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SOLID WASTE SECTION
ASHEVILLE REGIONAL OFFICE

S&ME

MEMORANDUM

TO: Meeting Attendees
CC: None
FROM: Ken Daly, Will Harrison
DATE: July 29, 2008
SUBJECT: July 30, 2008 Meeting with NCDENR
Plant Allen Retired Ash Basin (RAB) Ash Landfill

BACKGROUND

1. PTC Application submitted March 2008
2. 62 acre retired ash basin (RAB)
3. 23 acre Phase 1
4. Cell 1 = 10.7 acres; Cell 2 = 12.8
5. Base grading plans slopes and accommodate estimated settlement
6. LCS/LDS Plans
7. Response to Comments: June 9, 2008

GEOCOMPOSITE DESIGN TRANSMISSIVITY SUMMARY

1. Objective: develop design transmissivity to account for in service flow reductions
2. Proposed product: GSE Permanet TRx
3. Reported transmissivity = 1 x 10^{-3} m^2/s
4. Laboratory testing transmissivity = 4.45 to 5.77 x 10^{-3} m^2/s
5. Applied reduction factors = 1.4
6. design transmissivity = 3.18 to 4.12 x 10^{-3} m^2/s
7. Calculation attached

ACTION LEAKAGE RATE SUMMARY

1. Objective: develop technical basis for ALR
2. Two cases considered
   a. EPA definition – 1-ft of head on primary liner; and
   b. "Unconfined Flow" basis - flow through geocomposite drainage layer limited to the product thickness
3. Assumptions
   a. Flow from a single penetration (assumed 1 per acre)
4. Results
   a. EPA = 21,500 gpad

   b. Unconfined Flow = 500 gpad
5. Calculation attached

TEST FILL SUMMARY

1. Start construction 1/15/08
2. Complete construction 4/23/08
3. 20-ft fill height over 2 acres
4. Settlement plates, magnet extensometers, piezometers, horizontal inclinometers
5. Presentation (Time Permitting)
6. Results
   a. Approximate settlement of 18-19 inches
   b. Estimated settlement approximately 30 inches (preliminary estimate)
   c. Quick settlement – little secondary response observed
   d. Groundwater response is not generally distinguishable from seasonal fluctuation

PROPOSED PERMIT TO CONSTRUCT APPLICATION MODIFICATIONS

1. Remove aggregate and pipe from the LDS corridor
2. expand protective cover soil types from only sandy to include also silty soils (ML, MH)
3. Existing conditions topography update

S&ME

JOB NO.	1356-06-825
SHEET NO.	1 / 6
DATE	3/5/08
COMPUTED BY	WMH
CHECKED BY	KB

JOB NAME Duke Energy – Allen Steam Station Ash Landfill

SUBJECT Action Leakage Rate

COMPUTATIONS BY:

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Name William Harrison, E.I.

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ASSUMPTIONS AND PROCEDURES CHECKED BY:

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Name Kenneth Daly, P.E.

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Name Kyle Baucom, E.I.

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Name Jack Amar, P.E.

Title Vice President

REVIEW NOTES / COMMENTS:

S&ME

JOB NO. 1356-06-825
SHEET NO. 2 / 6
DATE 3/5/08
JOB NAME Duke Energy – Allen Steam Station Ash Landfill
COMPUTED BY WMH
SUBJECT Action Leakage Rate
CHECKED BY KB

OBJECTIVE:

The objective of this analysis is to establish the action leakage rate (ALR) for the proposed ash landfill constructed over the retired ash basin (RAB) at the Allen Steam Station.

METHOD:

An ALR was evaluated by considering flows within the leak detection system (LDS) resulting from the following two conditions: a leachate head of 1-ft driving flow through a defect in the primary liner and into the leak detection system (EPA's ALR Definition); and unconfined flow where leachate thickness is limited to the thickness of the LDS drainage layer. Giroud et al. (1997) developed flow estimation equations for both these cases (presented in Attachment 1).

The proposed ash landfill liner system consists of, from top-to-bottom: a geocomposite drainage layer (leachate collection system, LCS); a primary 60-mil HDPE geomembrane; a secondary geocomposite drainage layer (LDS drainage layer); a secondary 60-mil HDPE geomembrane; a geosynthetic clay liner (GCL); and finally an 18-in thick, low permeability soil layer ($k<1*10^{-5}$cm/s).

EPA Definition

The ALR of the LDS is, according to the definition provided by CFR 40 § 264.302, the maximum design flow rate that the LDS can remove without the fluid head on the bottom liner exceeding 1 foot.

