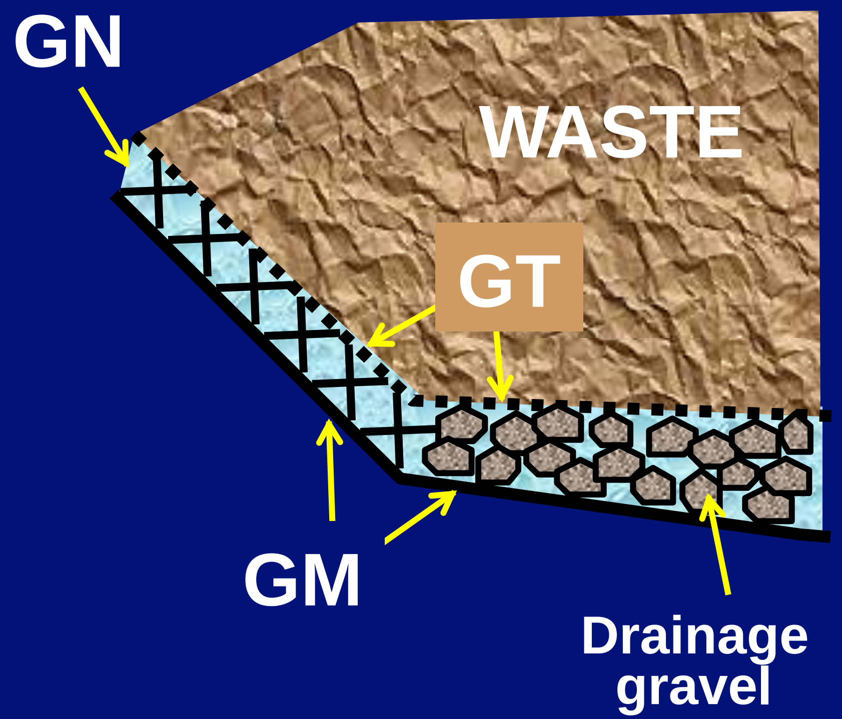
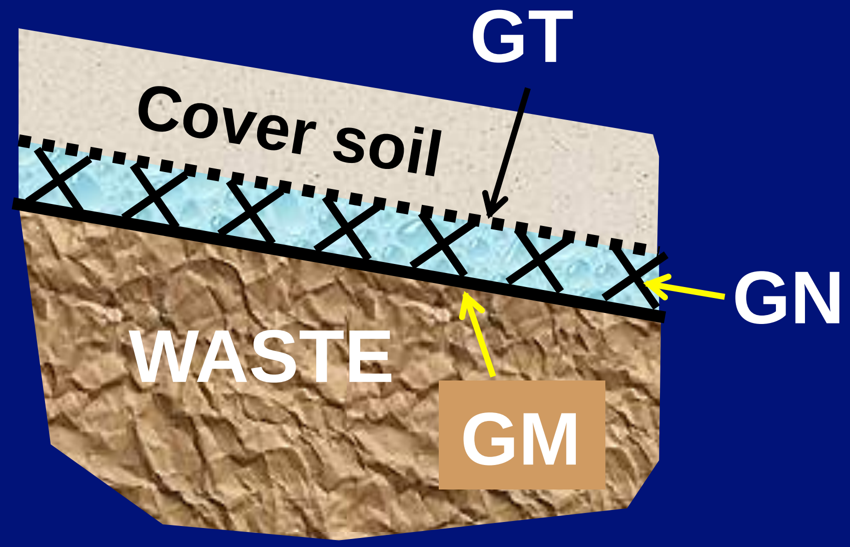
3.3(a) Geotextile Filter for Primary Leachate Collection Layer Design

also applies to

the GT Filter in the Cover Soil





Provide Adequate Flow

$$FS = \frac{k_{allow}}{k_{reqd}} \text{ or } \frac{\psi_{allow}}{\psi_{reqd}}$$

where

k = permeability
ψ = permittivity = k/t
t= thickness

furthermore:

ψ_{allow} = ASTM D4491
(modified for site specific reduction factors) ψ_{reqd}
= leachate (or surface water) generation

Provide Adequate Particle Retention

$$FS = \frac{\lambda d_{85}}{0_{95}}$$

where

λ = 2 to 5

d_{85} = particle size of upstream soil

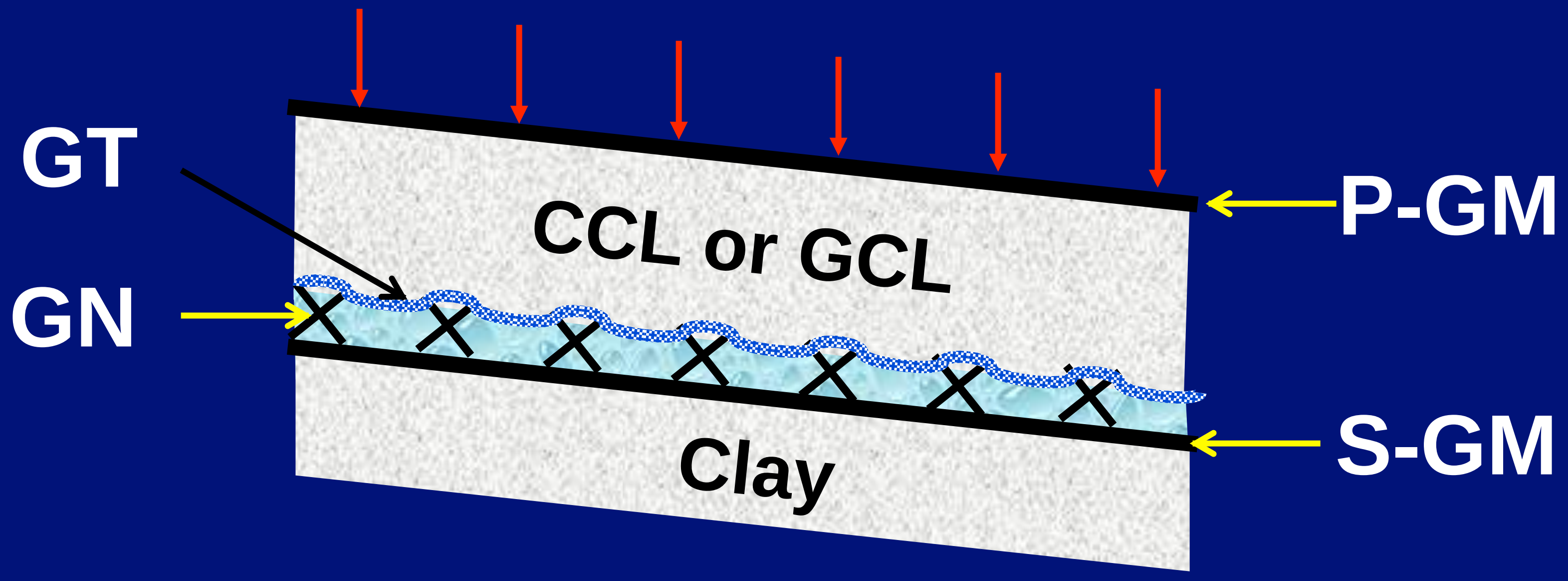
0_{95} = GT opening size (ASTM D4751)

Check Against Excessive Clogging

- long term flow test (ASTM D1987)

- more discussion later

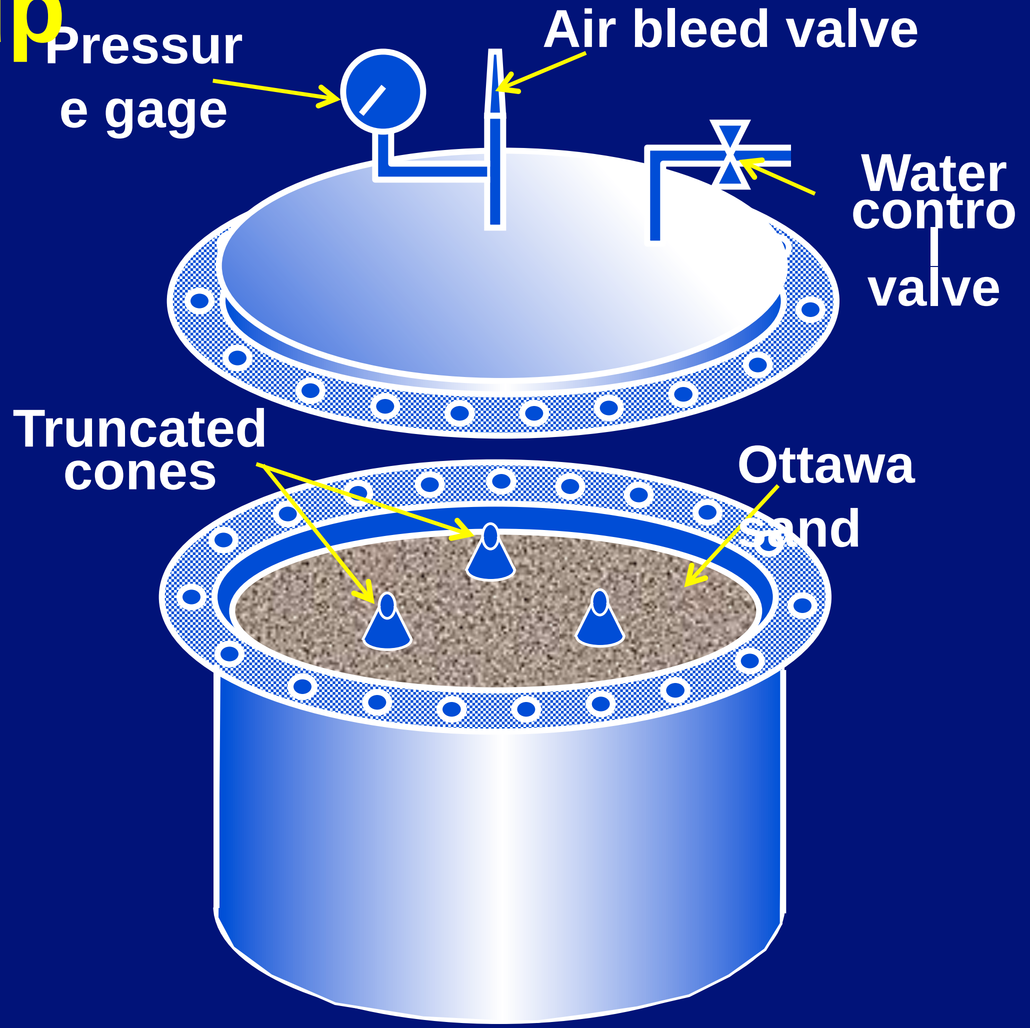
3.3(b) Geotextile Separator Between CCL or GCL and Leak Detection Geonet or Geocomposite

