Analysis of Geocomposite Drainage Layers (GDLs) for Landfills and Ponds

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What are Geocomposite Drainage Layers?

Multiple Terms:

- **Geocomposite drainage nets (GDNs)**
- **Composite drainage nets (CDNs)**
- **Geosynthetic drainage composites (GDCs)**
- **Geocomposites**

- **Define Geocomposite (ASTM D4439 – Standard Terminology for Geosynthetics)**
- **geocomposite,** *n*—a product composed of two or more materials, at least one of which is a geosynthetic.

Objectives of this Webinar

- Description of CDNs
- Manufacturing
- Importance of understanding deployment (layout)
- Landfill Closure Design
  - Daylighting CDN through the cover soil layer
  - Improper anchor trench design (closure toe-of-slope)
- Attachment to pipes
- Use in sumps
- ~~Handling and Storage~~
- Installation
  - Repairs

FGI

Design Calculations

Leachate Collection Systems Design & Management I
Presented by Bob Mackey, P.E., BCEE,
Principal Engineer at S2L, Inc.
August 12, 2021

Design of Leachate Collection Systems Part II
Presented by Bob Mackey, PE, BCEE, Principal
Engineer at S2L, Inc.
March 29, 2022

Special Thank You to:

Eric Blond, eng., M.Sc.A

Eric Blond Consultant, Montreal, Canada

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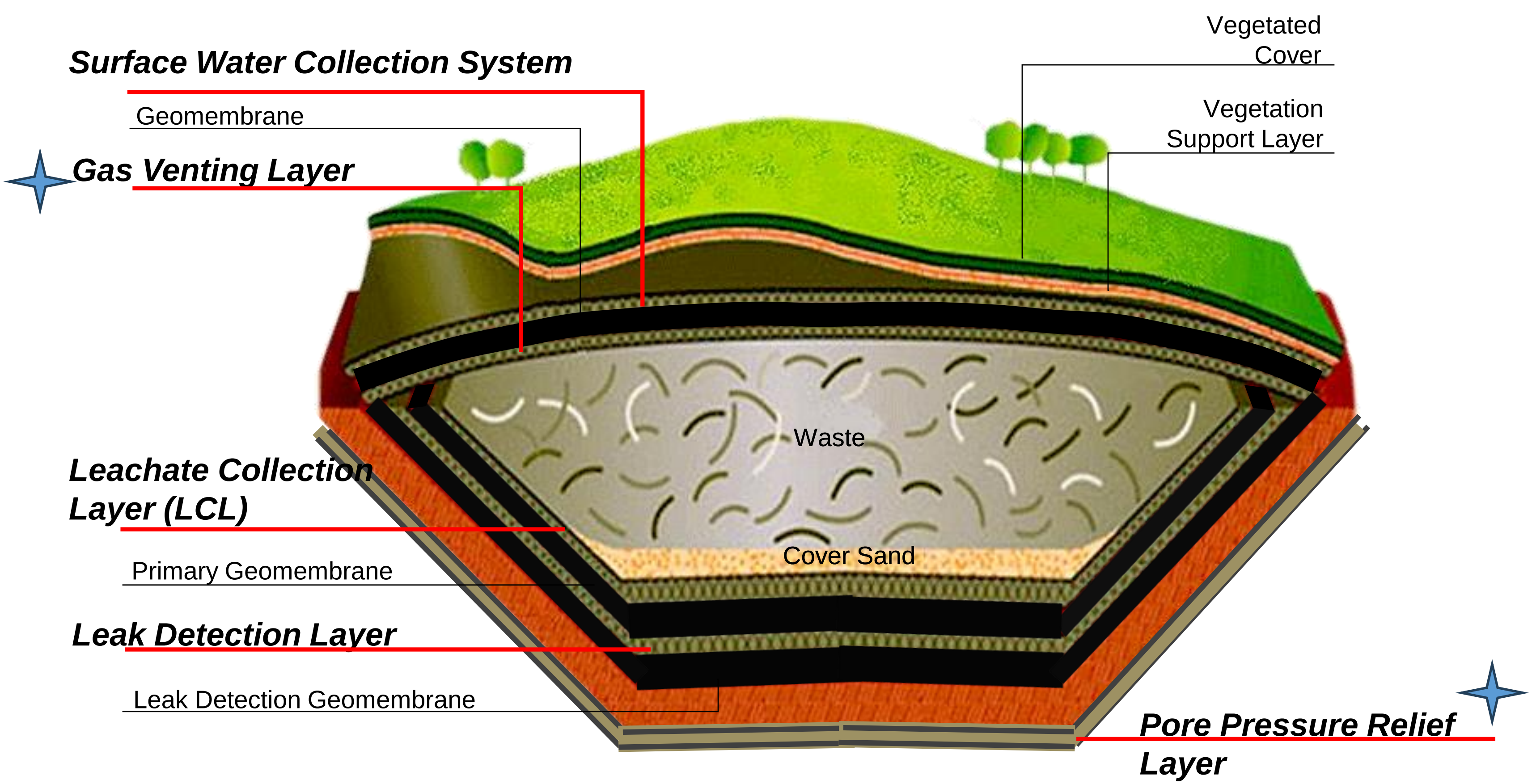
“Designing Geocomposites Drains in Leachate Collection Layers and Double Lining Systems”, Sardinia 2021

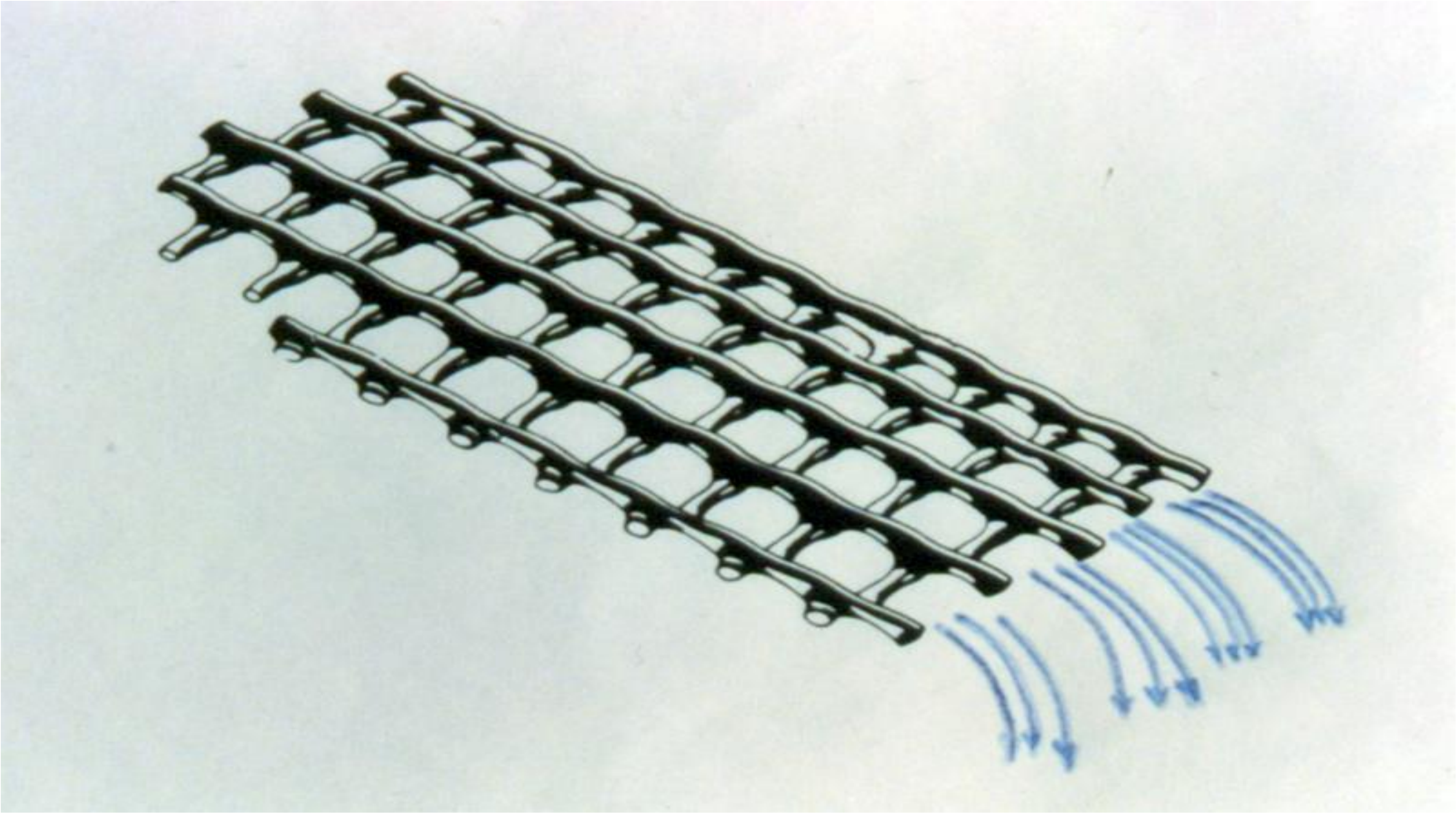
Typical Landfill Cross-Section



Failed Drainage → Leachate Head Build → Increased Leakage

Geonet Core

Flow In Geonet Channels
(or any other geosynthetic drainage medium)



Geotextile Product

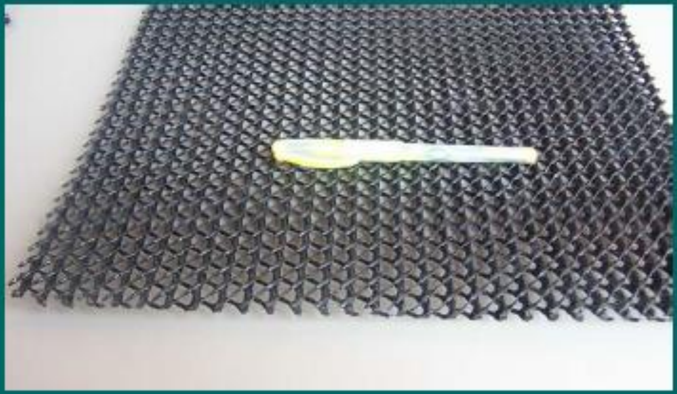
Designed for:

- **Retention**
- **Permeability (after load)**
- **Clogging Resistance**

Typical geotextile; AOS – 70 sieve
Soil retention: $O_{95} \leq 0.212$ mm

Geonet

Biplanar Geonet



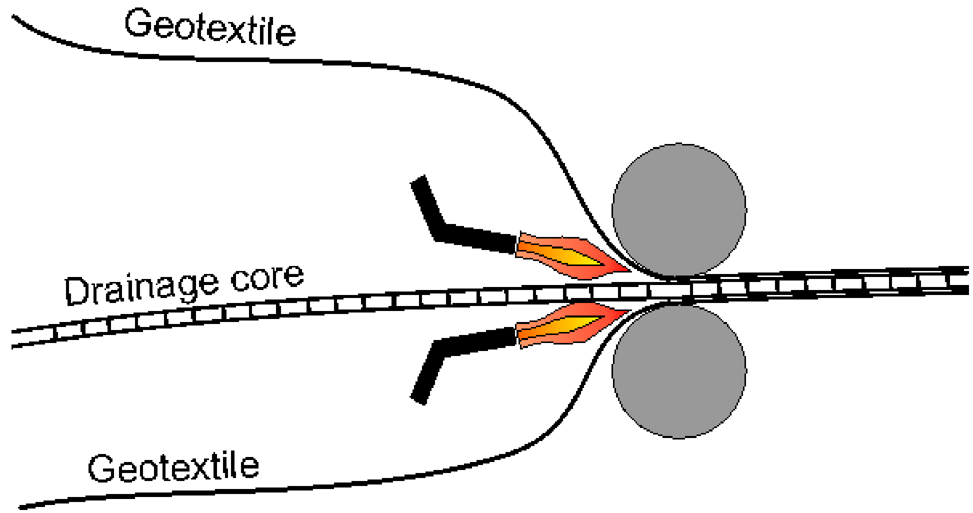
Triplanar Geonet

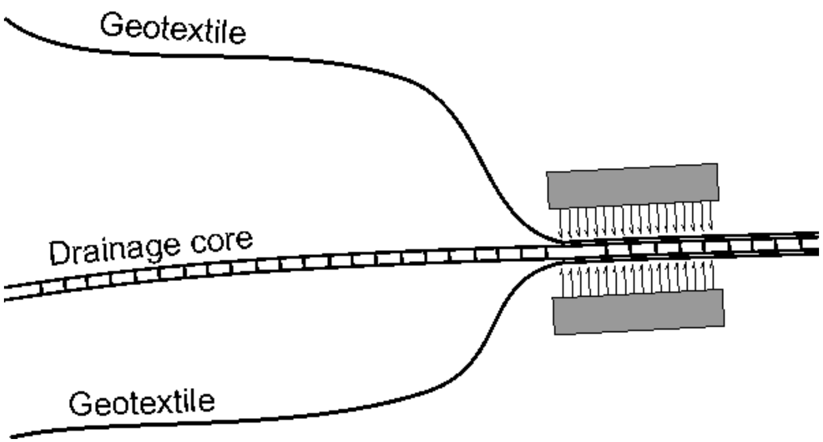
Geonet Composite

Drainage Composite

Manufacturing Process

Heat-bonded Geonet -





- Tube, Needle-punched

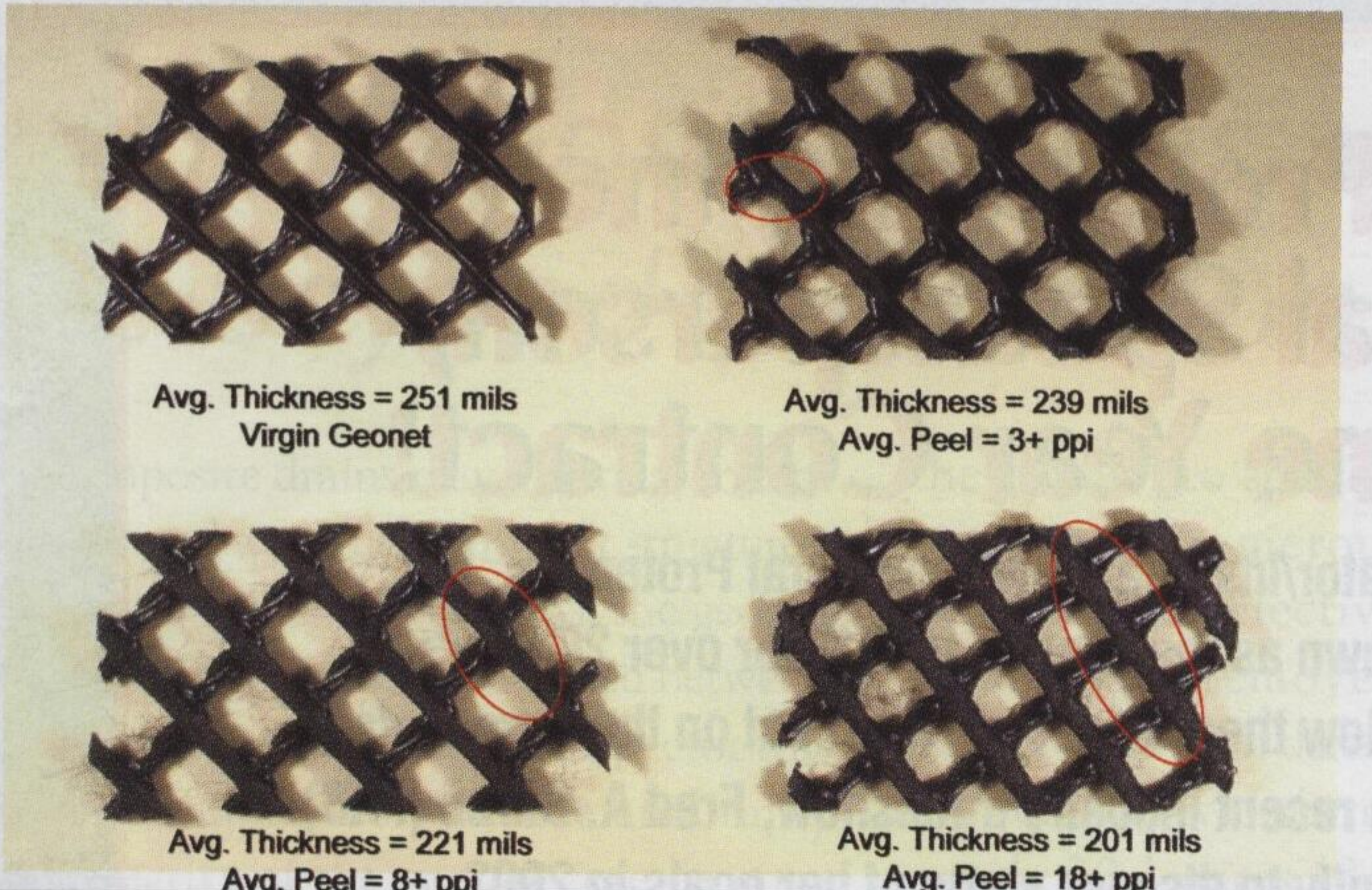
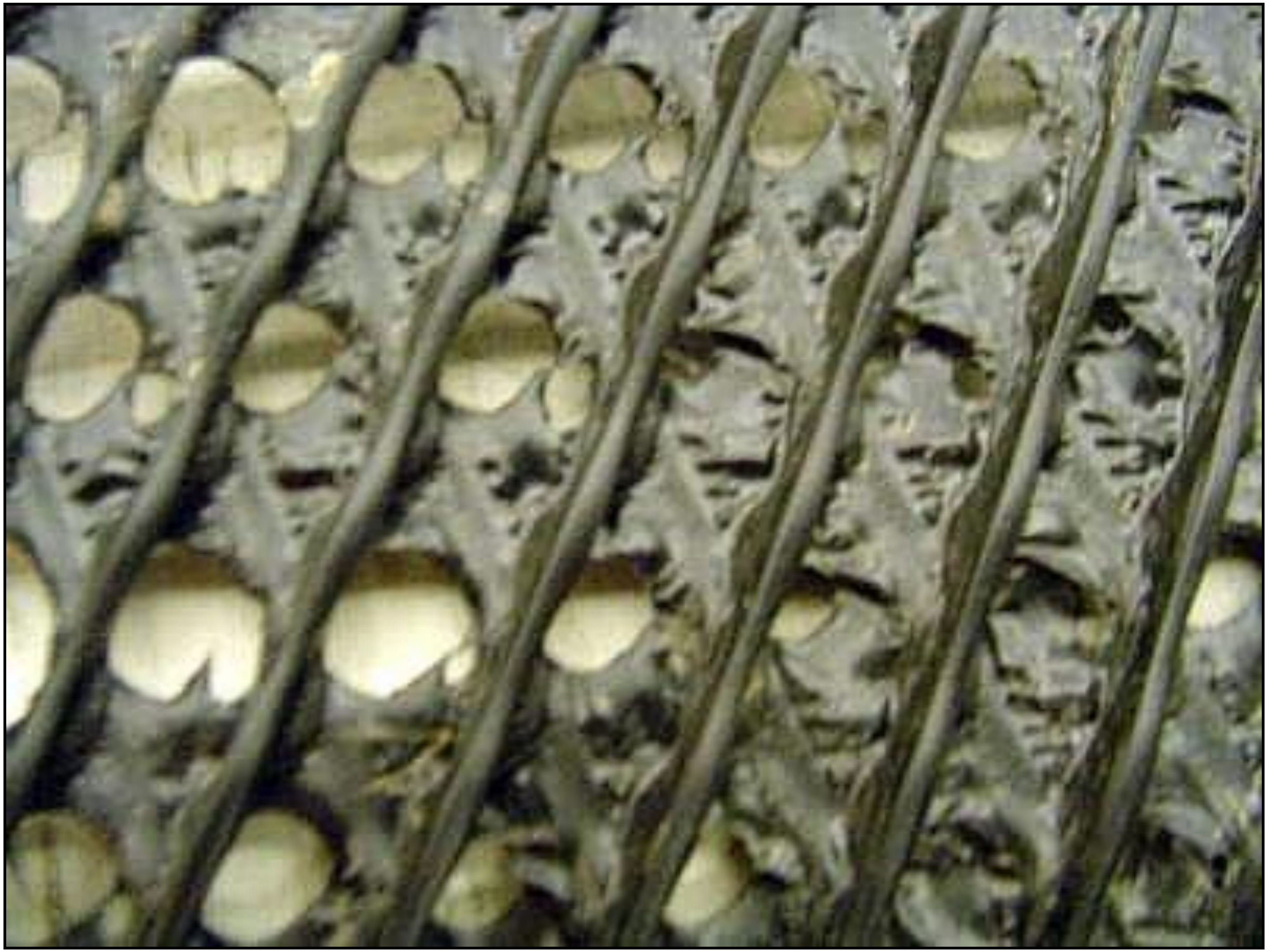


Photo 3. Peel strength vs. thickness for increasingly aggressive bonding heat and pressure. Transmissivity from 3 to 18 ppi products differed by nearly one order of magnitude.

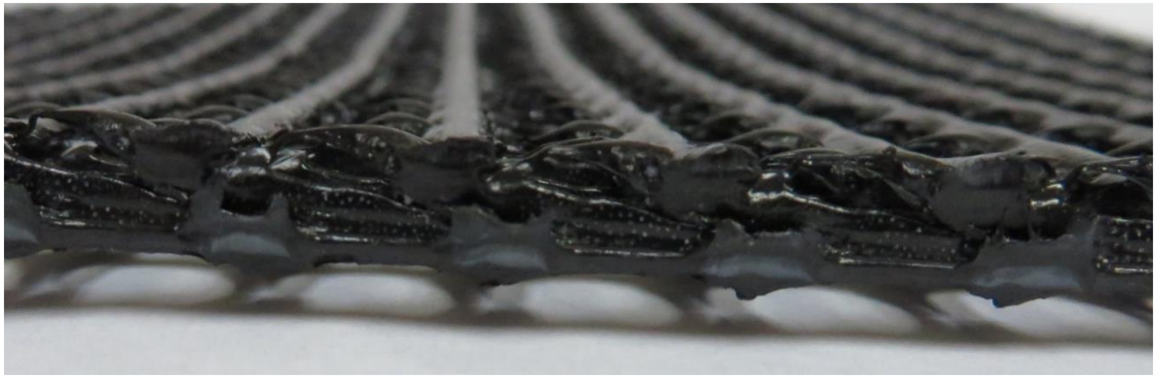
A little too much heat



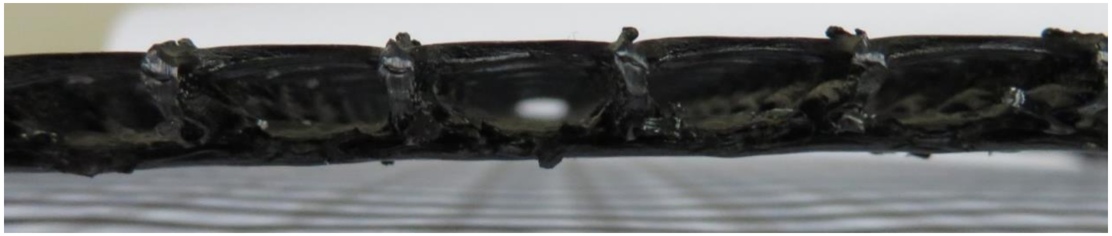
Impact of Drainage Core Structure

How are geonets manufactured?
Impact on their structure!

- **Bi-planar geonets are not homogeneous!**
  - **Structure**
  - **Manufacturing process**

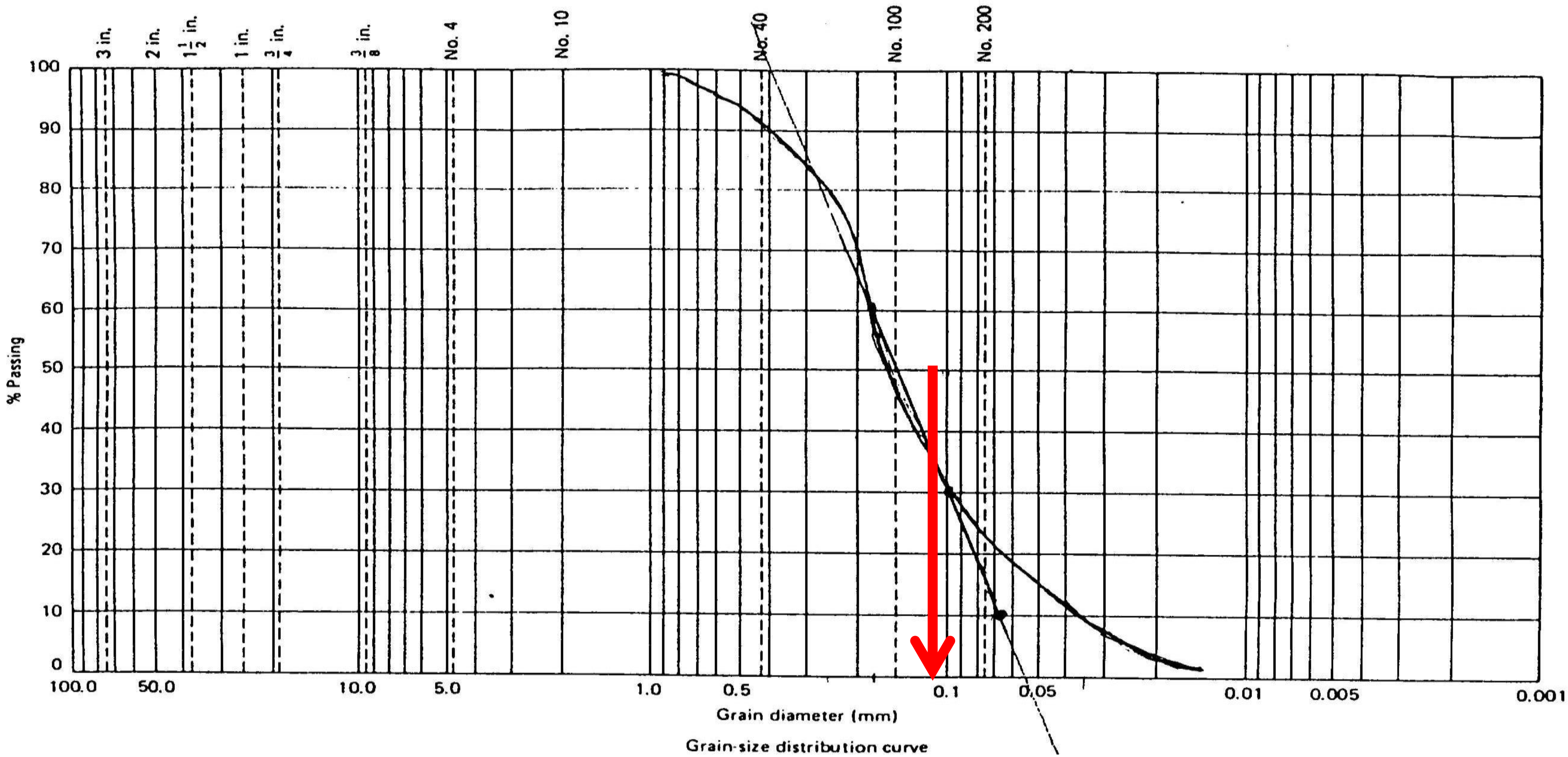


- **Tri-planar geonets**
  - **Unidirectional**
  - **High flow channels**



- **Installation layout**

Well Graded Drainage Soil

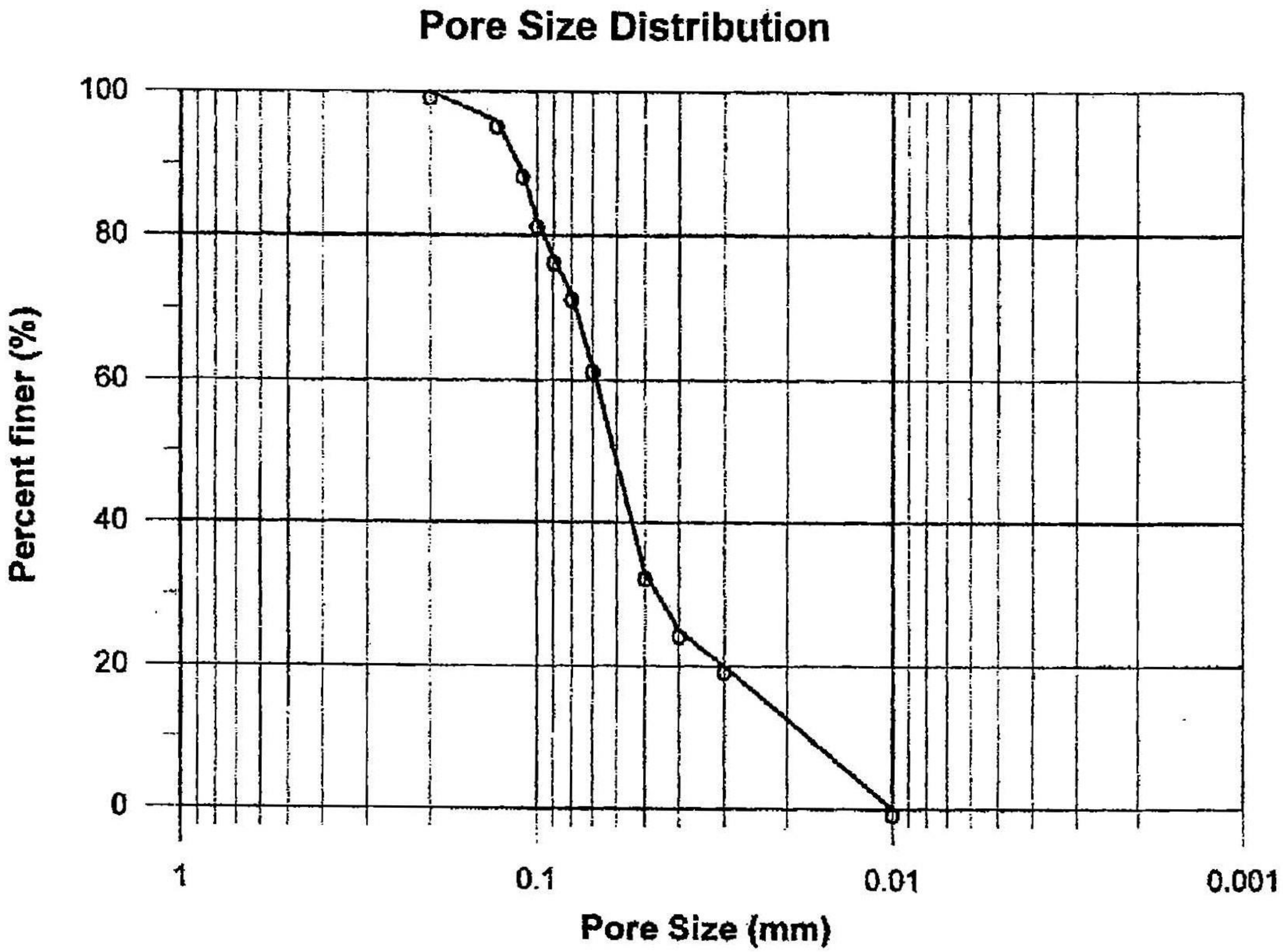


How do we determine the pore opening sizes of a geotextile?

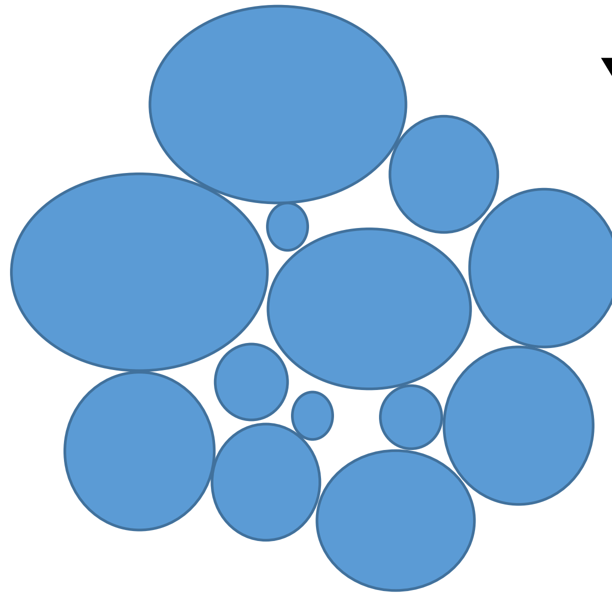
- ASTM D4751 – 20b: Standard Test Method for Determining Apparent Opening Size of a Geotextile (AOS)

- ASTM D6767 – 20a: Standard Test Method for Pore Size Characteristics of Geotextiles by Capillary Flow Test (pore size distribution test)

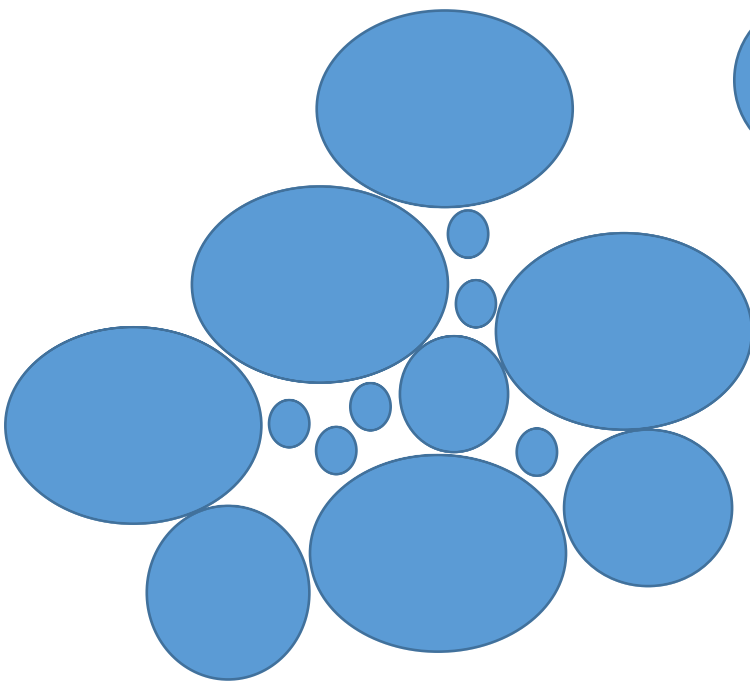
Poorly Graded Drainage Soil



Good Gradation?



