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# CALCULATION SUMMARY SHEET



PROJECT NUMBER: 143418

PROJECT NAME: USEN - Trench 13 Design

DATE: January 16, 2015

CALCULATION NUMBER: C.08 Revision: 1 (March 11, 2016)

**CALCULATION TITLE: LDS Flow Capacity, ALR, and Extraction Rate**

**DESCRIPTION OF CALCULATION:**

Calculation to determine LDS Flow Capacity, Action Leakage Rate, and Extraction Rate

**REFERENCES USED:**

1. 300 mil Geocomposite Specifications (Typical).
2. Designing with Geosynthetics, Koerner, 1998.
3. GSE Design Manual, 2007.
4. Darilek and Laine, Geosynthetics, A new sensible approach, 2009.

**REVIEW COMMENTS:**

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| | | | |
|---|---|---|---|
| CALCULATION MADE BY: | CWK | DATE: | 01/16/15 |
| CALCULATION CHECKED BY: | CAB | DATE: | 02/10/15 |
| CALCULATION REVISED BY: | PAZ | DATE: | 05/07/15 |
| CALCULATION REVIEWED BY: | CAB | DATE: | 05/14/15 |

## PURPOSE OF CALCULATION

Determine the flow carrying capacity of the 300-mil geocomposite drainage material in the leak detection system (LDS) portion of the liner system on the floor of Trench 13 and determine the restrictions of flow associated with entry into the LDS Sump and restrictions on fluid removal. The LDS flow rates will be used to determine the maximum design flow that the LDS can remove without the fluid head on the LDS Floor liner exceeding one foot, and an Action Leakage Rate (ALR). The ALR is required by CFR 264.302. Fluid accumulation equal to or exceeding the ALR will be used to trigger a response action.

Determine the flow capacity of the LDS pump, capable of evacuating the flow from the sumps.

## METHOD

Calculate the flow through the 300-mil geoocomposite, using average or literature-specific reduction factors.

Use the LDS Sump geometry to determine if flow restrictions exist at the entry to the sump.

Assign a single action leakage rate (ALR) for each of the Trench 13 phases that is: 1) a rate that is greater than the amount expected for small leaks through the primary liner, and 2) a rate that is less than the capacity of the LDS Floor (geocomposite liner) and LDS Sump to transmit liquids without backups on the secondary liner exceeding one foot.

## ANALYSIS

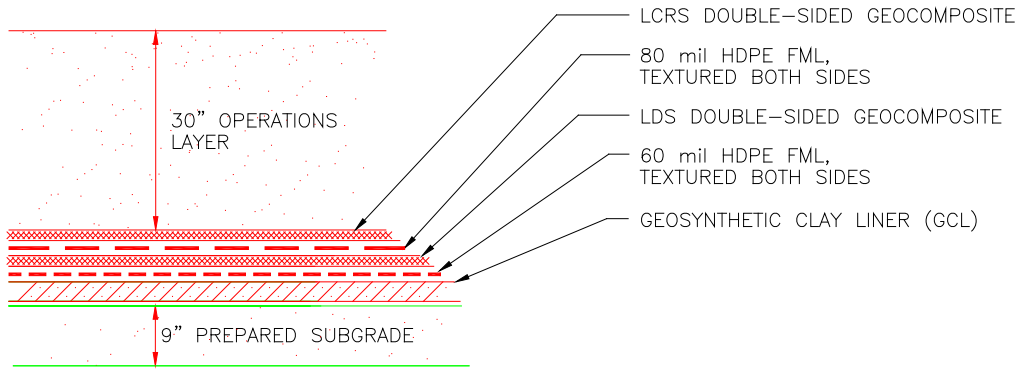
### Applicable Regulations

The regulatory definition of the ALR is the maximum design flow rate that the LDS can remove without the fluid head on the bottom (secondary composite) liner exceeding one foot. The action leakage rate must include an adequate safety margin to allow for uncertainties in the design (e.g., slope, hydraulic conductivity, thickness of drainage material), construction, operation, and location of the LDS, waste and leachate characteristics, likelihood and amounts of other sources of liquids in the LDS, and proposed response actions (e.g., the action leakage rate must consider decreases in the flow capacity of the system over time resulting from siltation and clogging, rib layover and creep of synthetic components of the system, overburden pressures, etc.).

### Geometry

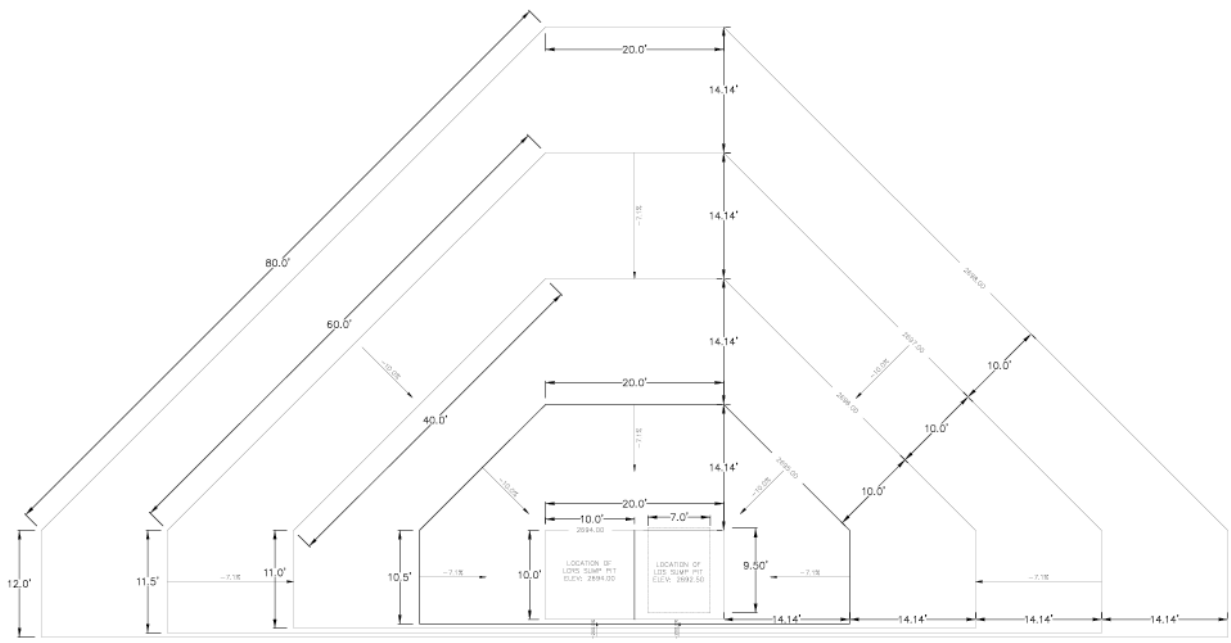
The typical bottom liner is shown below.