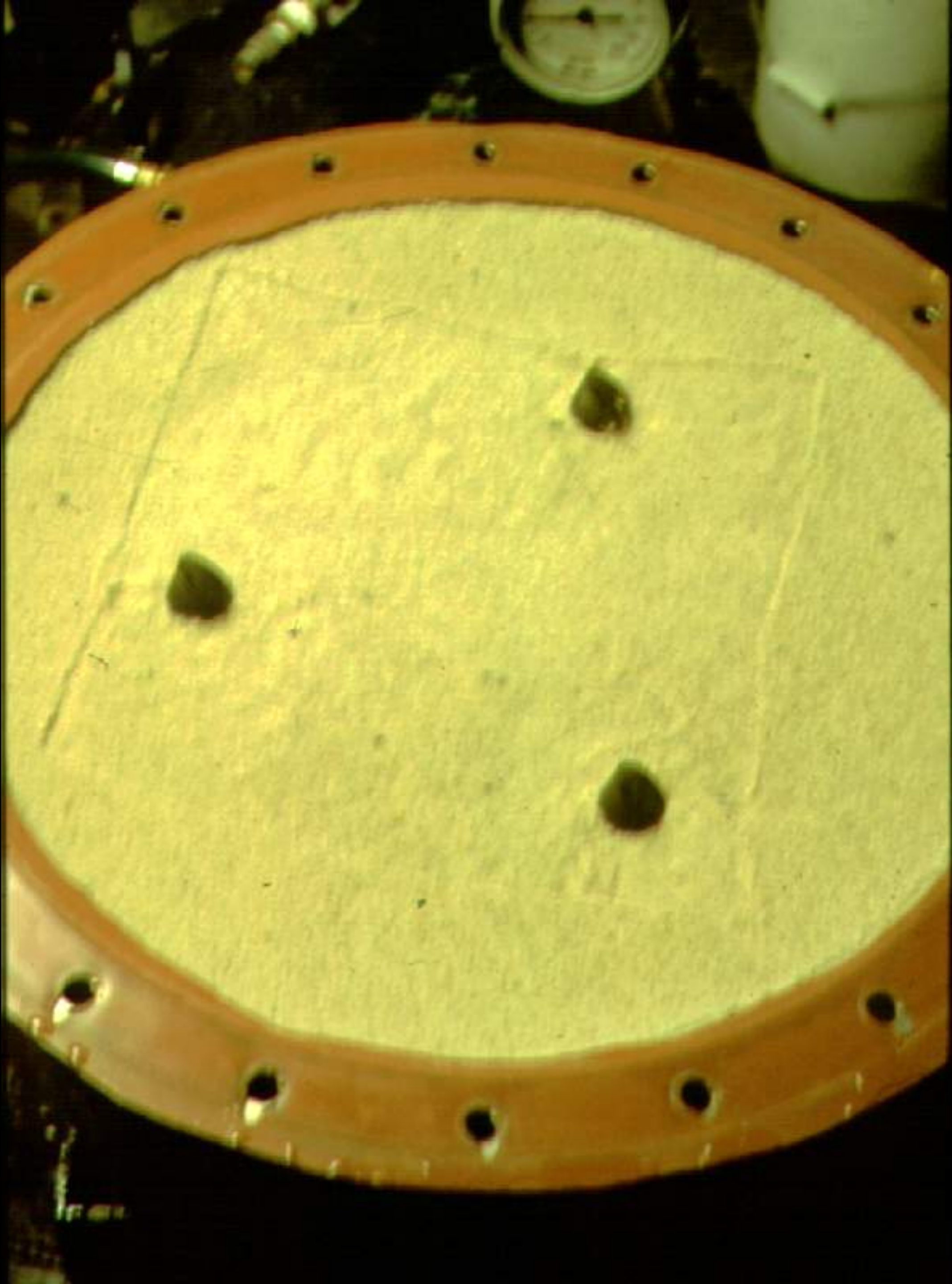


- completely empirical design
- needs simulated lab testing to verify
- of great regulatory concern
- intrusion can be accommodated
- extrusion cannot be handled without GN clogging

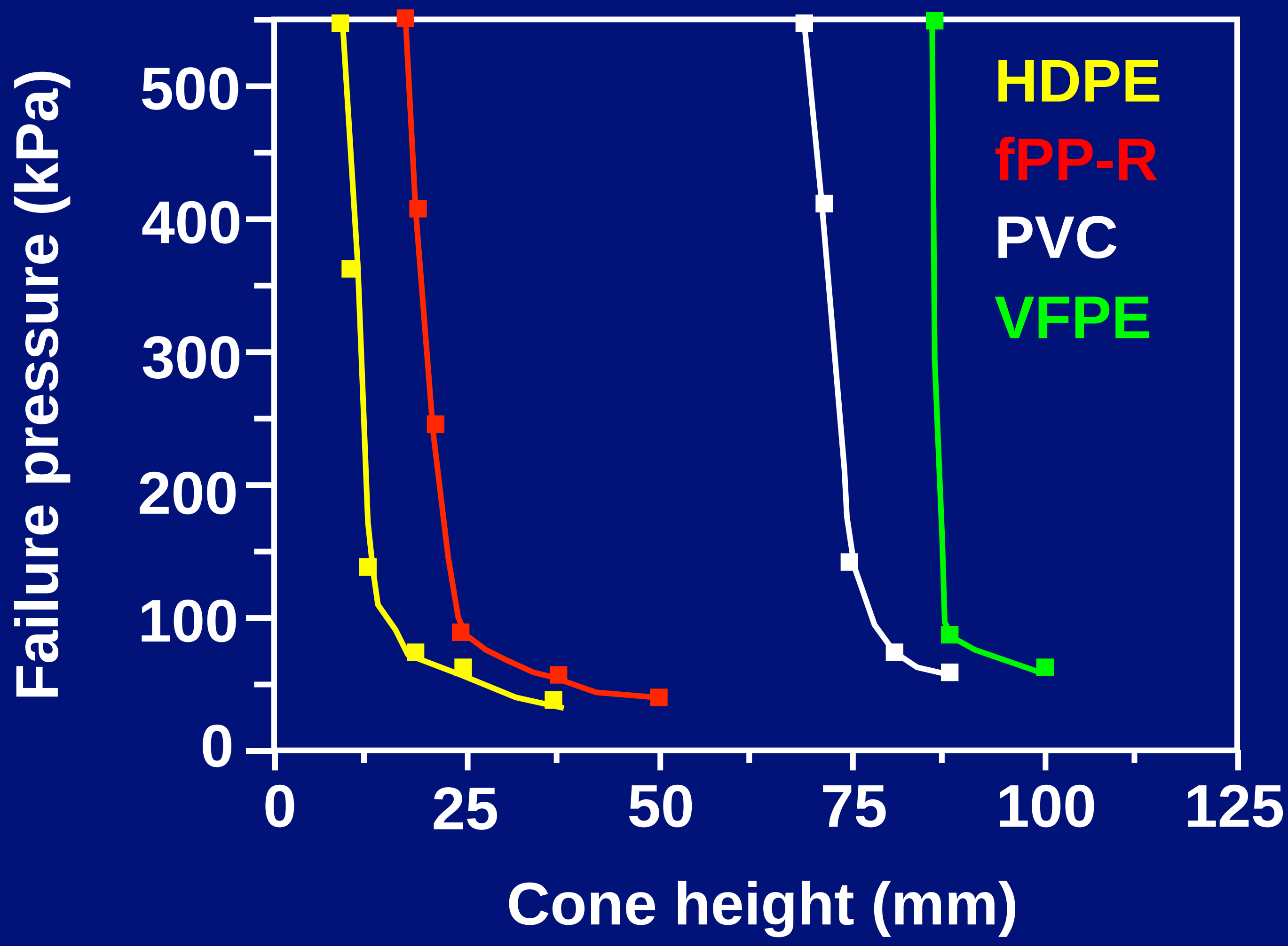
3.3(c) Geotextile Puncture Protection for Geomembranes