YES!

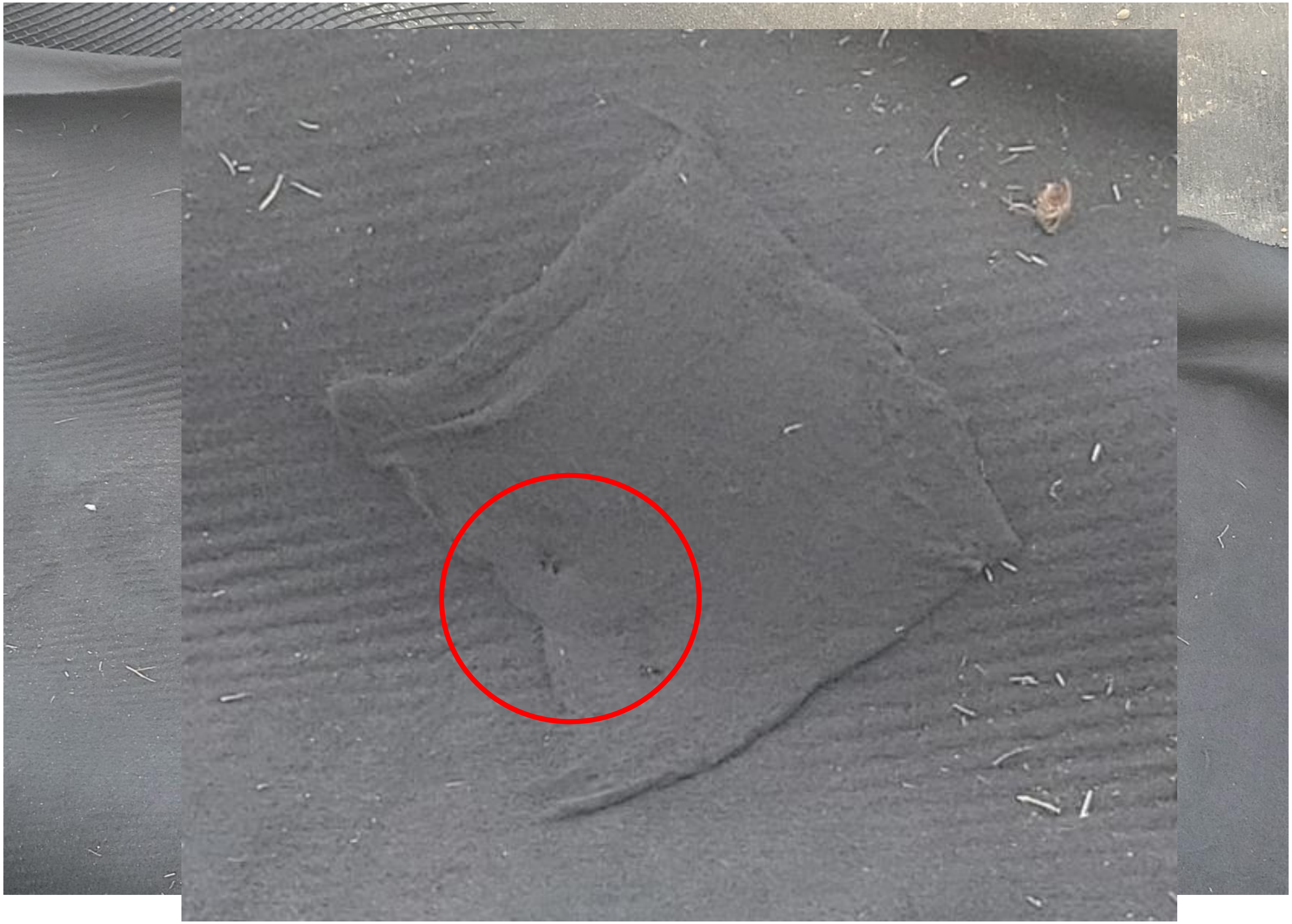


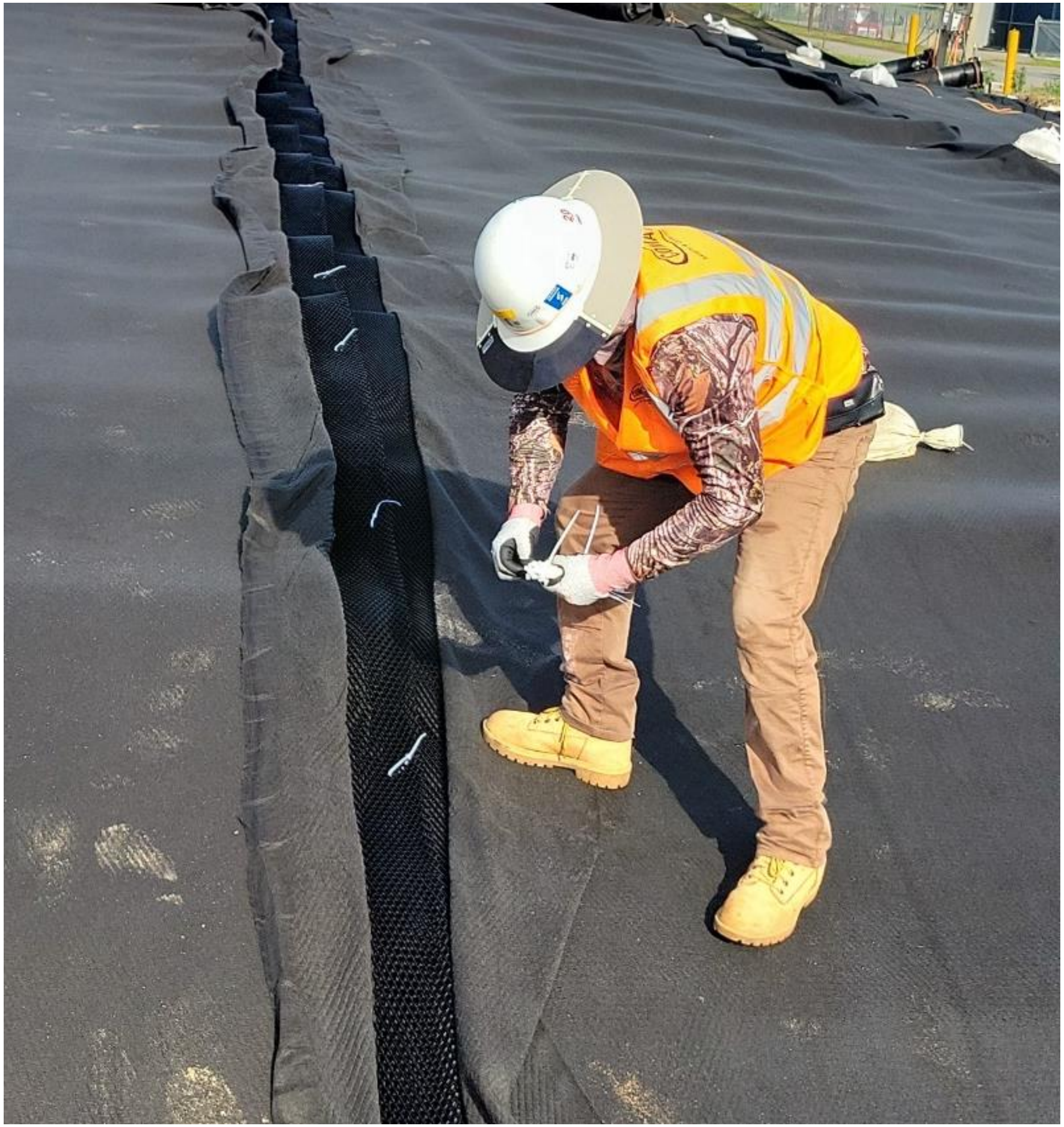
No!

Fines Infiltration

After Zhao, Blond, Recalcati (2012)


COMANCO





Requirements:

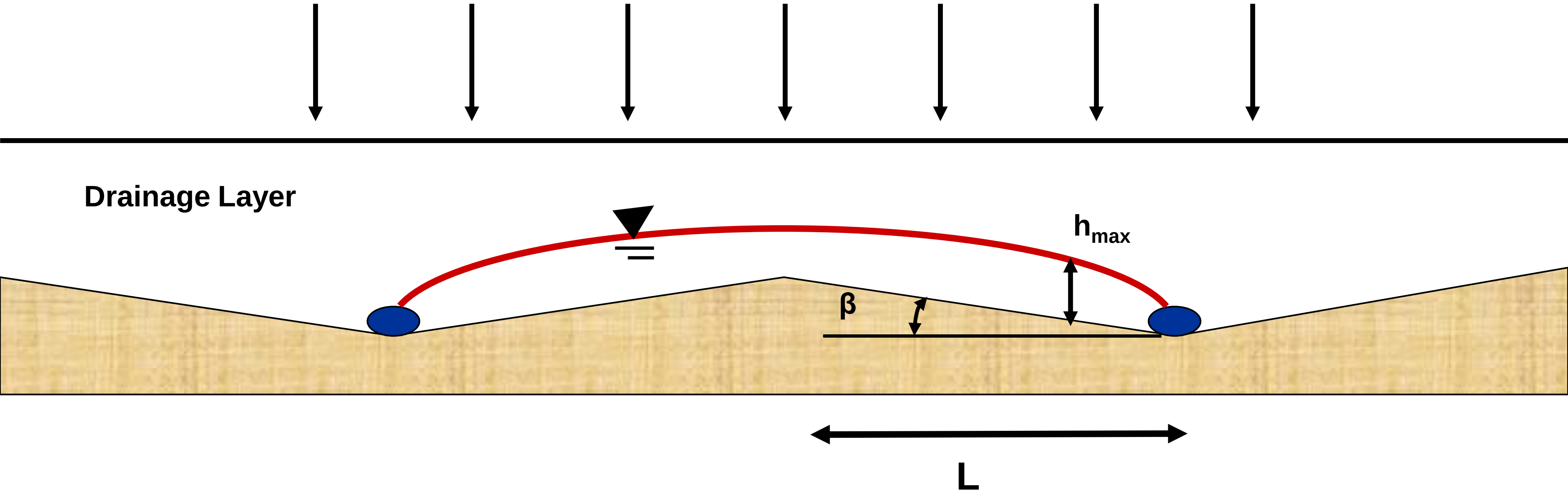
- Geonet component of the CDN shall be bound with plastic ties at a spacing of 1 per 5 feet on slopes flatter than 10 horizontal/vertical (10H:IV),
- 1 per 2 feet on slopes greater than 10H:IV, and
- 1 per 6 inches at the bounding of the end of one roll of CDN to another.
- All repairs will require ties at 1 per 6 inches

Geotextile Filters

Other Clogging Conditions:

- High alkalinity - precipitation of soluble constituents (calcium, sodium, magnesium) at GT interface
- Biological/chemical clogging - especially in landfill leachates.

Inflow (from HELP analysis)



Leachate Head versus Collection Pipe Spacing

Giroud's Equation

$$t_{max} = \frac{\left(\sqrt{\tan^2\beta + 4\, q_h/k}\right) - (\tan\beta)}{2\cos\beta} L$$

where:

t_{max} = head over liner (m)

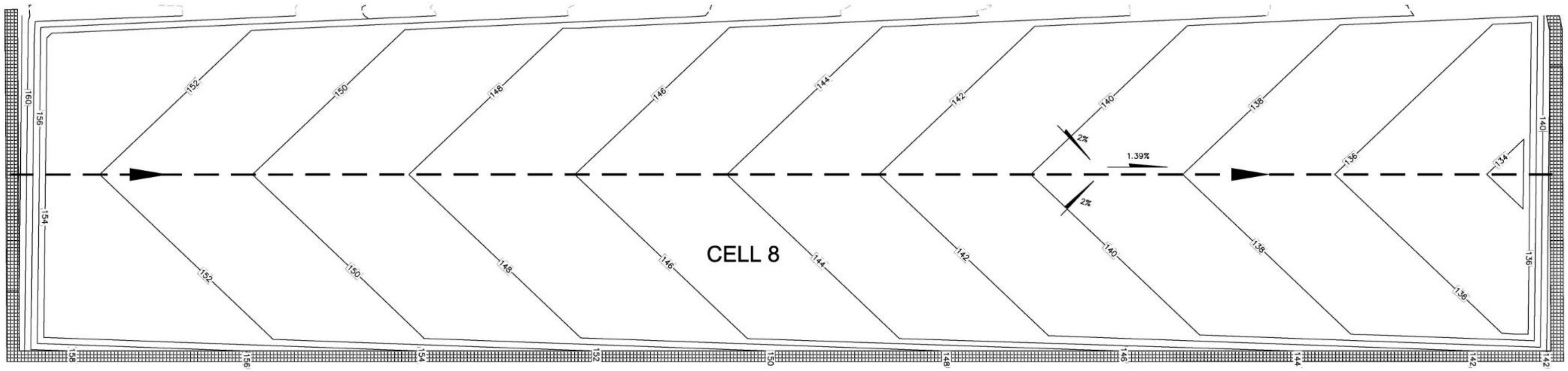
β = slope of liner (degrees)

q_h = impingement rate (i.e. HELP Model) (m/sec)

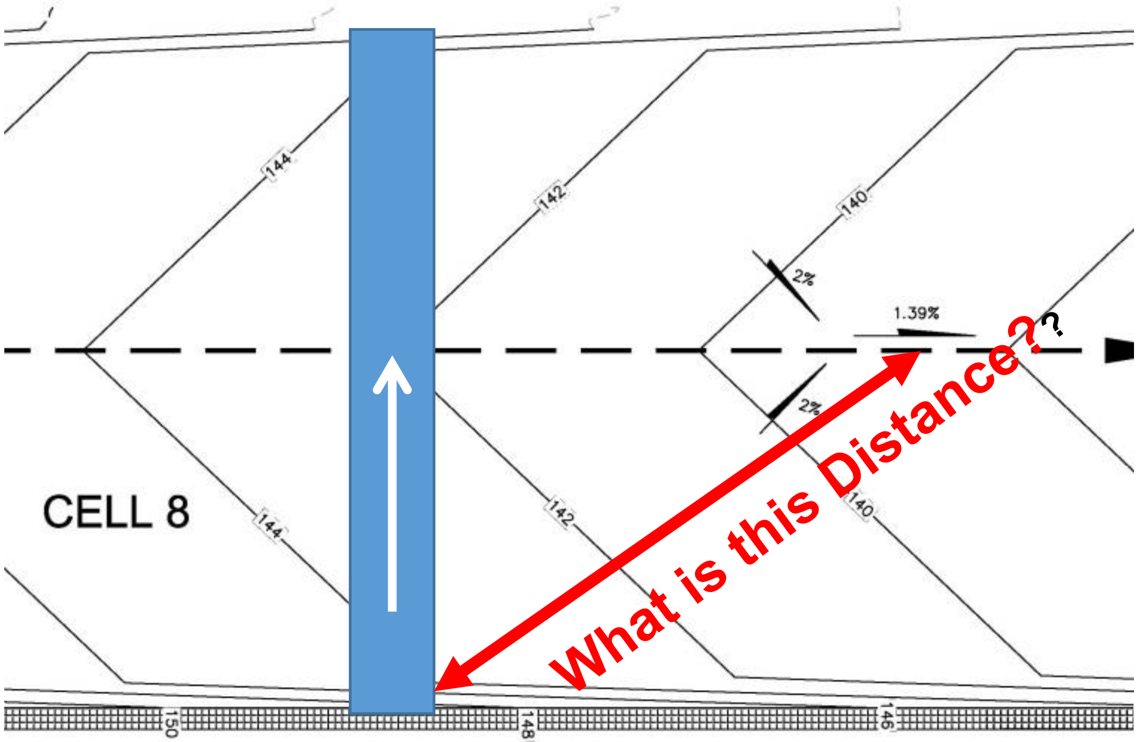
k = hydraulic conductivity of drainage layer (m/sec)

