Equivalency of Double Liner System for Florida Coal Ash Landfills

TAG Meeting 1

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HINKLEY CENTER FOR SOLID AND HAZARDOUS WASTE MANAGEMENT

FAMU-FSU Engineering

FAST FACTS

- CCR materials are created when coal is burned by power plants to create electricity. CCR materials include fly ash, bottom ash, flue gas desulfurization materials and boiler slag.
- Beneficial use and disposal occurs in all 50 states.
- CCR materials are not classified as a "hazardous waste."
- Federal and state rules regulate the beneficial use and disposal of CCR materials.
- 40 CFR, Part 257, became effective on April 19, 2015, and applies to all facilities, including coal-fired power plants that generate CCR materials in operation after October 19, 2015.
- 40 CFR, Part 257, allows for the disposal of CCR materials in a Class I municipal solid waste landfill, since these facilities have protective liner and leachate collection systems that meet federal requirements.

Florida CCR Facilities

- Florida currently has **nine active power plants** that generate CCR materials.
- **CCR landfills:** There are **nine active or in-active CCR landfills** that are regulated under 40 CFR, Part 257.
- **Six CCR** landfills in Florida are also regulated under the state's Power Plant Siting Act.
- **CCR Surface Impoundments:** There are **ten active or in-active CCR surface impoundments** regulated under 40 CFR, Part 257.

Regulation of COAL ASH

- CCR materials generated by power plants are required to **be disposed of in landfills** and surface impoundments in accordance with state and federal requirements.
- 40 CFR, Part 257 allows for the disposal of CCR materials in **a Class I municipal solid waste landfill**, as the material is not classified a hazardous waste.
- These facilities have **protective liner and leachate collection systems** that meet federal requirements.
- Facilities are required to determine the nature of the waste and ensure compliance with state rules and regulations.
- FDEP strongly recommends that the receiving facility request a special waste profile be performed, as well as a Toxicity Characteristic Leaching Procedure (TCLP) test.

Motivation

- Federal and state regulations are requiring new CCR landfills, new CCR surface impoundments, and all lateral expansions be constructed **with a composite liner.**
- The composite liner must consist of two components;
  - an upper component consisting of **a geomembrane liner** … and
  - a lower component consisting of **at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than 1 x 10^{-7} cm/sec**
  - GM components should consist of **(HDPE) and** must be at least **60-mil** thick.
  - The GM … must be installed in **direct and uniform contact** with the compacted soil

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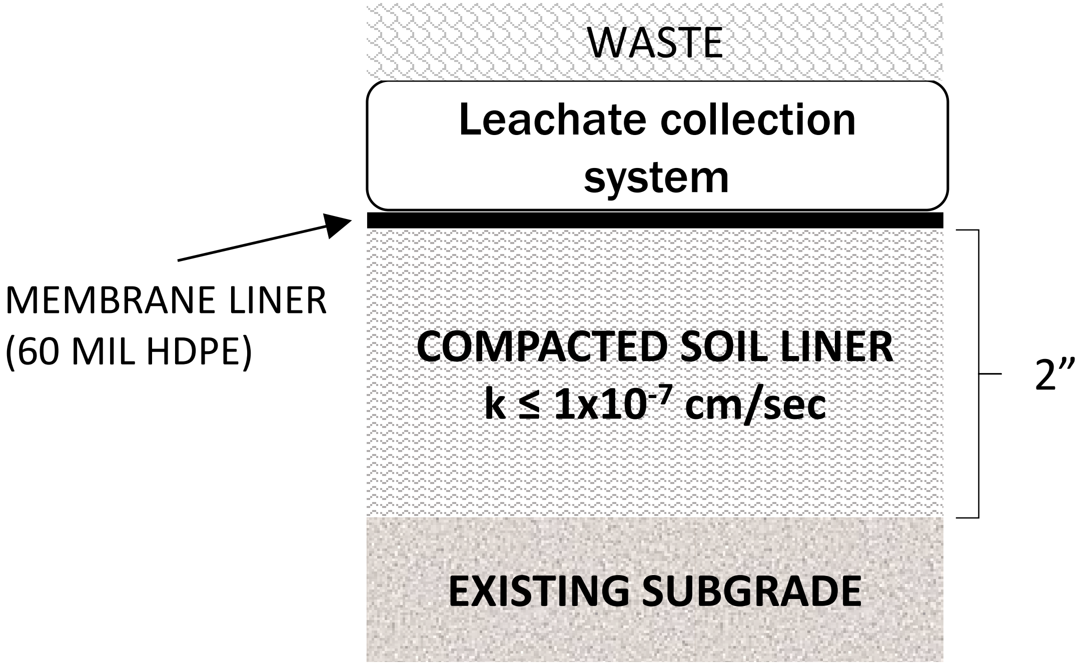
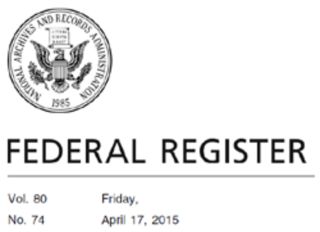


EPA Required Liner System

Motivation

- On April 15, 2015, in the preamble to EPA coal ash rule, EPA considered that Florida's double liner system design may not be appropriate for coal ash landfills and stated:
- **"Florida's double-liner system does not meet the level of performance achieved by EPA's composite liner system or the alternative liner system option."**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Vol. 80 Friday,
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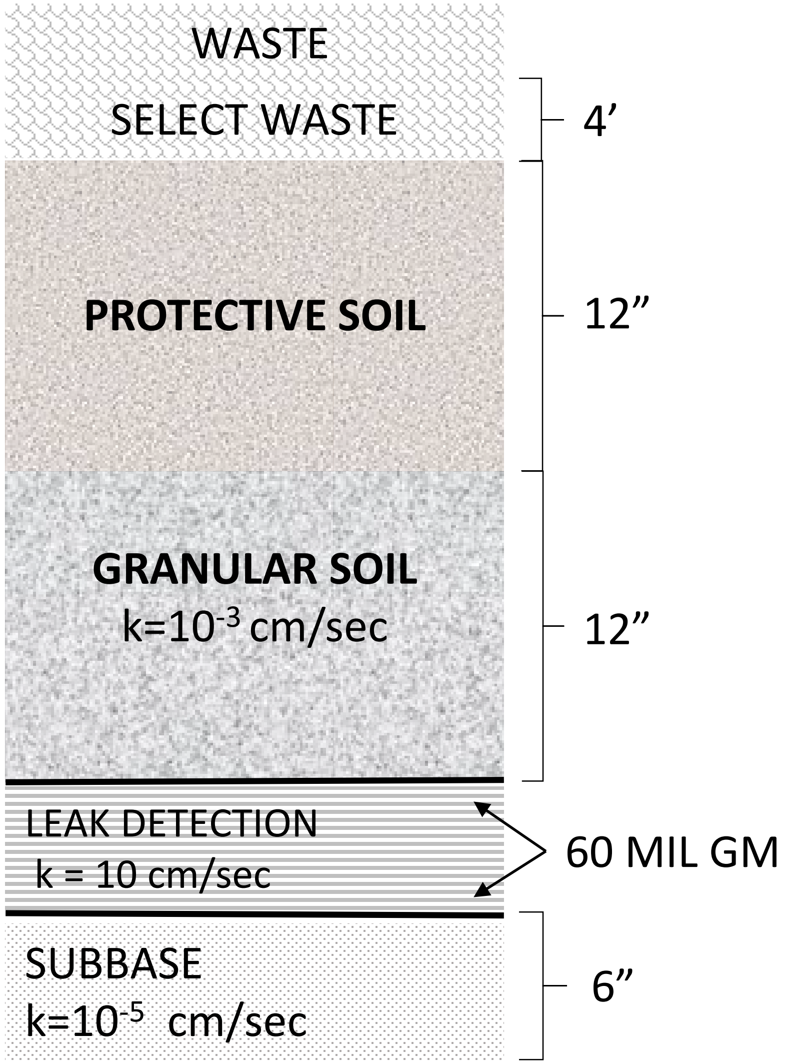
Disposal of CCR Materials

40 CFR, Part 257 allows for the **disposal of CCR materials in a Class I municipal solid waste** landfill, as the material is not classified a hazardous waste. These facilities have protective liner and leachate collection systems that meet federal requirements. ??



Double Liner Option

EPA New Coal Combustion Residuals (CCR) Regulation for alternative liner system:

In the final rule EPA has provided the owner or operator with an option to install an alternative composite liner provided “it meets the required performance standard and it is certified by a qualified professional engineer

"Liner Designs That Would Not Meet the Requirements of a Composite Liner or Alternative Liner"

- "Contrary to the arguments made by several commenters, EPA has concluded that a composite liner consisting of **two 30-mil GMs (GM/GM)** will not provide an equivalent degree of protection as a composite liner consisting of a GM and two feet of compacted soil, or an alternative composite liner such as a GM/GCL."
- "… a critical component of a composite liner is the compacted soil or GCL component beneath the GM layer that will impede the flow of liquid that may leak through a hole or defect in the GM. This added protection cannot be achieved using two GMs for the composite liner…."
- "..Consistent with the previous determination, EPA has also determined that ***the double liner system set forth in Florida regulations (see Florida Rules 62–701.400(3)(c), F.A.C) also does not meet the level of performance achieved by EPA's composite liner system or the alternative liner system.***

We are not sure about how these statements were obtained.

"Liner Designs That Would Not Meet the Requirements of a Composite Liner or Alternative Liner"

- "…While this **double liner system** provides the advantage of a leak detection system between the two GMLs, the lower composite liner, consisting of a 60-mil HDPE over six inches of soil with a saturated hydraulic conductivity of less than or equal to 1×10^{-5} cm/sec, **is not equivalent** to a GM over two feet of compacted soil with a hydraulic conductivity of less than or equal to 1×10^{-7} cm/sec."
- "….To be hydraulically equivalent, **soil with a hydraulic conductivity of 1×10^{-5} cm/sec would need to be on the order of 100 times thicker than soil with a hydraulic conductivity of less than or equal to 1×10^{-7} cm/sec**.
- Similarly, a lower composite liner consisting of a **60-mil HDPE over a GCL** with a hydraulic conductivity not greater than 1×10^{-7} cm/sec would require a GCL thickness of 24 inches to be equivalent to a GM over two feet of compacted soil with a hydraulic conductivity of less than or equal to 1×10^{-7} cm/sec…**"**

We are not sure about how these statements were obtained.

OBJECTIVES

1. Verify the equivalency of the **Florida Double Liner System** to **EPA's composite liner system** when used for coal disposal applications, and
2. Determine if the state of the art, from the literature and from current knowledge about landfill barriers, support the EPA conclusions.

"For instance, it is not evident if the EPA has compared performance of the Florida double liner system, as a whole, but rather they compared the theoretical performance of its different components. As stated in the Center's research agenda, comparing only parts of a liner system to components of another liner system might not be the right approach to assess equivalency between two liner systems."

RESEARCH TASKS

Task 1: (Update: Collected Most of the Documents-Being Reviewed)

We will **first** review the process used by EPA to calculate leakage flow rates through the federal proposed composite liner system and through the Florida Class-I landfill double liner system (All options considered by FDEP).

We will compare the methodology used by EPA for the CCP to that used for Subtitle D regulations for MSW landfill.

In particular, we will use the following reference:

Rowe, R.K. (2012). Short and Long-term Leakage Through Composite Liners, 7th Arther Casagrande Lecture, Canadian Geotechnical Journal, Vol. 49, pp. 141-169.

Rowe, R.K. (2005). Long-term Performance of Containment Barrier Systems. Fourth Rankine Lecture. Geotechnique 55, No. 9, pp. 631-678.

Rowe, R.K., and Booker, J.R. (1998). Theoretical Solutions for Calculating Leakage Through Composite Liner System. Geotechnical Research Center Report GEOT-18-98.

RESEARCH TASKS

Task 2: (Update: Collected Most of the Documents-Being Reviewed)

Second, we will review all previous documentations (FDEP reports, published journal and conference papers) used by the State of Florida to successfully obtain approval for the double liner system as Florida's Subtitle D alternative.

There is a clear contradiction in EPA decision to allow the Florida double-liner system for MSW Landfills and not CCP landfills.

In particular, we will review:

Bonaparte, R., Giroud, J.P., and Gross B.A. (1989). Rates of Leakage Through Landfill Liners. Proceedings of Geosynthetics, San Diego, CA, IFAI, St. Paul, MN, Vol. I, PP. 18-28.

Fluent, J.E., Jr., Badu-Tweneboah, K., and Khatami, A. (1992). A Review of Geosynthetic Liner System Technology, Waste Management and Research, Copenhagen, Denmark, Vol. 10, No. 1, pp. 47-65.

Giroud, J.P., 1997. Equations for calculating the rate of liquid migration through composite liners due to geomembrane defects. Geosynthetics International 4 (3/4), 335-348.

Giroud, J.P., and Bonaparte, R. (1989). Leakage Through Liners Constructed with Geomembranes, Part I: Geomembrane Liners. Geotextiles and Geomembranes, Vol. 8, No. 1, pp. 27-67.

Giroud, J.P., and Bonaparte, R. (1989). Leakage Through Liners Constructed with Geomembranes, Part II: Composite Liners. Geotextiles and Geomembranes, Vol. 8, No. 2, pp. 71-111.

Giroud, J.P., Khatami, A., and Badu-Tweneboah, K. (1989). Evaluation of the Rate of Leakage Through Composite Liners, Geotextiles and Geomembranes, Vol. 8, No. 4, pp. 337-340.

Giroud, J.P., Soderman, K.L., Khire, M.V. & Badu-Tweneboah, K. 1998. New developments in landfill liner leakage evaluation. Proc. of 6th intern. conf. on geosynthetics, Atlanta, Industrial Fabrics Association International.

RESEARCH TASKS

Task 3: (Update: Collected Most of the Documents-Being Reviewed)

Third, we will use the findings of first two tasks to recalculate theoretical leakage flow rates through Florida and EPA liner systems to assess if any errors were committed, by not actually comparing the two liner systems, but comparing only theoretical leakage rates through parts of each liner system.