Truncated Cone Puncture Test Setup



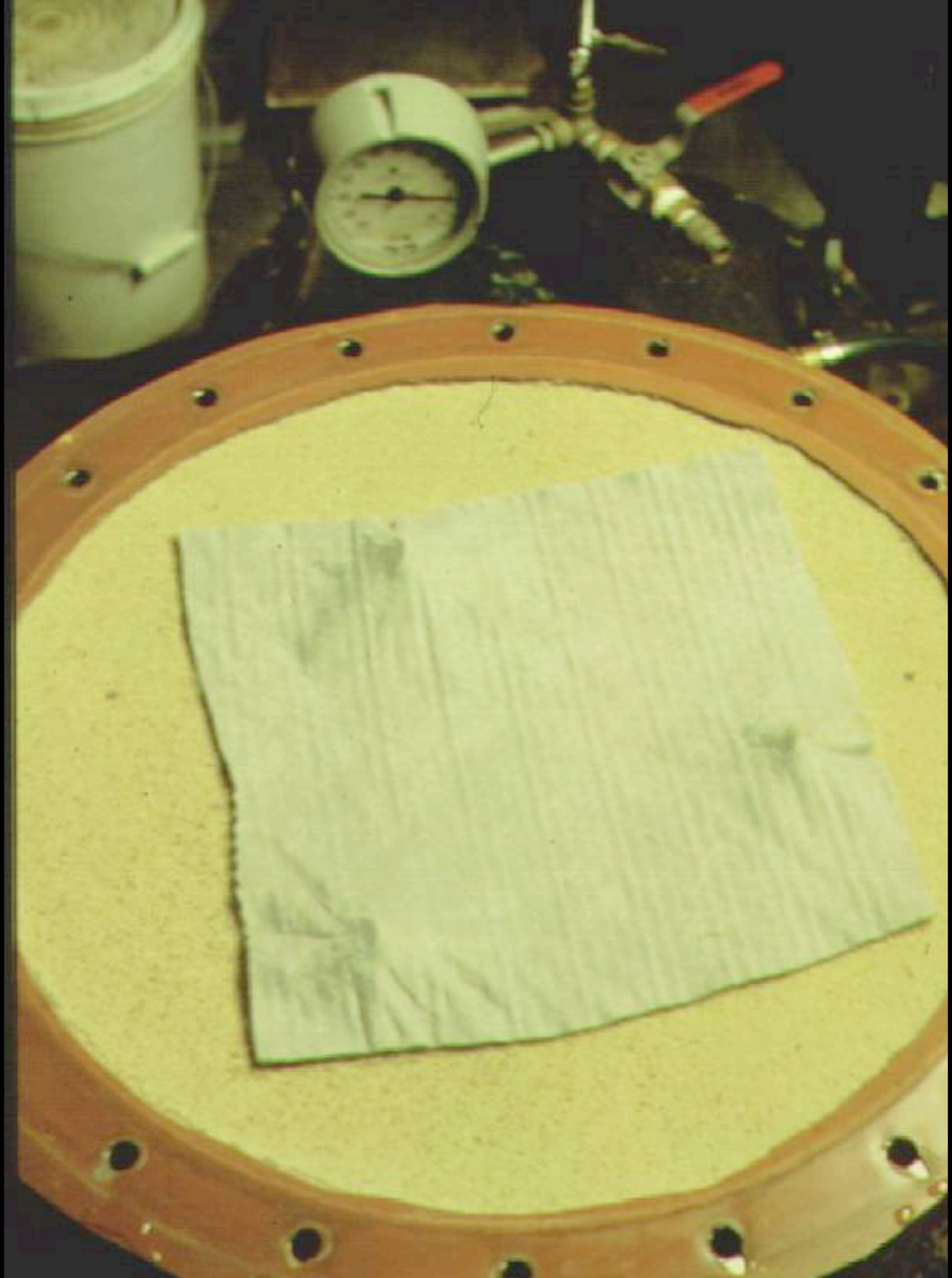


Truncated Cone Puncture Resistance of Different Geomembranes

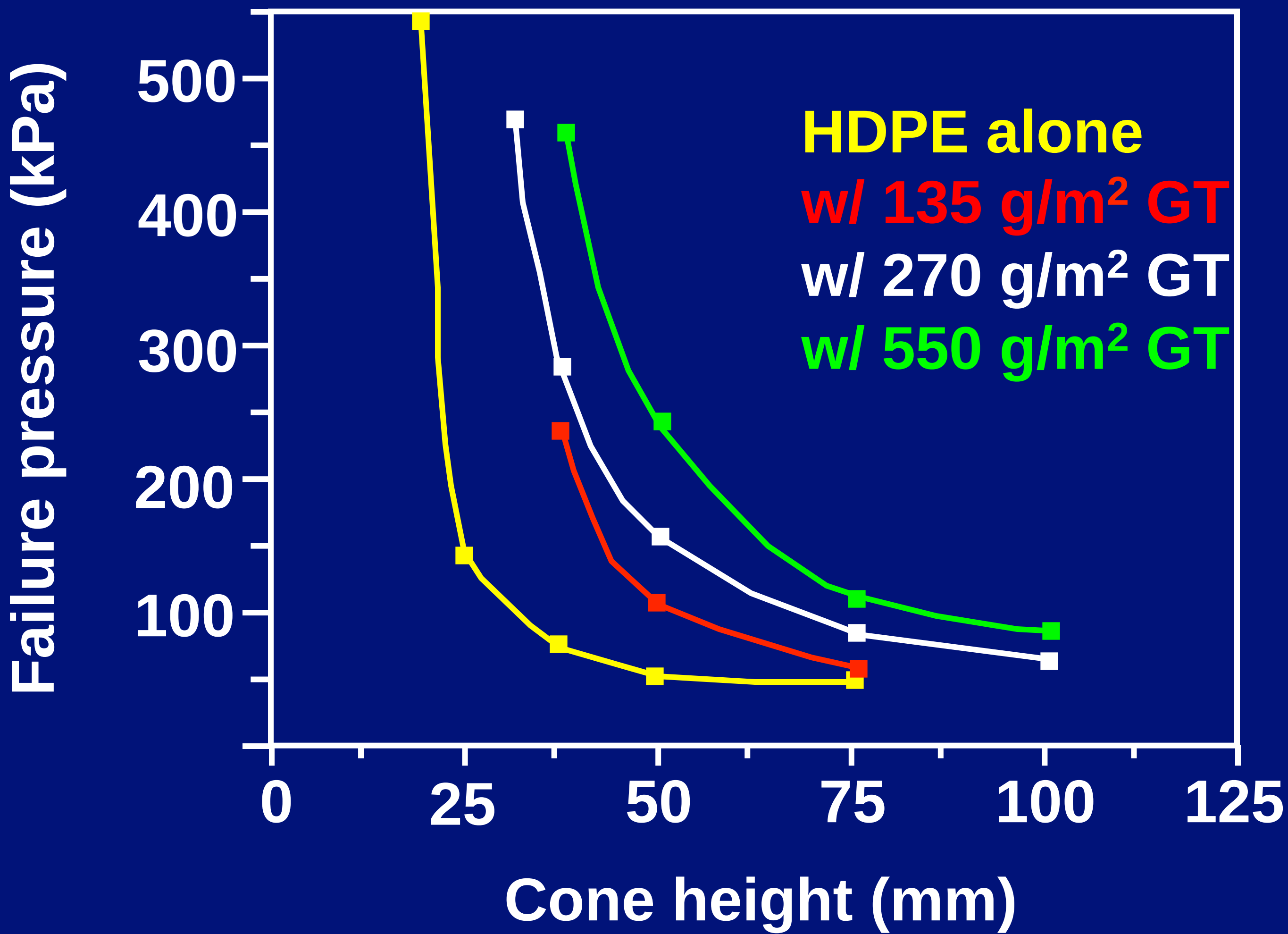


Critical Cone Heights:

- HDPE (1.5 mm) = 10 mm
- fPP-R (0.91 mm) = 15 mm
- PVC (0.75 mm) = 70 mm
- VFPE (1.0 mm) = 90 mm



Truncated Cone Results



NP-NW geotextiles give major improvement,
but what is required mass/unit area??

Puncture Protection of 1.5 mm HDPE Geomembranes

$$FS = \frac{p_{allow}}{p_{act}}$$

where

FS = factor-of-safety

p_{act} = actual pressure above protrusion (hydrostatic or geostatic)

p_{allow} = allowable puncture resistance (the unknown in this analysis)

Basic Equation for "p_{allow}"

$$p_{allow} = \left(50 + 0.00045\frac{M}{H^2}\right)\left[\frac{1}{MF_S \times MF_{PD} \times MF_A}\right]\left[\frac{1}{RF_{CR} \times RF_{CBD}}\right]$$

where

p_{allow}	=	allowable pressure (kPa)
M	=	mass per unit area (g/m^2)
H	=	protrusion height (m)
MF_S	=	mod. factor for protrusion shape
MF_{PD}	=	mod. factor for packing density
MF_A	=	mod. factor for arching in solids
RF_{CR}	=	red. factor for long term creep
RF_{CBD}	=	red. factor for chem./bio. degradation

note:

MF values ≤ 1.0 RF values ≥ 1.0

Modification Factors (MF's) for GM Protection Using NW-NP GTs

MF_S		MF_{PD}		MF_A	
Angular	1.0	Isolated	1.0	Hydrostatic	1.0
Subrounded	0.5	Dense, 38 mm	0.83	Geostatic, shallow	0.75
Rounded	0.25	Dense, 25 mm	0.67	Geostatic, mod.	0.50
		Dense, 12 mm	0.50	Geostatic, deep	0.25

(ref. Koerner, Designing-with-Geosynthetics, 4th Ed., Prentice-Hall, 1998)

Reduction Factors (RF' s) for GM Protection Using NW-NP GTs

		RF_{CR}			
RF_{CBD}		GT Mass per unit area (g/m^2)	Protrusion Ht. (mm)		
			38	25	12
Mild leachate	1.1	Geomembrane alone	N/R	N/R	N/R
Moderate leachate	1.3	270	N/R	N/R	>1.5
Harsh leachate	1.5	550	N/R	1.5	1.3
		1100	1.3	1.2	1.1
		>1100	$\underline{\sim}$1.2	$\underline{\sim}$1.1	$\underline{\sim}$1.0

N/R = not recommended

(ref. Koerner, Designing-with-Geosynthetics, 4th Ed., Prentice-Hall, 1998)

Example:

Coarse gravel (d_{50} = 38 mm) on 1.5 mm thick HDPE under 50 m landfill at 12 kN/m^3. What GT mass for FS = 3.0.

Solution:

Use

H	= 25 mm	MF_S	= 0.5
MF_{PD}	= 0.83	MF_A	= 0.25
RF_{CR}	= 1.5	RF_{CBD}	= 1.3

Determine p_{allow}

$$FS = \frac{p_{allow}}{p_{act}}$$

$$3.0 = \frac{p_{allow}}{(50)(12)}$$

$$p_{allow} = 1800 \, kN/m^2$$

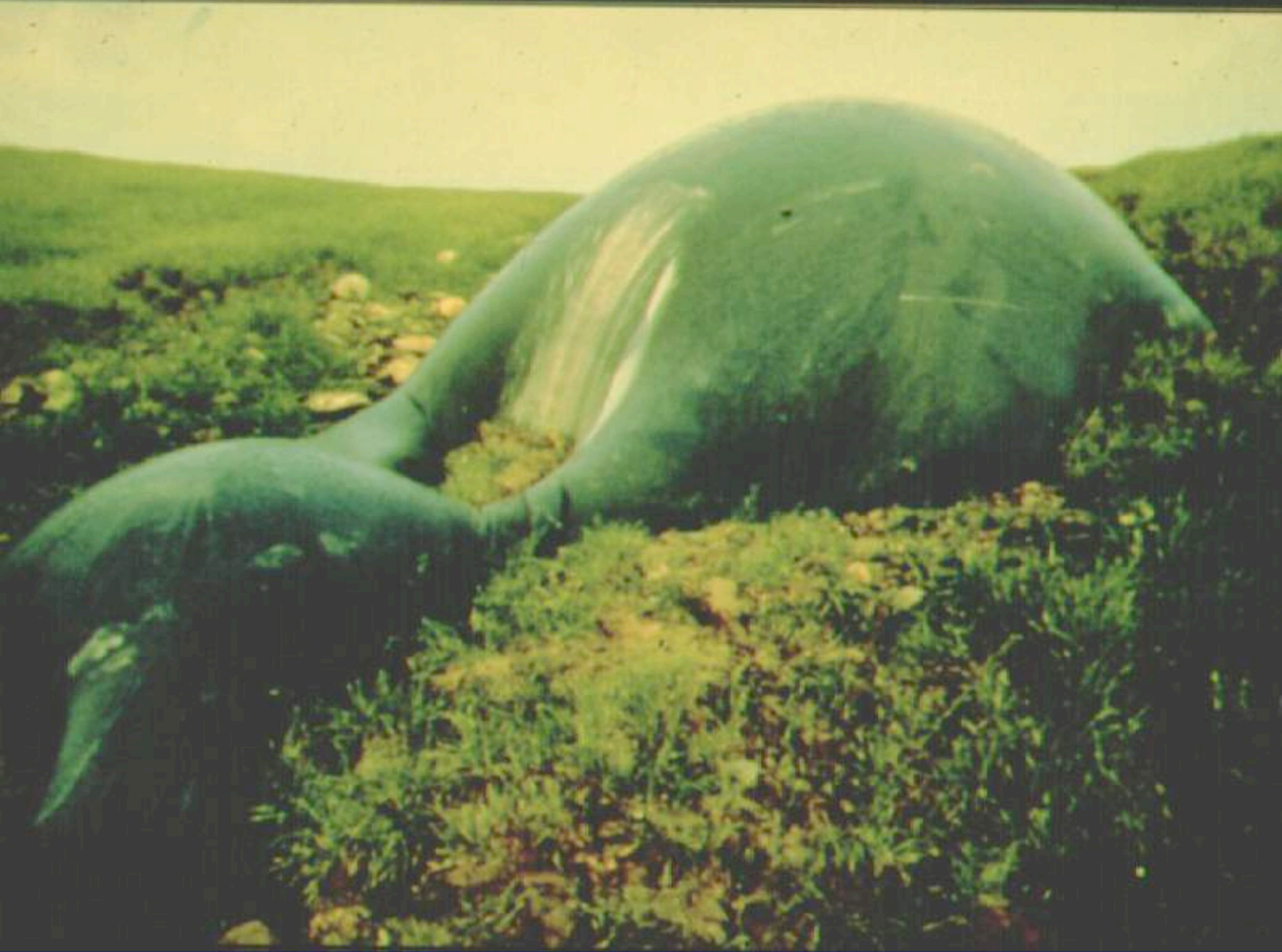
Calculate reqd GT mass

$$1800 = \left[50 + 0.00045 \frac{M}{(0.025)^2}\right] \left[\frac{1}{0.5 \times 0.83 \times 0.25}\right] \left[\frac{1}{1.5 \times 1.3}\right]$$

M = 436 g/m^2; use a 500 g/m^2 geotextile


96 10

3.3(d) Geotextile Gas Collector Beneath Cover Barrier Layer (GM, GM/GCL or GM/CCL)



