		Very Good		Ok but borderline	

xTD and yTB: Eliminated

t_{SL} = service life = time until it no longer limits leakage to design value

t_{SL} (exp) = expected (most likely) service life

t_{SL} (WC) = worst case (most conservative) service life



Best Available Technology

Six Lines of Defence

6. Long travel time required to reach any receptor.

5. Contingency plan for the “unexpected”.

4. Monitoring wells outside the ECM.

Best Available Technology

Six Lines of Defence

3a Secondary leachate collection and removal system
(to collect and remove any leakage through primary liner)

3b Secondary composite liner
(to direct primary liner leakage to secondary collection system)

Service Life > 1000 years

Best Available Technology

Six Lines of Defence

2a Primary leachate collection and removal system
(to collect and remove leachate for treatment)

2b Primary composite liner
(to minimize and leakage)

Service Life > 1000 years

3a Secondary leachate collection and removal system
(to collect and remove any leakage through primary liner)

3b Secondary composite liner
(to direct primary liner leakage to secondary collection system)

Service Life > 1000 years

Best Available Technology

1 **Cover** (to minimize water into the waste)

2a Primary leachate collection and removal system
(to collect and remove leachate for treatment)

2b Primary composite liner
(to minimize and leakage)

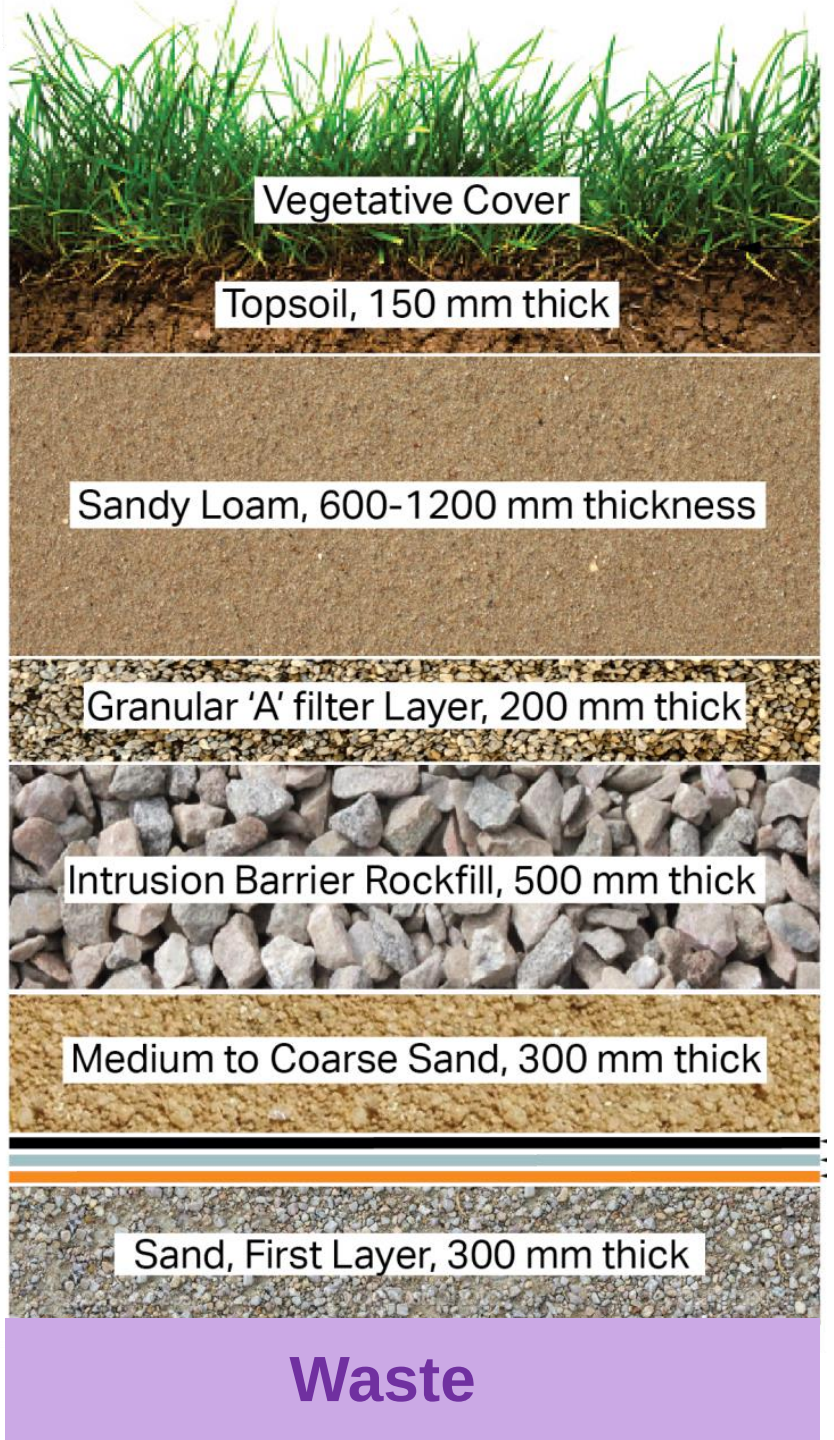
Service Life > 1000 years

3a Secondary leachate collection and removal system
(to collect and remove any leakage through primary liner)

3b Secondary composite liner
(to direct primary liner leakage to secondary collection system)

Service Life > 1000 years

Cover: 9 Layers



- As good or better than those in US LLW facilities
- Can always be repaired

Construction Quality Assurance

Great care and investigation has gone into the design – **BUT** to achieve the performance

It must be built according to the design and so:

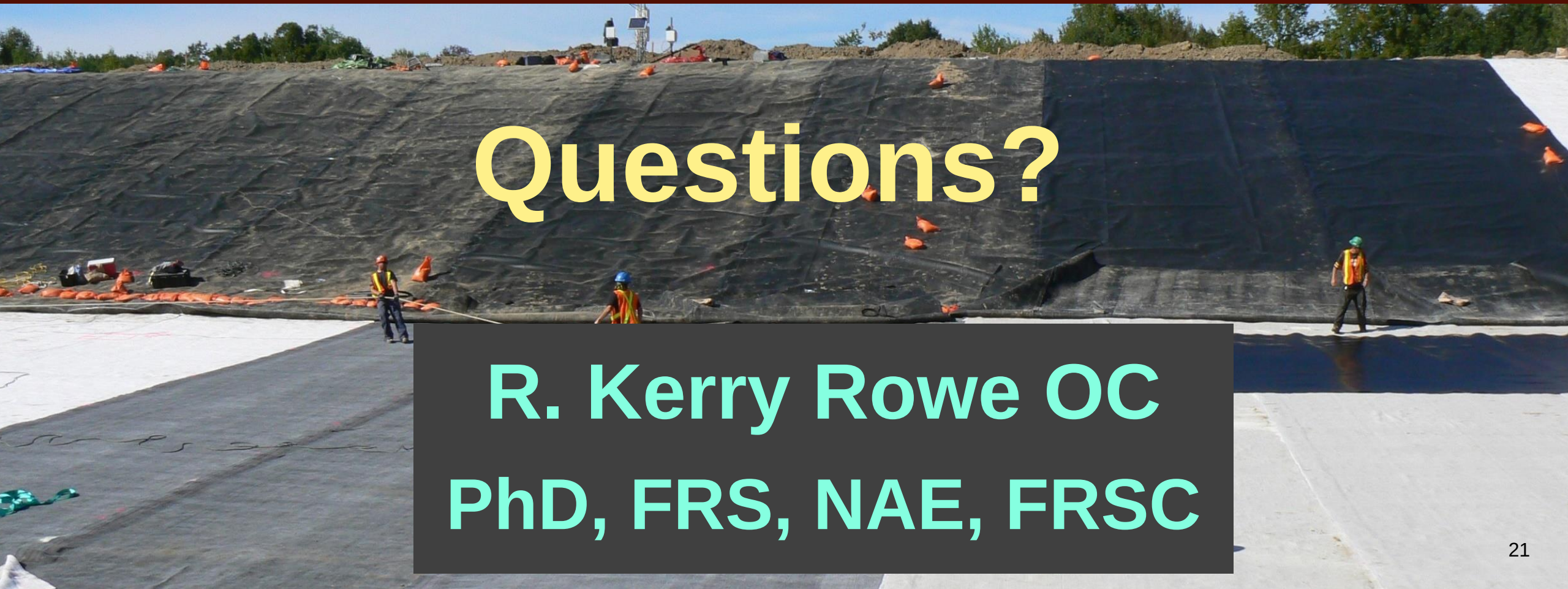
- Excellent construction quality assurance (CQA) is ESSENTIAL to ensure
  - Correct materials are used
  - The construction is in accordance with the design and specifications.