Flow through the LDS may be estimated for a single primary liner defect based on the following equation developed by Giroud et al. (1997):

$$Q = kt_1(2t_o - t_1) \qquad \text{(Equation 1)}$$

Where:
Q = flow rate in the LDS (drainage layer);
k = hydraulic conductivity of the LDS drainage material;
t_1 = thickness of the LDS drainage material; and
t_o = thickness or head of leachate on the secondary liner.

If evaluated using the EPA definition, the ALR may be established from the flow rate of Equation 1 by considering the anticipated defect frequency and factor of safety.

Unconfined Flow Condition

The method of ALR evaluation relying upon the EPA definition allows for a head buildup of 1-ft on the primary liner causing a region of confined flow in the LDS. Alternatively, the unconfined capacity of the LDS can be evaluated. According to Giroud et al. (1997) this capacity can be evaluated with the following equation:

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$$Q_{full} = kt_1^{\,2}$$ (Equation 2)

Where:
Q_{full} = flow rate in the LDS when the leachate thickness is the same as the drainage layer thickness;
k = hydraulic conductivity of the LDS drainage material (m/s); and,
t_1 = thickness of the LDS drainage material (m).

CALCULATIONS:

Material Parameters

k = 46 cm/s from Table 1 (most conservative value was chosen considering the decreasing flow capacity of the system over time measured for GSE Permanet TRx) [estimated for GSE Permanet TRx]
t_o = 0.3 m (1.0 ft) [assumed]
t_1 = 6.9 mm [property of GSE Permanet TRx]
Defect Frequency = 1 hole/acre [Qian et al. 2002]

Table 1 presents hydraulic conductivity design values for the three cases considered within the companion calculation package titled "Leachate Generation Rates": Case 1, open without waste; Case 2, open with (10 and 80 ft) waste; Case 3, closed landfill waste. Hydraulic conductivity design values are based on laboratory test results of representative materials and boundary conditions accounting for appropriate flow reduction factors as outlined in the companion calculation package "Design Transmissivity".

Table 1: Drainage Layer Hydraulic Conductivity Design Values for LDS

Operation Conditions	$\Theta_{measured}$ (m^2/s)	Θ_{LTIS} (m^2/s)	FS	Θ_{design} (m^2/s)	k_{design} (cm/s)
Case 1 (No Waste)	5.77E-03	4.12E-03	1.0	4.12E-03	60
Case 2 (10'-80' Waste)	4.45E-03	3.18E-03	1.0	3.18E-03	46
Case 3 (Closed Landfill)	4.45E-03	3.18E-03	1.0	3.18E-03	46

EPA Definition (1-ft Head, Maximum LDS Flow)

$Q = k * t_1 * (2t_o - t_1)$ = 0.46 m/s * 0.0069 m *[(2*0.3 m)-0.0069m] =
Q = 1.88 x 10^{-3} m^3/s = 43000 gal/day/defect
Q = 43000 gal/day/defect * 1 defect/acre = 43000 gal/acre/day
Q * (1/ FS) 43000 gal/acre/day * ½ = 21,500 gal/acre/day, or for measurement,
Q_{EPA} = **21,500 gpad**

Unconfined Flow Condition (Head within LDS, Maximum LDS Flow)

Q = $k*t_1^2$ = (0.46 m/s)*$(0.0069\ m)^2$ = 2.19E-05 m^3/s = 500 gal/acre/day
$Q_{Unconfined}$ = **500 gpad**

RESULTS:

Table 2 presents the estimated flow rates in the LDS by the two methods considered. For comparison purposes, the peak and average daily LDS flows estimated using the HELP model are summarized in Table 3, originally presented in the companion calculation package titled "Leachate Generation Rates". Estimated peak daily and average daily flows for Cases 1-3 are less than the LDS flow rates.

Table 2. Estimated LDS Flow Rates by Various Methods

LDS Flow Condition	Q (gpad)
EPA Definition (1-ft Head on Primary Liner)	21,500
Unconfined Flow (Head Restricted to LDS Thickness)	500

Table 3. HELP-Predicted LDS Flow Rates

Operation Conditions	Peak Daily Q_{LDS} (gpad)	Average Daily Q_{LDS} (gpad)
Case 1	175.0	23.2
Case 2a	99.0	37.1
Case 2b	71.3	25.2
Case 3	7.7	0.3

DISCUSSION:

The function of the LDS drainage layer is to quickly remove liquids that may migrate through the primary geomembrane liner and convey the liquid to the sumps. The liquids are then pumped out of the landfill. The average daily pump rates are to be monitored as required by regulations, and if LDS flow rates exceed the established ALR, appropriate response actions will be implemented.

Based on the analysis herein it is believed reasonable to evaluate the ALR considering unconfined flow within the LDS originating from a defect in the primary liner. According to this method and assuming 1 defect per acre, the ALR is 500 gpad.