Geotextile Gas Collector Design

$$FS = \frac{q_{allow}}{q_{reqd}}$$

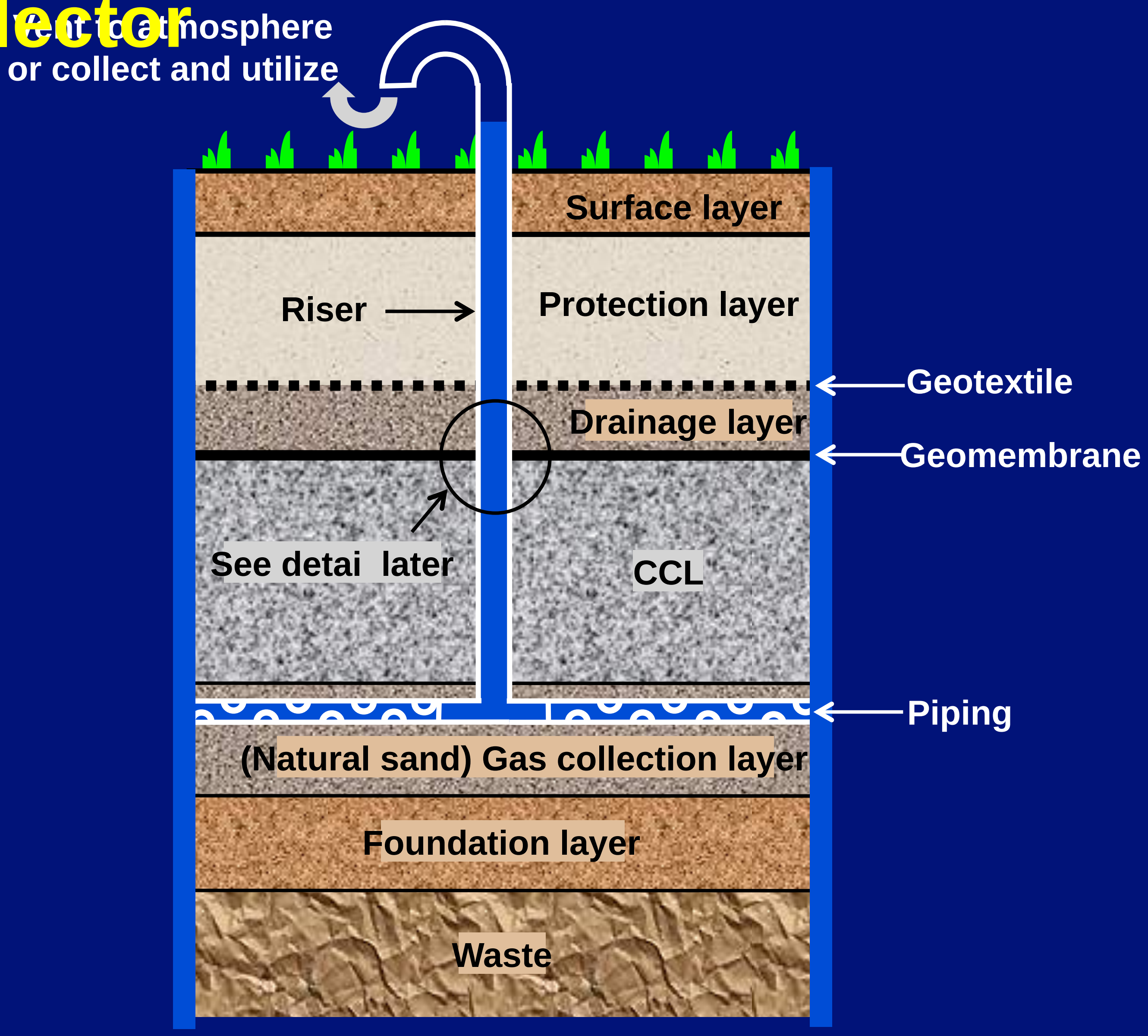
where

q_{allow} = radial flow rate (note, gas >> liquid by approx. 1000 times)