Design Summary

The design

- Is such that the service-life of the ECM is in excess of 1000 years.
- Well in excess of the design-life (550 years) and estimated contaminating lifespan.
- The design has multiple levels of defence before one even considers the natural system.
- The system will still protect the environment even if there is an unexpected failure of any component (i.e., it is robust).

Long-term design and safety of the NSDF Engineered Containment Mound

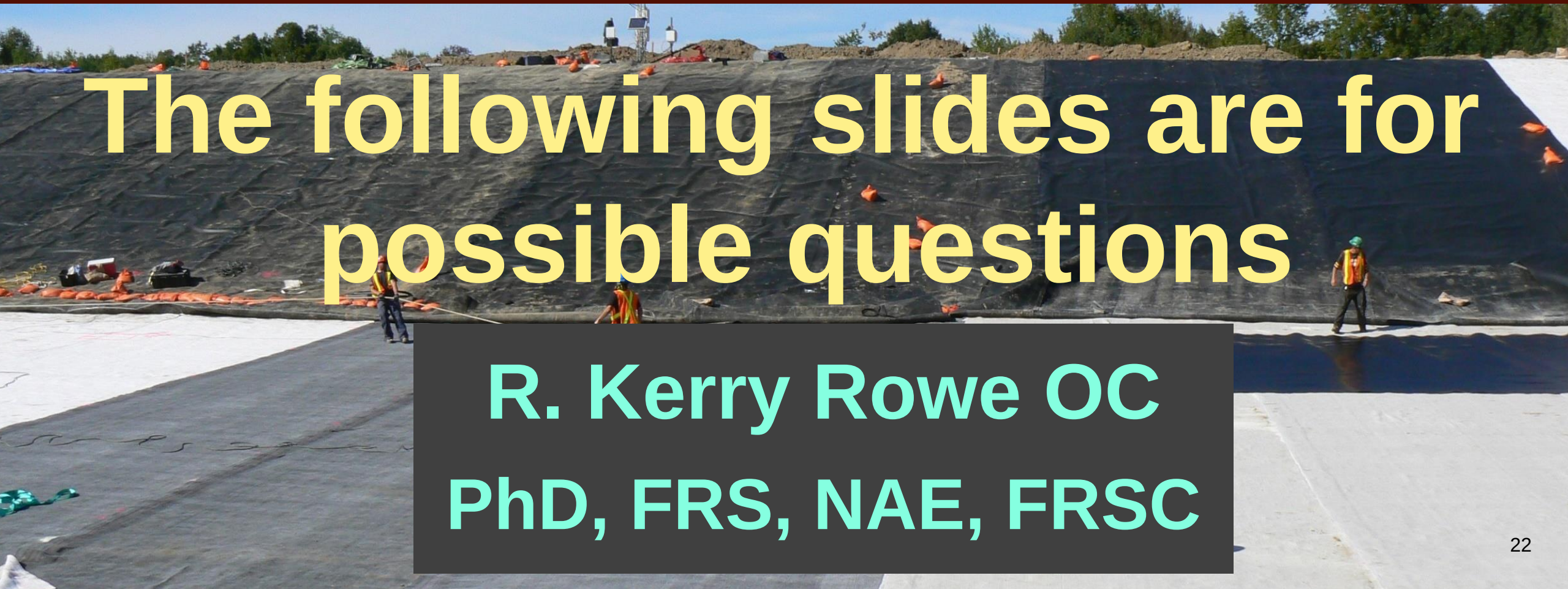


Questions?