L = spacing of leachate collection laterals (m)

Basic Sawtooth Bottom Liner Design



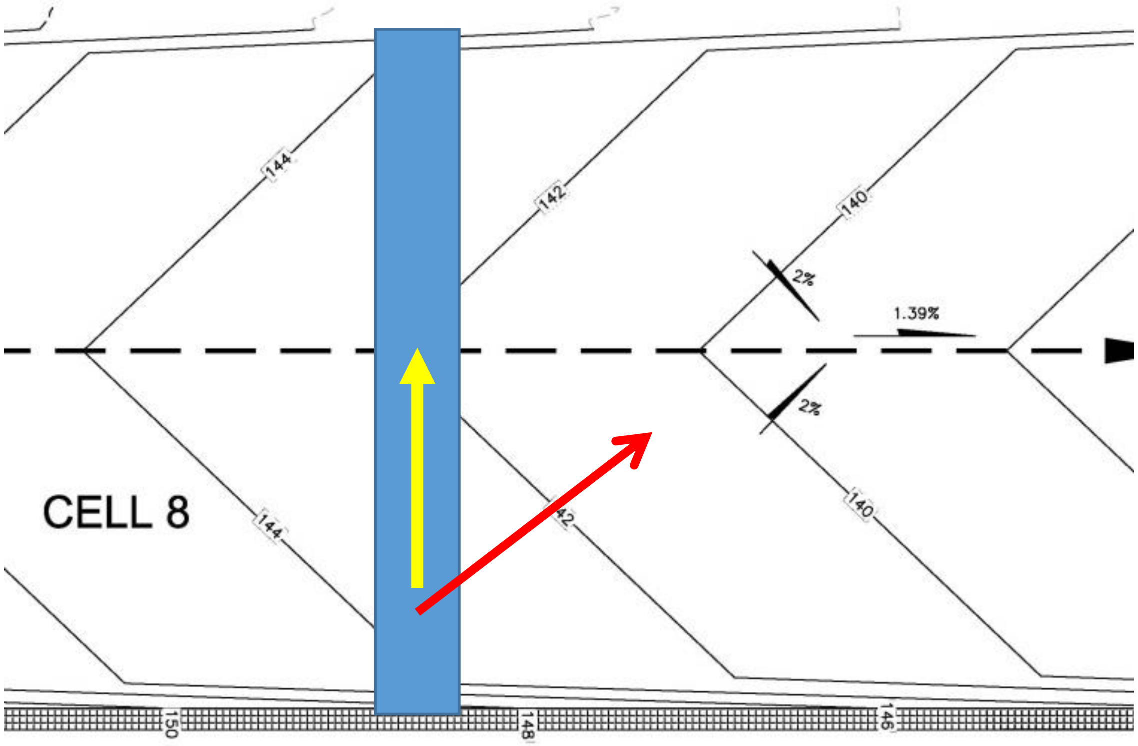
What is the “TRUE” Flow Pattern?



Installation Layout

Flow characteristics of commonly used types of geonets (Sieracke and Maxson 2001) with 100% representing the direction of product manufacturing.

What is the Hydraulic Gradient?



Hydraulic Gradient

- Difference in results for:
  - i = 0.02 (flow distance = 233’)
  - i = 0.0125 (flow distance = 160’)
- Testing Requirements
  - Less than 0.1
  - Difficulty of reading manometer
  - Redundant systems for measuring hydraulic gradients
  - Pressure transducers
- Test at design hydraulic gradient(s)

Permit vs. Design Requirements

- Design at Maximum Load
- 1st lift of waste
- Highest period of demand on the products performance
- Use of HELP Model
- Minimize variability

Reduction Factors and Safety Factors

$$q_{allow} = q_{100}\left[\frac{1}{RF_{CR} \times RF_{CC} \times RF_{BC}}\right]$$

(from GRI-GC8)

- **q_{allow}** = allowable flow rate per unit time per unit width (m3/sec-m)
- **q_{100}** = initial flow rate determined under simulated conditions for 100-hour duration
- **RF_{CR}** = reduction factor for creep to account for long-term behavior
- **RF_{CC}** = reduction factor for chemical clogging
- **RF_{BC}** = reduction factor for biological clogging

Additional Safety Factor

$$q_{allow} = \frac{q_{100}}{2}\left[\frac{1}{RF_{CR} \times RF_{CC} \times RF_{BC}}\right]$$

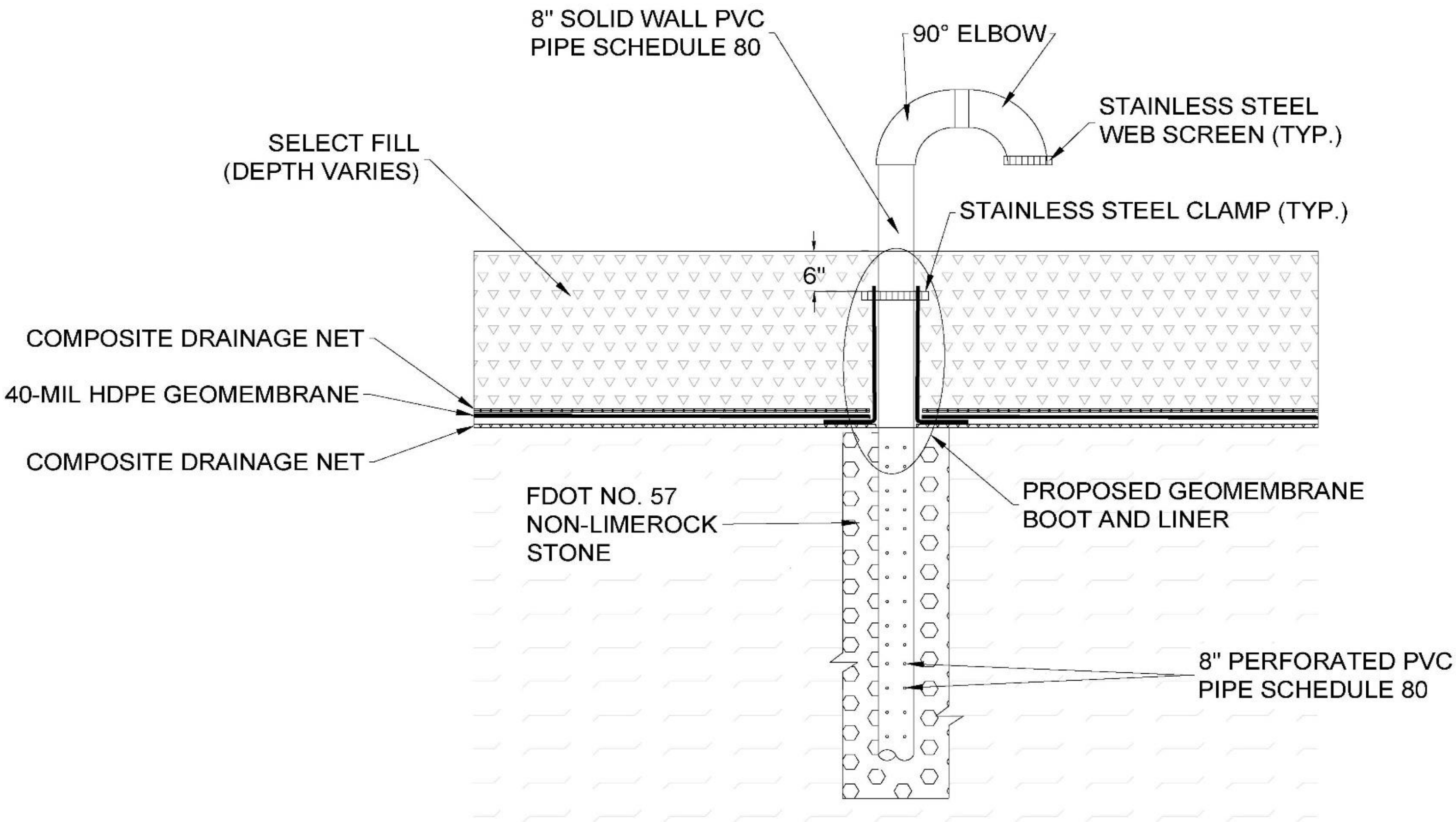
"2" for uncertainty or unknowns

Material	Average l/s·m (gpm/ft)	Repeatability Limit[b]	Reproducibility Limit[c]	95 % Confidence Repeatability Limit	95 % Confidence Reproducibility Limit
Geonet	2.18 (10.5)	7.0 %	7.3 %	19.8 %	20.5 %
Composite I	0.212 (1.02)	10.6 %	21.2 %	29.8 %	59.5 %
Composite II	0.92 (0.443)	15.2 %	42.6 %	44.8 %	125 %
Composite III	0.931 (4.48)	6.1 %	17.1 %	20.7 %	57.8 %

Range of Clogging Reduction Factors (GC8)

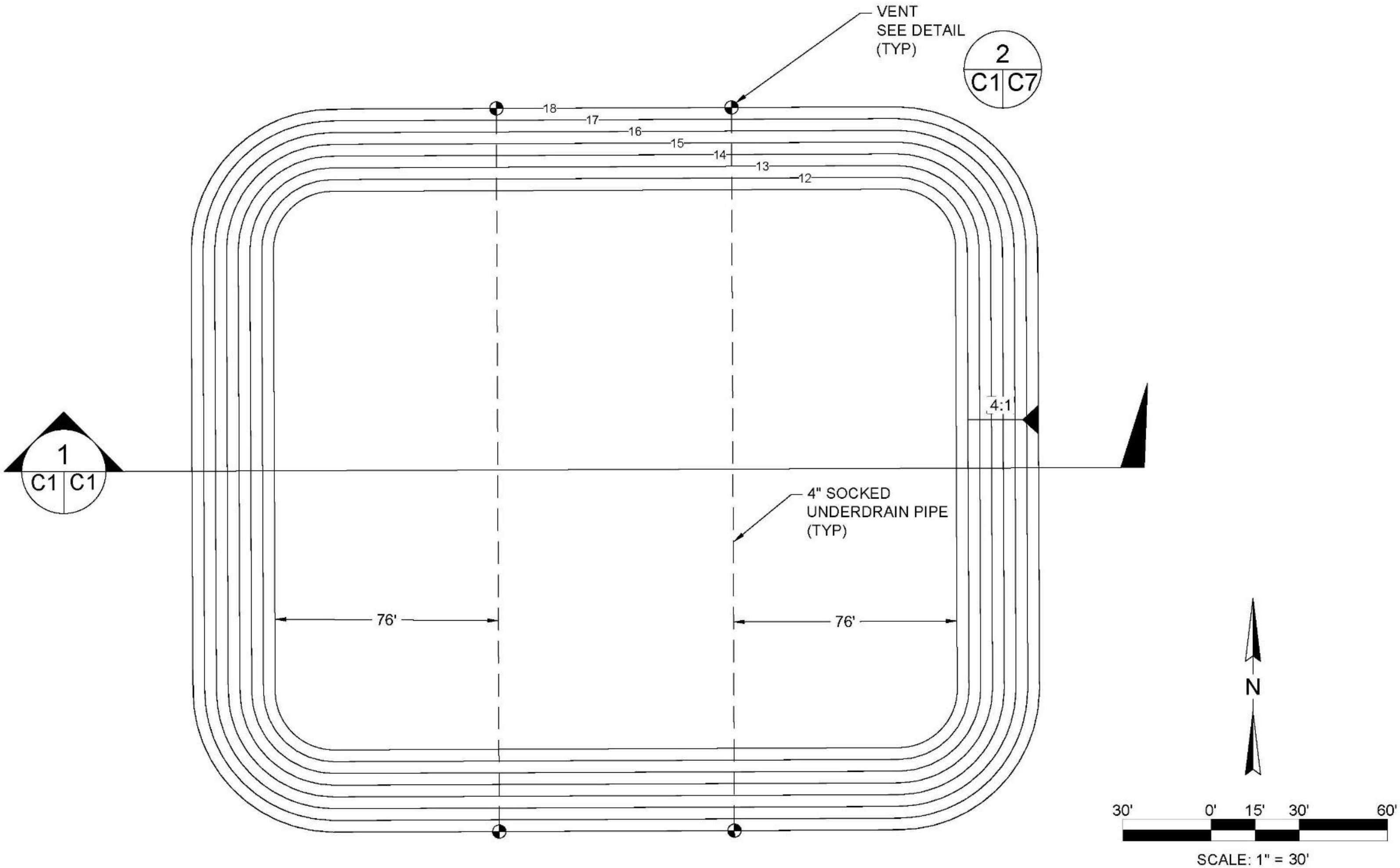
Application	Chemical Clogging (RFCC)	Biological Clogging (RFBC)
Sport fields	1.0 to 1.2	1.1 to 1.3
Capillary breaks	1.0 to 1.2	1.1 to 1.3
Roof and plaza decks	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock and soil slopes	1.1 to 1.5	1.0 to 1.2
Drainage blankets	1.0 to 1.2	1.0 to 1.2
Landfill caps	1.0 to 1.2	1.2 to 3.5
Landfill leak detection	1.1 to 1.5	1.1 to 1.3
Landfill leachate collection	1.5 to 2.0	1.1 to 1.3