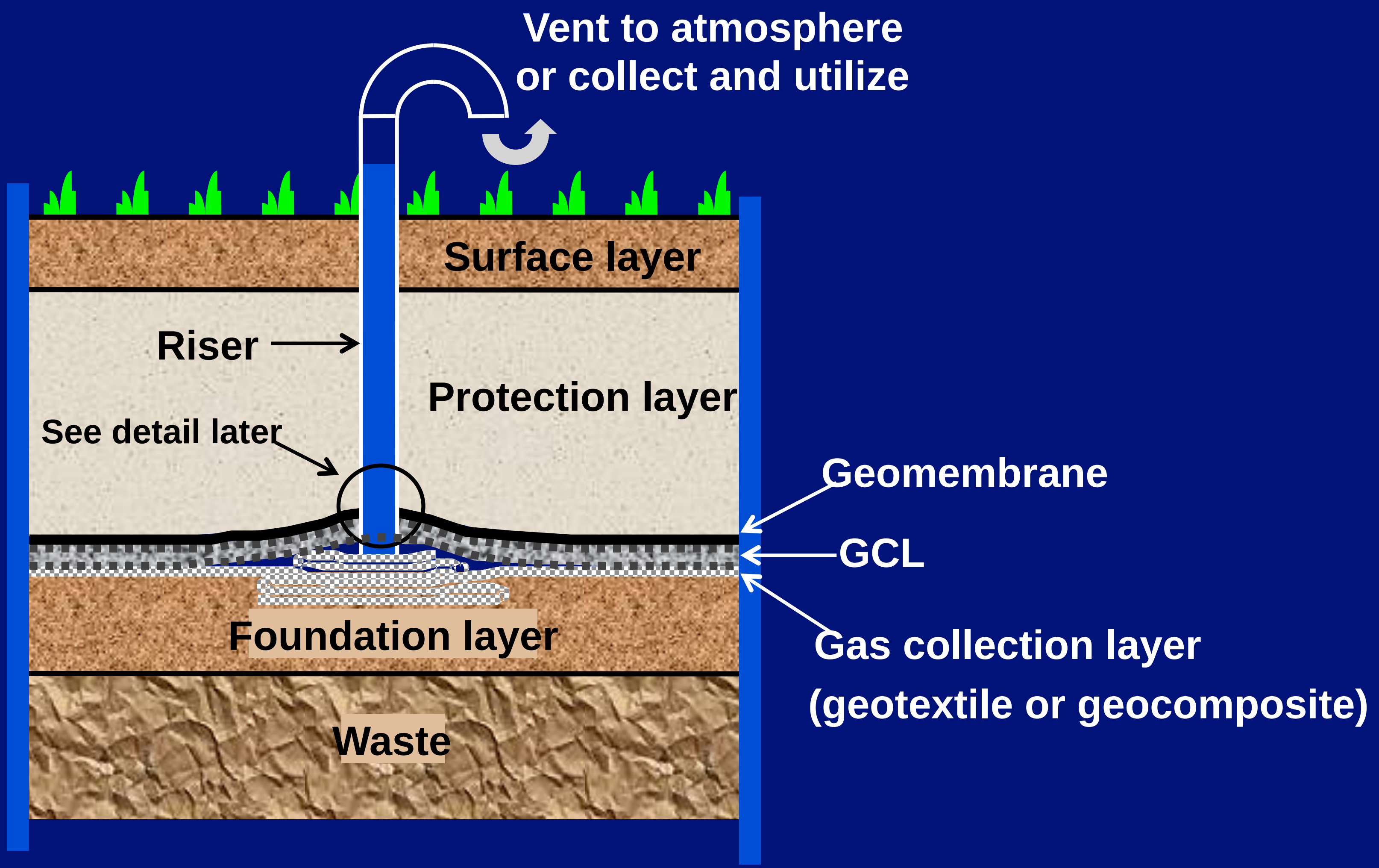
q_{reqd} = methane generation rate

- Typically, 550 g/m^2 GT should be adequate
- Grading and Venting are critical

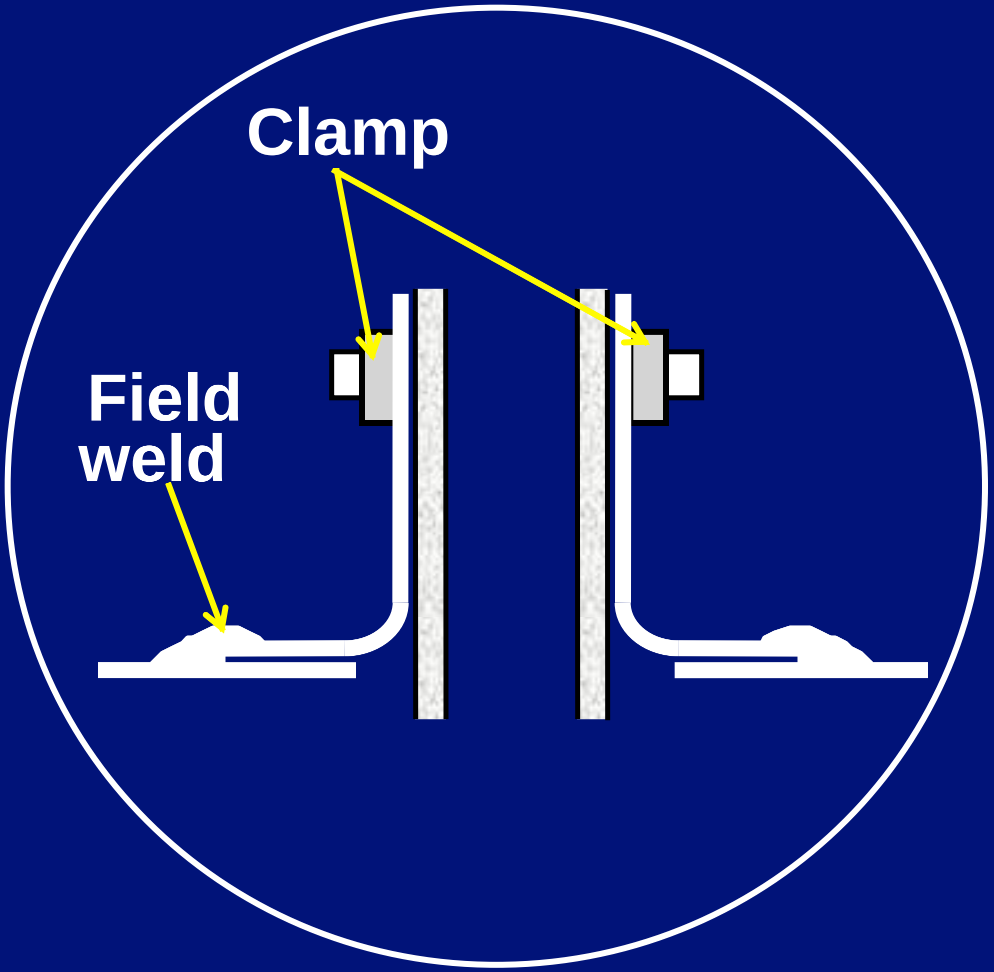
Gas venting system from soil collector



Gas venting system from GT collector

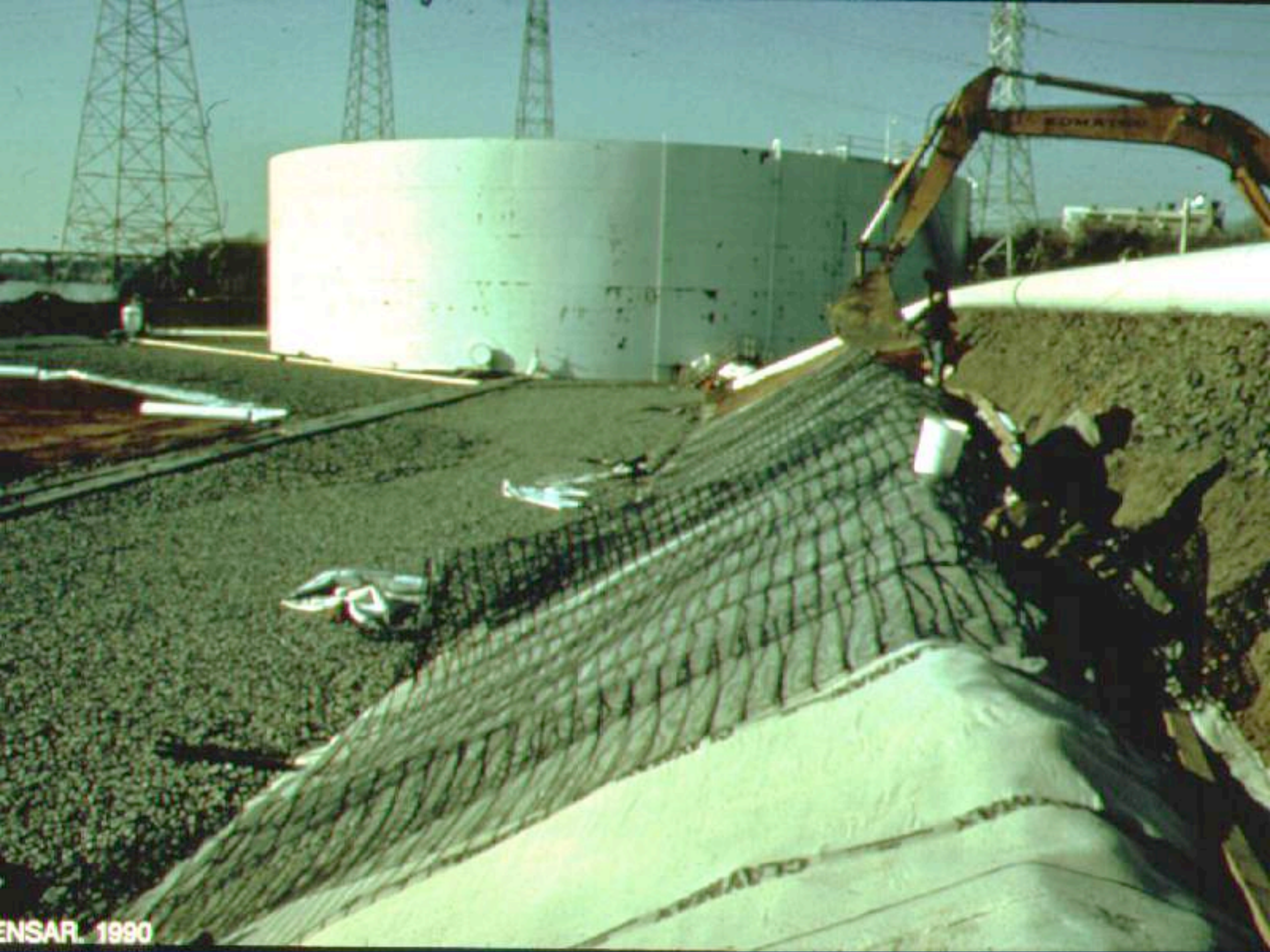


Connection detail using prefabricated pipe boot

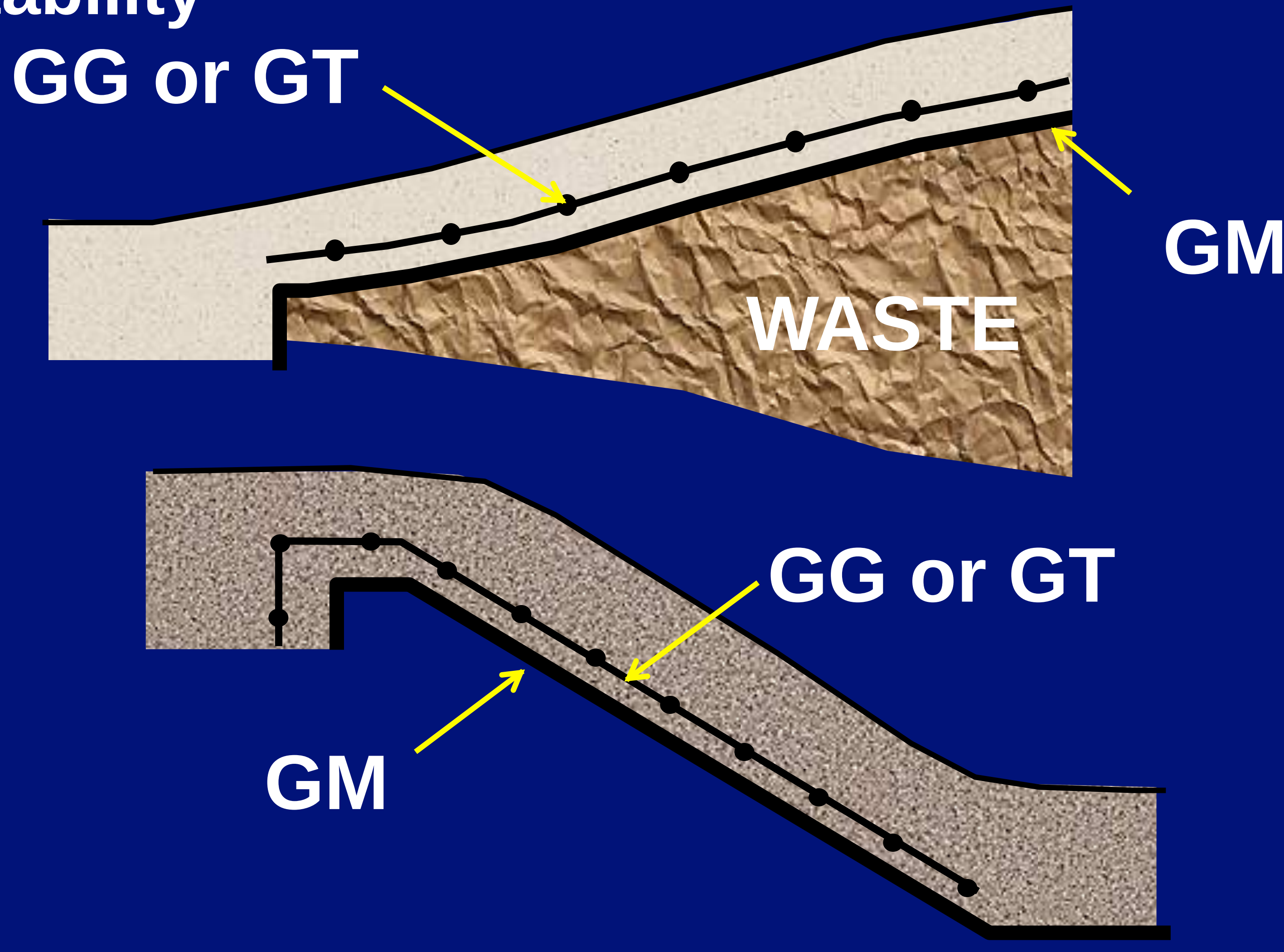


3.4(a) Geogrid (or Geotextile) Design for Veneer Stability

- leachate collection soil
- cover soil in final closures
- cover soil for liquid impoundments
- cover soil in tank farms


TENSAR. 1990

Geogrid (or Geotextile) Design for Veneer Stability



Example (a):

Cover soil on GM 30 m long slope at 3(H)-to-1(V); 900 mm thick soil at 18 kN/m^3, ϕ = 30° and δ = 18° what is the FS?

Limit equilibrium analysis which includes geometry and material properties: see Koerner (1998)

FS = 1.11

Example (b):

Using a GG of T_{ult} = 150 kN/m and ΠRF = 4.5, what is FS?

Solution: T_{allow} = 150/4.5 = 33.3 kN/m

analytic formulation is quite complex: see Koerner (1998)

FS = 1.45

Veneer Reinforcement Failure

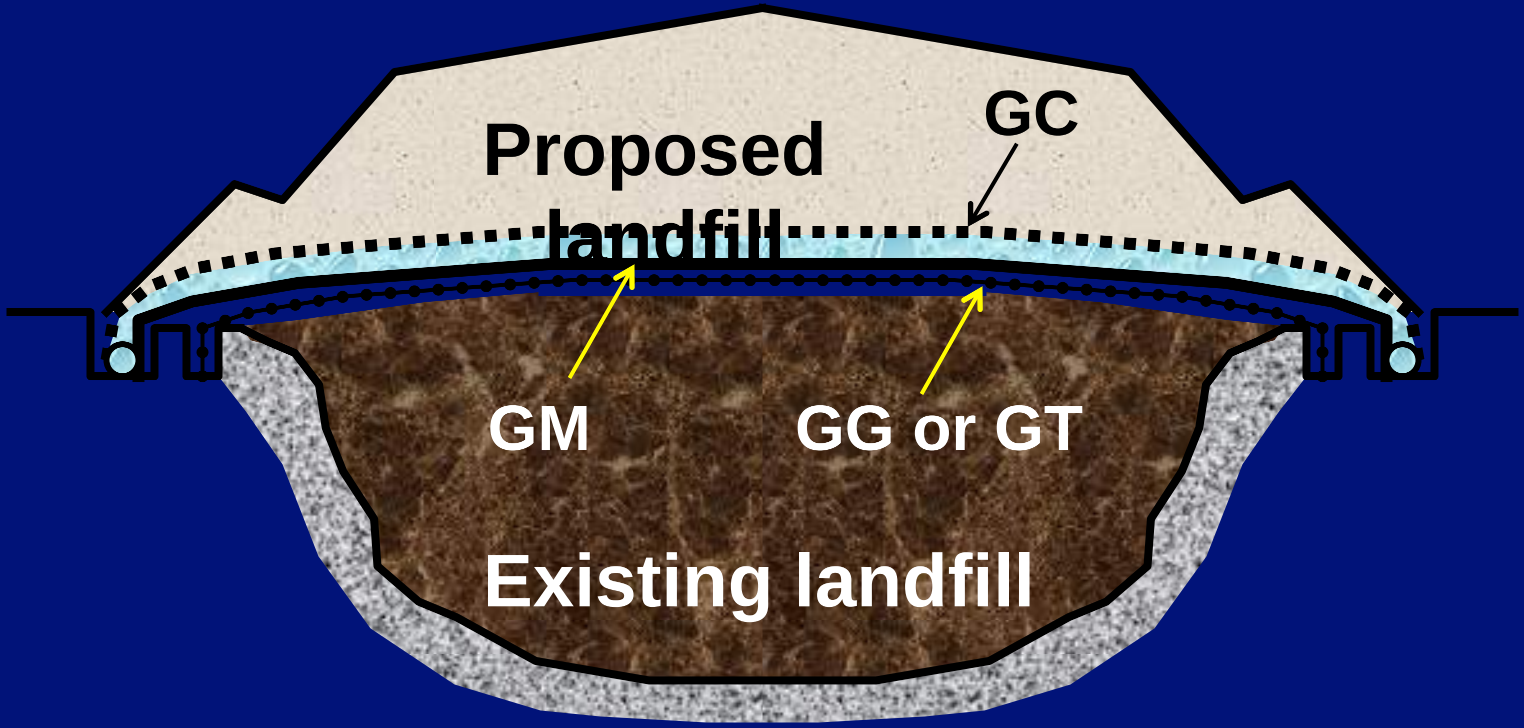
- closure of landfill
- sand on GG, over GT, over GM
- backfilling from top down
- failed while placing sand soil