The following FDEP publications were widely used for the same purpose more than a decade ago

Florida Department of Environmental Protection (1995). Report on Leakage Flow Rates from Double-Lined Landfills in Florida, June 7th 1995. FDEP Solid Waste Section, 2600 Blair Stone Road, Tallahassee, FL. 32399-2400.

Tedder, R., 1997, "Evaluating the Performance of Florida Double-Lined Landfills," Geosynthetics '97 Conference Proceedings, Vol. 1, IFAI, Long Beach, California, USA, March 1997, pages 425 -438.

RESEARCH TASKS

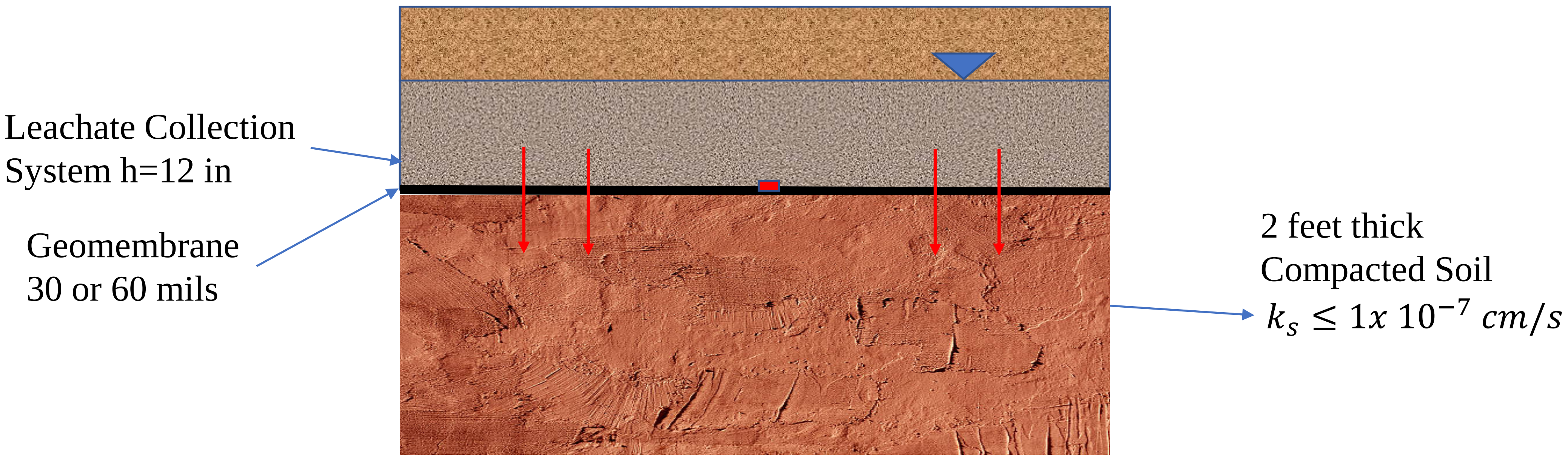
Task 4:

Finally, we will collect actual leachate flow rates into the leak detection system (LDS) at Florida’s active and closed double-lined Subtitle D landfills to update the performance and see if liner leakage rate equations should be updated.

Where possible, we will revisit the sites the original data was collected.

- Medley landfill cell 1, cells 3 and
- Berman road landfill
- …
- …
- *More landfills will be added*

Federal Minimum Design Standard (RCRA-Subtitle D)



<u>Leakage Through Composite Liner</u>

$$Q = \beta_c(1 + 2\left(\frac{h_w}{L_s}\right)^{0.95})a^{0.1}{h_w}^{0.9}{k_s}^{0.74}$$

β_c=0.21 Good Contact
=1.15 Poor Contact

RCRA-Subtitle D

Theoretical Leakage:

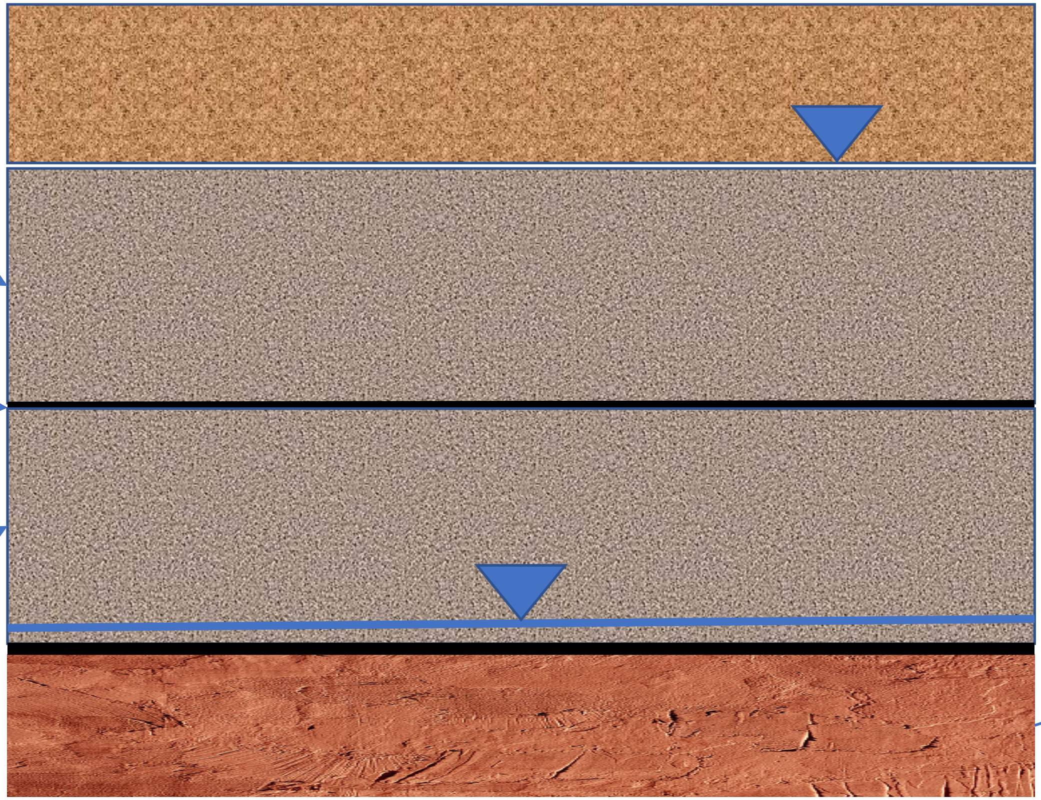
Variable	Value	Units
Area of Hole	1	cm^2
Leachate Head above primary Liner	0.3	m
Hydraulic Conductivity of Soil beneath Liner	$1x10^{-9}$	m/sec
Assuming Medium Contact, β	0.68	
Thickness of Soil	0.61	m
Leakage through Composite Liner	0.9439	gpad

Florida Double Liner Standard

Leachate Collection System
h ≤ 1 ft
$k_c \geq 1x\ 10^{-3}\ cm/s$

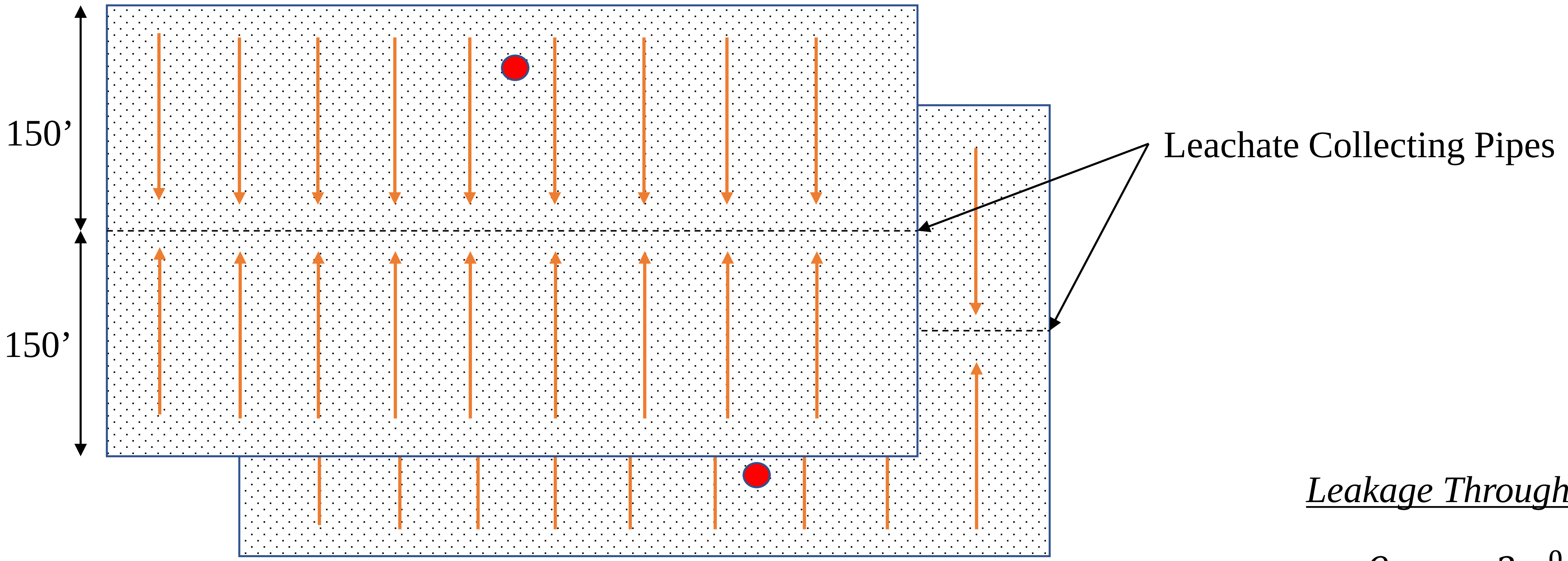
Geomembrane
60 mils

Leachate Detection System
h varies
$k_d \geq 1\ cm/s$



Compacted Soil

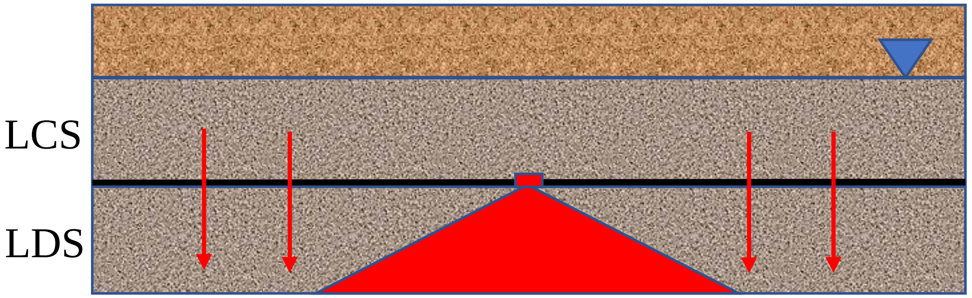
Min thickness Varies
1 ft to 3 ft depending on K_s and h
$k_s \leq 1x10^{-5}\ cm/s$



Leakage Through Primary Liner

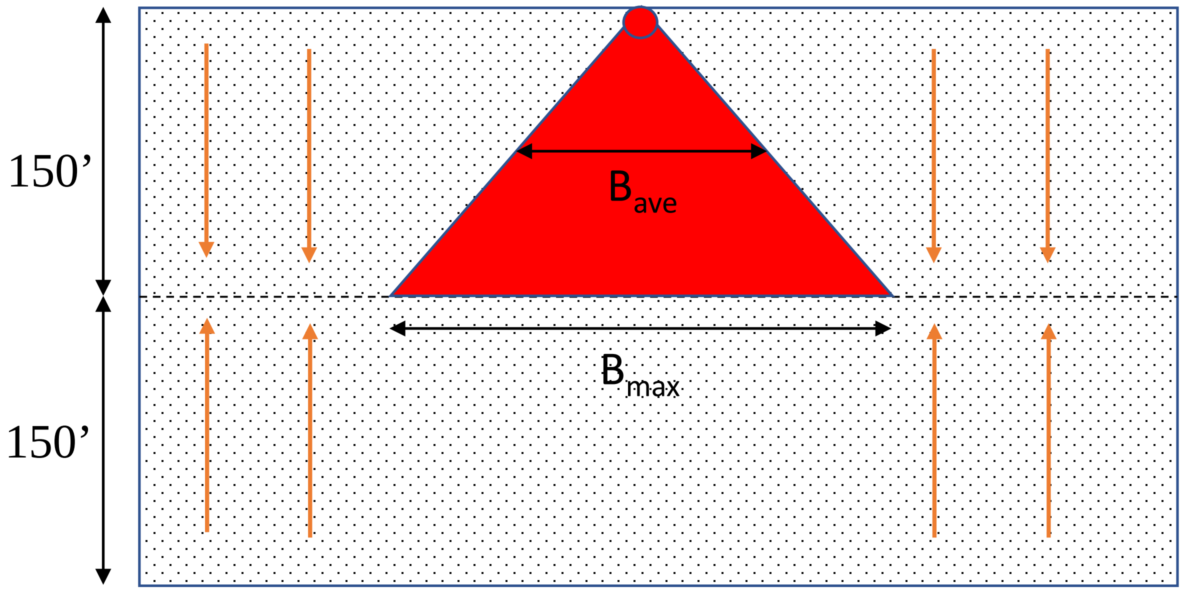
$$Q_{1(R)} = 3\, a^{0.75} h^{0.75} {k_d}^{0.5}$$