**Figure 1 Typical Trench 13 Floor Components**




There are five sumps in the Trench 13 design. The typical geometry is shown below.

**Figure 2 Typical Sump Plan**




## Flow Capacities

A single, continuous layer of double-sided geocomposite (300-mil, **References 1a, 1b, and 1c**) will be used in the LDS system to transmit fluids escaping the primary drainage and liner system and entering the secondary drainage system were they can be transmitted to the LDS sump for collection and removal. The trench floor components and the sump layout are shown in **Figure 1** and **Figure 2**, respectively. Flow within the

LDS is controlled by the minimum bottom slope of the landfill trench floor slope and the geometry of the sump entry.

Flow within the geocomposite is calculated using Darcy's Law (which assumes laminar flow).

$$q_{reported} = \Theta * i$$

Where

$q_{reported}$ = flow per unit width, based on reported material transmissivity

$\Theta$ = transmissivity as reported by the material manufacturers

i = hydraulic gradient

The flow-carrying capacity of the geocomposite is assumed to be equal to material test values, as reported by the manufacturer (i.e., transmissivity values provided by the manufacturers as included in **References 1a, 1b, and 1c**). In actual use as a landfill liner system component, the capacity of the material decreases over time in response to elastic deformation, creep, chemical, and biological factors. Although these factors likely only begin to apply at a point late in the life of the landfill, to make the calculation of flow-carrying capacity appropriately conservative, these factors are considered (as shown below) to reduce the manufacturer's determination of material property throughout the life of the system.

Reduction factors are taken from the literature Designing with Geosynthetics, Koerner 1998 (**Reference 2**) or from a manufacturer's recommendations for a specific material type (GSE, 2007, **Reference 3**).

Flow capacities are shown at hydraulic gradients of 2 percent and 7.1 percent for the nominal cell bottom slope and the minimum sump slope, respectively. Gravel is used within the sump boundaries around the riser pipes. In gravel, flow capacities will exceed those of the geocomposite; but, flow rates in gravel are not considered in this evaluation.

The following formula (**Reference 2**) is used to estimate allowable flow per unit width for the geocomposite. Because the geonet transmissivity test data from the manufacturer is for short duration testing, the effective flow equation using four reduction factors is applied. Koerner recommends the use of average reduction values in the absence of additional information regarding geocomposite behavior.

$$q_{allow} = q_{reported} \frac{1}{\left(RF_{in} \times RF_{CR} \times RF_{CC} \times RF_{BC}\right)}$$

where:

$q_{allow}$ = allowable flow rate under long term design conditions
$q_{reported}$ = manufacturer short term test flow rate

$RF_{IN}$ = reduction factor to flow caused by intrusion of adjacent geosynthetics into geonet
$RF_{CR}$ = reduction factor to flow caused by geonet elastic deformation (creep)
$RF_{CC}$ = reduction factor to flow caused by chemical precipitation clogging
$RF_{BC}$ = reduction factor to flow caused by biological clogging

The following table shows the unit flow capacity ($q_{allow}$) for the geocomposite based on the applicable transmissivity, hydraulic gradients, calculated volumetric flow based on manufacturers test data for transmissivity, and reduction factors. The creep reduction factor for long-term application at the final design loading of about 15,000 psf was selected as 1.19 based on literature test values (GSE, 2007, **Reference 3**), so this value was used rather than the average range.

| Flow Element | Θ | *i* | $q_{reported}$ | $q_{reported}$ | $FS_{IN}$ | $FS_{CR}$ | $FS_{CC}$ | $FS_{BC}$ | $q_{allow}$ | $q_{allow}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Units | $m^2/s$ | m/m | m3/s/m | gal/min/ft | NA | NA | NA | NA | gal/min/ft | gal/day/ft |
| Floor LDS Geocomposite – 300 mil with double layer of 8oz/yd geotextile | $9x10^{-4}$ | 0.02 | 0.000018 | 0.087 | 1.75 | 1.19 | 1.75 | 1.75 | 0.0136 | 20 |
| Sump LDS Geocomposite – 300 mil with double layer of 8oz/yd geotextile | $9x10^{-4}$ | 0.071 | 6.39E-05 | 0.305 | 1.75 | 1.19 | 1.75 | 1.75 | 0.0478 | 69 |

Controlling Section at 2% to 7.1% Grade Break at Outer Sump Entry

A potential choke point (small flow window) occurs at the perimeter of the grade break between the main landfill cell floor (2% minimum slope) and the entry slope of the outer sump area (7.1% minimum slope).