8 11 '93

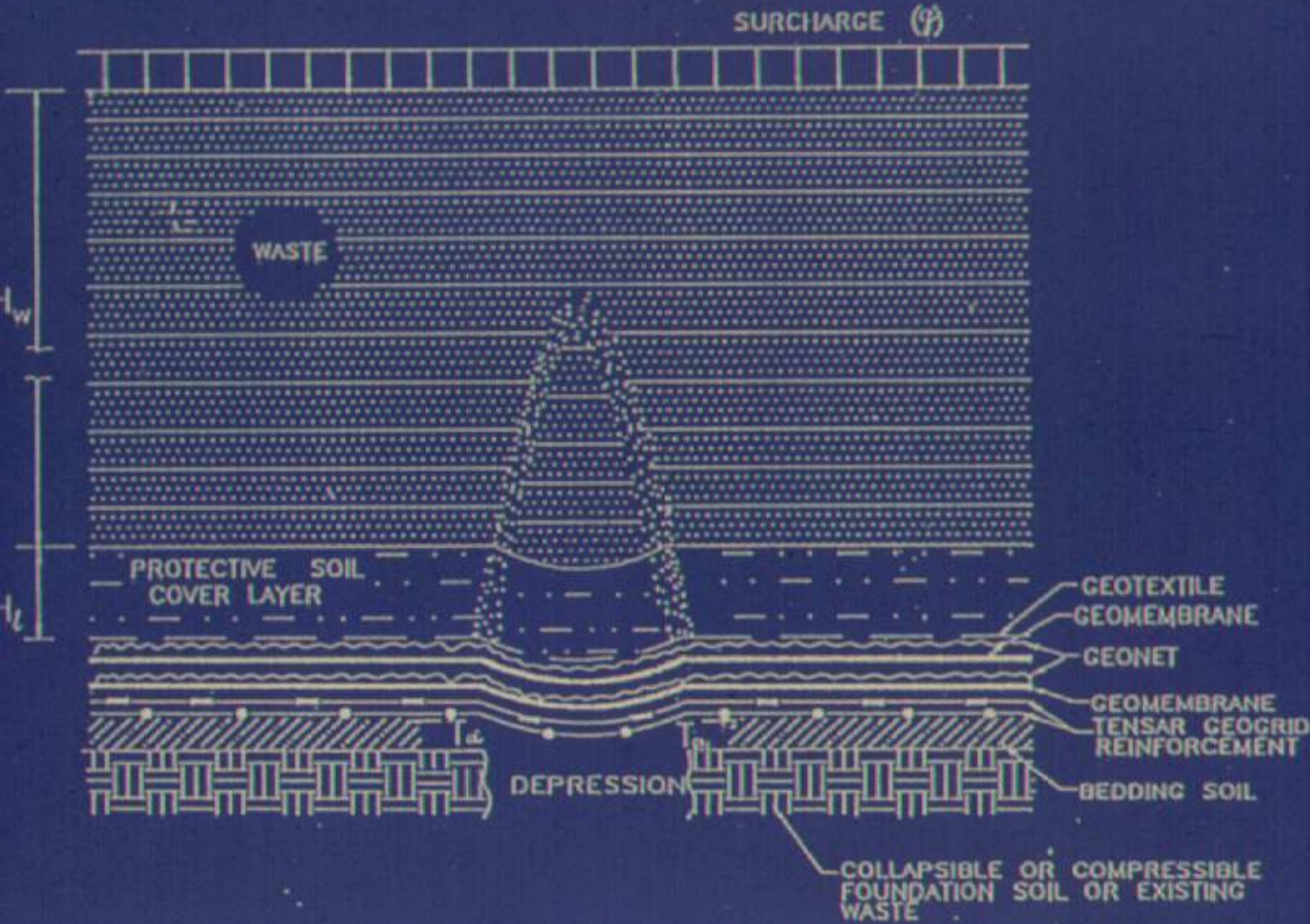
3.4(b) Geogrid (or Geotextile) Design for Vertical Landfill Expansions

- Total settlement can be accommodated
- Differential settlement is a concern
- Estimate of size and depth of subsidence void is required (difficult to estimate)
- Arching is considered for large overburden (expansion) thickness

The Concept of "Piggybacking"



Geogrid Reinforced Landfill
at
Islip, Long Island, New York


SURCHARGE (q)
WASTE
PROTECTIVE SOIL COVER LAYER
GEOTEXTILE
GEOMEMBRANE
GEONET
GEOMEMBRANE
TENSAR GEOGRID REINFORCEMENT
BEDDING SOIL
DEPRESSION
COLLAPSIBLE OR COMPRESSIBLE FOUNDATION SOIL OR EXISTING WASTE

Required Formulae:

$$\sigma_z = 2\gamma_{ave} R\left[1 - e^{-0.5H/R}\right] + qe^{-0.5H/R}$$

For large values of "H", above equation reduces to

$$\sigma_z = 2\gamma_{ave} R$$

To determine a horizontal value for T_{reqd}

$T_{reqd} = 2\gamma_{ave} R^2 \Omega$ **where** $\Omega = 0.25[(2y)/B + B/(2y)]$

Also

$$T_{allow} = T_{WW}\left[\frac{1}{RF_{ID} \times RF_{CR} \times RF_{CBD}}\right]$$

Finally

$$FS = \frac{T_{allow}}{T_{reqd}}$$

Example:

Calculate the FS-value for a new 30 m high landfill of γ = 12 kN/m^3 placed on an existing one where the radius of differential settlement is estimated at 1.0 m. Use a 10% strain criterion, i.e., Ω = 0.73 and a geogrid with T_{ult} = 125 kN/m and ΠRF = 5.0.

Solution:

$$T_{reqd} = 2\gamma_{ave}R^2\Omega$$

$$= 2(12)(1.0)^2(0.73)$$

$$= 17.5\ kN/m$$

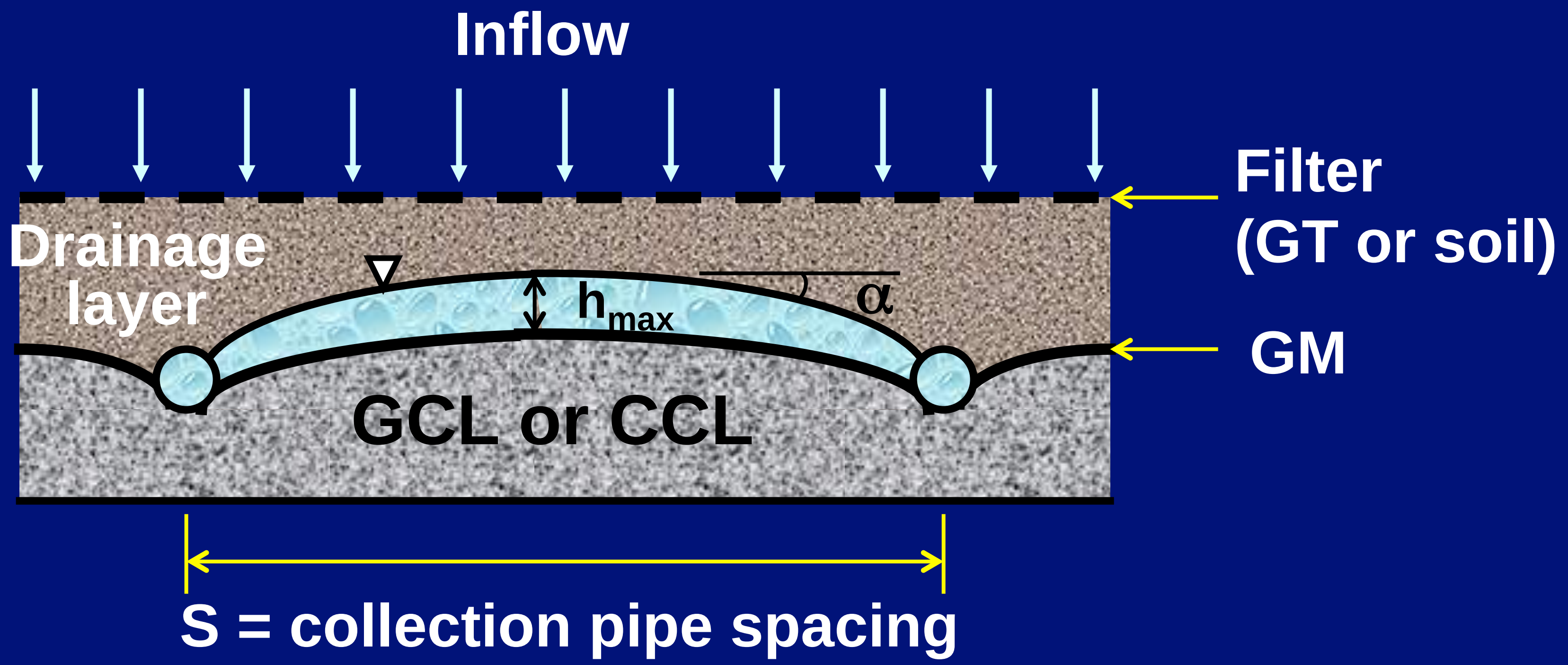
$$T_{allow} = \frac{125}{5} = 25 kN/m$$

$$FS = \frac{T_{allow}}{T_{reqd}} = \frac{25}{17.5}$$

$$FS = 1.43,\ OK$$

3.5 Geopipe Design for Leachate Collection Systems

3.5(a) Geopipe Spacing Design for Leachate Collection



Example:

**3 ha landfill (300 m × 100 m), with perforated pipes at 2% slope, near Philadelphia. Determine the pipe spacing for 30 mm/hr
(1-yr storm) with drainage stone permeability of 0.01 m/s.**

Solution:

Using the mound equation for no waste in cell:

$$h_c = \frac{S\sqrt{c}}{2}\left[\frac{\tan^2\alpha}{c} + 1 - \frac{\tan\alpha}{c}\sqrt{\tan^2\alpha + c}\right]$$

where

$$h_c = 300\ \text{mm (regulatory limit)}$$

$$c = q / k$$

$$= \frac{0.030}{(0.01)(60)(60)}$$

$$= 8.3 \times 10^{-4}$$

Results in S = 32.4m, use 30 m pipe spacing

3.5(b) Geopipe Size (Diameter) Design

- Uses conventional hydraulics design
- After cell construction and before first lift of waste, system is used for dewatering
- After first list of waste, liquid is leachate and must be collected and treated as such

Example:

Continuing the previous problem the pipe size before waste is placed, the *header* pipe diameter uses Manning equation and direct precipitation of 30 mm/hr (1-yr storm in Phila.)

Solution:

$$Q = \frac{(0.030)(100)(300)}{(60)(60)}$$

$$= 0.25 m^3/s$$

which for n = 0.010 is D ~ 300 mm (from design charts)

for *feeder* pipe diameter:

$$Q = \frac{(0.030)(50)(30)}{(60)(60)}$$

$$= 0.0125 m^3/s$$

which for n = 0.010 is D ~ 150 mm.

Solution *(cont'd)*

However, after the first lift of waste is placed and using the HELP computer model for 4 m waste in the cell gives q = 0.26 mm/hr (which compared to 30 mm/hr is 115 times lower than with no waste)

$$Q = \frac{(0.00026)(100)(300)}{(60)(60)}$$

$$= 0.00217 m^3 / s$$

which for n = 0.010 is a header pipe D ~ 50 mm (compared to 300 mm with no waste).

The feeder pipe is 25 mm (compared to 150 mm with no waste). Many facilities compromise between these two extremes; i.e., 150 mm for header and 100 mm for feeders.

3.5(c) Geopipe Design for High Normal Stresses

Example:

Consider a PVC pipe (C = 150) at 0.035 slope with a required discharge of 1.0 m^3/sec. What is required diameter? If the pipe is buried under 6 m soil at 19 kN/m^3, Class II compaction, what is the total pipe deflection?