To evaluate LDS flows, the owner or operator must convert the weekly or monthly flow rate from recorded monitoring data, to an average daily flow rate (gallons per acre per day) for each sump. The average daily flow rate for each sump must be calculated weekly during the active life and monthly during the post-closure care period.

It is important to note that Equation 2 is based on LDS drainage material thickness and permeability, k. The value of k used herein was developed from project specific testing replicating anticipated landfill conditions as presented in the companion calculation package titled "Design Transmissivity". We emphasize that in the context of typical flow characteristics for a range of commonly available geocomposite drainage layer materials a relatively high-flow geocomposite drainage material was selected. The specific product is a GSE Permanet

TRx. This product was selected on the basis of maximizing leachate collection and leak detection system performance.

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JOB NO. 1356-06-825
SHEET NO. 6 / 6
DATE 3/5/08

JOB NAME Duke Energy – Allen Steam Station Ash Landfill
COMPUTED BY WMH
SUBJECT Action Leakage Rate
CHECKED BY KB

REFERENCES

United States Environmental Protection Agency (USEPA) (1992) "Liners and Leak detection Systems for Hazardous Waste Land Disposal Units" 57, 19, 3462.

X. Qian et al. (2002) "Geotechnical Aspects of Landfill Design and Construction" Prentice Hall, NJ.

J.P. Giroud et al. (1997) "Liquid Migration Through Defects in a Geomembrane Overlain and Underlain by Permeable Media" Geosynthetics International, Vol. 4, Nos. 3-4.

United States Environmental Protection Agency (USEPA) (1992) "Action Leakage Rates for Leak Detection Systems" EPA-530-R-92-004

Bonaparte and Gross (1993) "LDCRS Flow from Double-Lined Landfills and Surface Impoundments" Supplement to EPA-600-R-93-070

ALR: Attachment 1

approximately the same in all directions. Since the hydraulic gradient is closely related to the slope of the phreatic surface, it may then be assumed that the slope of the cone generatrices is the same in all directions. The slope of the phreatic surface (i.e. the slope of the cone generatrix) in the direction of the slope of the leakage collection layer is approximately known: it is close to the slope angle, β, since the flow thickness is small compared to the length of the leakage collection layer. Therefore, it is assumed that the angle between all generatrices of the cone that form the phreatic surface of leachate and a horizontal plane is β (Figure 4).

From the foregoing discussion, it appears that the wetted zone (Figure 1b) is parabolic since the intersection of a cone and a plane parallel to a generatrix of the cone is a parabola. However, the actual wetted zone is only approximately parabolic because several simplifying assumptions were made, as indicated in Section 2.1 and, above, in Section 2.2.

2.3 Assumptions Specific to the Case Where the Leakage Collection Layer is Full

The case where "the leakage collection layer is full" is the case where the flow rate through the considered defect in the primary liner is large enough that the thickness of leachate in the leakage collection layer is equal to the thickness of the leakage collection layer in an area greater than zero around the defect in the primary liner. At the periphery of this area, the leachate phreatic surface is in contact with the primary liner.

As indicated in Section 2.2, the case where the leakage collection layer is not full is the lead case. Accordingly, assumptions regarding the hydraulic gradient and the shape of the phreatic surface (described in Section 2.2 for the case where the leakage collection layer is not full) will be adapted to the case where the leakage collection layer is full, as shown in Section 3.2.

3 RATE OF LEACHATE FLOW

3.1 Rate of Leachate Flow When the Leakage Collection Layer is not Full

The leakage collection layer is not full if the following condition is met:

$$t_o \leq t_{LCL} \quad (1)$$

where: t_o = maximum thickness of leachate in the leakage collection layer, which occurs at the defect of the primary liner, i.e. at the apex of the phreatic surface (Figure 4a); and t_{LCL} = thickness of the leakage collection layer (Figures 3 and 4a).

In the case where the leakage collection layer is not full, the vertical cross section of the flow in a plane passing through the defect and containing the horizontal contour lines of the liners (Figure 4b) is a triangle whose surface area is:

$$S = D_o^2 / \tan\beta \quad (2)$$

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ALR: Attachment 1

where: D_o = depth of leachate in the leakage collection layer at the primary liner defect (i.e. at the apex of the phreatic surface); and β = angle of the slope of the leakage collection layer, which is also the angle of the cone that forms the assumed phreatic surface.