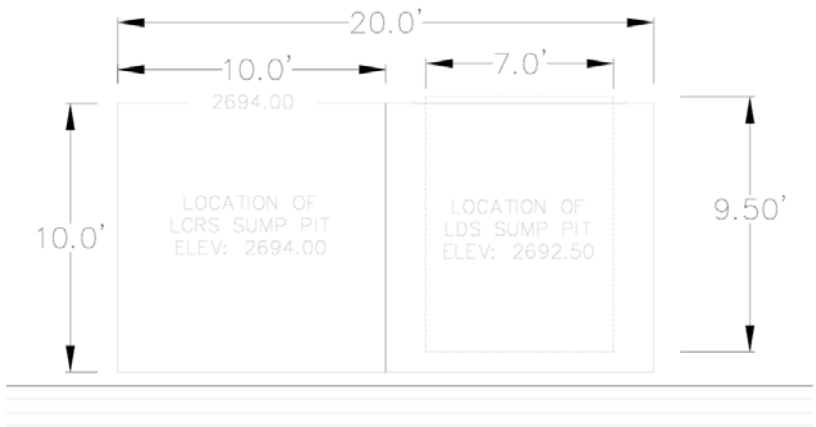
The sump has a perimeter of 204 feet at the grade break between 2% and 7.1% slope, refer to **Figure 2**. This dimension does not include the sump side that is against the sidewall because little flow is contributed from the sidewall, the sidewall slope is steep (increasing flow), and a double-thickness of geocomposite is installed at the sidewall/floor transition. The following table shows the volume of flow the system can handle at the sump entry without backups occurring on the liner.

| Volumetric Flow ($q_{allow}$) | Sump Perimeter Length | Total Flow | Maximum Phase Size | Flow |
|---|---|---|---|---|
| gal/day/ft | feet | gal/day | acres | gal/acre/day |
| 20 | 204 | 4,080 | 9.88 | 413 |

Controlling Section at 7.1% Grade Break at Main Sump Entry

A second potential choke point occurs at the perimeter of the extraction portion of the LDS sump (7.1% minimum slope) and the area immediately surrounding the LDS riser pipe.

**Figure 3 Perimeter of LDS Sump**




At the lowest sump area (around the LDS riser pipe), the sump has a perimeter of 22.5 feet (not including the sump side that is against the sidewall) as shown in **Figure 3**. The following table shows the volume of flow the system can handle at the sump entry without backups occurring on the liner.

| Volumetric Flow ($q_{allow}$) | Sump Perimeter Length at Base | Total Flow | Maximum Phase Size | Flow |
|---|---|---|---|---|
| gal/day/ft | feet | gal/day | acres | gal/acre/day |
| 69 | 26 | 1,790 | 9.88 | 182 |

Estimate of Possible Leakage from Installation Defects and Diffusion of Liquids through the Primary Liner

Minor liner defects and construction damage should be considered unavoidable. Research has shown that for even small holes, less than 0.1 inches in diameter, up to 100 gallons per day can result from a head of 1 foot (**Reference 4**).

## Trench 13 ALR

The ALR for Trench 13 should be set to ensure that leachate heads greater than 1 foot above the liner do not occur. Therefore, the flow entering the sump becomes the limiting factor. As presented above, this amount occurs at the potential choke point were leachate enters the area immediately surrounding the LDS riser pipe at the main sump entry or 182 gallons per acre day. For conservatism, and consistent with Trench 12 ALR, a value of 150 gallons per acre day will be applied.

| Sump | Phase Area (acres) | ALR (gpad) | Flow into Sump at ALR (gpd) |
|---|---|---|---|
| Phases 13 A and E | 9.88 | 150 | 1,480 |
| Phases 13 B,C, and D | 9.16 | 150 | 1,370 |

## LDS Pump

Since the maximum flow to the sump is approximately 1,480 gallons per day (Sump 13A, 13E - ALR), a pump with a capacity of at least 1.1 gpm and a 114 feet, (total head recommended for the LCRS, **Calculation C.04**) of dynamic head (lift) is recommended. It is anticipated that liquid will be allowed to accumulate in the LDS until sufficient volume is present to be efficiently removed with a pump. Thus, with a continuous leak, daily liquid removal would be necessary.

## RESULT

Flow through the 300-mil double-sided geocomposite at a 2.0 percent slope up to the perimeter of the sump (at the grade break) provides sufficient flow to meet the ALR requirements for each of the five Trench 13 sumps (i.e., the same ALR for each sump). Flow through the 300-mil double-sided geocomposite at a 7.1 percent gradient up to the perimeter of the main LDS sump entry is controlling. An ALR of 150 gallons per acre day, for each of the five phases of Trench 13 is less than the volume that would cause backups of leachate on the liner exceeding 1.0 foot. Therefore, the LDS system can identify leaks prior to backups occurring.

A pump capable of extracting at least 1.1 gpm at 114 feet of dynamic head is recommended for the LDS.

## REFERENCES

**Reference 1: Material Specifications**

**Reference 1a: AGRU 300 mil Geocomposite**

**Reference 1b: GSE 300-mil Geocomposite**

**Reference 1c: SKAPS 300-mil Geocomposite**

**Reference 2: Koerner, Robert 1994. Designing with Geosynthetics**

**Reference 3: GSE Drainage Design Manual (2007)**

**Reference 4: Darilek, Glenn T. and Laine, Daren L. September 2, 2009. Geosynthetics. A New Sensible Approach**

REFERENCE 1a

# 300 mil Geocomposite

## Geonet Component (1)

| Property | Test Method | Frequency | Minimum Average Roll Value |
|---|---|---|---|
| Thickness, mil (mm) | ASTM D5199 | 50,000 sf | 300 (7.6) |
| Peak Tensile Strength MD, lbs./in. (N/mm) | ASTM D5035/7179 | 50,000 sf | 75 (13.3) |
| Density, g/cm$^3$ | ASTM D792, Method B | 50,000 sf | 0.94 |
| Carbon Black Content (%) | ASTM D4218 | 50,000 sf | 2 - 3 |
| Transmissivity(2), m$^2$/sec. (gal/min/ft) | ASTM D4716 | 500,000 sf | 8 x 10$^{-3}$ (38.6) |