When there is a sand layer above or below Primary Liner

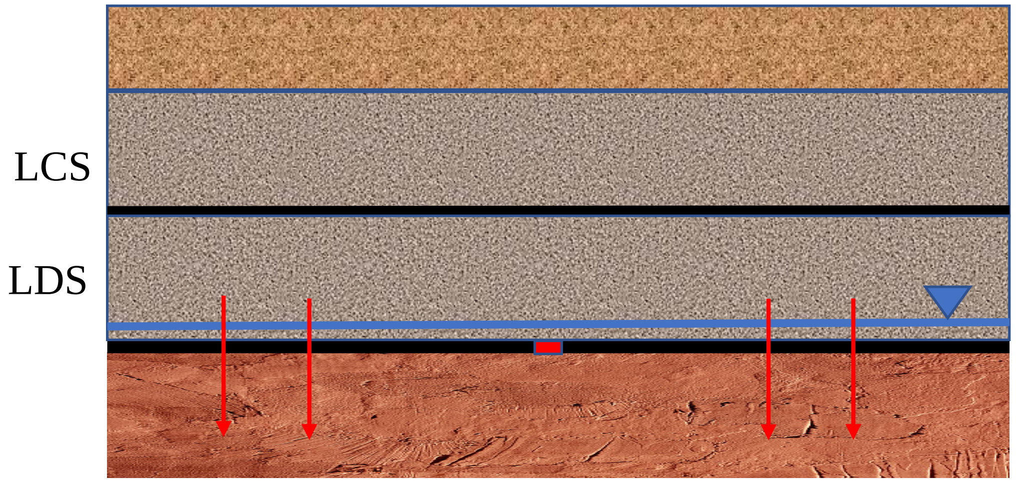


$$Q_1 = C C_B a \sqrt{2gh}$$

When free-flow through primary liner
(occurs when there is geonet above and below geomembrane)



Secondary Liner



Width of wetted area beneath hole in primary liner

$$B_{ave} = \frac{2\sqrt{\frac{Q_1}{k_d}}}{\sin\alpha} * \sqrt{1 + \frac{2X_{ave}\sin\alpha}{\sqrt{\frac{Q_1}{k_d}}}}$$

Average Depth of Flow in LDS

$$D_{ave} = \frac{Q_1}{B_{ave}\, k_d \sin\propto}$$

Leakage Through Secondary Liner

$$Q_2 = \beta_c(1 + 2\left(\frac{D_{ave}}{L_s}\right)^{0.95})a^{0.1}D_{ave}{}^{0.9}k_s{}^{0.74}$$

Sites With Data From Landfill

Facility	Oculus Site ID	Symbol	Data (years)	Cells	Data Source	Data Remarks
Hernando Northwest Class I LF	40722	A	2003-2020	2	Landfill	Data Processing Complete
Palm Beach County Landfill	65551	B	1989-2020	16	Landfill	Data Processing Complete
Orange County Landfill	21847	C	2005-2019	2	Landfill	Data Processing Complete
Southeast County Landfill - Hillsborough	41193	D	2018-2020	2	Landfill	Data Processing Complete
Sarasota Central Landfill	51614	E	2011, 2015-2020	2	Landfill	Data Processing Complete
Volusia County LF	27540	F	2018-2020	8	Landfill	Data Processing Complete

Sites with Data From Oculus/FDEP Study

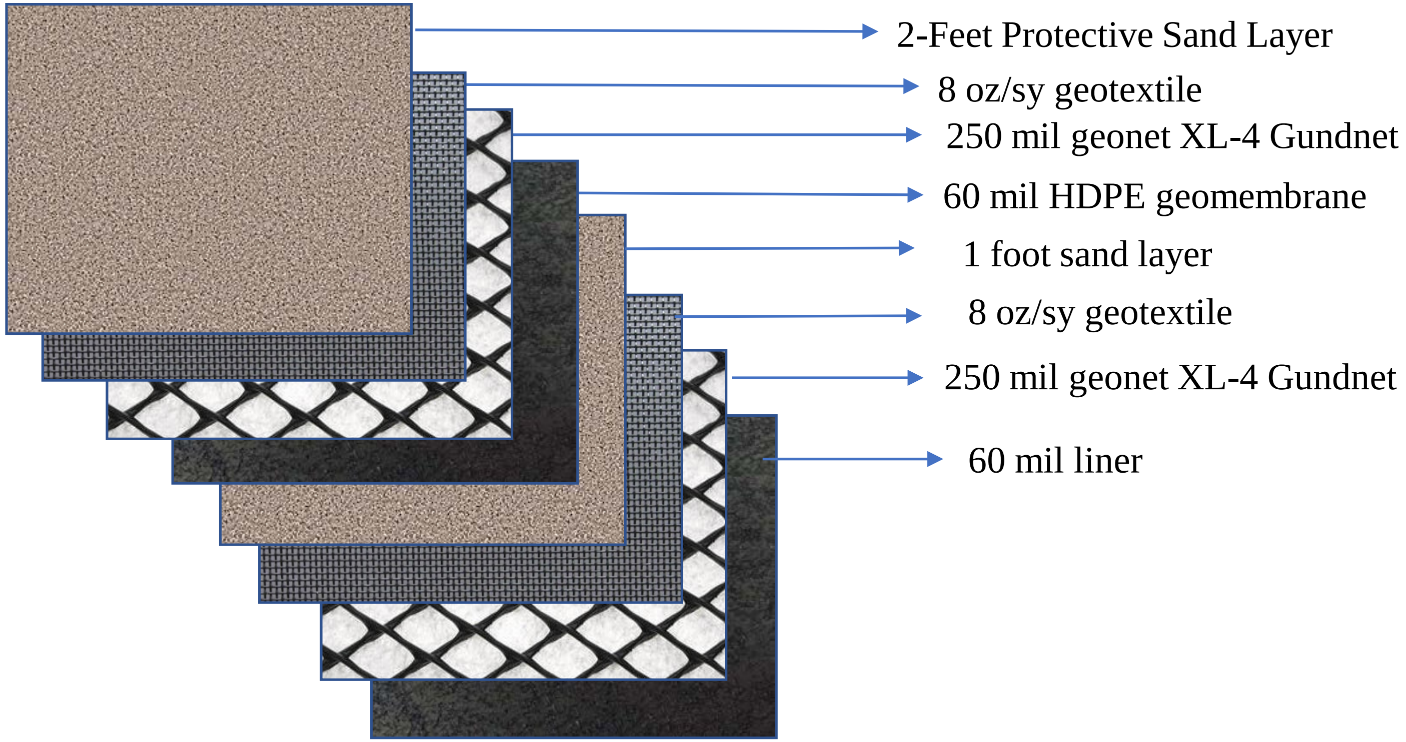
Facility	Oculus Site ID	Symbol	Data (years)	Cells	Data Source	Data Remarks
Polk North Central Class I LF	49722	G	2015-2020	3	Oculus	Data Processing Complete
Trail Ridge Landfill	33628	H	2004-2008	1	Oculus	Data Processing Complete
New River Regional Landfill	39815	I	2009-2010	6	Oculus	Data Processing in Progress
Winfield Waste Management Facility	31495	J	2007-2012	4	Oculus	Data Processing in Progress
Medley Landfill	60080	K	1992-1995	3	1995 FDEP Study	Data Processing Complete
Monarch Hill Landfill	55093	L	1994-1995	3	1995 FDEP Study	Data Processing Complete
Baseline Landfill	20906	M	1993-1995	2	1995 FDEP Study	Data Processing Complete
Berman Rd Landfill	70436	N	1994-1995	2	1995 FDEP Study	Data Processing Complete
West Pasco Landfill	45799	O	2019-2020	6	Oculus	Data Processing Complete

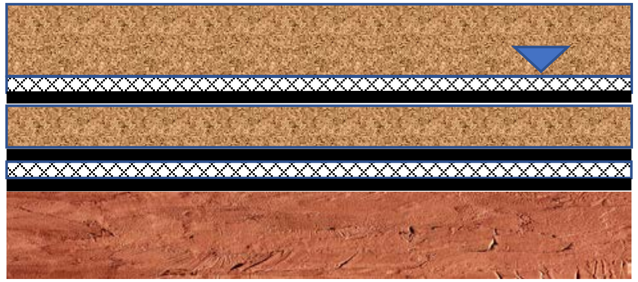
Special Case-Double Composite Liner

Awaiting on Data

Test Site B

Liner System For Test Site B – Cell 1-5
(Top to Bottom)

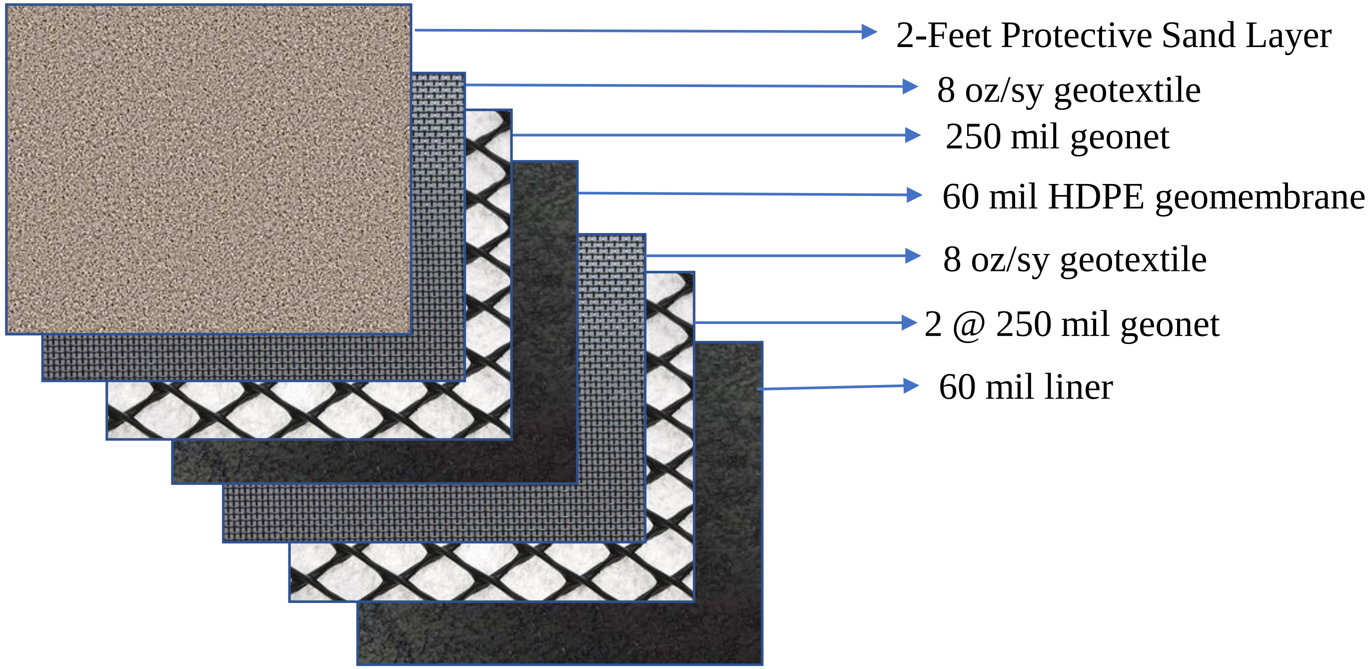


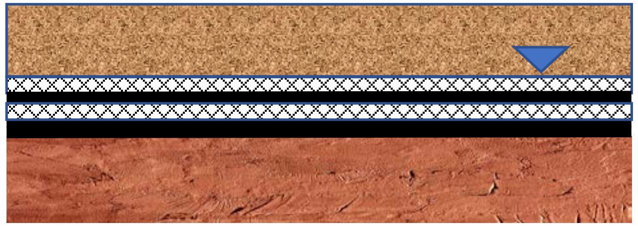


Liner cross-section

Test Site B

Liner System For Test Site B – Cell 6
(Top to Bottom)

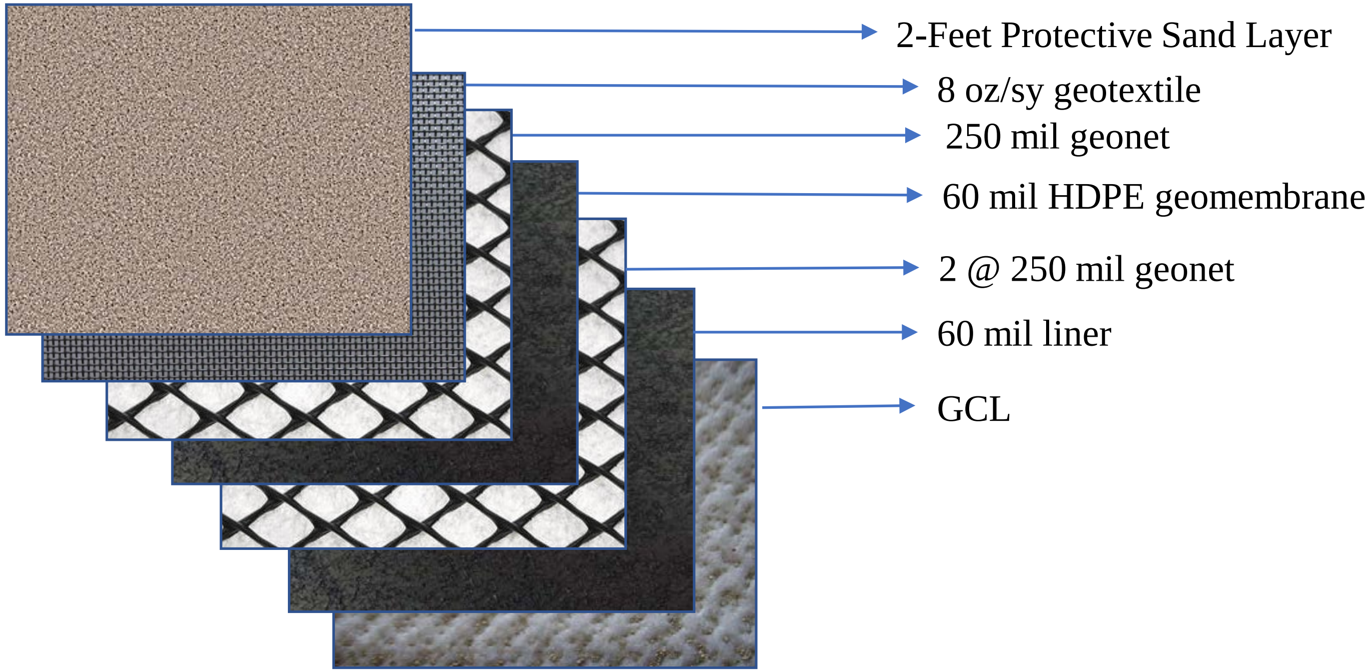


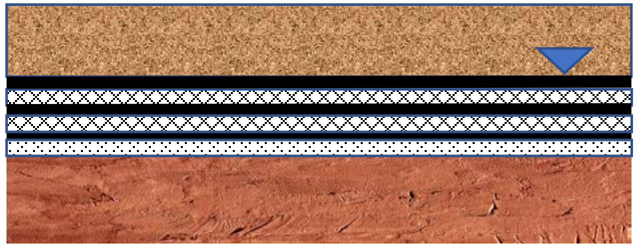


Liner cross-section

Test Site B

Liner System For Test Site B – Cell 7-10
(Top to Bottom)