Landfill Gas Venting under Liner System



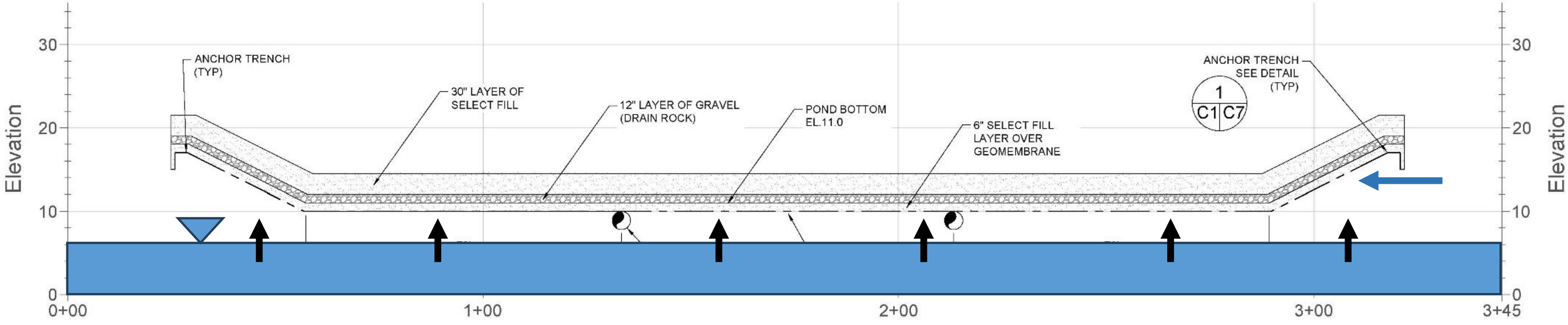
VENT DETAIL
NTS

Their Use in Ponds



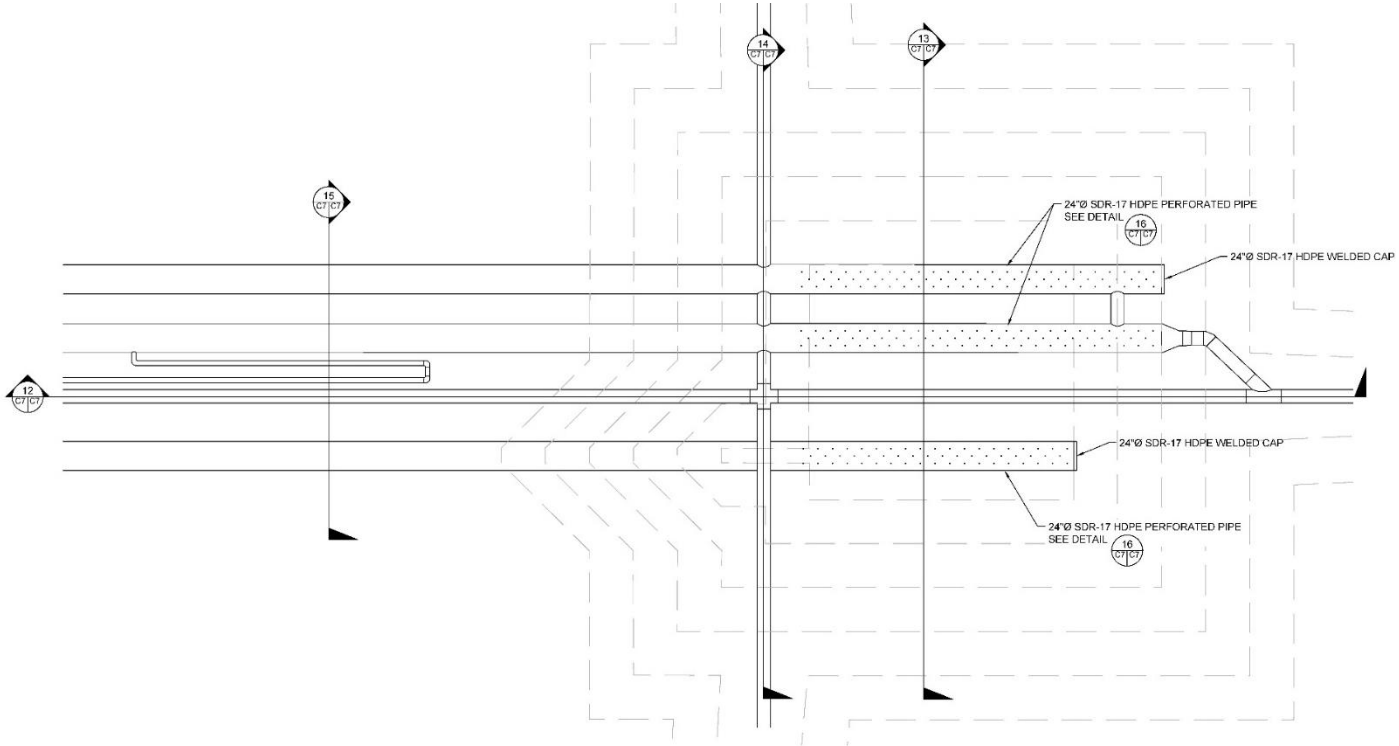
PONDS: A.1 & A.2

Their Use in Ponds

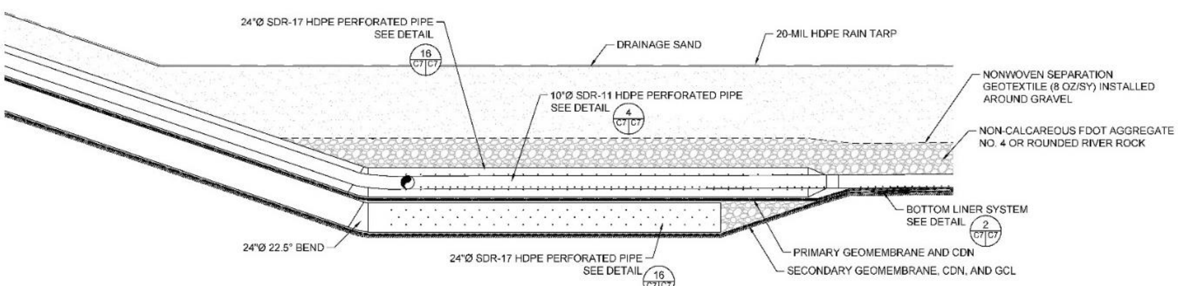


- Uplift of the geomembrane due to:
    - Rising of the groundwater table
    - Organic subgrade
    - Lateral flow of groundwater

Leachate Collection Sump

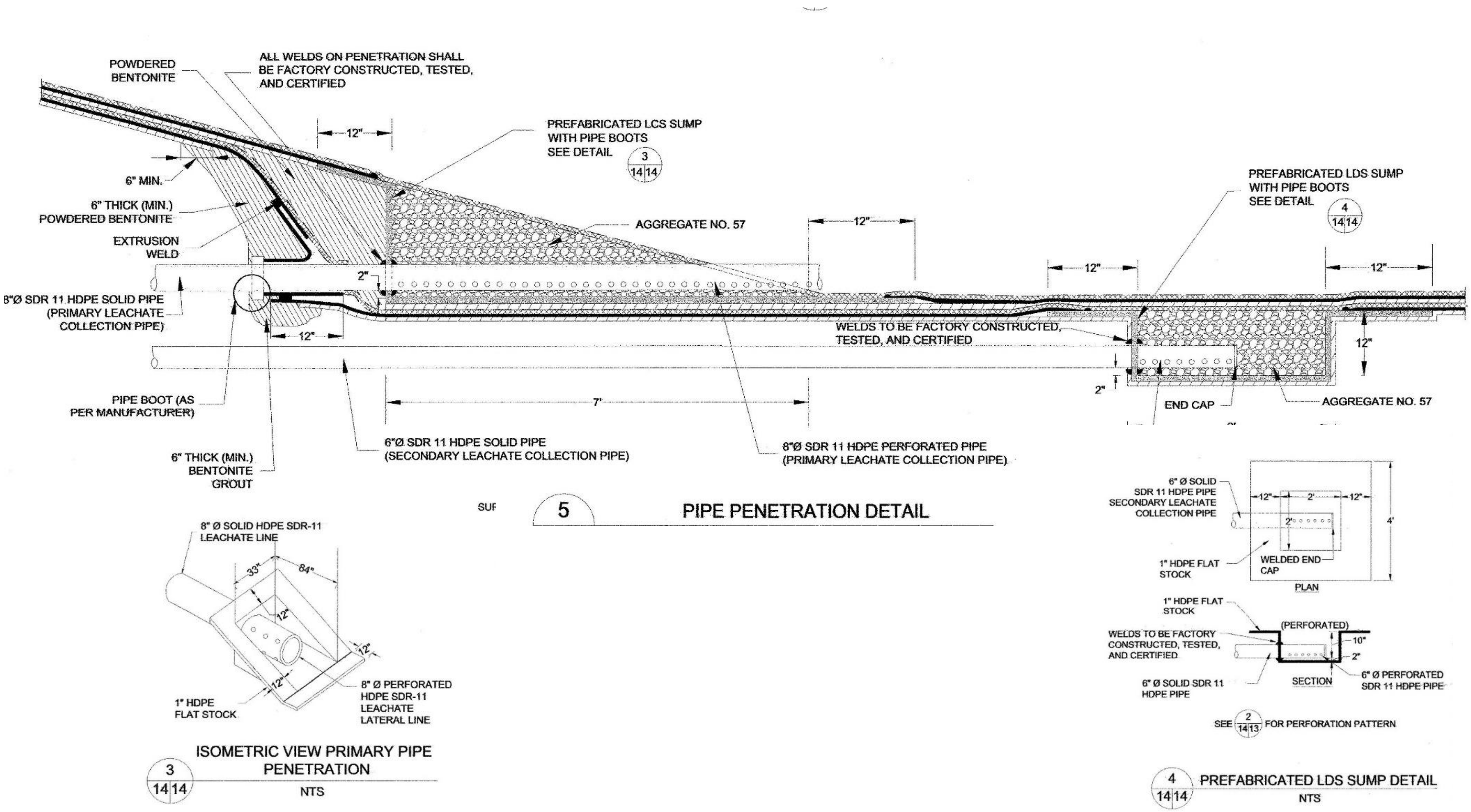


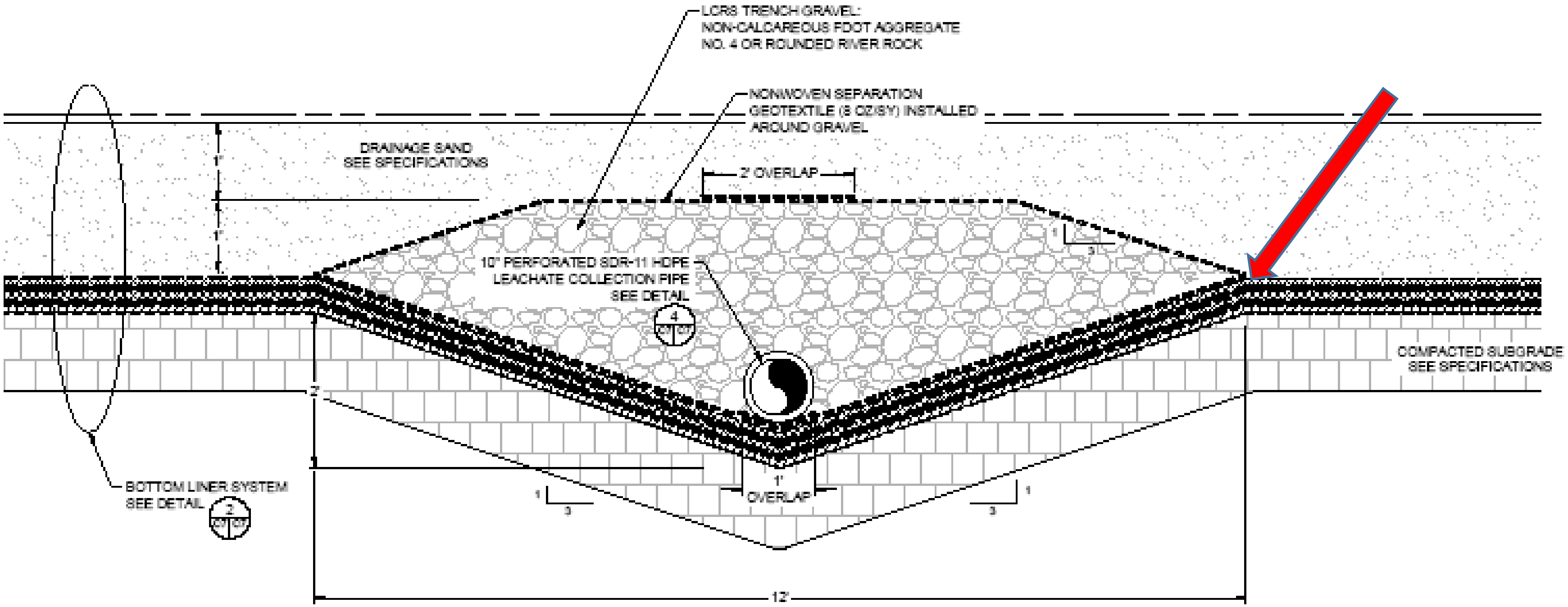
LEACHATE COLLECTION SUMP
SCALE: NTS



LEACHATE COLLECTION SUMP CROSS SECTION
SCALE: 1" = 4'

Leachate Removal by Gravity





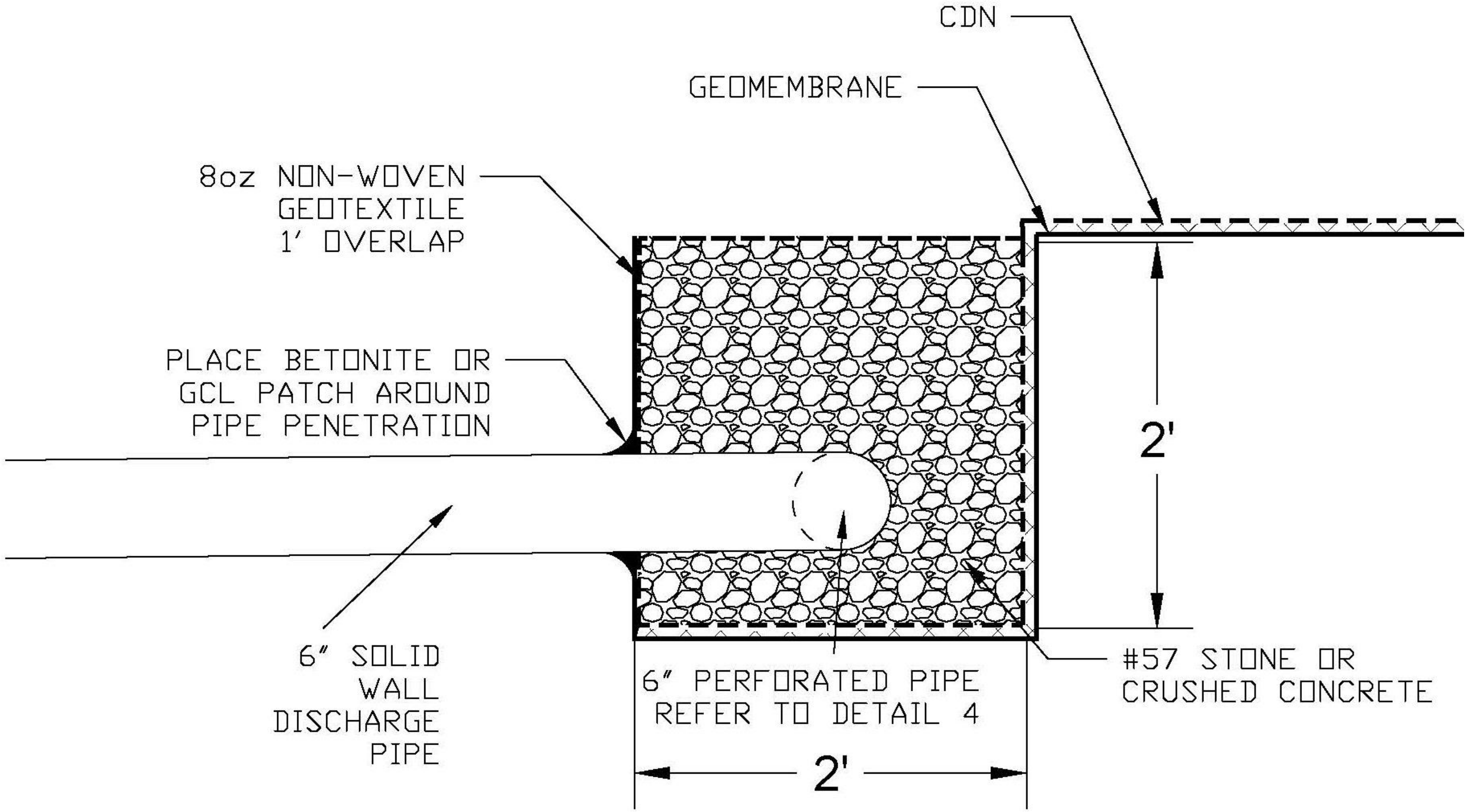
LEACHATE COLLECTION PIPING HEADER AND LATERAL TRENCH DETAIL

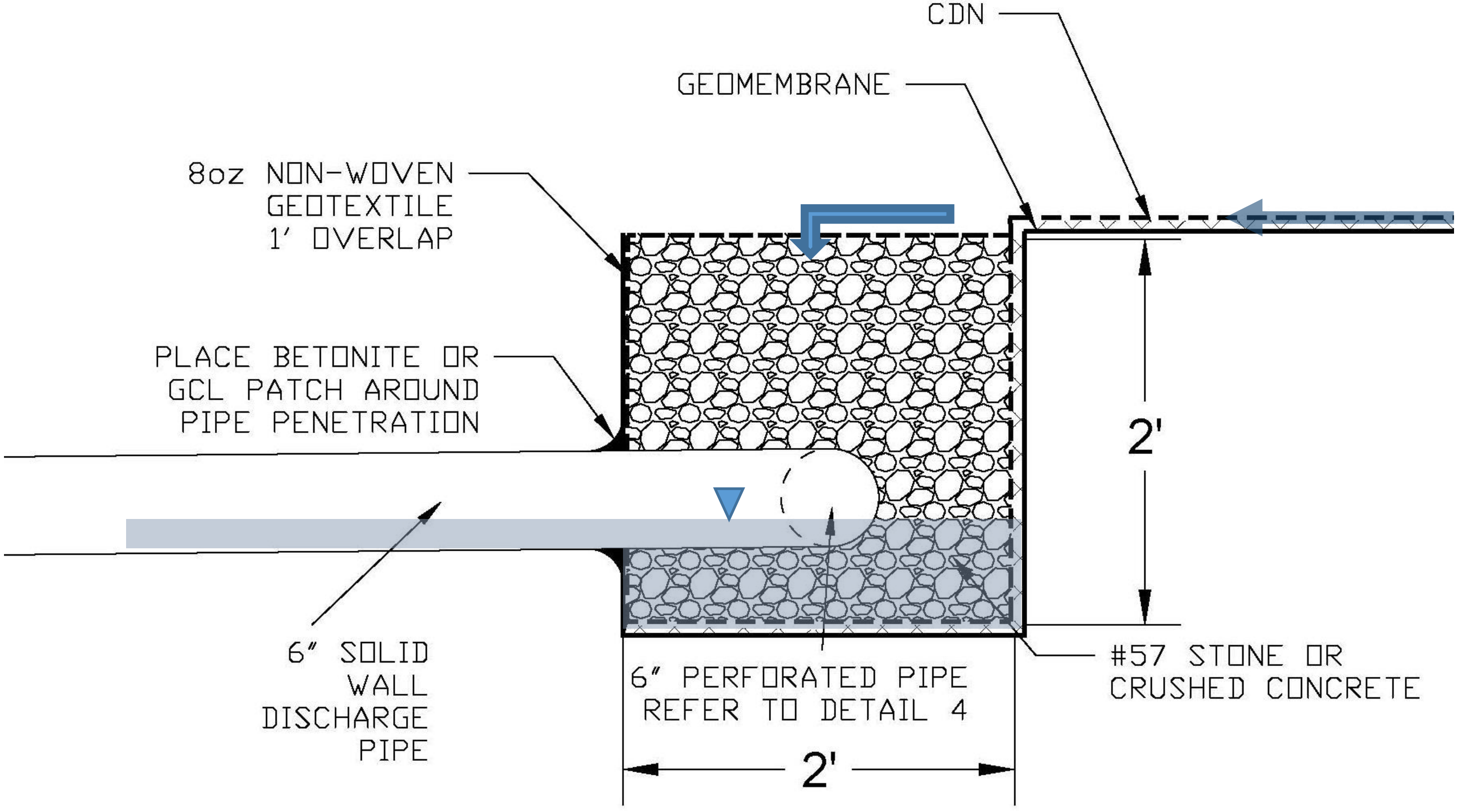
SCALE: 1" = 1'

NOTES:

1. LCRS TRENCH GRAVEL SHALL BE WRAPPED IN 8OZ/SY NONWOVEN GEOTEXTILE.
2. GEOTEXTILE ROLLS SHALL BE A MINIMUM 14' WIDTH, OVERLAPPING BY 1' AT THE BOTTOM OF THE TRENCH AND 2' AT THE TOP OF THE TRENCH.
3. LEACHATE HEADER PIPE SHALL BE 10"Ø SDR-11 HDPE PIPE.