## Geotextile Component(1)

| Property | Test Method | Frequency | Minimum | Average | Roll Value |
|---|---|---|---|---|---|
| Mass per Unit Area, oz./sq. yd. (g/m$^2$) | ASTM D5261 | 100,000 sf | 6.0 (203) | 8.0 (271) | 10.0 (339) |
| Grab Tensile Strength, lbs.(N) | ASTM D4632 | 100,000 sf | 170 (757) | 220 (979) | 270 (1200) |
| Grab Elongation, % | ASTM D4632 | 100,000 sf | 50 | 50 | 50 |
| Trapezoidal Tear, lbs. (N) | ASTM D4533 | 100,000 sf | 65 (289) | 95 (423) | 105 (467) |
| CBR Puncture , lbs (N) | ASTM D6241 | 500,000 sf | 435 (1935) | 600 (2670) | 725 (3230) |
| Puncture, lbs. (N) | ASTM D4833 | 100,000 sf | 90 (398) | 120 (530) | 165 (730) |
| Permittivity(3), sec.$^{-1}$ | ASTM D4491 | 500,000 sf | 1.5 | 1.3 | 1.1 |
| Water Flow, (3) gpm./ft$^2$ (l/min/m$^2$) | ASTM D4491 | 500,000 sf | 110 (4479) | 95 (3895) | 80 (3280) |
| AOS, U.S. Sieve max (mm)(3) | ASTM D4751 | 500,000 sf | 70 (0.212) | 80 (0.180) | 100 (0.150) |

## Geocomposite

| Property | Test Method | Frequency | | Minimum | Average | Roll Value |
|---|---|---|---|---|---|---|
| Ply Adhesion, lbs./in. (g/cm) | ASTM D7005 | 50,000 sf | | 1 (178) | 1 (178) | 1 (178) |
| Transmissivity (2), m$^2$/sec. (gal/min/ft) | ASTM D4716 | 500,000 sf | Double | 9 x 10$^{-4}$ (4.3) | 9 x 10$^{-4}$ (4.3) | 7 x 10$^{-4}$ (3.4) |
| | ASTM D4716 | 500,000 sf | Single | 3 x 10$^{-3}$ (14.5) | 3 x 10$^{-3}$ (14.5) | 2 x 10$^{-3}$ (9.6) |

## Supply Information

| Standard Roll Length(4) | at Fabric Weight | 6-oz | 8-oz | 10-oz |
|---|---|---|---|---|
| Double Sided | | 160 | 150 | 140 |
| Single Sided | | 180 | 180 | 170 |

Notes:
(1) Component properties are prior to lamination
(2) Geonet & Geocomposite. Transmissivity at 21°C, gradient of 0.1, load of 10,000psf, seat time 15 min. between steel plates.
(3) At time of manufacture. Handling may change these properties.
(4) All roll widths are 14.5 feet. All roll lengths and widths have a tolerance of ±1%
(5) UV Resistance after 500 hours for the geotextile componet exhibits 70% strength retained via ASTM D4355

All information, recommendations and suggestions appearing in this literature concerning the use of our products are based upon tests and data believed to be reliable; however, it is the user's responsibility to determine the suitability for their own use of the products described herein. Since the actual use by others is beyond our control, no guarantee or warranty of any kind, expressed or implied, is made by Agru/America as to the effects of such use or the results to be obtained, nor does Agru/America assume any liability in connection herewith. Any statement made herein may not be absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. Nothing herein is to be construed as permission or as a recommendation to infringe any patent.

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REFERENCE 1b

PRODUCT DATA SHEET

# GSE FabriNet 300 mil Geocomposite

GSE FabriNet 300 mil geocomposite consists of a 300 mil thick GSE HyperNet geonet heat-laminated on one or both sides with a GSE nonwoven needlepunched geotextile. The geotextile is available in mass per unit area range of 6 oz/yd² to 16 oz/yd². The geocomposite is designed and formulated to perform drainage function under a range of anticipated site loads, gradients and boundary conditions.

**AT THE CORE:**
**A 300 mil thick GSE HyperNet geonet heat-laminated on one or both sides with a nonwoven needlepunched geotextile.**

## Product Specifications

| Tested Property | Test Method | Frequency | Minimum Average Roll Value[1] | | |
|---|---|---|---|---|---|
| **Geocomposite** | | | 6 oz/yd² | 8 oz/yd² | 10 oz/yd² |
| Transmissivity[2], gal/min/ft (m²/sec)<br>Double-Sided Composite<br>Single-Sided Composite | ASTM D 4716 | 1/540,000 ft² | <br>4.3 (9 x $10^{-4}$)<br>14.5 (3 x $10^{-3}$) | <br>4.3 (9 x $10^{-4}$)<br>14.5 (3 x $10^{-3}$) | <br>3.4 (7 x $10^{-4}$)<br>9.6 (2 x $10^{-3}$) |
| Ply Adhesion, lb/in | ASTM D 7005 | 1/50,000 ft² | 1.0 | 1.0 | 1.0 |
| **Geonet Core [1,3] – GSE HyperNet** | | | | | |
| Geonet Core Thickness, mil | ASTM D 5199 | 1/50,000 ft² | 300 | 300 | 300 |
| Transmissivity[2], gal/min/ft (m²/sec) | ASTM D 4716 | | 38.6 (8 x $10^{-3}$) | 38.6 (8 x $10^{-3}$) | 38.6 (8 x $10^{-3}$) |
| Density, g/cm³ | ASTM D 1505 | 1/50,000 ft² | 0.94 | 0.94 | 0.94 |
| Tensile Strength (MD), lb/in | ASTM D 7179 | 1/50,000 ft² | 75 | 75 | 75 |
| Carbon Black Content, % | ASTM D 4218 | 1/50,000 ft² | 2.0 | 2.0 | 2.0 |
| **Geotextile[1,3]** | | | | | |
| Mass per Unit Area, oz/yd² | ASTM D 5261 | 1/90,000 ft² | 6 | 8 | 10 |
| Grab Tensile Strength, lb | ASTM D 4632 | 1/90,000 ft² | 160 | 220 | 260 |
| Grab Elongation | ASTM D 4632 | 1/90,000 ft² | 50% | 50% | 50% |
| CBR Puncture Strength, lb | ASTM D 6241 | 1/540,000 ft² | 435 | 575 | 725 |
| Trapezoidal Tear Strength, lb | ASTM D 4533 | 1/90,000 ft² | 65 | 90 | 100 |
| AOS, US sieve[1] (mm) | ASTM D 4751 | 1/540,000 ft² | 70 (0.212) | 80 (0.180) | 100 (0.150) |
| Permittivity, $sec^{-1}$ | ASTM D 4491 | 1/540,000 ft² | 1.5 | 1.3 | 1.0 |
| Water Flow Rate, gpm/ft² | ASTM D 4491 | 1/540,000 ft² | 110 | 95 | 75 |
| UV Resistance, % retained | ASTM D 4355 (after 500 hours) | per formulation | 70 | 70 | 70 |
| **NOMINAL ROLL DIMENSIONS[4]** | | | | | |
| Roll Width, ft | | | 15 | 15 | 15 |
| Roll Length, ft | Double-Sided Composite<br>Single-Sided Composite | | 180<br>220 | 170<br>220 | 160<br>200 |
| Roll Area, ft² | Double-Sided Composite<br>Single-Sided Composite | | 2,700<br>3,300 | 2,550<br>3,300 | 2,400<br>3,000 |