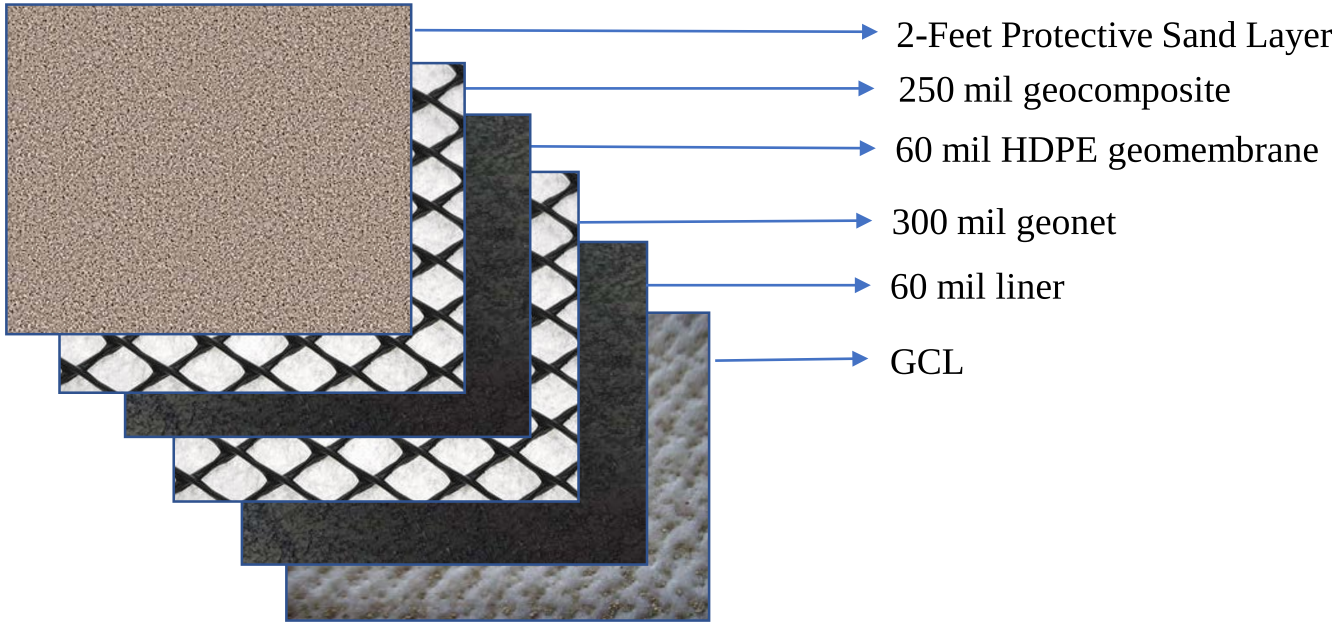


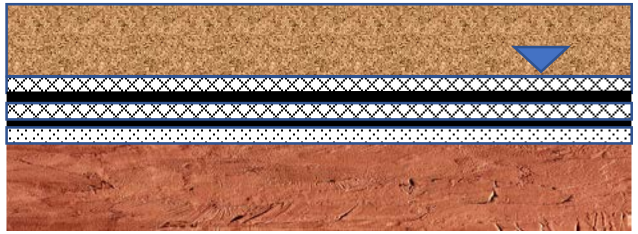


Liner cross-section

Test Site B

Liner System For Test Site B – Cell 11-16
(Top to Bottom)





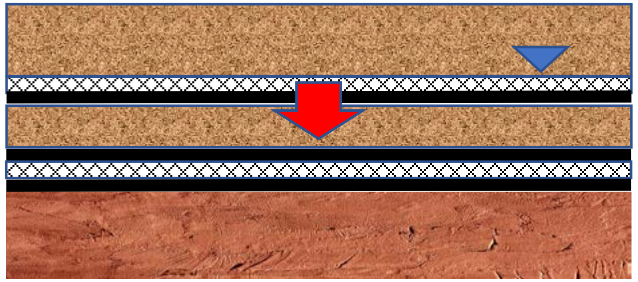
Liner cross-section

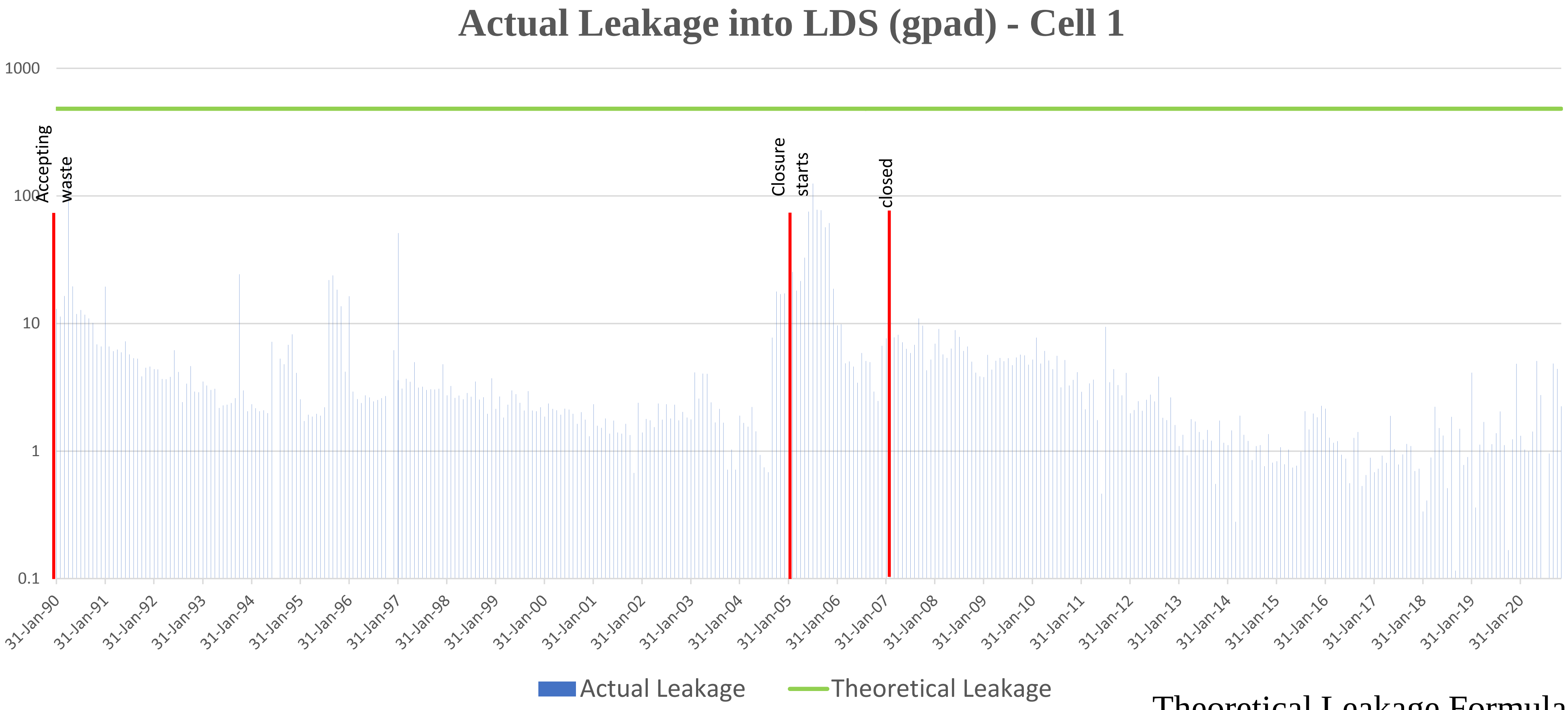
Test Site B

Theoretical Leakage:

Variable	Cell 1-5	Cell 6	Cell 7-10	Cell 11-16	Units
Area of Hole	1	1	1	1	cm^2
Leachate Head above primary Liner	0.00635	0.00635	0.00635	0.00635	m
Hydraulic Conductivity of LCS	0.2	0.2	0.2	0.2	m/sec
Leakage Through Primary Liner	483	483	483	483	gpad
Hydraulic Conductivity of LDS	0.2	0.2	0.2	0.2	m/sec
Hydraulic Conductivity of layer beneath secondary liner	$1x10^{-7}$	$1x10^{-7}$	$1x10^{-9}$	$1x10^{-9}$	m/sec
Assume Medium Contact, β	0.68	0.68	0.68	0.68	
Thickness of component below secondary liner	0.1524	0.1524	0.015	0.015	m
B_{ave}	9.76	9.76	9.76	9.76	m
D_{ave}	$5.4x10^{-4}$	$5.4x10^{-4}$	$5.4x10^{-4}$	$5.4x10^{-4}$	m
Probability of Zero Leakage	84	84	84	84	%
Leakage Through Secondary Liner	$4.7x10^{-2}$	$4.7x10^{-2}$	$1.6x10^{-3}$	$1.6x10^{-3}$	gpad

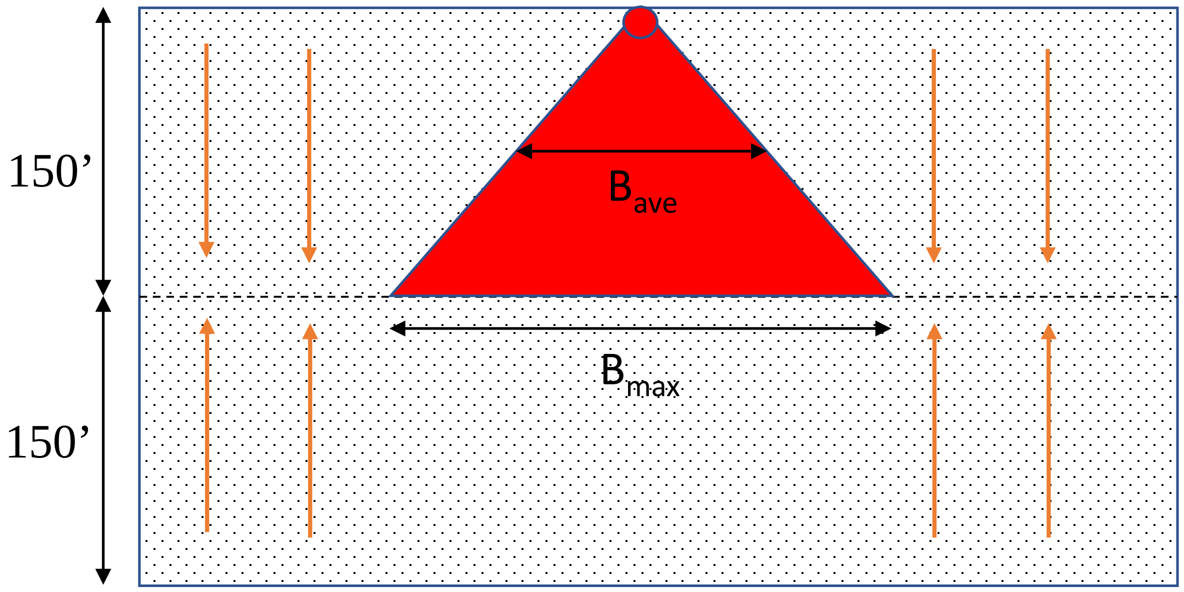
Test Site B



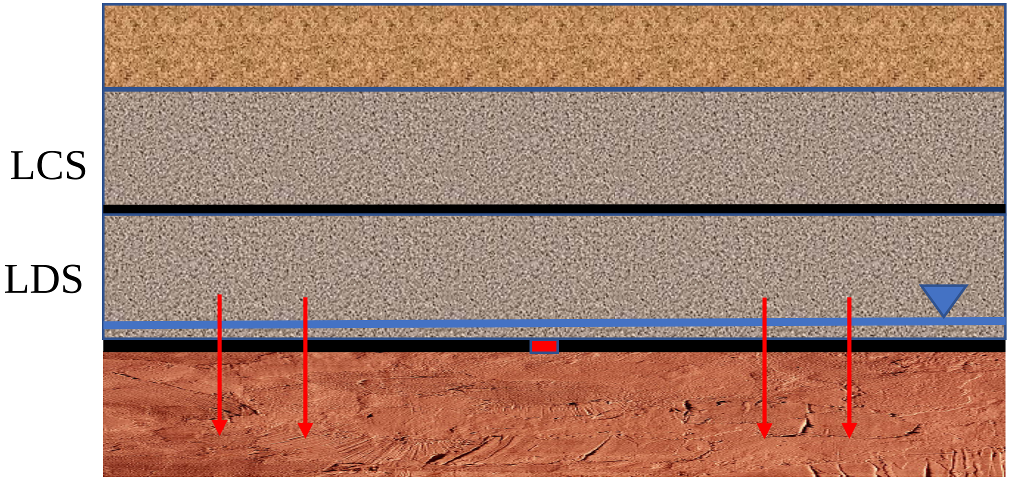


Theoretical Leakage Formula

$$Q = CC_B a\sqrt{2gh}$$



Secondary Liner



Width of wetted area beneath hole in primary liner

$$B_{ave} = \frac{2\sqrt{\frac{Q_1}{k_d}}}{\sin\alpha} * \sqrt{1 + \frac{2X_{ave}\sin\alpha}{\sqrt{\frac{Q_1}{k_d}}}}$$