Solution:

For the pipe diameter, use Hazen-Williams nomograph to obtain a pipe diameter of 0.5 m. Use T1-PVC pipe as the closest size.

- **525 mm inside diameter**
- **560 mm outside diameter**
- **16.0 mm wall thickness**
- **317 kN/m^2 pipe stiffness**

Solution *(cont'd)*:

The pipe deflection is found from the soil load plus installation stresses

$$\Delta X = \frac{D_L K W_c}{\left(EI / r^3\right) + \left(0.061 E'\right)}$$

$$= \frac{(1.2)(0.2)(63.8)}{(317/6.71) + (0.061)(21{,}000)}$$

$$\Delta X = 0.0115 \text{ m} \quad (= \Delta y, \text{ see ASTM D2412})$$

$$\therefore \delta_{soil} = \frac{y}{D} = \frac{11.5}{525}(100) = 2.2\%$$

δ_{inst} is found empirically and is based on pipe stiffness

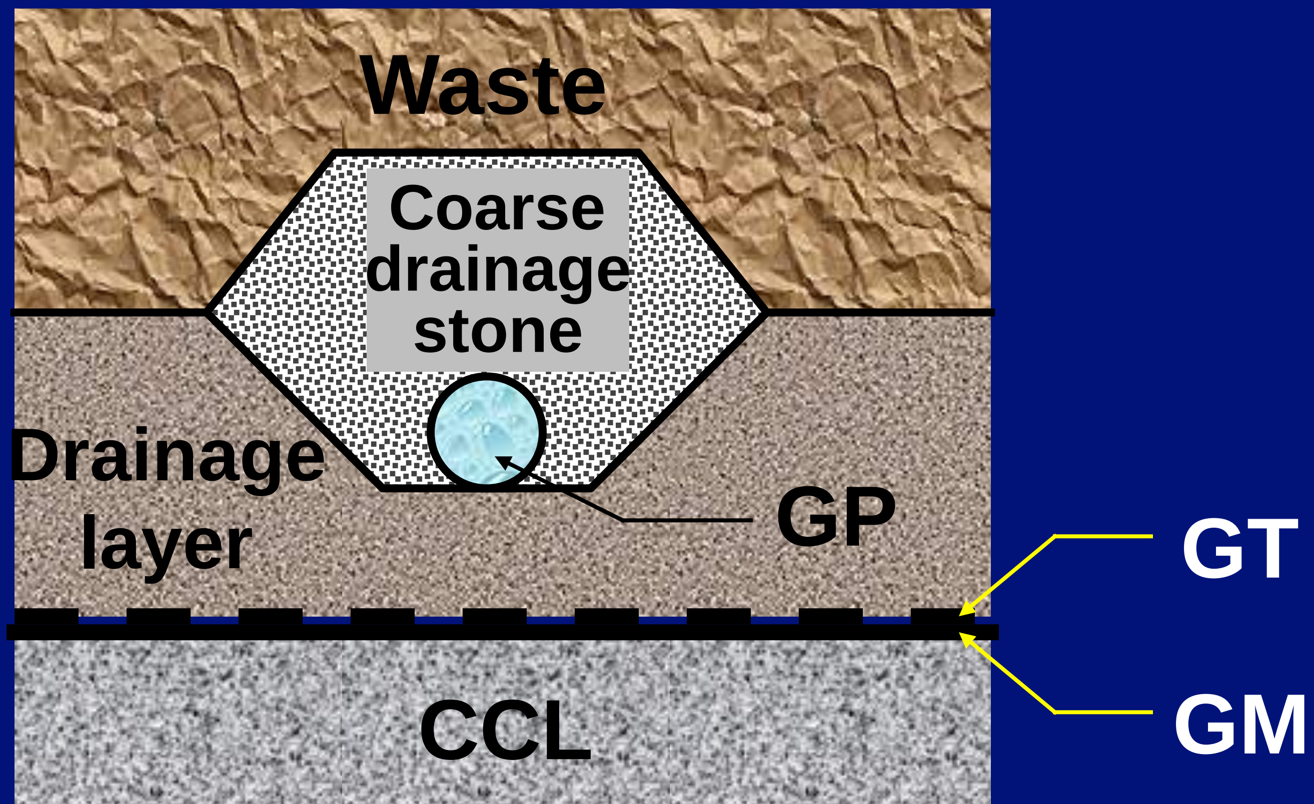
$$\delta_{inst} = 2.0\%$$

$$\text{therefore, } \delta_{total} = 2.2 + 2.0$$

$$= 4.2 < 10\%, \text{ OK}$$

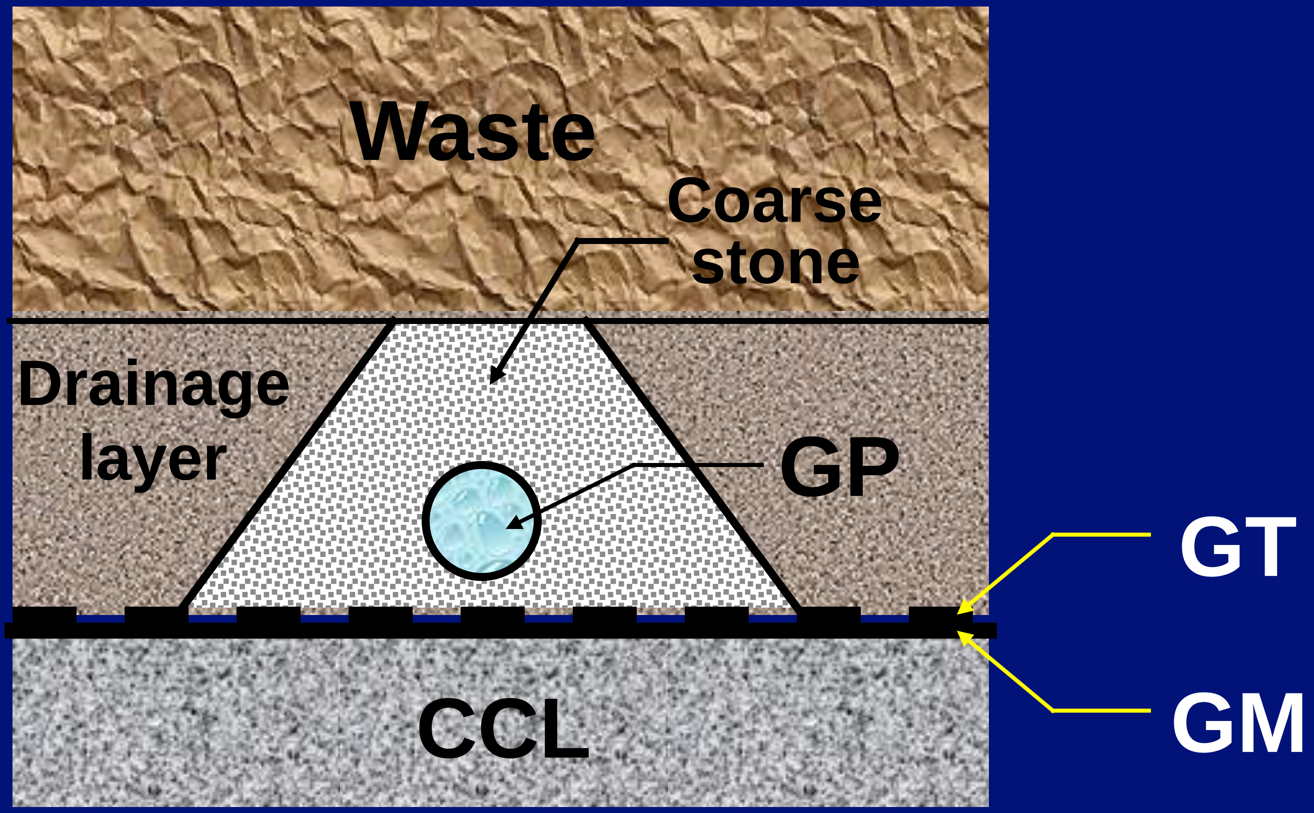
Installation of Pipes in Drainage Layer

(a) Trench Type



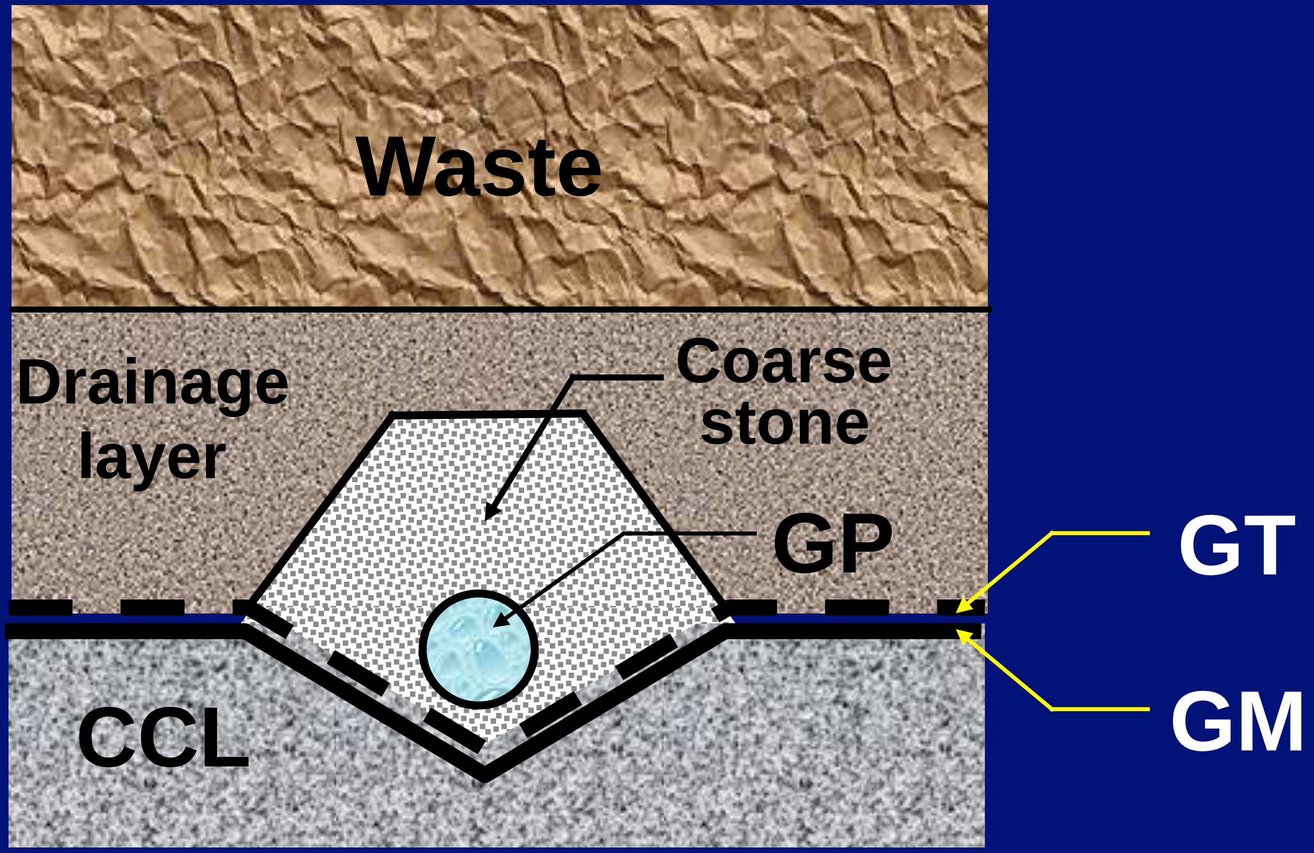
Installation of Pipes in Drainage Layer *(cont'd)*