NOTES:
- [1]All geotextile properties are minimum average roll values except AOS which is maximum average roll value and UV resistance is typical value. Geonet core thickness is nominal value.
- [2]Gradient of 0.1, normal load of 10,000 psf, water at 70˚F between steel plates for 15 minutes. Contact GSE for performance transmissivity value for use in design.
- [3]Component properties prior to lamination.
- [4]Roll widths and lengths have a tolerance of ±1%.

GSE is a leading manufacturer and marketer of geosynthetic lining products and services. We've built a reputation of reliability through our dedication to providing consistency of product, price and protection to our global customers.

Our commitment to innovation, our focus on quality and our industry expertise allow us the flexibility to collaborate with our clients to develop a custom, purpose-fit solution.

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REFERENCE 1c

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DRAINAGE PRODUCT DESCRIPTION SHEET

## US Ecology Nevada, Inc.

### TRANSNET 330-2-8

Transnet 330-2-8 is a superior quality drainage media made by extruding two sets of HDPE strands together to form a diamond shaped net. The net is then heat laminated to an 8 ounce non-woven fabric. This three dimensional structure provides excellent planar liquid flow. The Transnet 330-2-8 conforms to the physical property values listed below:

| NET PROPERTY | TEST METHOD | UNITS | MINIMUM AVERAGE ROLL VALUE |
|---|---|---|---|
| Mass Per Unit Area | ASTM D-5261 | $lbs/ft^2$ | 0.300 |
| Thickness | ASTM D-5199 | mils | 330 +/- 30 |
| Density of Polymer | ASTM D-1505 | $g/cm^2$ | 0.94 |
| Carbon Black | ASTM D-1603 | % | 2 |
| Transmissivity (Geocomposite) | ASTM D-4716 | $Gpm/ft^2$ | 4.35 |
| Transmissivity (Geonet) | ASTM D-4716 | $Gpm/ft^2$ | 38.64 |
| Tensile Strength | ASTM D-5035 | lbs/in | 75 |
| Ply Adhesion | GRI GC7 | Lbs/in | 1.0 |

*Transmissivity measured using water at 20 Degrees C with a gradient of 0.02, between 2 steel plates, under a confining pressure of 10,000 psf after fifteen minutes. Values may vary based on dimension of the transmissivity specimen and specific laboratory.

### STYLE GE-180

GE-180 is a superior quality, nonwoven geotextile produced by needlepunching together 100% polypropylene staple fibers in a random network to form a high strength dimensionally stable fabric. The polypropylene fibers are specially formulated to resist ultraviolet light deterioration, and are inert to commonly encountered soil chemicals. The fabric will not mildew, is non-biodegradable, and is resistant to damage from insects and rodents. Polypropylene is stable within a ph range of 2 to 13. GE180 conforms to the physical property values below:

| FABRIC PROPERTY | TEST METHOD | UNITS | MINIMUM AVERAGE ROLL VALUE |
|---|---|---|---|
| Weight | ASTM D-5261 | oz | 8.0 |
| Grab Tensile | ASTM D-4632 | lbs | 220 |
| Grab Elongation | ASTM D-4632 | % | 50 |
| Puncture | ASTM D-4833 | lbs | 120 |
| Water Flow Rate | ATMD D-4491 | $gpm/ft^2$ | 100 |
| Permittivity* | ASTM D-4491 | $sec^{-1}$ | 1.26 |
| AOS | ASTM D-4751 | US Sieve | 80 (max) |

*At time of manufacturing. Handling may change these properties.

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REFERENCE 2

Fourth Edition

# Designing with Geosynthetics

Robert M. Koerner, Ph.D., P.E.

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REFERENCE 2



### 4.1.6 Allowable Flow Rate

As described previously, the very essence of the design-by-function concept is the establishment of an adequate factor of safety. For geonets, where flow rate is the primary function, this takes the following form.

$$\mathrm{FS} = \frac{q_{\mathrm{allow}}}{q_{\mathrm{reqd}}} \tag{4.3}$$

where

FS = factor of safety (to handle unknown loading conditions or uncertainties in the design method, etc.),
$q_{\mathrm{allow}}$ = allowable flow rate as obtained from laboratory testing, and
$q_{\mathrm{reqd}}$ = required flow rate as obtained from design of the actual system.

Alternatively, we could work from transmissivity to obtain the equivalent relationship.

$$\mathrm{FS} = \frac{\theta_{\mathrm{allow}}}{\theta_{\mathrm{reqd}}} \tag{4.4}$$

where $\theta$ is the transmissivity, under definitions as above. As discussed previously, however, it is preferable to design with flow rate rather than with transmissivity because of nonlaminar flow conditions in geonets.