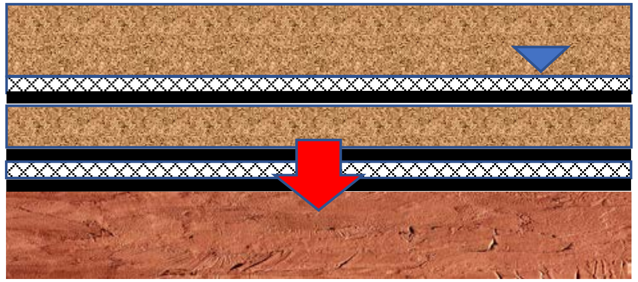
Average Depth of Flow in LDS

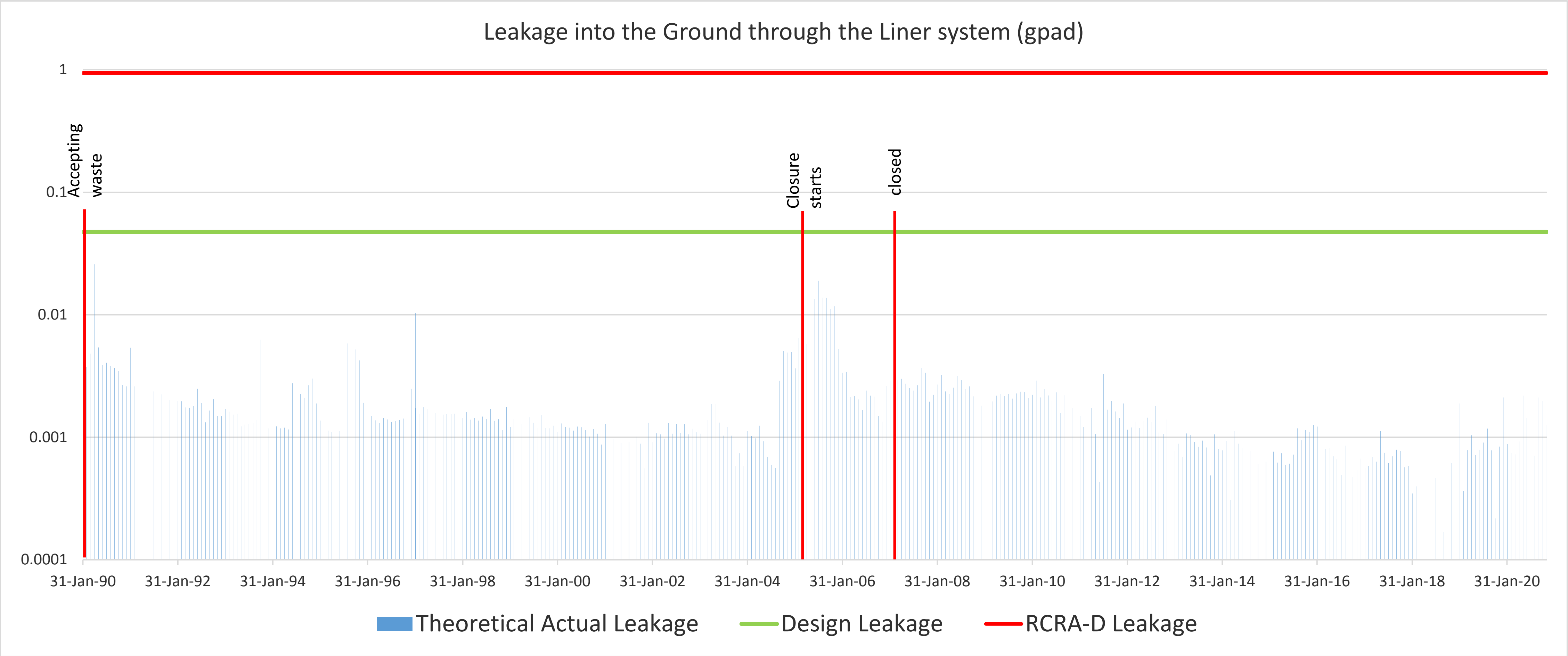
$$D_{ave} = \frac{Q_1}{B_{ave}\, k_d \sin \propto}$$

Leakage Through Secondary Liner

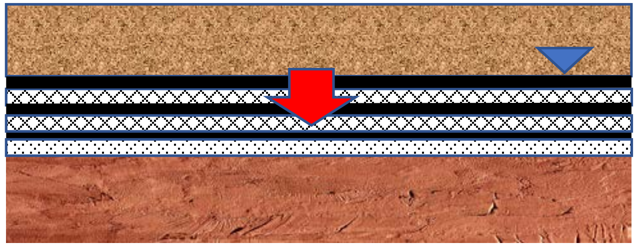
$$Q_2 = \beta_c (1 + 2\left(\frac{D_{ave}}{L_s}\right)^{0.95})a^{0.1} D_{ave}{}^{0.9} k_s{}^{0.74}$$

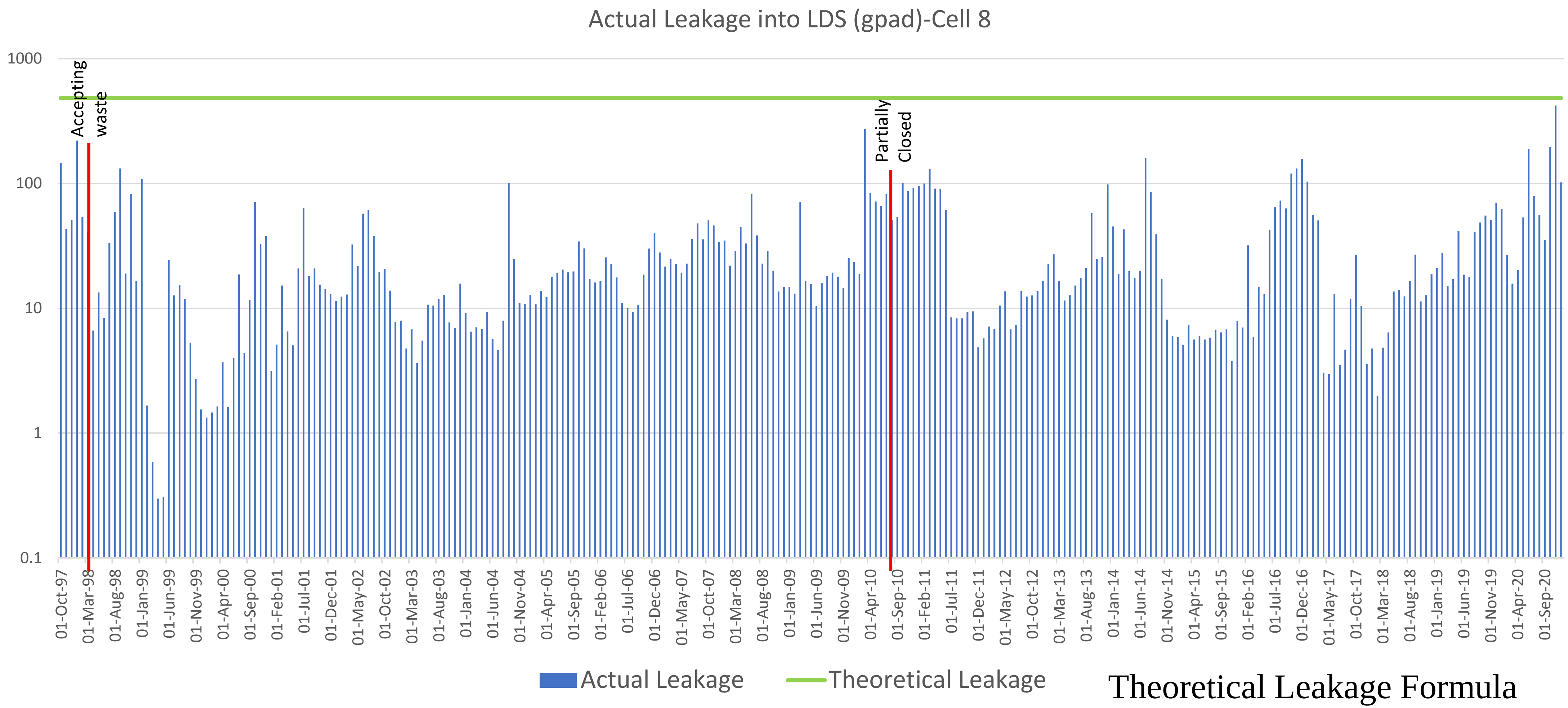
Test Site B




Leakage into the Ground through the Liner system (gpad)
1
0.1
0.01
0.001
0.0001
Accepting waste
Closure starts
closed
31-Jan-90
31-Jan-92
31-Jan-94
31-Jan-96
31-Jan-98
31-Jan-00
31-Jan-02
31-Jan-04
31-Jan-06
31-Jan-08
31-Jan-10
31-Jan-12
31-Jan-14
31-Jan-16
31-Jan-18
31-Jan-20
Theoretical Actual Leakage
Design Leakage
RCRA-D Leakage

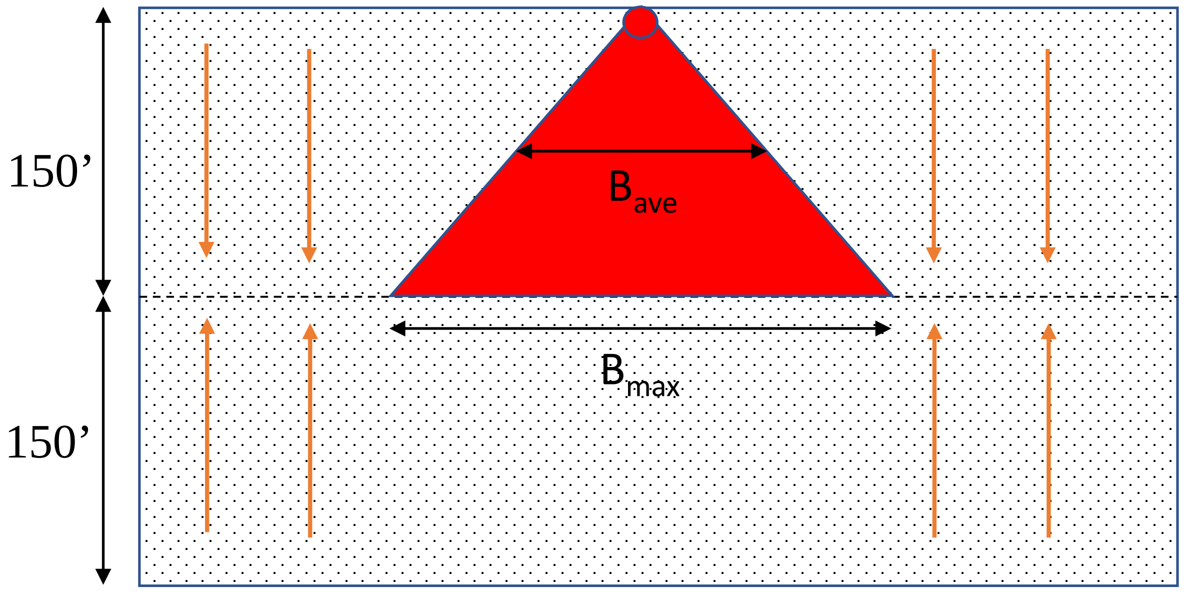
Test Site B



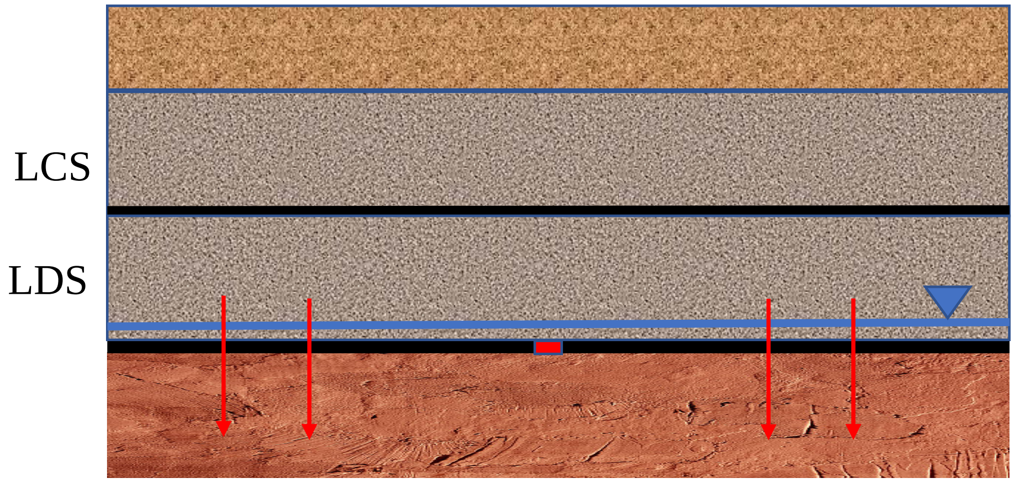


Theoretical Leakage Formula

$$Q = CC_B a\sqrt{2gh}$$



Secondary Liner



Width of wetted area beneath hole in primary liner

$$B_{ave} = \frac{2\sqrt{\frac{Q_1}{k_d}}}{\sin\alpha} * \sqrt{1 + \frac{2X_{ave}\sin\alpha}{\sqrt{\frac{Q_1}{k_d}}}}$$