(b) Embankment Type



Installation of Pipes in Drainage Layer *(cont'd)*

(c) Embankment with V-Trench Type

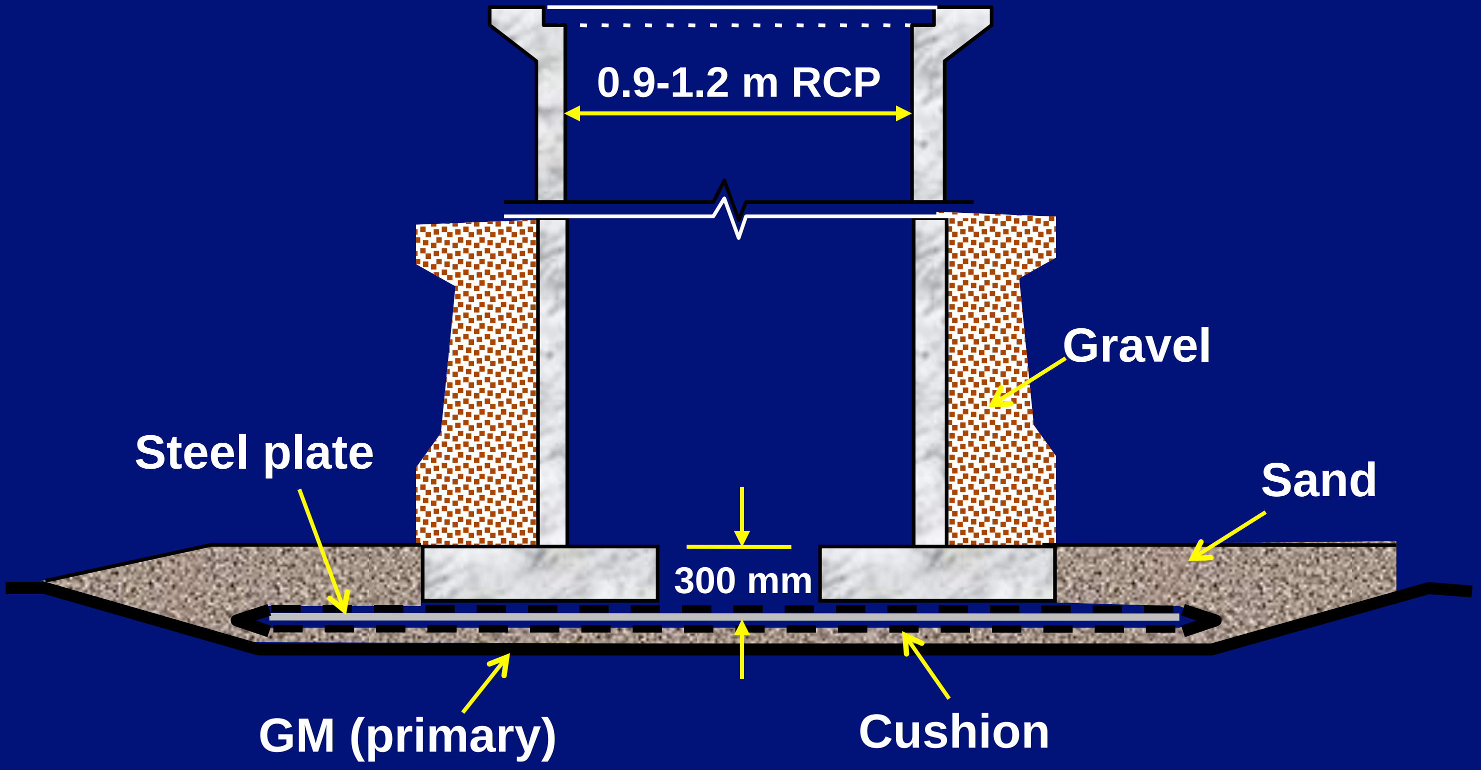


Leachate Sumps and Removal Systems

- penetrating liners at base of landfill (generally not recommended)
- sumps with vertical manholes (low volume and high volume)
- enlarged sumps with sidewall risers

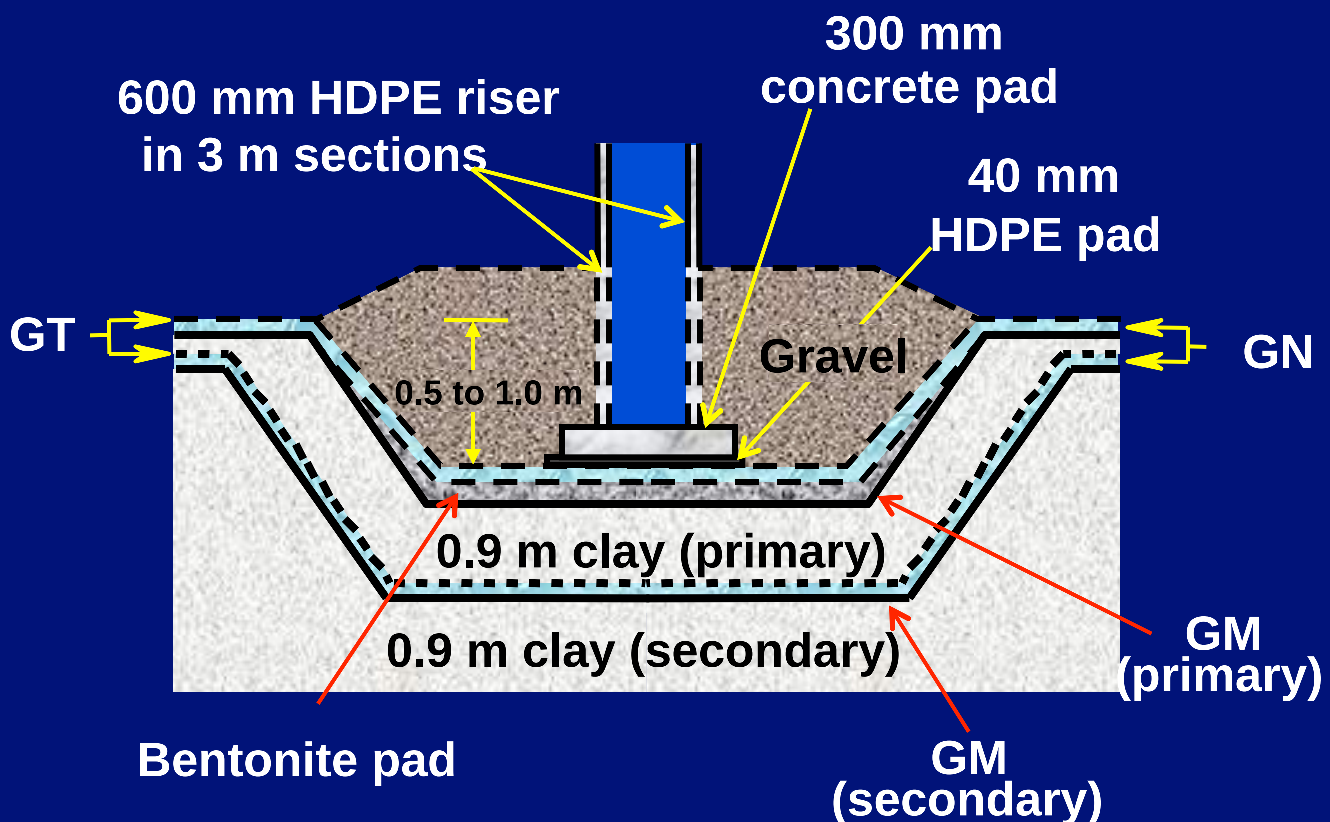
Removal Designs for Primary LCRS

(a) Low-volume primary leachate collection



Removal Designs for LCRS *(cont'd)*

(b) High-volume primary leachate collection man

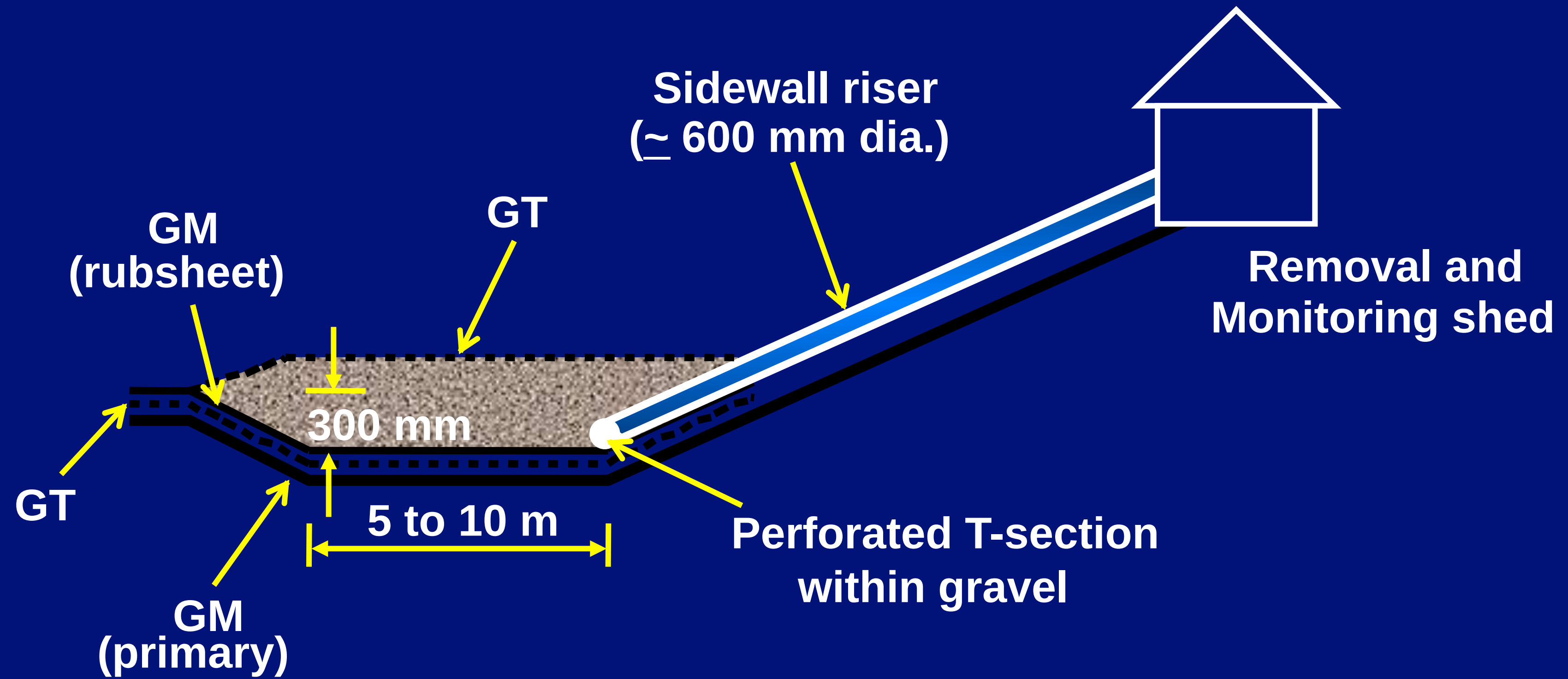


Problems with Vertical Manholes

- must be raised lift-by-lift
- operation equipment must avoid contact
- problem to spread and compact waste
- must penetrate cover
- waste subsidence causes downdrag via negative skin friction

Removal Designs for LCRS *(cont'd)*

(c) Side wall primary leachate collection riser



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