Concerning the allowable flow rate or transmissivity value, which comes from hydraulic testing of the type described in Section 4.1.3, we must assess the realism of the test setup in contrast to the actual field system. If the test setup does not model site-specific conditions adequately, then adjustments to the laboratory value must be made. This is usually the case. Thus the laboratory-generated value is an ultimate value that must be reduced before use in design; that is,

$$q_{\mathrm{allow}} < q_{\mathrm{ult}}$$

One way of doing this is to ascribe reduction factors on each of the items not adequately assessed in the laboratory test. For example,

$$q_{\mathrm{allow}} = q_{\mathrm{ult}}\left[\frac{1}{\mathrm{RF}_{IN} \times \mathrm{RF}_{CR} \times \mathrm{RF}_{CC} \times \mathrm{RF}_{BC}}\right] \tag{4.5}$$

or if all of the reduction factors are considered together.

$$q_{\mathrm{allow}} = q_{\mathrm{ult}}\left[\frac{1}{\Pi\mathrm{RF}}\right] \tag{4.6}$$

where

$q_{\mathrm{ult}}$ = flow rate determined using ASTM D4716 or ISO/DIS 12958 for short-term tests between solid platens using water as the transported liquid under laboratory test temperatures,

REFERENCE 2



$q_{allow}$ = allowable flow rate to be used in Eq. (4.3) for final design purposes,
$RF_{IN}$ = reduction factor for elastic deformation, or intrusion, of the adjacent geosynthetics into the geonet's core space,
$RF_{CR}$ = reduction factor for creep deformation of the geonet and/or adjacent geosynthetics into the geonet's core space,
$RF_{CC}$ = reduction factor for chemical clogging and/or precipitation of chemicals in the geonet's core space,
$RF_{BC}$ = reduction factor for biological clogging in the geonet's core space, and
$\Pi RF$ = product of all reduction factors for the site-specific conditions.

Some guidelines for the various reduction factors to be used in different situations are given in Table 4.2. Please note that some of these values are based on relatively sparse information. Other reduction factors, such as installation damage, temperature effects, and liquid turbidity, could also be included. If needed, they can be included on a site-specific basis. On the other hand, if the actual laboratory test procedure has included the particular item, it would appear in the above formulation as a value of unity. Examples 4.2 and 4.3 illustrate the use of geonets and serve to point out that high reduction factors are warranted in critical situations.

**Example 4.2**

What is the allowable geonet flow rate to be used in the design of a capillary break beneath a roadway to prevent frost heave? Assume that laboratory testing was done at the proper design load and hydraulic gradient and that this testing yielded a short-term between-rigid-plates value of $2.5 \times 10^{-4}$ m²/s.

**Solution:** Since better information is not known, average values from Table 4.2 are used in Eq. (4.5).

TABLE 4.2 RECOMMENDED PRELIMINARY REDUCTION FACTOR VALUES FOR EQ. (4.5) FOR DETERMINING ALLOWABLE FLOW RATE OR TRANSMISSIVITY OF GEONETS

| Application Area | $RF_{IN}$ | $RF_{CR}$* | $RF_{CC}$ | $RF_{BC}$ |
|---|---|---|---|---|
| Sport fields | 1.0 to 1.2 | 1.0 to 1.5 | 1.0 to 1.2 | 1.1 to 1.3 |
| Capillary breaks | 1.1 to 1.3 | 1.0 to 1.2 | 1.1 to 1.5 | 1.1 to 1.3 |
| Roof and plaza decks | 1.2 to 1.4 | 1.0 to 1.2 | 1.0 to 1.2 | 1.1 to 1.3 |
| Retaining walls, seeping rock, and soil slopes | 1.3 to 1.5 | 1.2 to 1.4 | 1.1 to 1.5 | 1.0 to 1.5 |
| Drainage blankets | 1.3 to 1.5 | 1.2 to 1.4 | 1.0 to 1.2 | 1.0 to 1.2 |
| Surface water drains for landfill covers | 1.3 to 1.5 | 1.1 to 1.4 | 1.0 to 1.2 | 1.2 to 1.5 |
| Secondary leachate collection (landfills) | 1.5 to 2.0 | 1.4 to 2.0 | 1.5 to 2.0 | 1.5 to 2.0 |
| Primary leachate collection (landfills) | 1.5 to 2.0 | 1.4 to 2.0 | 1.5 to 2.0 | 1.5 to 2.0 |

*These values are sensitive to the density of the resin used in the geonet's manufacture. The higher the density, the lower the reduction factor. Creep of the covering geotextile(s) is a product-specific issue.

REFERENCE 3

GSE ENVIRONMENTAL™

# DRAINAGE

## DESIGN MANUAL - SECOND EDITION

June 2007


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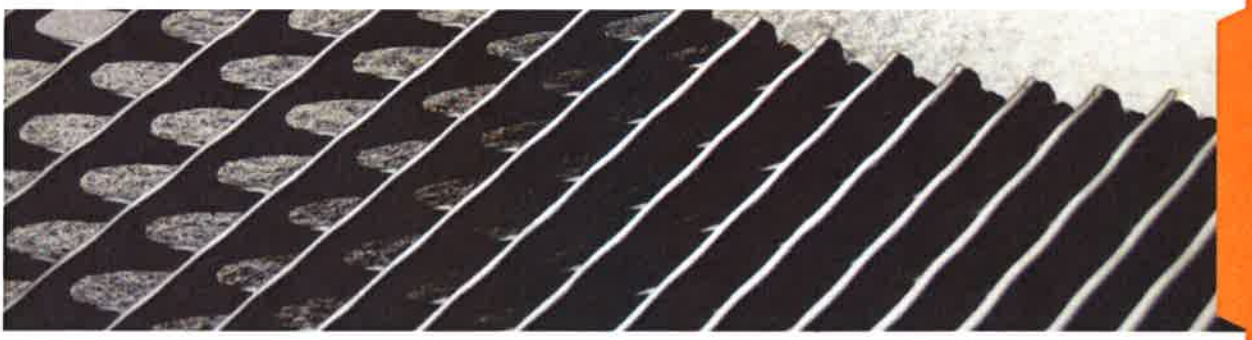