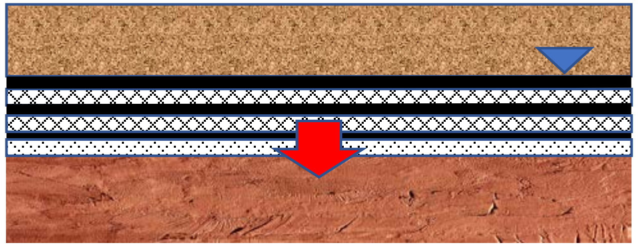
Average Depth of Flow in LDS

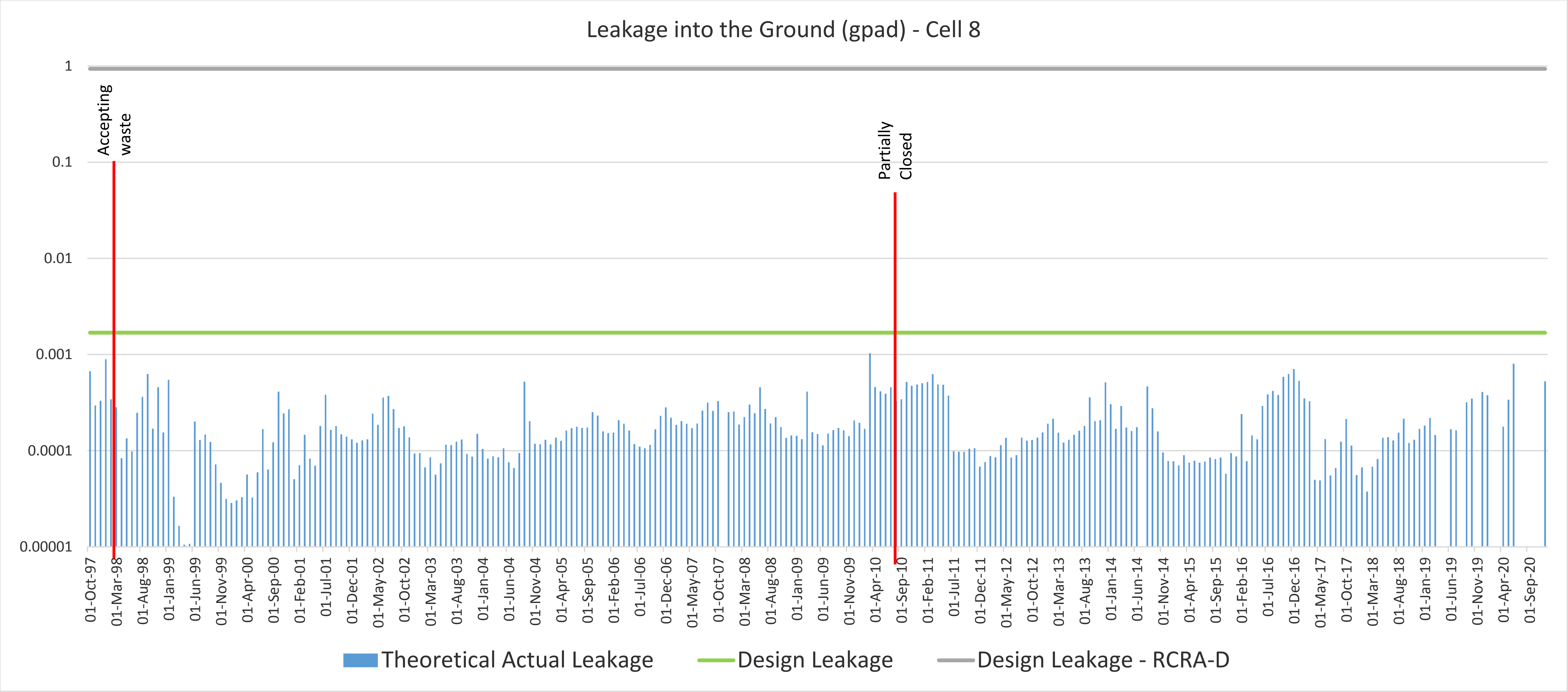
$$D_{ave} = \frac{Q_1}{B_{ave}\, k_d sin \propto}$$

Leakage Through Secondary Liner

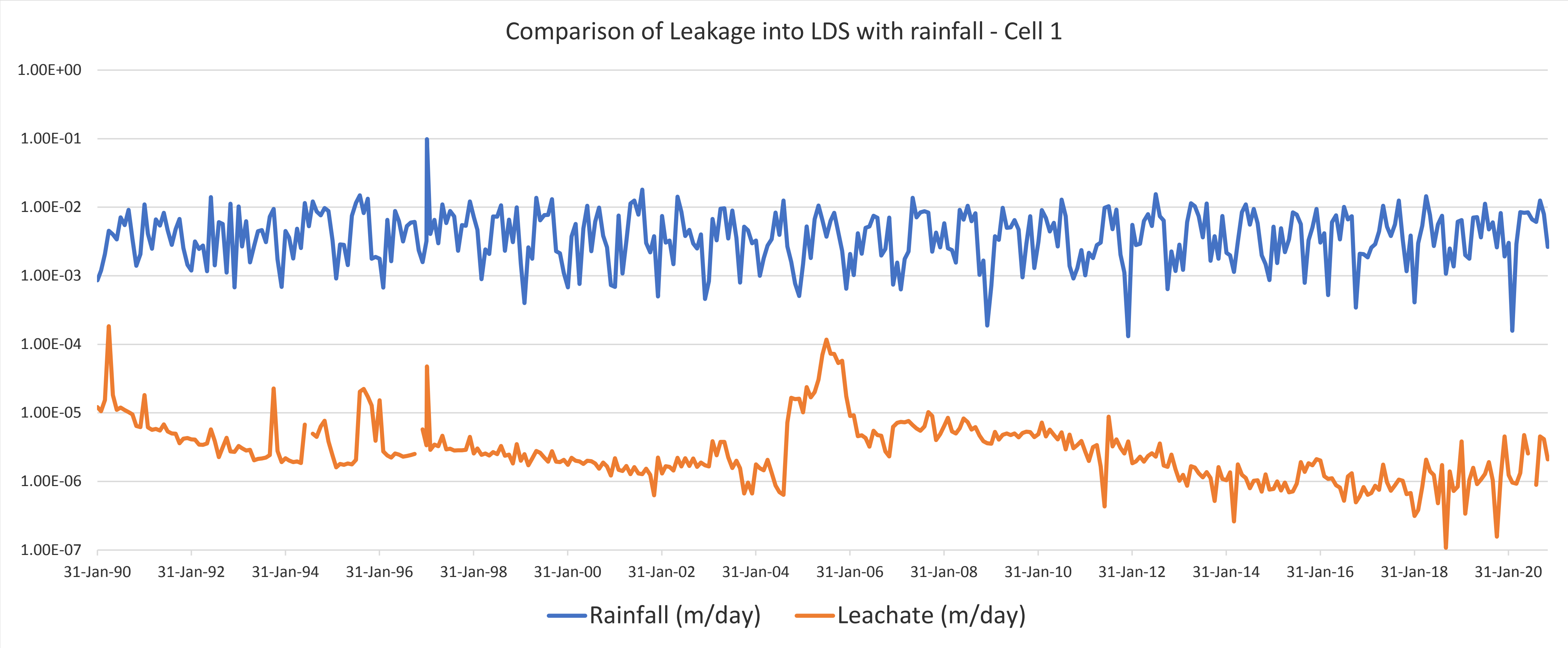
$$Q_2 = \beta_c(1 + 2\left(\frac{D_{ave}}{L_s}\right)^{0.95})a^{0.1}{D_{ave}}^{0.9}{k_s}^{0.74}$$

Test Site B

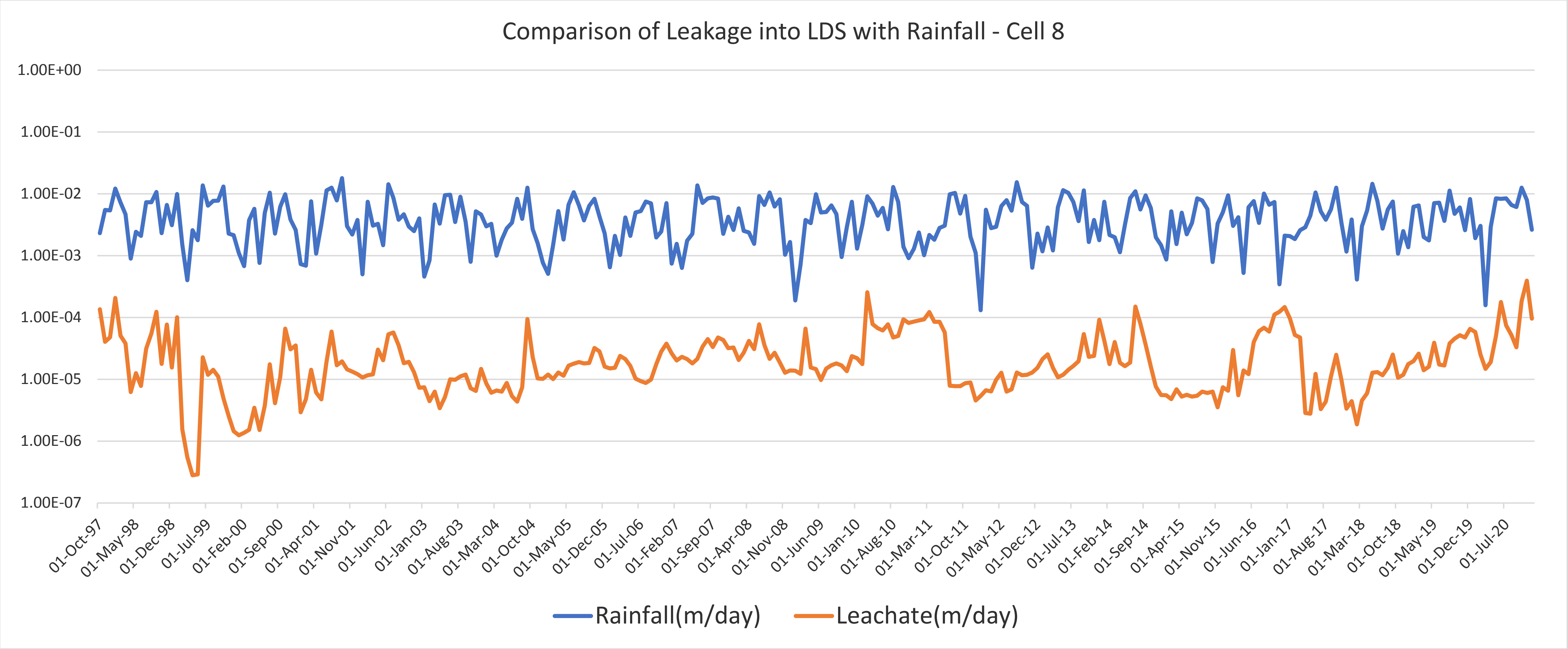



Leakage into the Ground (gpad) - Cell 8
1
0.1
0.01
0.001
0.0001
0.00001
Accepting waste
Partially Closed
01-Oct-97
01-Mar-98
01-Aug-98
01-Jan-99
01-Jun-99
01-Nov-99
01-Apr-00
01-Sep-00
01-Feb-01
01-Jul-01
01-Dec-01
01-May-02
01-Oct-02
01-Mar-03
01-Aug-03
01-Jan-04
01-Jun-04
01-Nov-04
01-Apr-05
01-Sep-05
01-Feb-06
01-Jul-06
01-Dec-06
01-May-07
01-Oct-07
01-Mar-08
01-Aug-08
01-Jan-09
01-Jun-09
01-Nov-09
01-Apr-10
01-Sep-10
01-Feb-11
01-Jul-11
01-Dec-11
01-May-12
01-Oct-12
01-Mar-13
01-Aug-13
01-Jan-14
01-Jun-14
01-Nov-14
01-Apr-15
01-Sep-15
01-Feb-16
01-Jul-16
01-Dec-16
01-May-17
01-Oct-17
01-Mar-18
01-Aug-18
01-Jan-19
01-Jun-19
01-Nov-19
01-Apr-20
01-Sep-20
Theoretical Actual Leakage
Design Leakage
Design Leakage - RCRA-D