R. Kerry Rowe OC

PhD, FRS, NAE, FRSC

Long-term design and safety of the NSDF Engineered Containment Mound

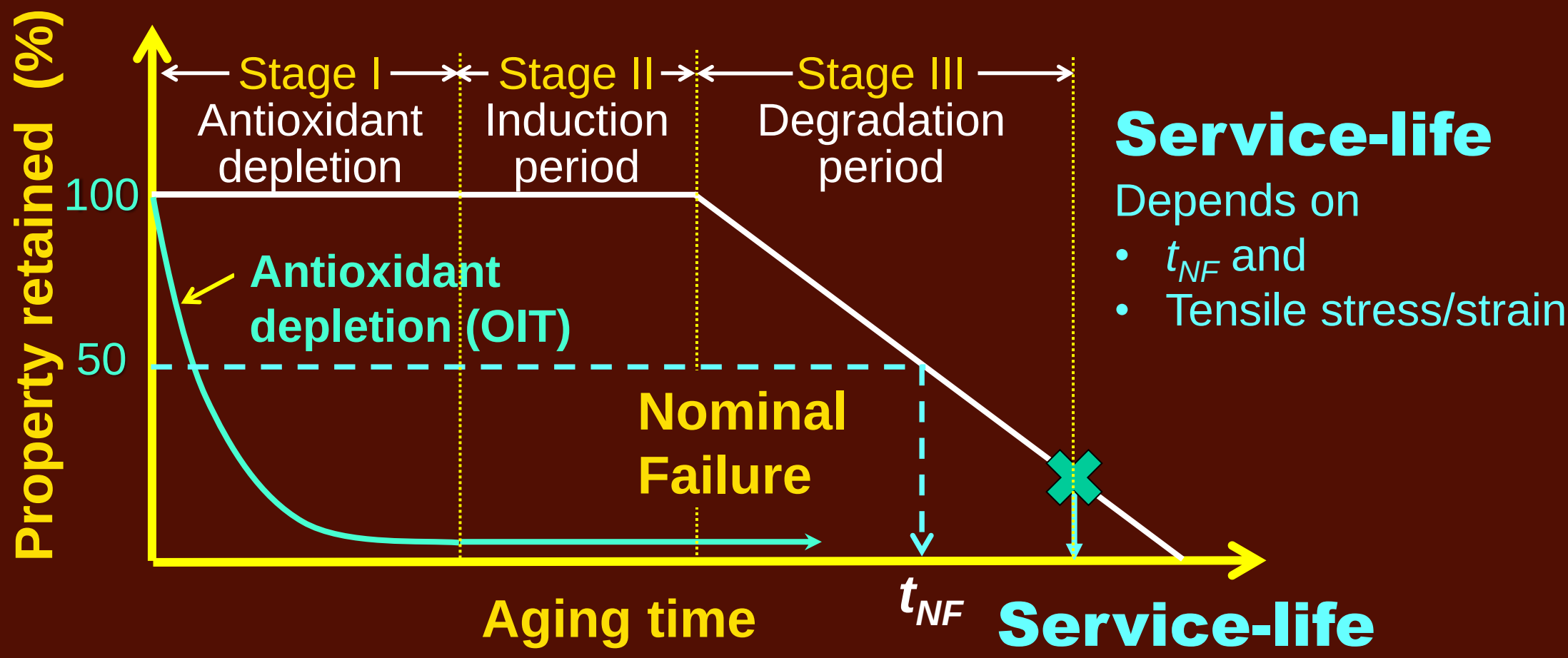


The following slides are for possible questions

R. Kerry Rowe OC

PhD, FRS, NAE, FRSC

How HDPE geomembranes age
Thermo-oxidative degradation



Service-life

Depends on

- t_{NF} and
- Tensile stress/strain

Modified from Hsuan & Koerner (1998)

HDPE Geomembrane Testing and Evaluation Program

Objective: to compare observed performance of candidate GMBs with 20 year database.

Based on this assess:

(a) the relative performance and the most suitable GMBs for the NSDF landfill based on the available data, and

(b) the likelihood that GMBs service-life exceeds design-life.