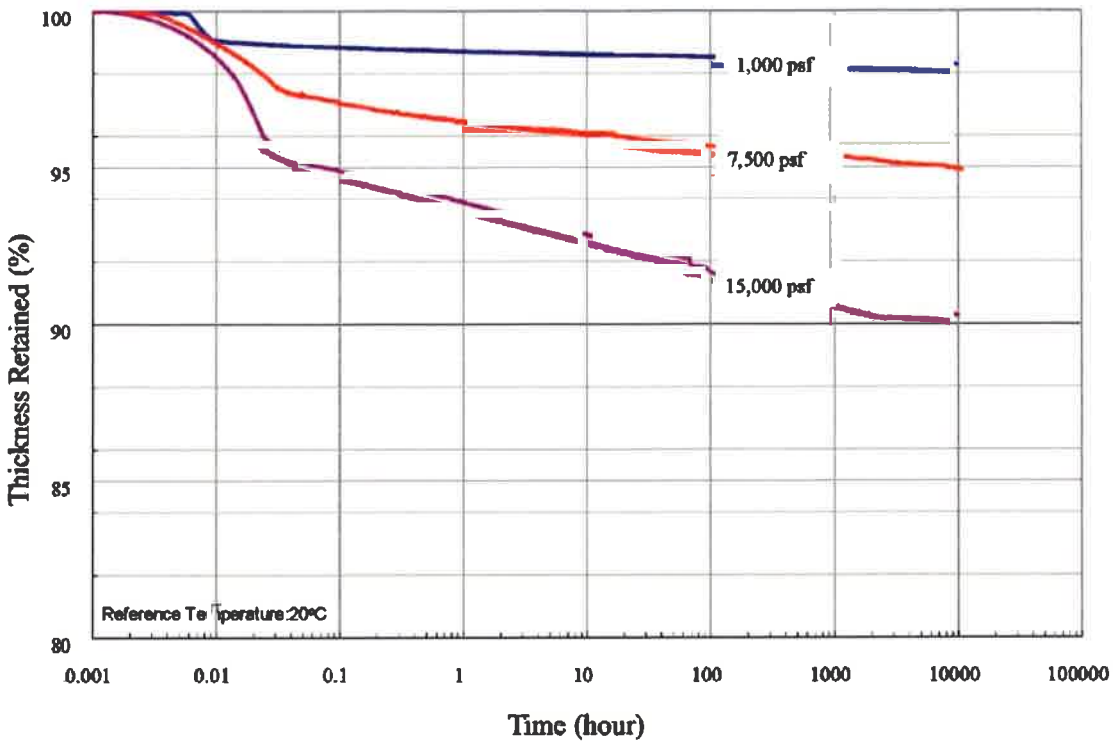



Figure B-3. Creep Curves for a 300 mil GSE HyperNet UF geonet.

Table B-3. Creep Reduction Factors for a 300 mil GSE HyperNet UF geonet from 100 hours to 50 Years

| Stress (psf) | Creep Reduction Factor |
|---|---|
| 1,000 | 1.00 |
| 5,000 | 1.06 |
| 15,000 | 1.19 |

**REFERENCE 4**

Geosynthetics

# A new sensible approach: Are we specifying action leakage rates or actionable leakage rates?

Geosyntheticsmagazine.com | September 2, 2009

By Glenn T. Darilek and Daren L. Laine

**Introduction**

The logical criteria for specifying an action leakage rate (ALR) is not whether a certain rate is achievable with good construction practices, but whether there is a practical solution if the ALR is not achieved.

Specifying a low ALR can be a disaster if the source of the leakage cannot be located or logically explained. In that case, there is no practical solution other than to reline the facility and hope that the leak rate of the new geomembrane does not also exceed the low ALR.

When specifying an action leakage rate, it should not necessitate legal actions if the specification cannot be achieved with the existing technology. The practical approach is to specify an ALR to be compatible with the leak rate that would be caused by a leak (or leaks) that can be reliably located using geoelectric leak-location methods.

**Mathematical models**

This article illustrates the use of a mathematical model of the geoelectric leak signal vs. size of the leak, and a mathematical model of the leak rate vs. size of the leak to give a new perspective of what is achievable and what is unrealistic for the specification of action leakage rates.

The geoelectric leak signal model takes into consideration the geomembrane thickness, leak diameter, and the survey parameters, and assumes that the resistivity of the material in the leak and the resistivity of

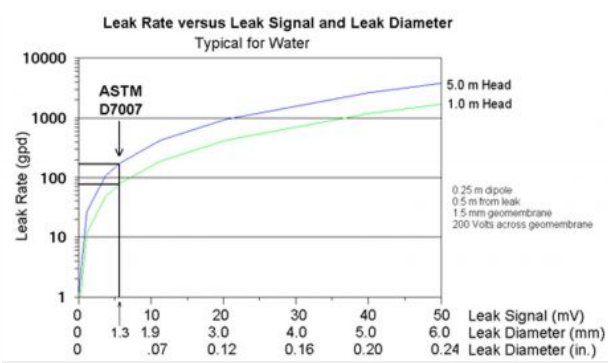
the materials above and below the leak are all the same. General articles about action leakage rates are posted by George Yazdani at www.poly-flex.com and by Ian Peggs at www.geosynthetica.net.

Action leakage rates should be specified to correspond to the leak rate that would be observed from the smallest reliably-detectable leak. Actually, even with such a specification, one assumes that the leakage is from one leak and not from many smaller undetectable leaks. The unsolvable problem continues to exist if the leakage is from a multitude of smaller undetectable leaks. So a safety factor must be applied to cover that contingency.

**Water-filled impoundments**

For geoelectric leak-location surveys, with only water covering the geomembrane and with the usually-specified ALRs, there is no problem currently because a properly-applied geoelectric survey can locate the very small leaks that would contribute to the ALRs.

Figure 1 shows a graph of the free flow leakage rate vs. the leak signal for some typical leak-location survey parameters for surveys with water on the geomembrane.




This is only an illustration. Actual survey parameters will be different.

Because the geoelectric leak signal is related to the leak diameter, Figure 1 also has scales that correspond to the leak diameters that would cause the leak signals. Note that the leak diameter scales are not linear with the leak signal. ASTM D7007 currently specifies a 1.3mm (0.05in.) test leak.

# REFERENCE 4

Assuming free flow, which is the case with a properly designed leak-detection system, the graph shows that the leak rate from such a leak is about 80 and 180 gallons per day for water depths of 1m (3.3ft) and 5m (16ft), respectively. Such a leak is very practical to detect, and those leak rates are typically a fraction of the usual ALR for water-filled impoundments.

This illustration is for only one leak. For large impoundments, it is reasonable to assume there would be multiple leaks. If one would expect one leak per acre (0.4 hectare), the illustration can be extrapolated to multi-acre impoundments by using the dimensions of gallons per acre per day (gpa/d) instead of gallons per day (gpd). However, one cannot logically interpolate for impoundments less than one acre, because that would result in a leak rate that may not be located using leak-location methods.