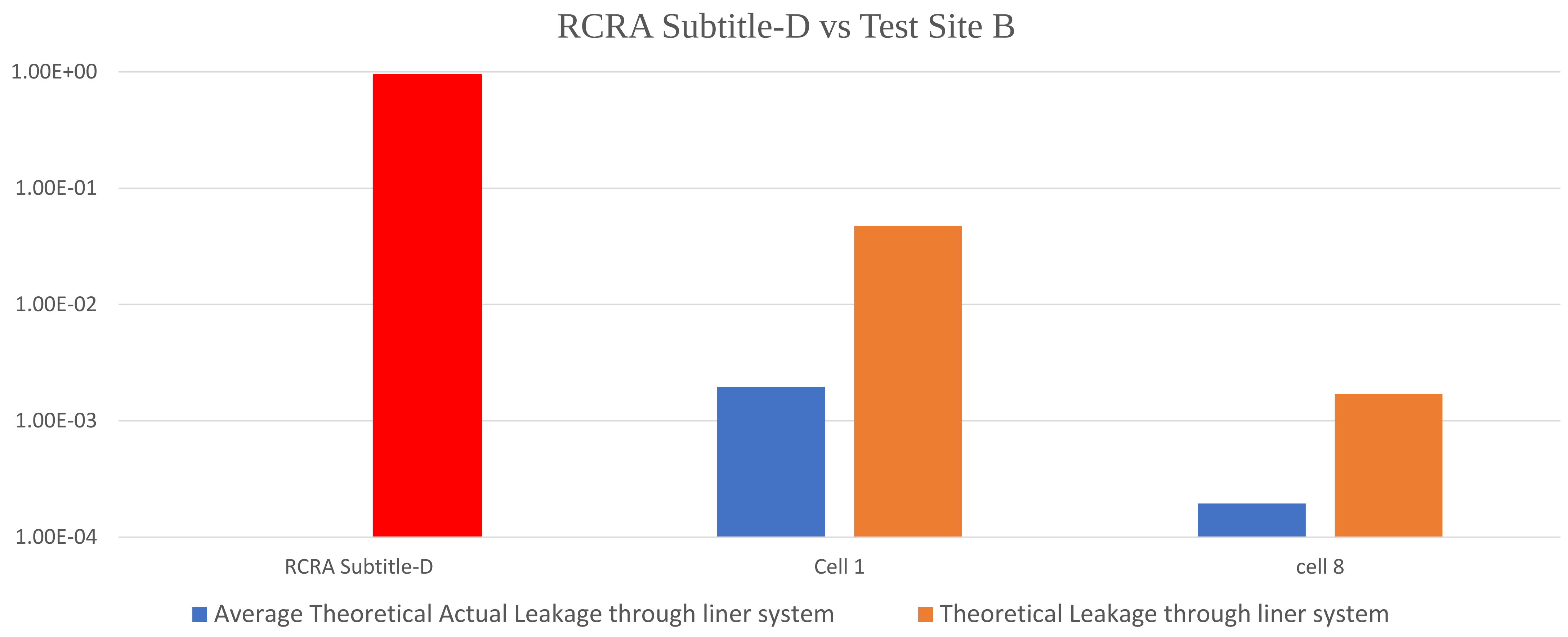
Leakage Comparison



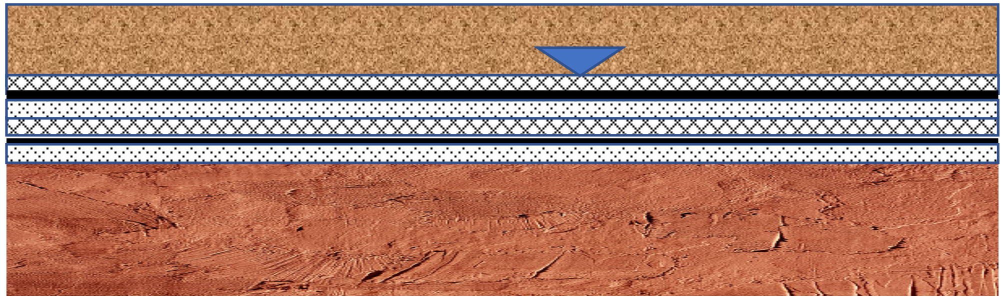
Leakage Comparison



Leakage through Liner System



Double Composite Liner System



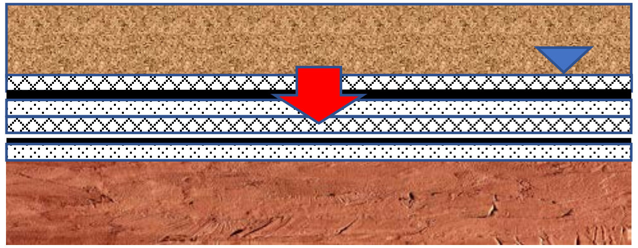
Leakage Through Primary Liner

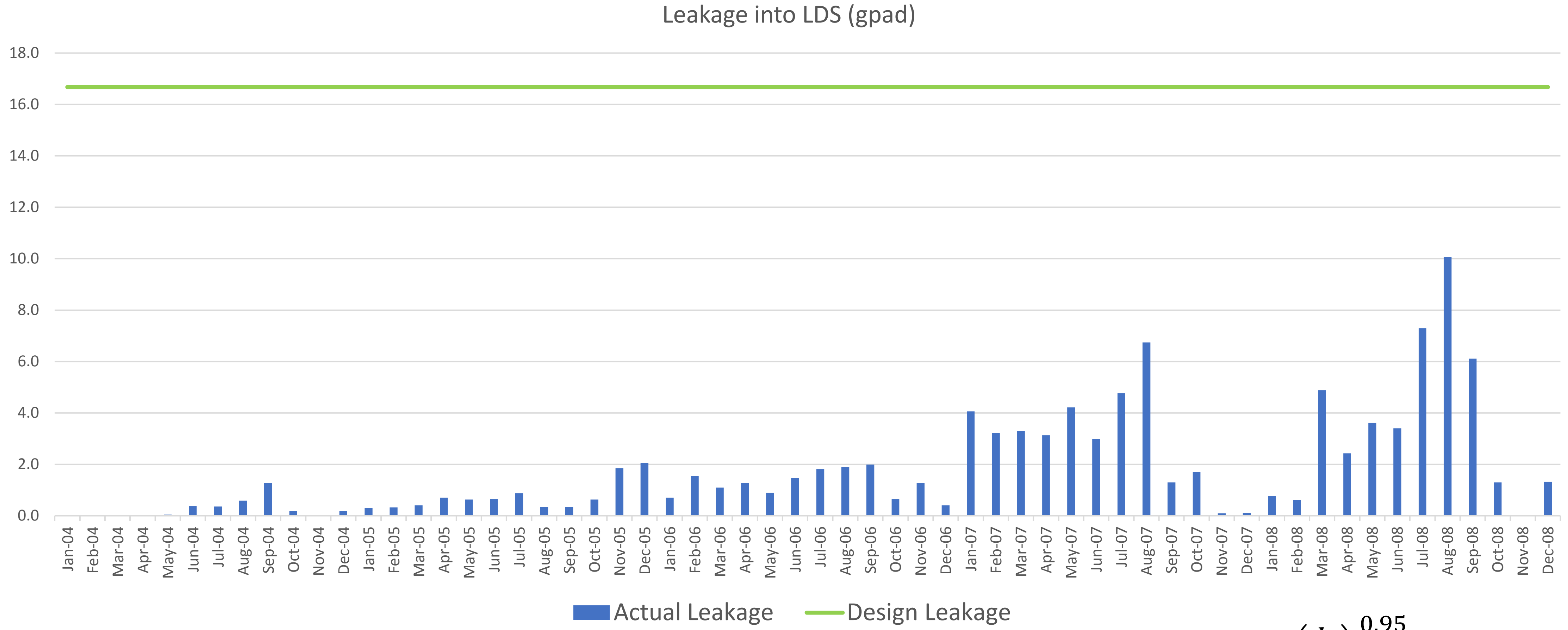
$$Q_1 = \beta_c(1 + 2\left(\frac{h}{L_s}\right)^{0.95})a^{0.1}h^{0.9}{k_{GCL}}^{0.74}$$

Leakage Through Secondary Liner

$$Q_2 = \beta_c(1 + 2\left(\frac{D_{ave}}{L_s}\right)^{0.95})a^{0.1}{D_{ave}}^{0.9}{k_S}^{0.74}$$

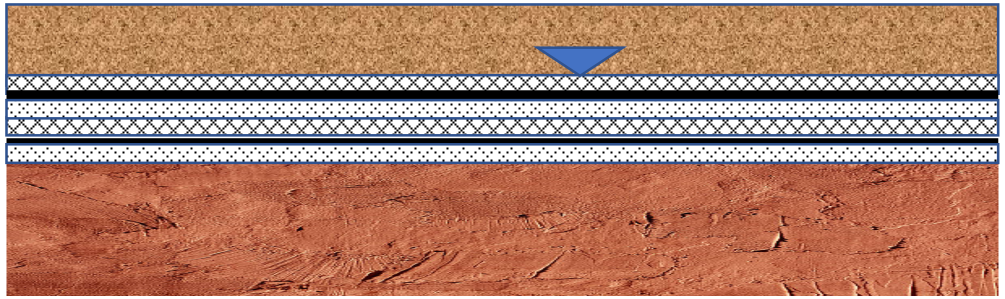
Test Site H (Double Composite Liner)





$$Q_1 = \beta_c\left(1 + 2\left(\frac{h}{L_s}\right)^{0.95}\right)a^{0.1}h^{0.9}{k_{GCL}}^{0.74}$$

Double Composite Liner System



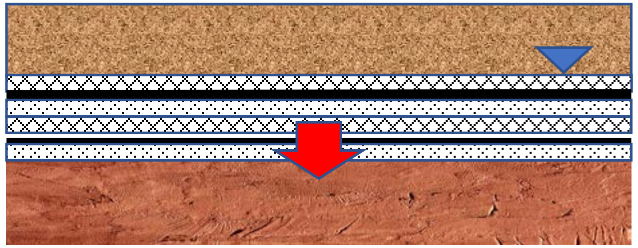
Leakage Through Primary Liner

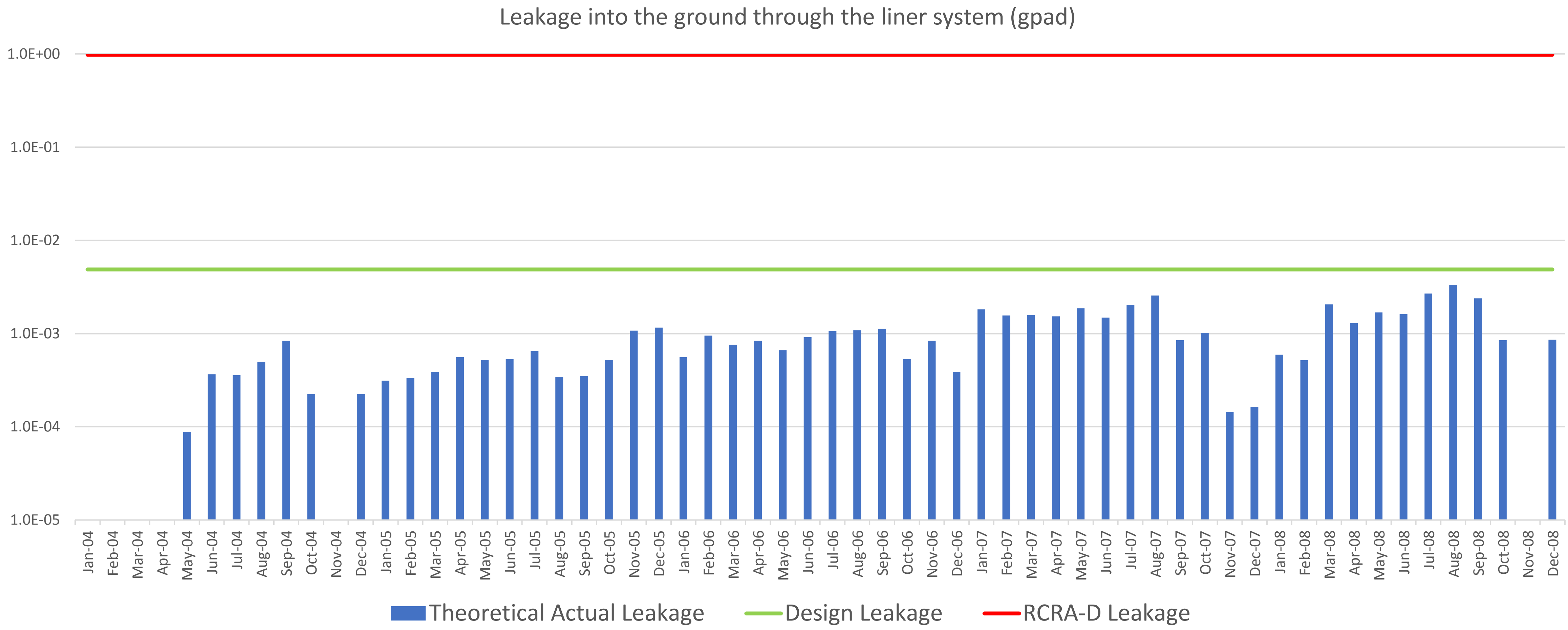
$$Q_1 = \beta_c(1 + 2\left(\frac{h}{L_s}\right)^{0.95})a^{0.1}h^{0.9}{k_{GCL}}^{0.74}$$

Leakage Through Secondary Liner

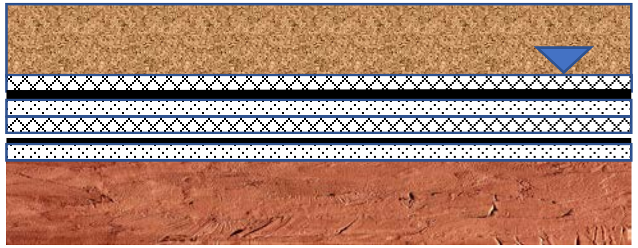
$$Q_2 = \beta_c(1 + 2\left(\frac{D_{ave}}{L_s}\right)^{0.95})a^{0.1}{D_{ave}}^{0.9}{k_S}^{0.74}$$

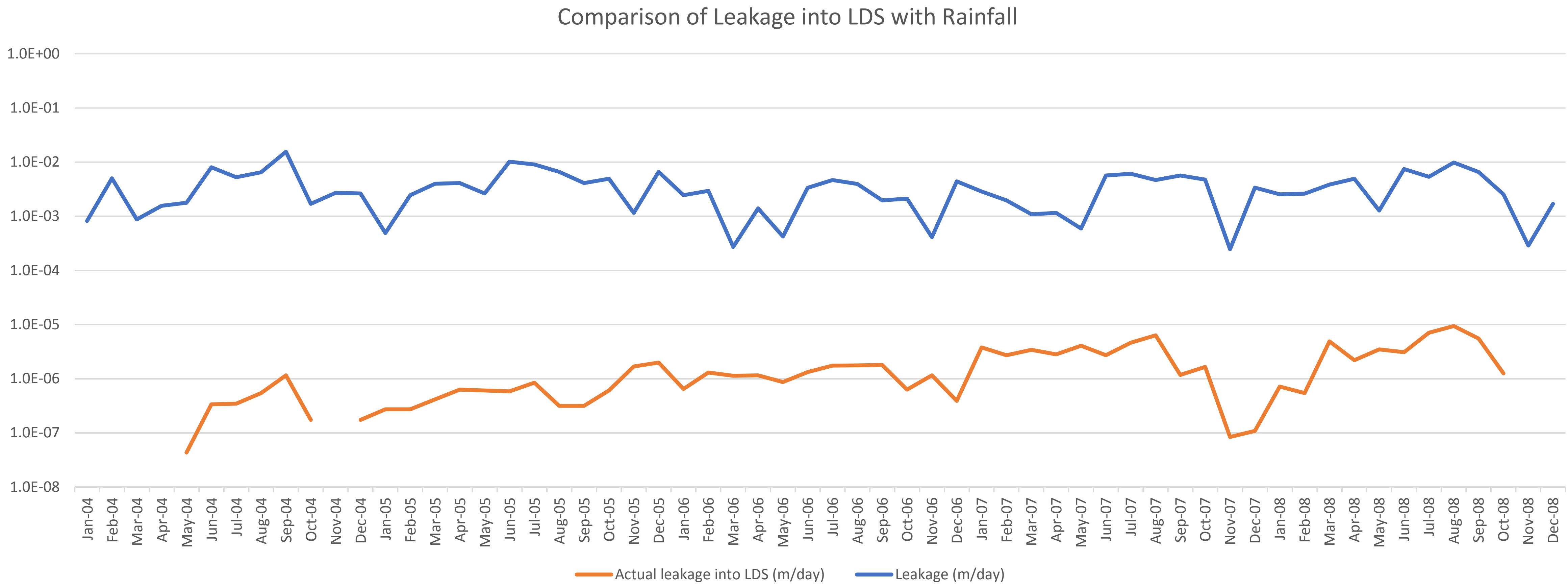
Test Site H (Double Composite Liner)