Priyanto et al. (2019); Rowe et al (2020)

How long will a geomembrane last?

depends on

- GMB used – (polymer and antioxidant/stabilizers)
  - 5 Candidate GMBs from 3 manufacturing plants examined
  - results compared with GMBs tested for up to 17 years

How long will a geomembrane last?

depends on

- GMB used – (polymer and antioxidant/stabilizers)
- The exposure conditions
  - Chemical composition of fluid in contact with GMB
    - NSDF GMB exposure 0.000011 Mrad vs 2.6 MRad ~ 5 orders of magnitude (230,000- fold) under this limit
    - GMBs tested for 3 solutions:
      - NSDF leachate with pH ~ 7 (expected) [L7]
      - NSDF leachate with pH ~ 9 (extreme) [L9]
      - MSW leachate (aggressive benchmark) [L3]

How long will a geomembrane last?

depends on

- GMB used – (polymer and antioxidant/stabilizers)
- The exposure conditions
  - Chemical composition of fluid in contact with GMB
  - Temperature (Test at 85, 75, 65, and 55^{o}C)
    - Annual average temperature at Chalk River, Ontario: 5.6^{o}C (1981-2010)
    - Design temperature is 10^{o}C

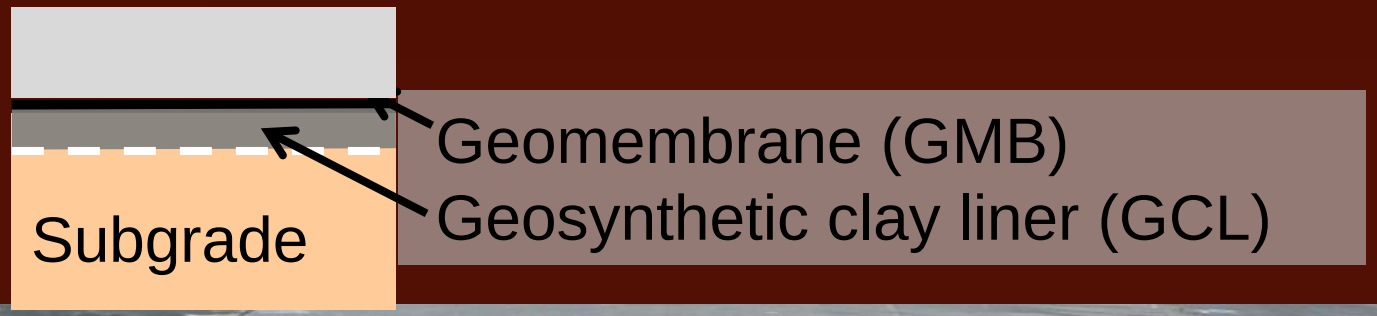
Construction Quality Assurance

- Must be supervised by someone with a graduate degree in, and sound understanding, of:
  - **modern** landfill design, and
  - current BEST practices, and
  - an excellent understanding of the design intentions
- All CQA inspectors must be trained with respect to the special features of this design

Construction Quality Assurance

- by very experienced personnel with a good knowledge of compacted clay liners, GCLs, and GMBs **watching** the construction work at all times prior to completion of the barrier system.
- with enough CQA inspectors that:
  - there is never a time any barrier construction is unobserved, and
  - people to do the needed paperwork and relieve the ‘eyes” without loss of eyes on observation