Toe of Slope Trench Drain (Anchor Trench)

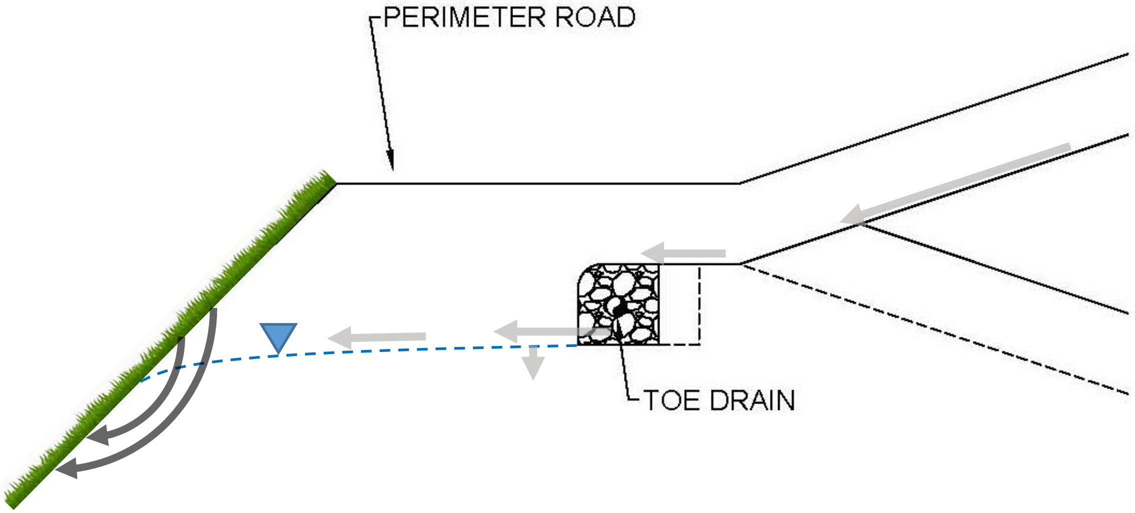




DETAIL 1A
(TYP. TOE DRAIN WITH DISCHARGE

Bad Toe Drain design

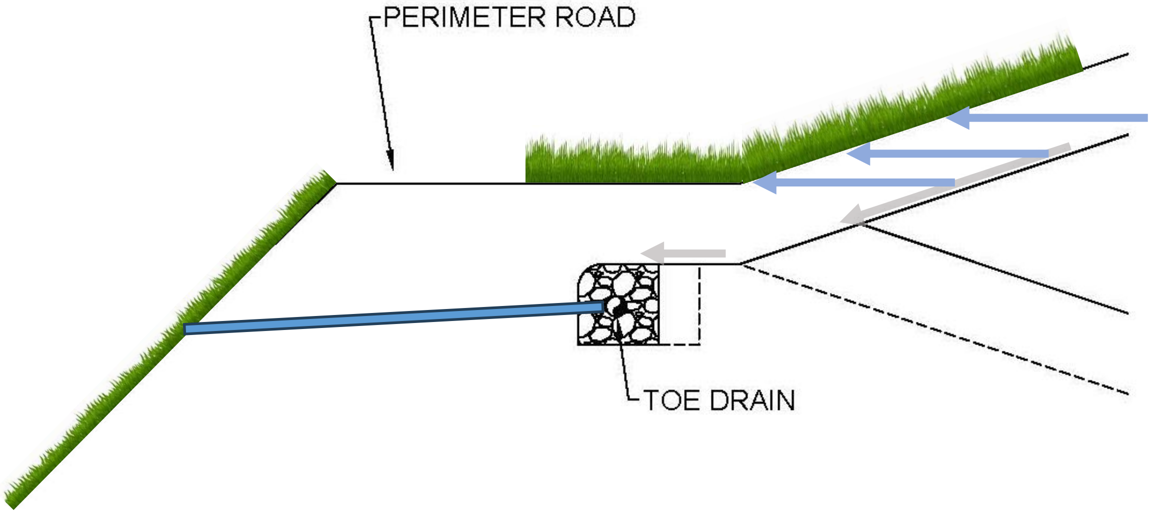
- **Contain the subsurface flow.**
- **If water cannot percolate down, it will flow laterally.**
- **CDN has high flow capacity**




Almost always flowing or trickling out the discharge pipe!

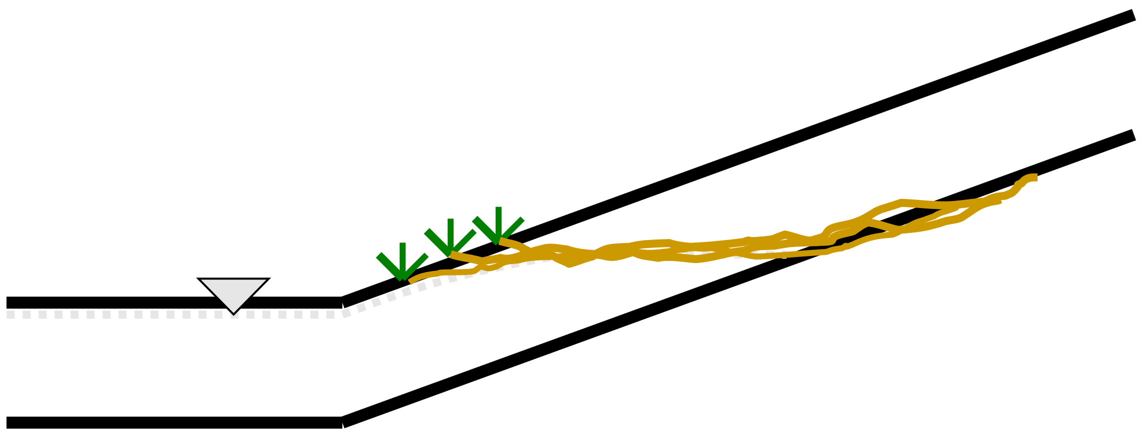
Another Bad Toe Drain design

- **Is this a failure?**
  - **Not catastrophic.**
- **Is this a failure?**
  - **Yes!**
  - **Increase in maintence cost.**
  - **Poor reflection on the engineering firm/design engineer!**



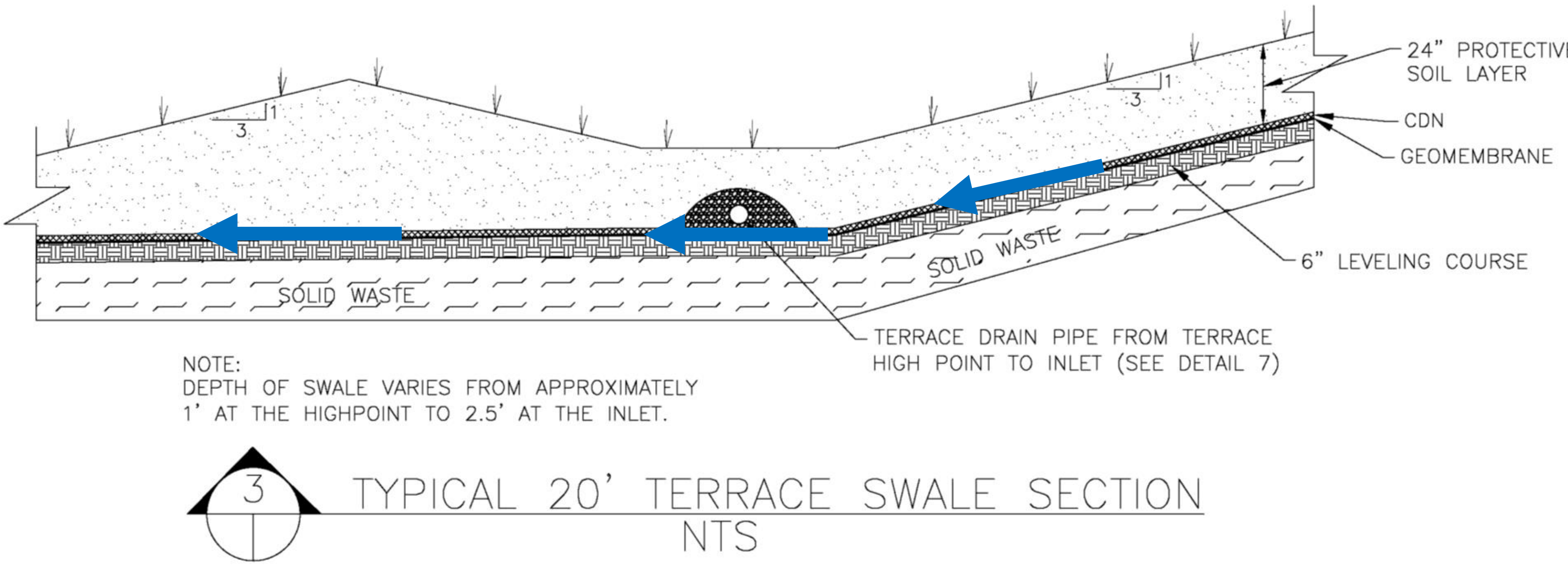
Do not try to Daylight the CDN

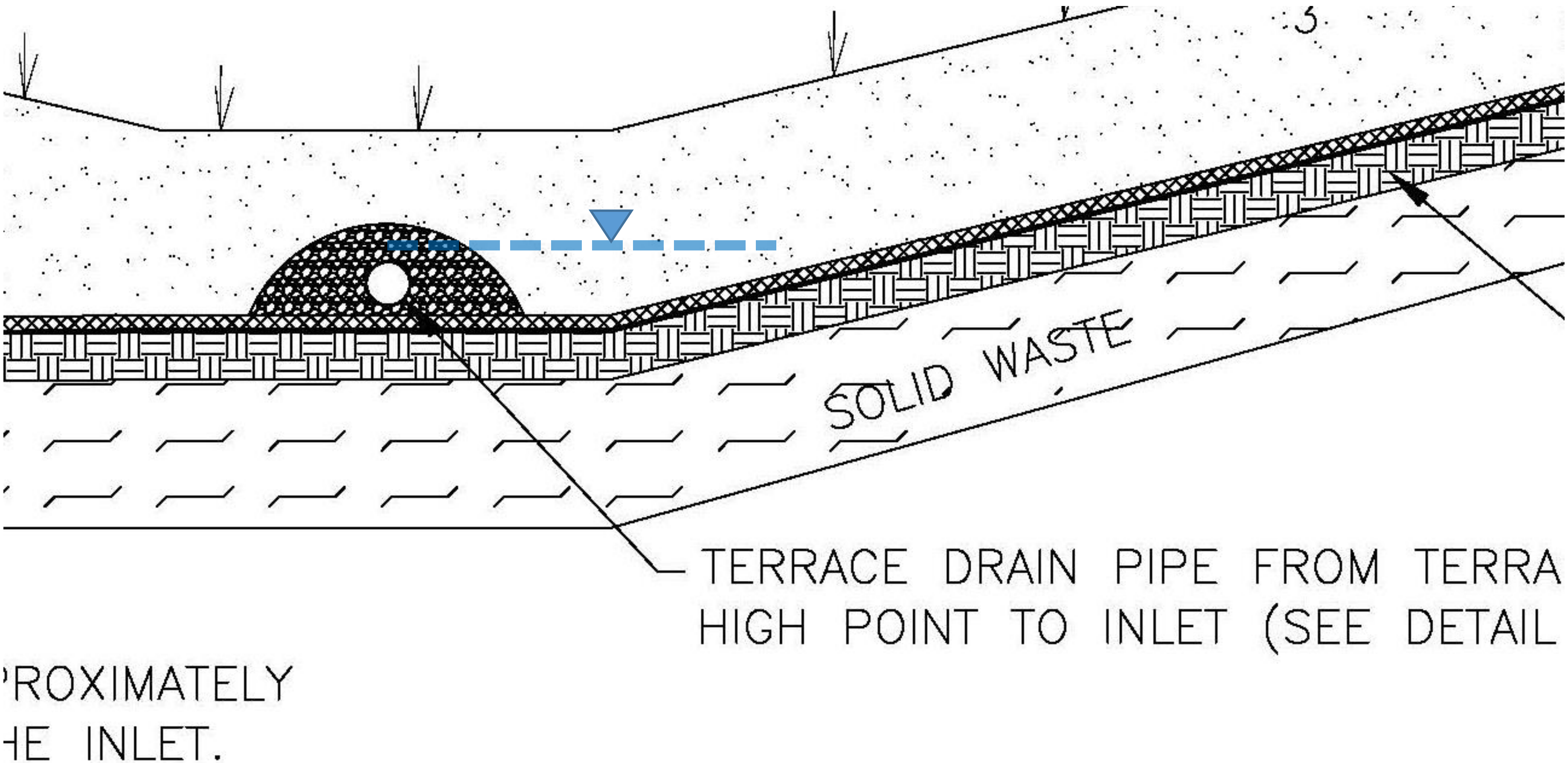
Roots following the available moisture:

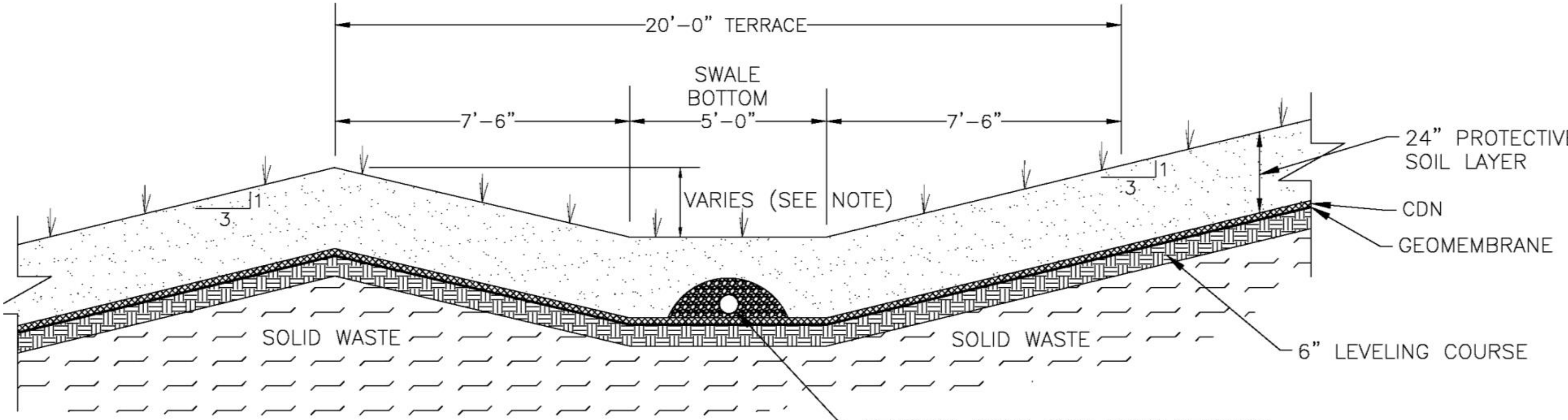


Water will take the easiest flowpath

Sorry for the Florida design!