Test Site H (Double Composite Liner)

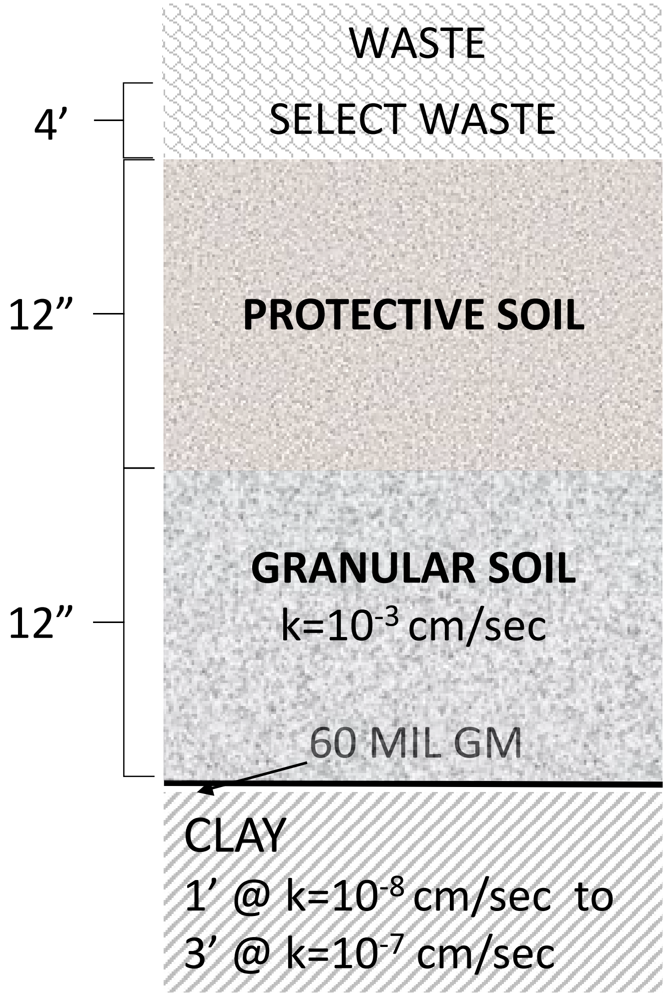




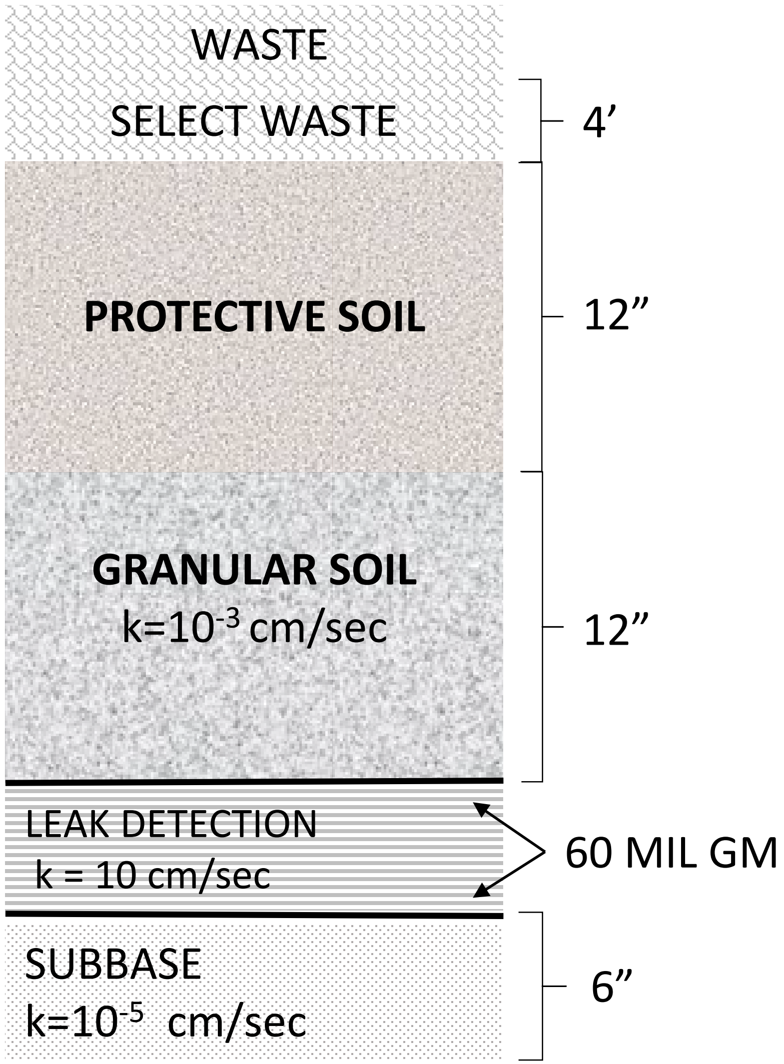
FUTURE PLANS

We plan to:

- Use the findings of this study to approach others to continue collecting data from Florida double lined landfills to better resolve the issue of equivalency between the federal composite liner design and the double liner design.
- Use Finite Element Modeling to analyze EPA vs FDEP liner systems to finally put the issue to rest



Composite Liner Option



Double Liner Option

Waste 360™

GWMS®

Global Waste Management Symposium

FEBRUARY 23-26, 2020

HYATT REGENCY INDIAN WELLS RESORT & SPA INDIAN WELLS, CALIFORNIA

Strategic Partner:

EREF

Environmental Research & Education Foundation™

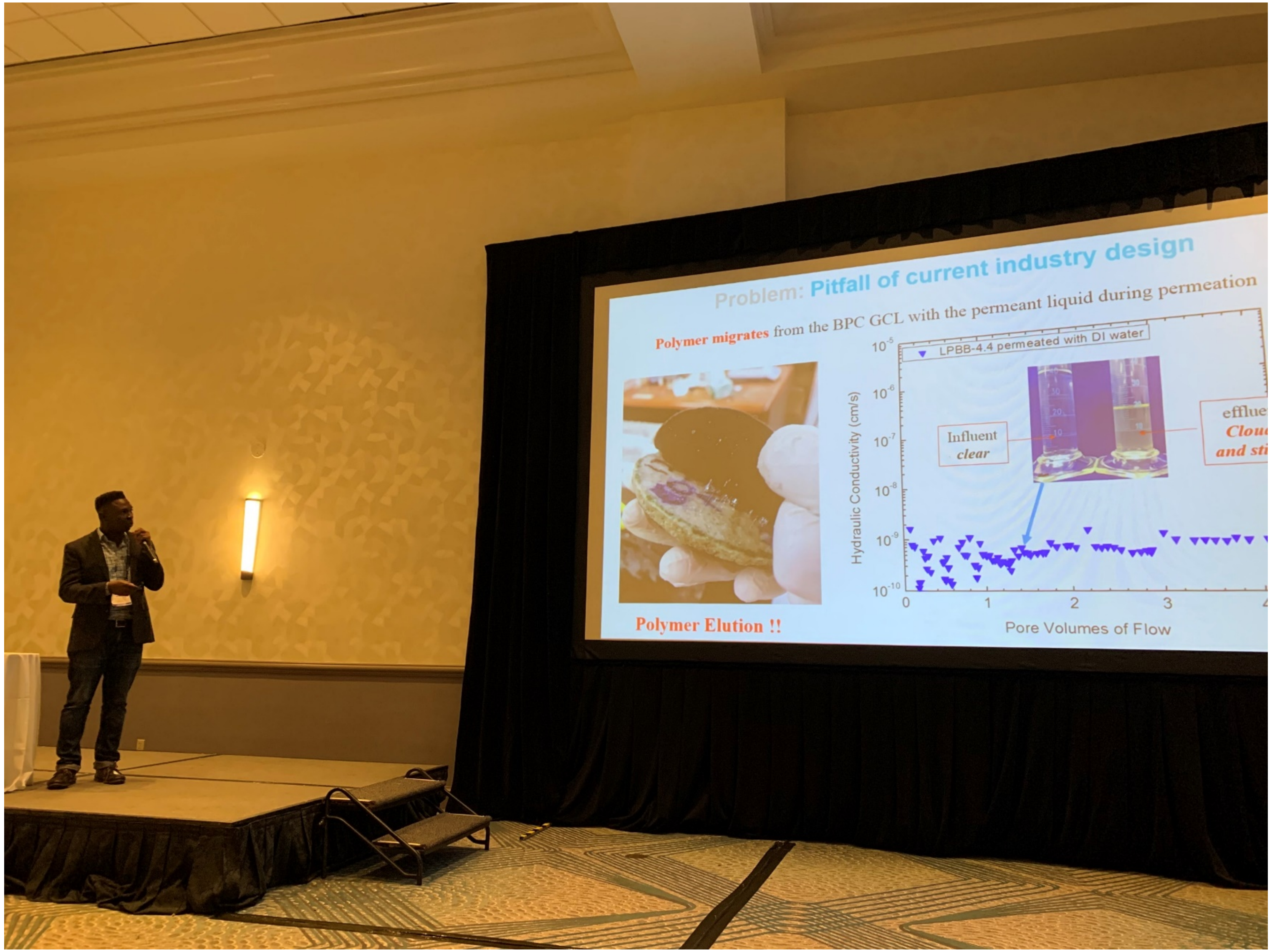
Lighting a path to sustainable waste management practices

Congratulations - GWMS Speaker Award - C.Wireko

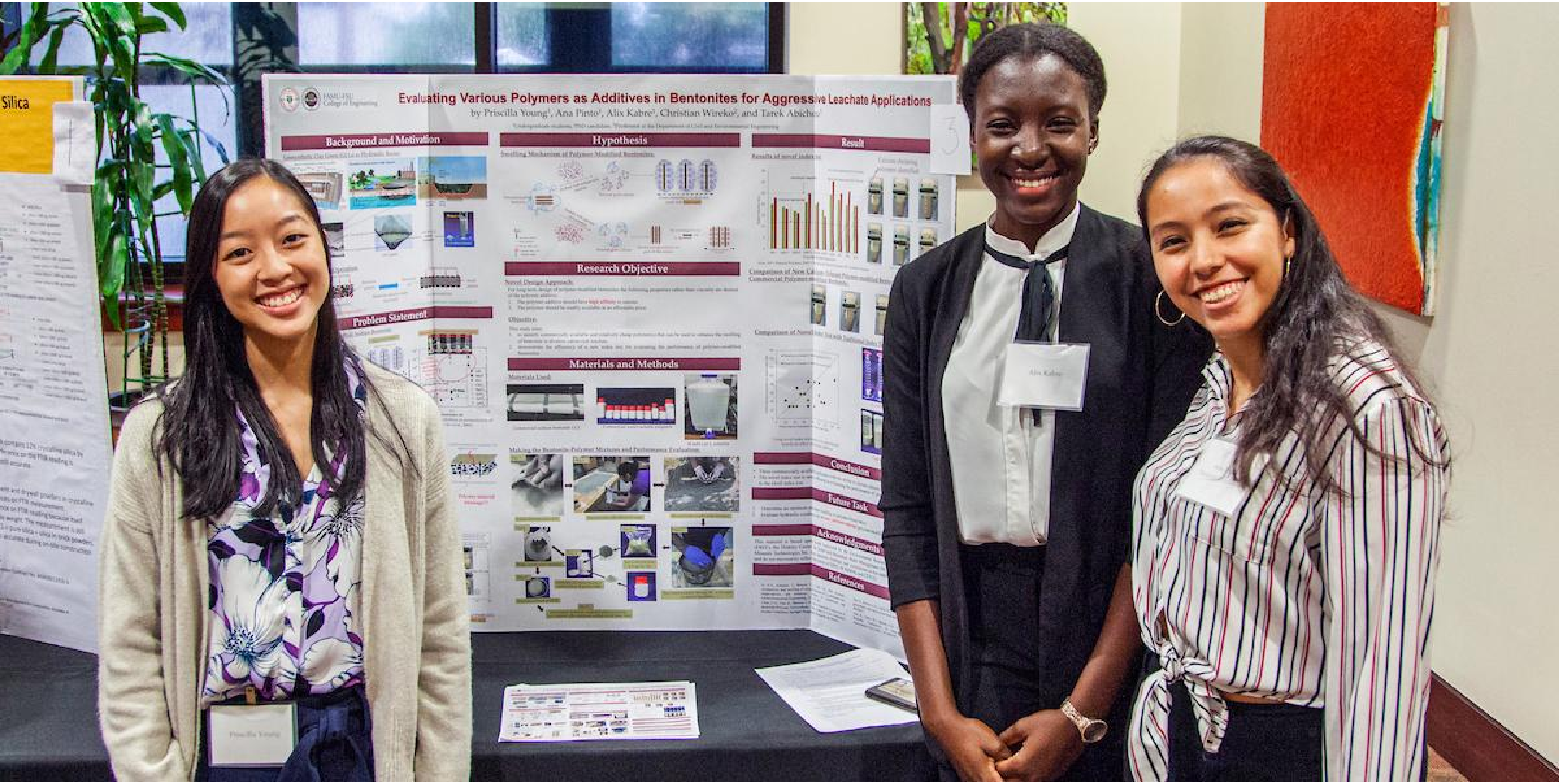
Today at 4:30 PM

Hi Christian,

I hope you are healthy and safe! We have finished tallying the responses from attendees and you came in second for Student speakers at the 2020 Global Waste Management Symposium. Congratulations!



Civil engineering undergraduates win first place in industry poster competition: Florida Air & Waste Management Association's 55th Annual Conference and Exhibition (ACE):



Florida Section
Air & Waste Management Association
55th Annual Conference & Expo
CALL FOR STUDENT POSTERS

Undergraduates: Priscilla Young, left, Ana Pinto, right, and Alix Kabre

FAMU-FSU Engineering