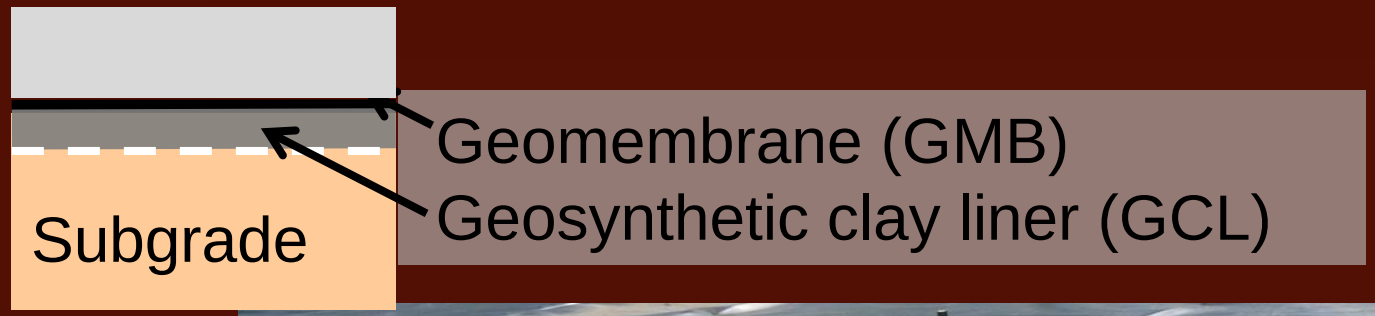
GMB in direct contact with GCL



A suitable time to cover the geomembrane

GMB with no wrinkles; cloudy November morning

GMB in direct contact with GCL

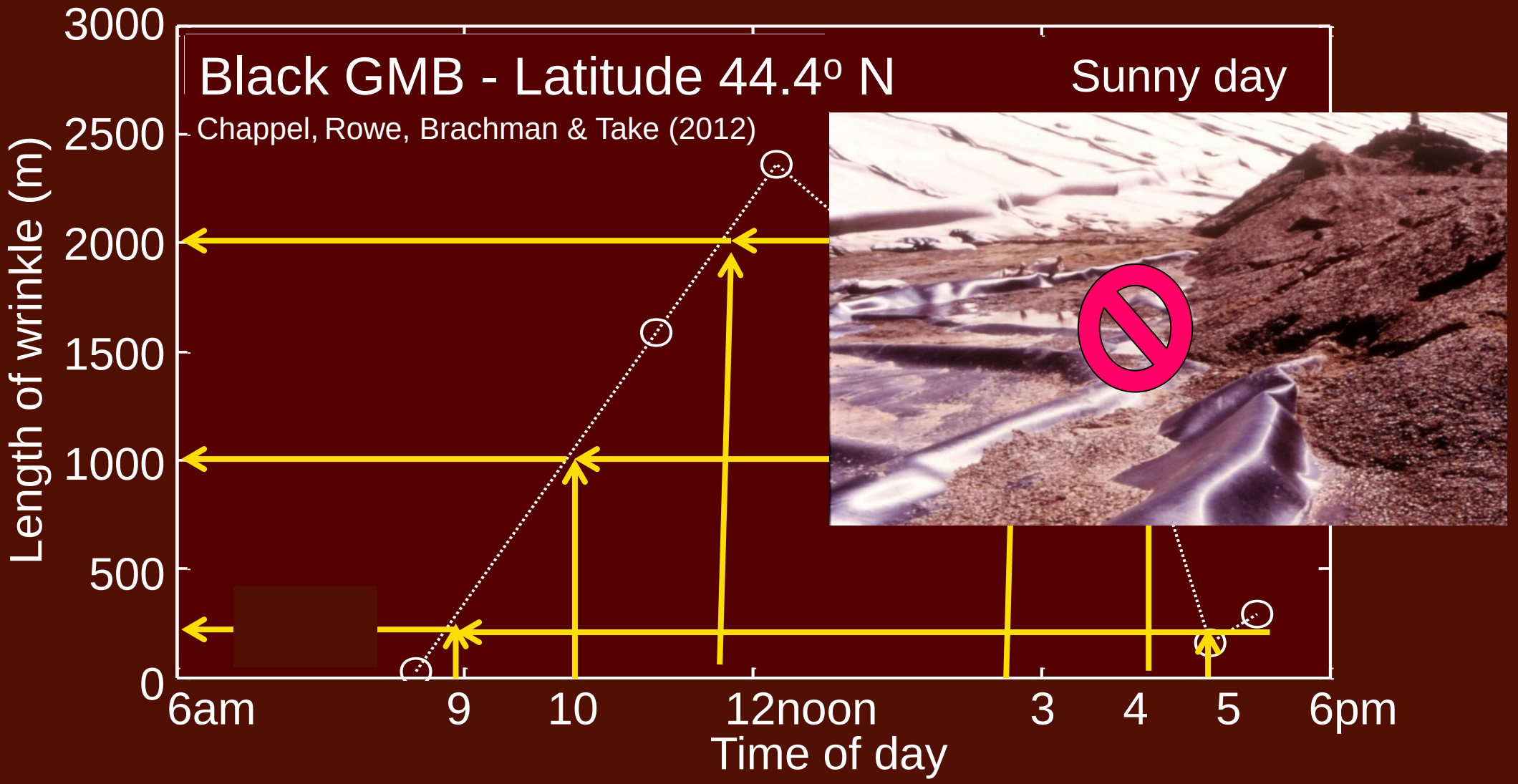


Not a suitable time to cover the geomembrane

Extent of wrinkle interconnections

Extent of wrinkle interconnections

Change in length of longest connected wrinkle with time of day



Maintaining Best Available Technology

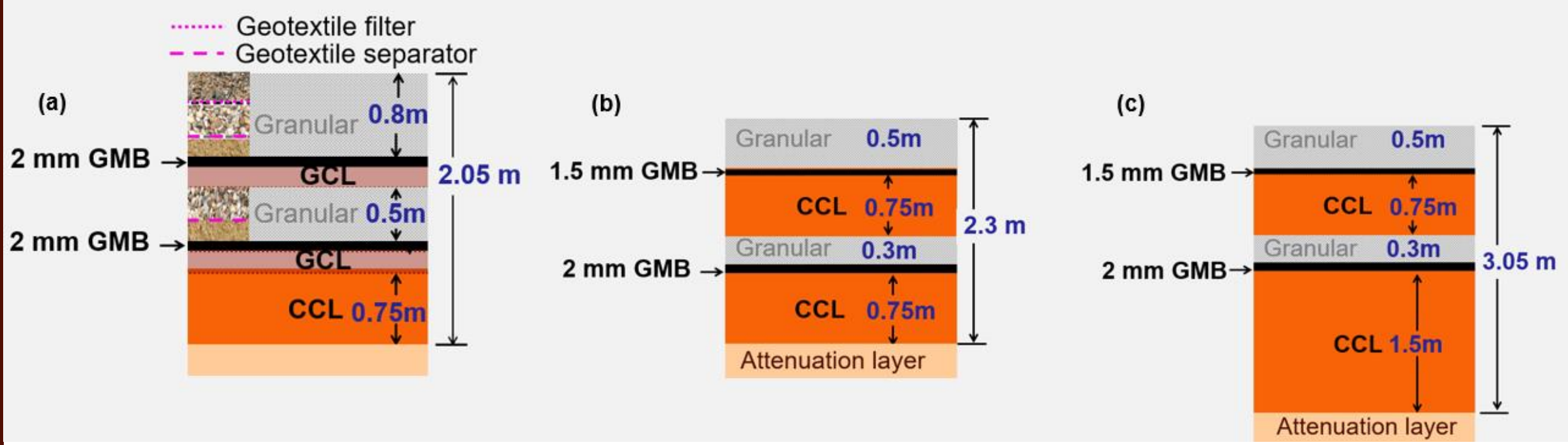
The design uses BEST available technology (it is expensive) – no changes should be made (even if the substitution meets the specification) without:

- a FULL understanding of the reasons behind the design
- approval by the designer AND an independent checking engineer

Why is “dump” a four-letter word?

- Dumps were sited at a location of convenience (e.g. old worked out sand or gravel pits; a hole in the ground - Love Canal, Niagara, NY)
- No design (no engineered barrier system)
- No control of waste (solid, liquid, hazardous and non-hazardous)
- Little or no engineered operations

A modern engineered containment facility is not a “dump”!



(a) NSDF ECM (b) Ontario Reg. 232/98 Generic Design (c) CCME Hazardous Waste

Primary clay liner 100 mm^2 slit/ha leakage over entire 12 ha

0.006 L/day 0.55 L/day 0.55 L/day

Probability of 0.0096 L/day leakage though a similar slit in secondary liner (except at a sump) less than 1.4×10^{-39} (1 in 7×10^{38})

“Perpetual Care”

ALL modern landfills and other waste, like LLW and mine waste, require “perpetual care”