SOLID WASTE
TERRACE DRAIN PIPE FROM TERRA
HIGH POINT TO INLET (SEE DETAIL
ROXIMATELY
HE INLET.

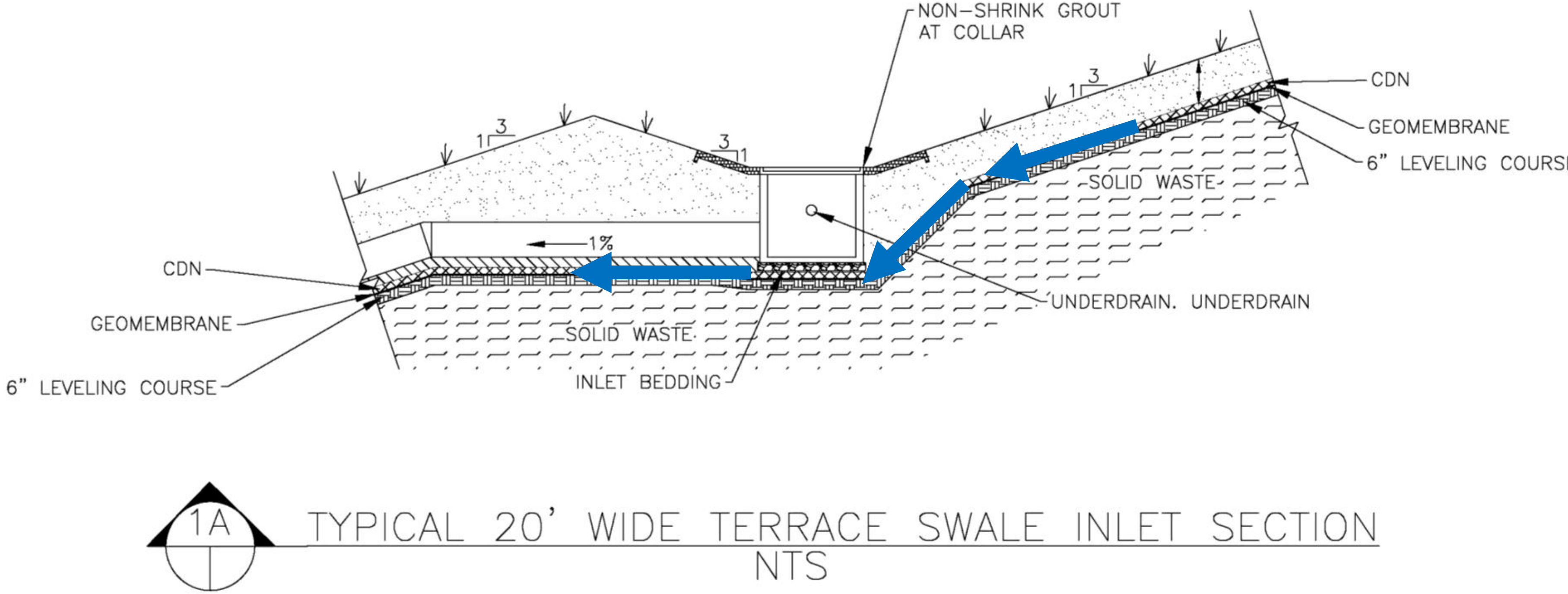


NOTE:
DEPTH OF SWALE VARIES FROM APPROXIMATELY 1' AT THE HIGHPOINT TO 2.5' AT THE INLET.

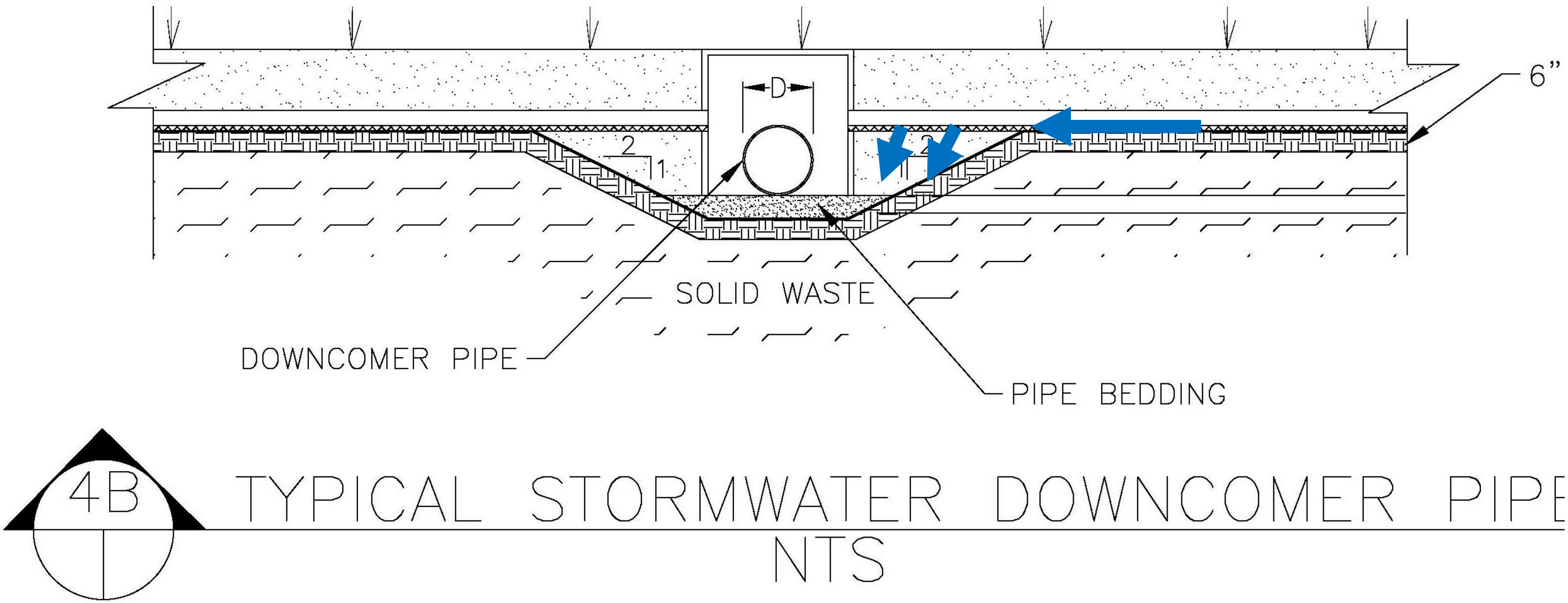
3

TYPICAL 20' TERRACE SWALE SECTION

NTS

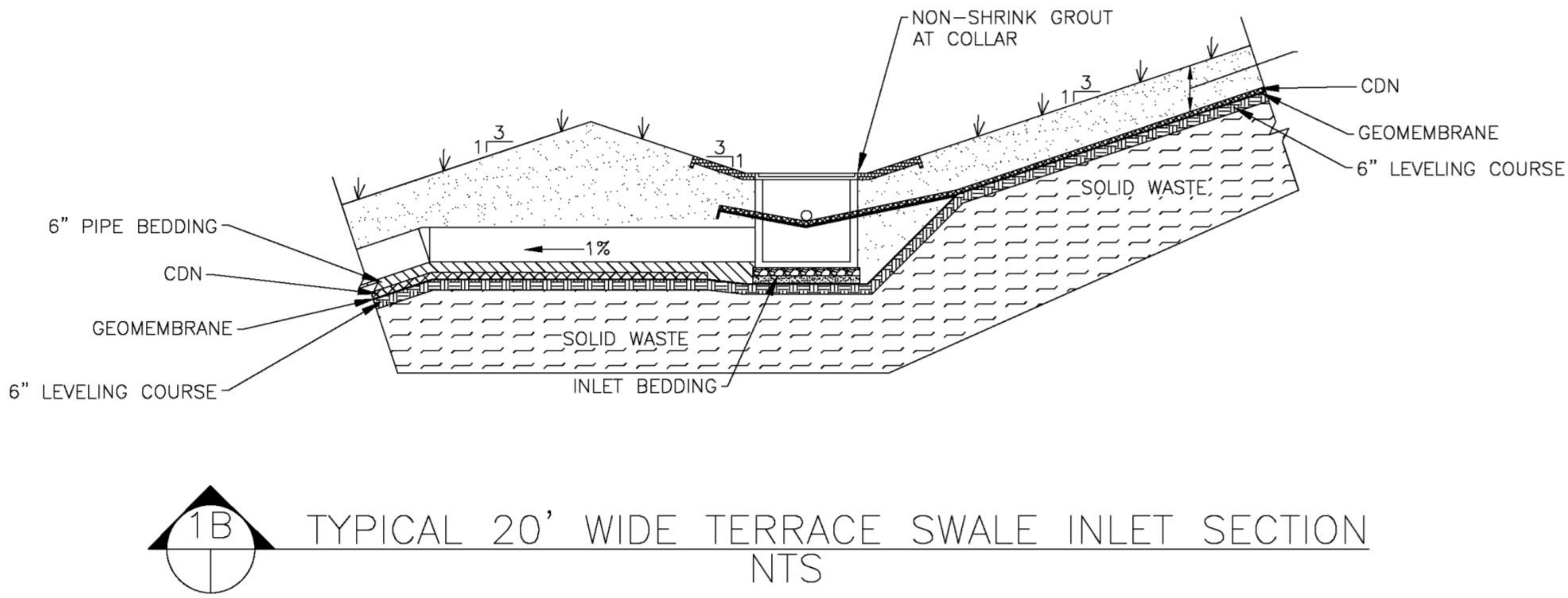


TYPICAL 20' WIDE TERRACE SWALE INLET SECTION
NTS



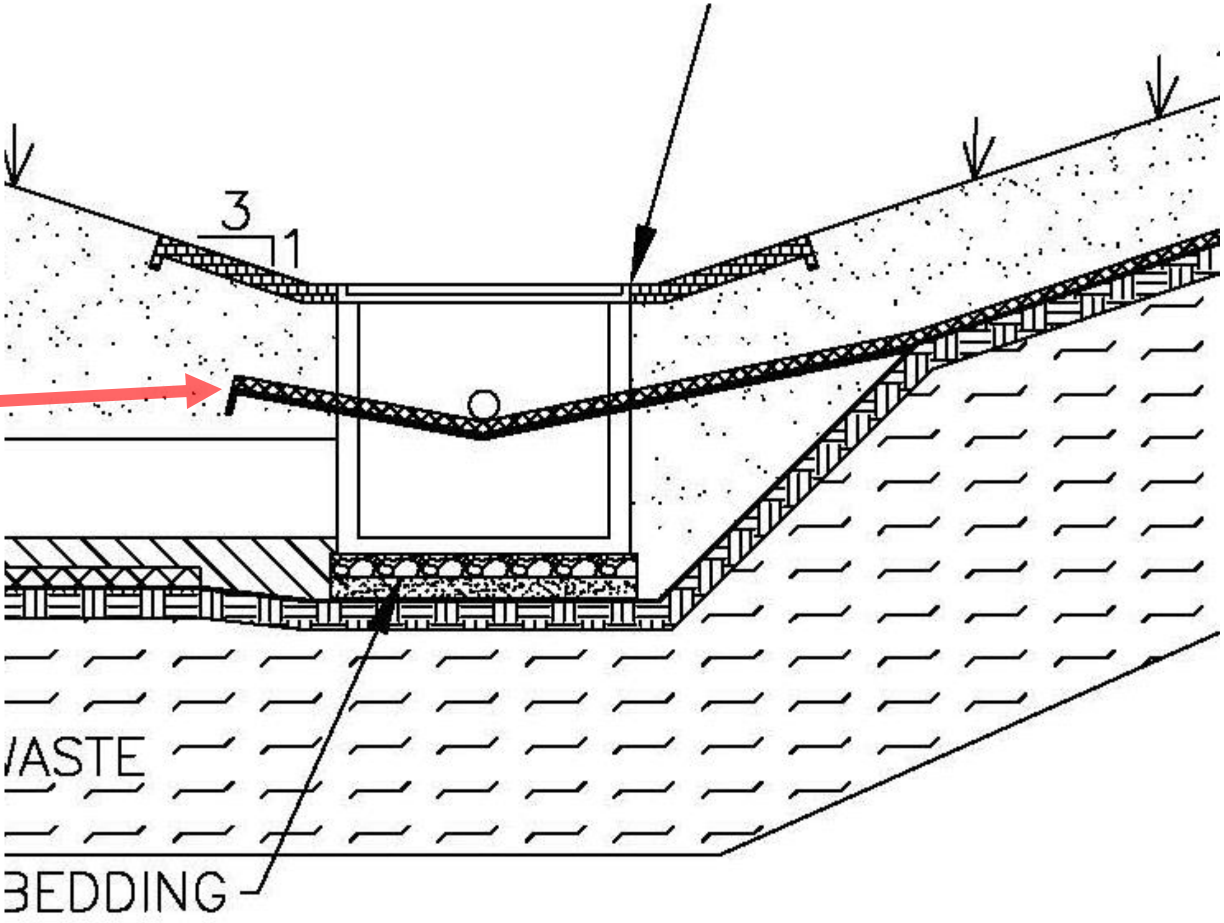
TYPICAL STORMWATER DOWNCOMER PIPE

NTS

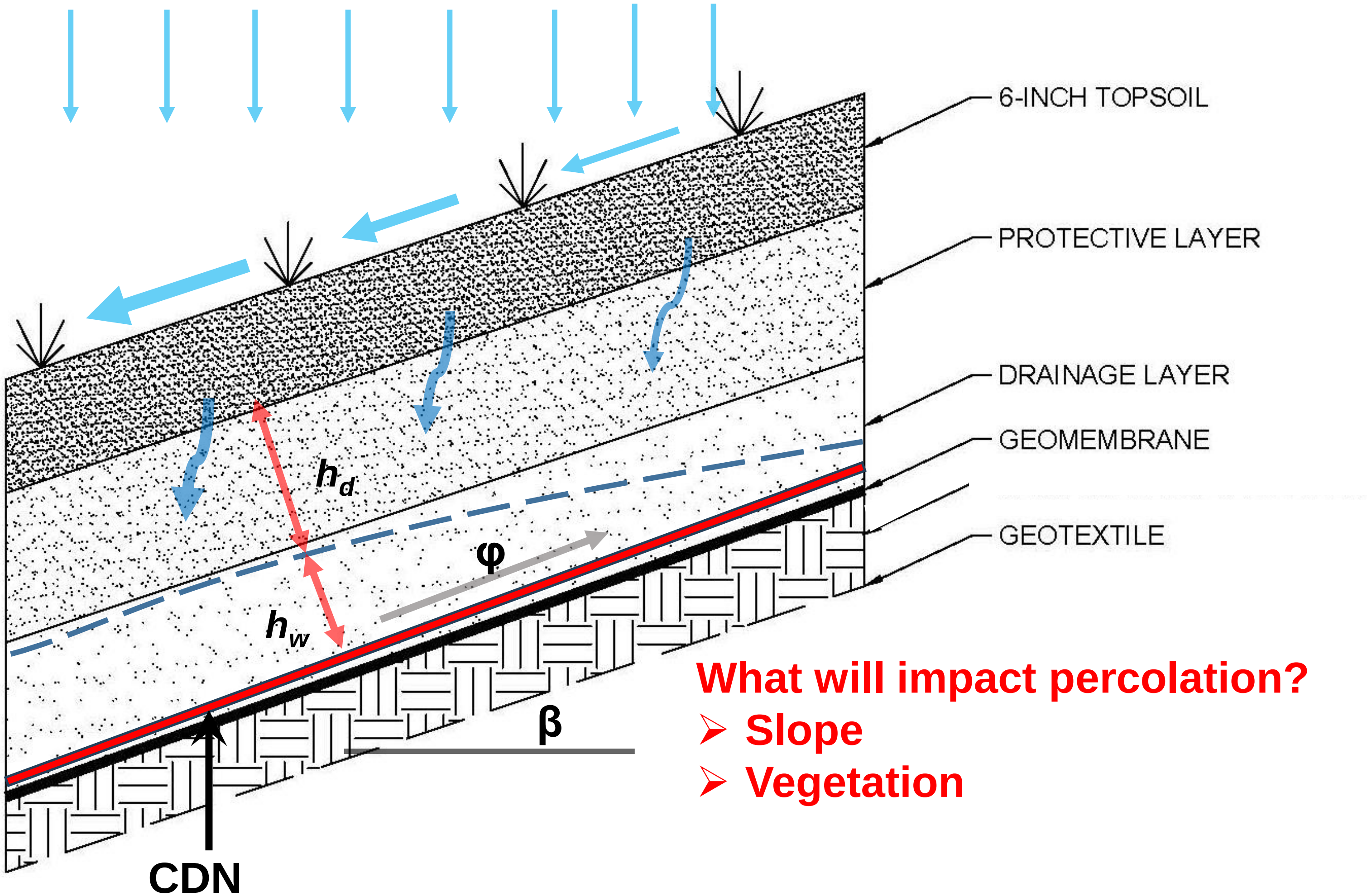


TYPICAL 20' WIDE TERRACE SWALE INLET SECTION
NTS

Geomembrane or GCL



Slope Stability



What will impact percolation?