In general, this analysis suggests that typical ALRs could be made more stringent for ponds larger than one acre.

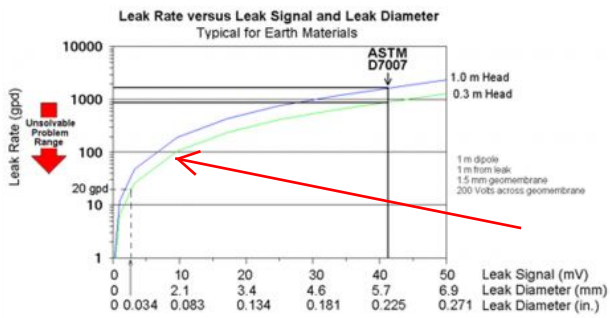
**Impoundments and landfills with earth materials on the geomembrane**

The problem gets much more interesting with earth materials covering the geomembrane.

Specifying an ALR that is too low for a geomembrane covered with earth materials can result in a problem with no practical solution. This is because the geoelectric leak-detection sensitivity is lower with earth materials on the geomembrane.

The thickness of the earth materials prevents detection of the smallest leaks for two reasons. One is that the leak-detection measurements are made from a greater distance from the leaks. This distance is at least the depth of the earth materials. Secondly, there is much more measurement noise when making the measurements on the earth materials.

Figure 2 shows a graph of the leak rate vs. leak signal for some typical leak-location survey parameters with earth materials on the geomembrane.




Again, this is only an illustration. The corresponding leak diameters are again shown on the abscissa. ASTM D7007 currently specifies a 6mm (0.236in.) test leak.

Assuming free flow, which is often the case with granular drainage materials or some geosynthetic materials above and below the geomembrane, the graph shows the leak rate from such a leak is about 950 and 1,700 gallons per day for typical hydrostatic heads of 0.3m (1ft) and 1m (3.3ft), respectively.

Such a leak is usually practical to detect, but these leakage rates are typically more than an order of magnitude higher than some present ALRs for landfills. This illustration shows that the existing typical ALRs can be unrealistic and can result in disastrous consequences that will not allow the permitting of the landfill cell.

A common geoelectric leak-location specification for landfills calls for detecting all leaks that could contribute to an ALR of 20 gallons per acre per day. The analysis below shows the paradox that meeting that geoelectric leak-location specification depends almost entirely on having intimate contact between the geomembrane and an underlying geosynthetic clay liner (GCL), or other leak-sealing layer, and not on the geoelectric leak-location survey.

It is an incorrect to assume a maximum of 1ft of water head on a landfill cell because it is common to have a few feet of water standing on the lowest part of a cell after rainfall or snowmelt. But assuming 1ft (0.3m) of head, Figure 2 shows that 20 gallons per day will flow through a 0.034-in.-diameter leak assuming free flow. For all practical purposes, free flow conditions will exist with such a small hole with drainage material above the geomembrane and a geonet or drainage material under the geomembrane.

Figure 2 shows the signal from such a leak is in the low-mill volt range. Measurement noise is typically much greater than that, so reliable detection of a leak of that size is problematic to say the least. Even without free flow conditions, the size of the leak will likely be small and probably undetectable.

In some cases, a saving grace for the specification of 20 gallons per acre per day is that a low permeability earth material or GCL often underlies the primary geomembrane. Therefore, the flow is greatly reduced, and larger leaks can be located or tolerated. However, if the geomembrane is not in intimate contact with the low-permeability layer, the unsolvable problem re-emerges.

Another approach is to test the bare geomembrane for leaks before the earth materials are placed to detect the smallest installation leaks and then assume no more small leaks will be caused as the earth materials are being placed on the geomembrane. Of course, another leak-location survey is needed to test for larger construction damage after the earth material is put on the geomembrane.

There has been at least one case where the ALR was set too low and the leaks could not be detected under 2 feet of sand. So the sand had to be removed from the lowest area of the landfill cell and that area had to be surveyed with water on the bare geomembrane. Needless to say, many more leaks were caused while removing the sand.

# REFERENCE 4

When the U.S. Environmental Protection Agency (EPA) promulgated the Final Rule for ALRs, it may not have considered the practical consequences of failing to meet the ALR, particularly for geomembranes covered with earth materials. In hindsight, the ALR for solid-waste facilities should be greater than the ALR for liquid-waste impoundments, which is the opposite of the guidance.

### The misconception of zero leakage

Specifying too low of an ALR, as untenable as that may be, is still a giant step more reasonable than specifying zero leakage.

Some engineers and owners are still specifying zero leakage or no leaks. A reasonable person could interpret zero leakage as never a drop. Ever.

Although one strives to obtain the best attainable results with a specification, it is naive to specify something that cannot be remedied if the specification is not met. That is the case when specifying zero leakage in a geomembrane of any practical size. Sometimes, one is fortunate and the leakage is zero or ignorable. But specifying zero leakage or specifying that a liner has no leaks almost always results in disputes and sometimes unsolvable problems.

### A workable specification

An important part of engineering and specification writing is to balance the desire for perfection with what is suitable for the purpose at a reasonable cost.

Although perfection may be the goal, specifying perfection without regard to consequences or cost is not good engineering. It does not make sense to provide a specification that if it is not met, there is no practical solution. So instead of specifying an ALR that may be legally actionable, proper engineering practice is to specify an ALR for which there is an action leakage plan that is workable.

| Specification | Performance Level | End Results |
|---|---|---|
| Perfection | Zero leakage | May not be attainable at any cost |
| Attainable in many or most situations | Very low ALR | Cost is reasonable if ALR is met, but cost may be prohibitive if ALR is not met |
| Attainable in all reasonable situations | ALR based on leaks that can be detected with geoelectric leak-location measurements | Cost is most reasonable |
| What is needed | ALR based on what is attainable with existing technology in all reasonable situations | Optimum benefit for the cost |

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### Comments

There are not yet any comments.

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