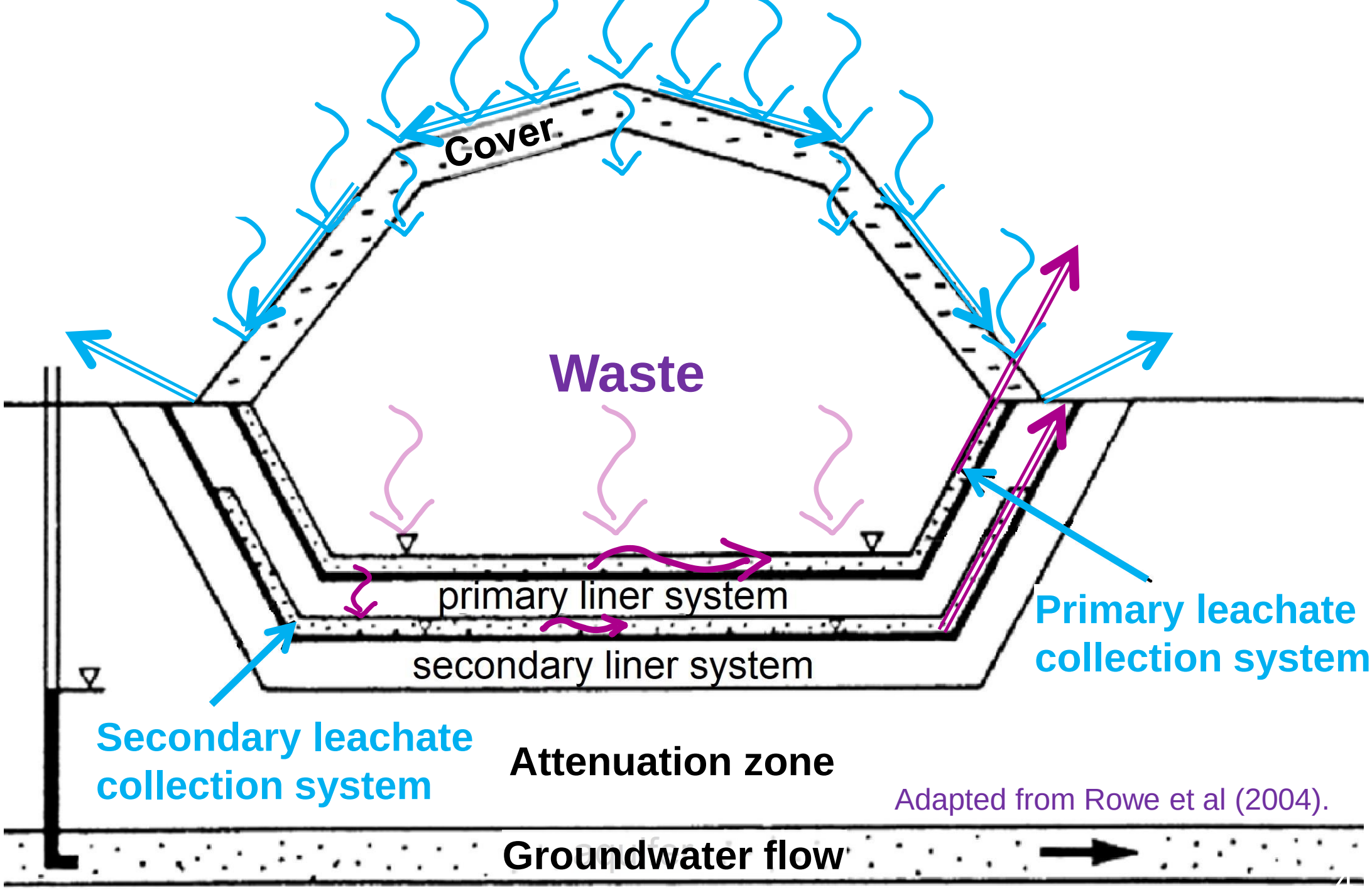
- on going monitoring and collection of leachate as needed
- maintenance of pumps, covers, monitoring devises etc.

for the contaminating life-span

Cover: 9 Layers

Final Cover Installation

- 150 mm Topsoil
- 600-1200 mm Sandy Loam
- 200 mm Filter
- 500 mm Cobble physical barrier/drain
- 300 mm Sand protection/drainage
- Geomembrane
- Geosynthetic clay liner (GCL)
- 300 mm Sand Foundation



Adapted from Rowe et al (2004).

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