- **Slope**
- **Vegetation**

$$F.S. = \frac{\left[h_t\gamma_t + \left(h_d - h_w\right)\gamma_{d_{dry}} + h_w\gamma_{d_{sat}} - h_w\gamma_w\right]\boxed{\tan\phi}}{\left[h_t\gamma_t + \left(h_d - h_w\right)\gamma_{d_{dry}} + h_w\gamma_{d_{sat}}\right]\tan\beta}$$

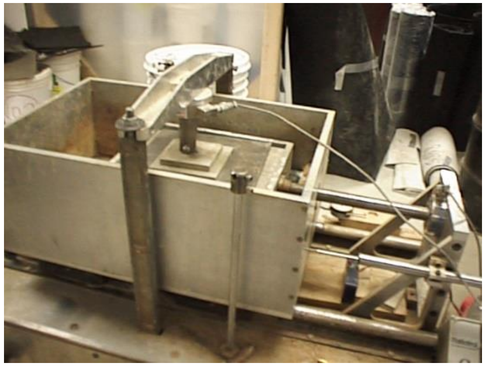
(1.5)

Obtained via Direct Sheer Test

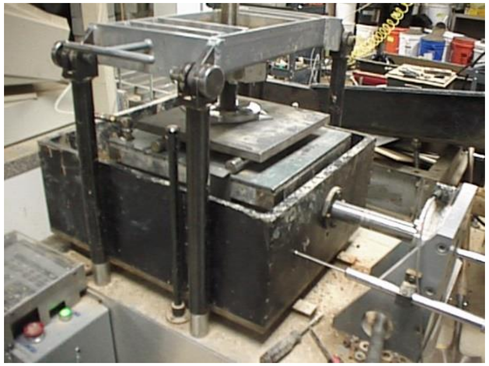
where:

h_t = thickness of topsoil (feet)
h_d = thickness of drainage layer (feet)
h_w = thickness of head over liner (feet)
γ_t = Unit weight of topsoil (pounds/cubic feet)
γ_t = Unit weight of drainage layer (pounds/cubic feet)
γ_t = Unit weight of water (62.4 pounds/cubic feet)
φ = friction angle for soil/geosynthetic interface
β = angle of slope

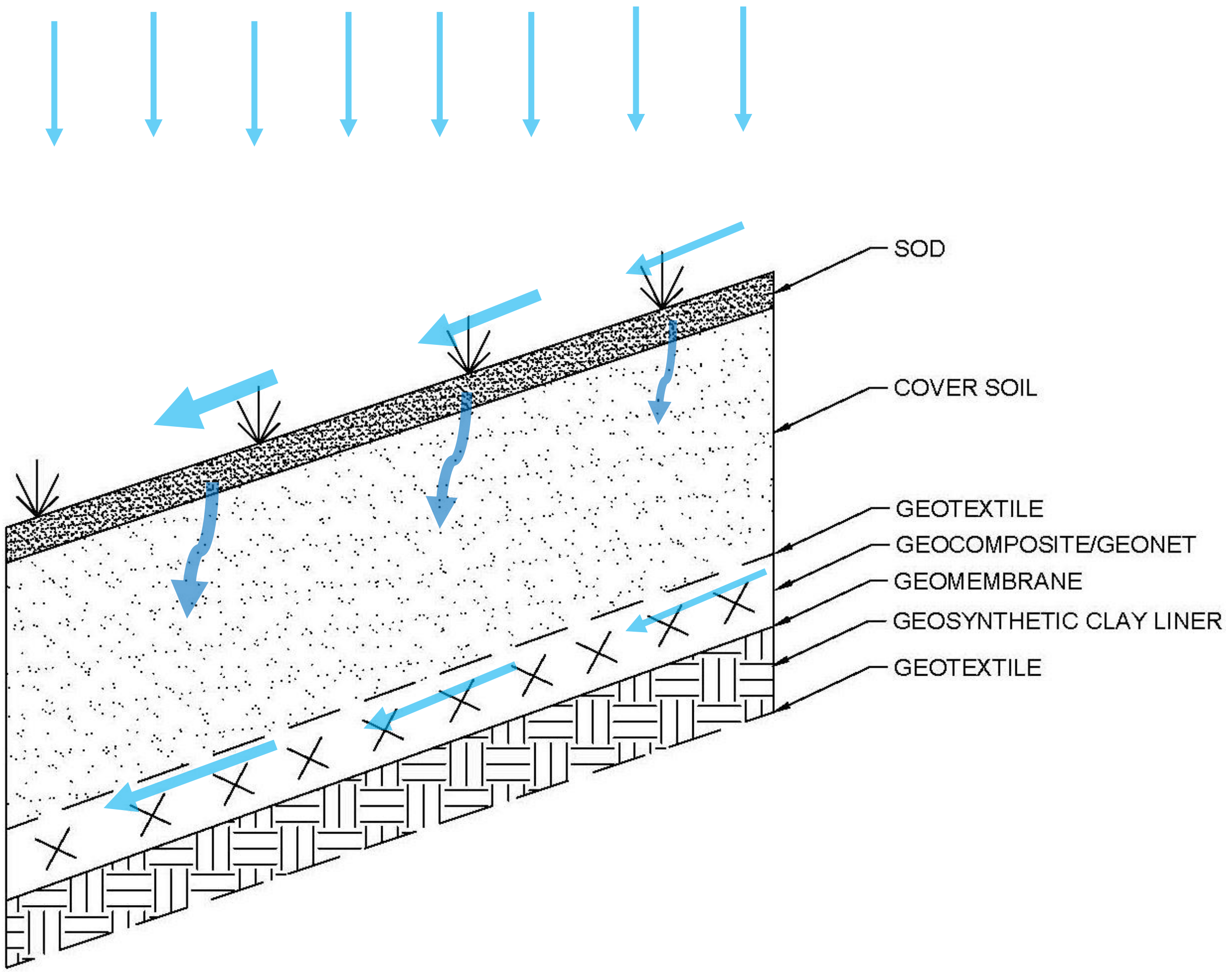
Large Direct Shear



Low-pressure shear box
σ_n = 50 to 3,000 psf
300 × 300 mm specimen
Δ = 75 mm



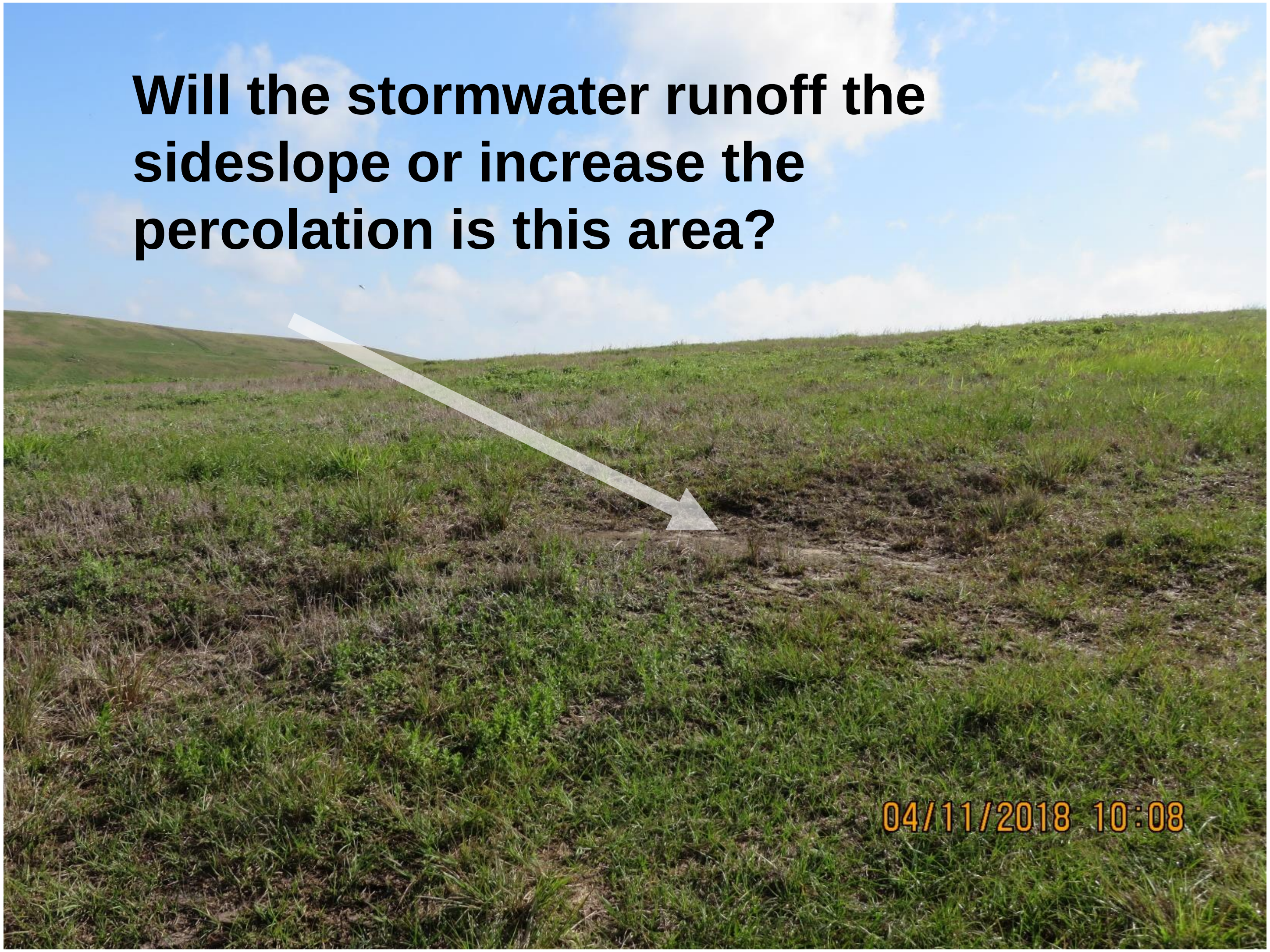
High-pressure shear box
σ_n = 1000 to 28,000 psf
(up to 58,000 psf on 150 by 150)
300 × 300 mm specimen
Δ = 75 mm

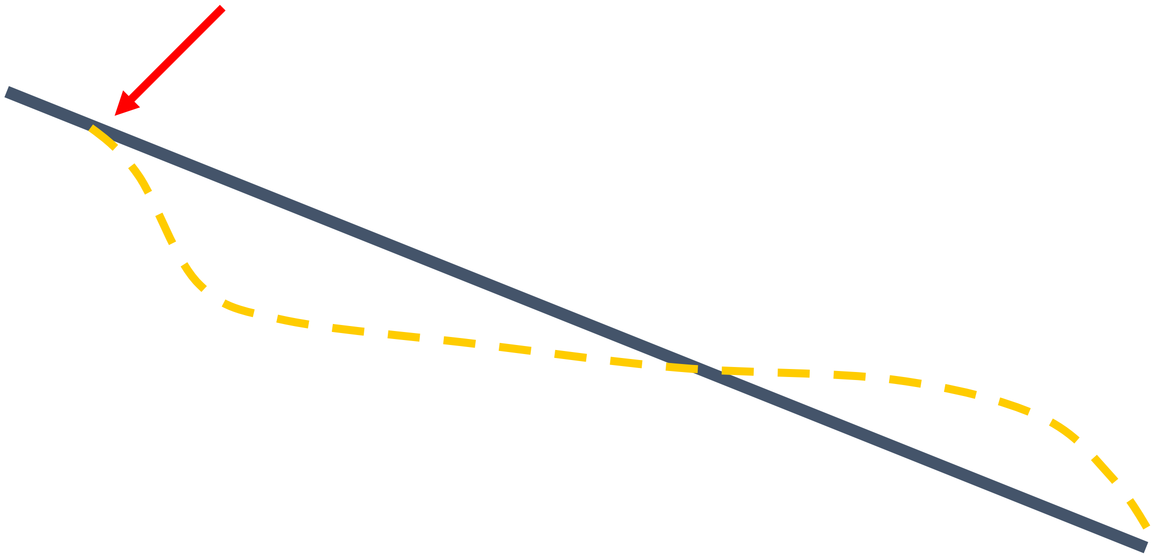

SOD
COVER SOIL
GEOTEXTILE
GEOCOMPOSITE/GEONET
GEOMEMBRANE
GEOSYNTHETIC CLAY LINER
GEOTEXTILE

What hydraulic conductivity (k) to use within the calculation?

The lowest hydraulic conductivity soil within the cover soil profile.

- **Topsoil?**
- **Drainage layer?**
- **Protective layer**
- ***Use a conservative "k"!!!!***


Will the stormwater runoff the sideslope or increase the percolation is this area?
04/11/2018 10:08



Sideslope Sloughing or Settlement

BOB’S RULES OF LANDFILL CLOSURE

Any stormwater issue without being immediately address can quickly go from:

- **A $500 repair,**
- **To a $5,000 repair,**
- **To a $50,000 repair.**

What Can we learn from examples?

- Soil/CDN is overly saturated.
- What is the cause?
  - The above terrace is not removing the subsurface flow.
  - Clogging of the geotextile?
  - CDN is not draining

What Can we learn from examples?

- **Soil/CDN is overly saturated.**
- **Slope failure?**
  - **Not a total veneer failure**
  - **Increased maintenance**
- **What can be done here?**
  - **Not much**
  - **<u>Continued regular mowing</u>**

Bob's Rule of Thumb?

- **Sloughing within the upper portion of the slope -**
  - **Failure within the upper terrace**
- **Sloughing within the lower portion of the slope –**
  - **CDN not draining**
  - **CDN is undersized**

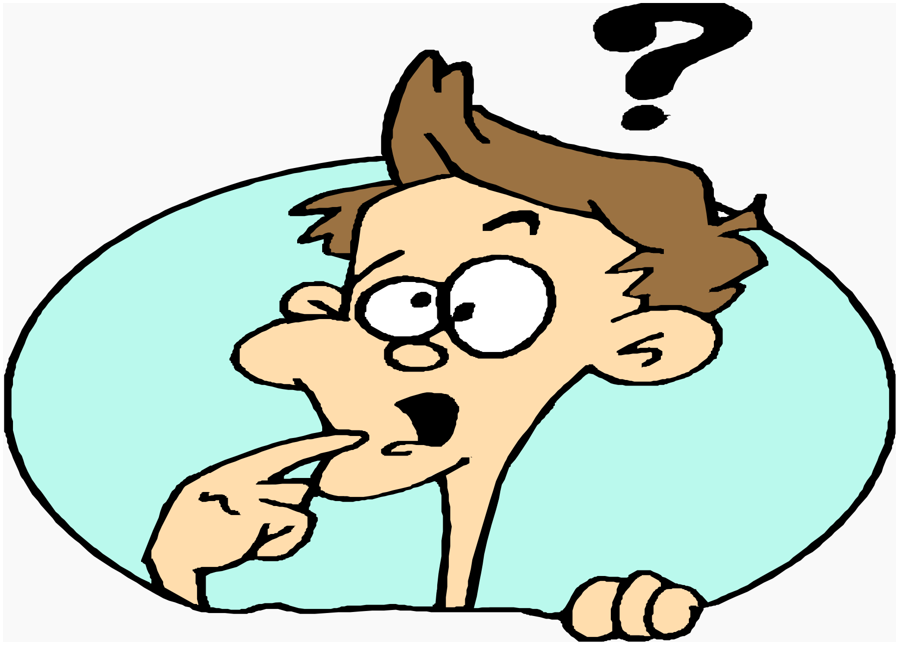
Summary

- GDLs/CDNs are a high flow capacity drainage material
  - Only if they are protected from the infiltration of soil!
- Bring the liquid within the GDLs/CDNs to the discharge point and contain it there.
- GDLs/CDNs can be use to evacuate gases under the liner system.

- Final Note – The more critical their use within a design the greater the safety factor for the specified transmissivity.

Questions?

Thank you for attending!!



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