The leachate depth is measured vertically, whereas the leachate thickness is measured perpendicularly to the liners. The following general (and classical) relationship exists between the leachate head on top of a liner, h, the leachate depth, D, and the leachate thickness, t:

$$h = t \cos\beta = D \cos^2\beta \tag{3}$$

Therefore, at the apex of the phreatic surface, the following relationship exists between the leachate head on top of the secondary liner, h_o, the leachate thickness, t_o, and the leachate depth, D_o:

$$h_o = t_o \cos\beta = D_o \cos^2\beta \tag{4}$$

The flow cross section area perpendicular to the flow in the leakage collection layer, S_F, is the projection of S, hence:

$$S_F = S \cos\beta \tag{5}$$

Combining Equations 2, 4 and 5 gives:

$$S_F = t_o^2 / \sin\beta \tag{6}$$

Flow in the leakage collection layer is governed by Darcy's equation:

$$Q = k\, i\, S_F \tag{7}$$

where: Q = steady-state rate of leachate flow in the leakage collection layer, which results from a defect in the primary liner and which is, therefore, equal to the rate of leachate migration through the defect; and i = hydraulic gradient in the leakage collection layer.

As discussed in Section 2.2, the slope of the leachate phreatic surface in the leakage collection layer is extremely close to the liner slope angle β. Therefore, the hydraulic gradient is virtually equal to the classical value of the hydraulic gradient for flow parallel to a slope, which is:

$$i = \sin\beta \tag{8}$$

Combining Equations 6, 7 and 8 gives:

$$Q = k\, t_o^2 \tag{9}$$

hence:

$$t_o = \sqrt{\frac{Q}{k}} \tag{10}$$

2/4

[redacted]

ALR:
Attachment 1

[redacted]

It appears that, when the leakage collection layer is not full, there is an extremely simple relationship between the rate of leachate migration through the primary liner defect, Q, and the thickness of leachate in the leakage collection layer beneath the defect, t_o. It is interesting to note that this relationship does not depend on the size of the defect in the primary liner or on the slope of the leakage collection layer.

An approximation that was made to establish Equations 9 and 10 was to assume that the downslope flow line from A (i.e. AB in Figure 4a) is parallel to the liner. This assumption is close to reality as discussed in Section 2.2. However, the actual flow line from A is below Line AB as the flow thickness decreases in the downslope direction, as discussed at the end of Section 5.1.2. Therefore, t_o should only be regarded as the flow thickness at a primary liner defect, and it is the maximum flow thickness.

Since the simple relationship expressed by Equations 9 and 10 was demonstrated for the case when the leakage collection layer is not full, the condition expressed by Equation 1 must be met for Equations 9 and 10 to be valid. Combining Equations 1 and 10 gives the following equation, which is another way to express the condition that should be met to ensure that the leakage collection layer is not full:

$$t_{LCL} \geq t_{LCLfull} = \sqrt{\frac{Q}{k}} \qquad (11)$$

where $t_{LCLfull}$ is the *minimum* thickness that a leakage collection layer with a hydraulic conductivity k should have to contain, without being full at any location, the leachate flow which results from a defect in the primary liner.

The following equation, derived from Equation 11, is another way to express the condition that should be met to ensure that the leakage collection layer is not full:

$$Q \leq Q_{full} = k\, t_{LCL}^2 \qquad (12)$$

where Q_{full} is the *maximum* steady-state rate of leachate migration through a defect in the primary liner that a leakage collection layer, with a thickness t_{LCL} and a hydraulic conductivity k, can accommodate without being filled with leachate.

It is important to remember that the subscript *full* corresponds to a *minimum* thickness of the leakage collection layer and to a *maximum* rate of leachate migration (which is also the *maximum* flow rate in the leakage collection layer). It is noteworthy that the minimum thickness of the leakage collection layer, $t_{LCLfull}$, and the maximum flow rate, Q_{full}, which are required to ensure that the leakage collection layer can contain, without being full, the flow that results from a defect in the primary liner, do not depend on the slope of the leakage collection layer.

It is not impossible to design a leakage collection layer with a thickness less than the value $t_{LCLfull}$ given by Equation 11, i.e. where the flow rate is greater than Q_{full} defined by Equation 12. In this case, the leakage collection layer is filled with leachate in a certain area around the defect of the primary liner (i.e. "the leachate collection layer is full"). This case is discussed in Section 3.2.

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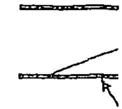

Figure 5. Vertica
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3.2 Rate of Leachate Flow When the Leachate Collection Layer is Full

If the thickness of the leakage collection layer is less than $t_{LCLfull}$ expressed by Equa tion 11 (or if the rate of leachate migration through a primary liner defect is greater tha Q_{full} expressed by Equation 12, which is equivalent), the leakage collection layer i filled with leachate in a certain area around the defect. Following the approach de scribed in Section 2.2, it may then be assumed that the leachate phreatic surface in th leakage collection layer is a truncated cone (Figure 5). The virtual apex of the truncate cone, A′, is above the leakage collection layer (i.e. above the primary liner, which i the upper boundary of the leakage collection layer). The virtual leachate depth, D_o, anu the virtual leachate thickness, t_o, are related to the actual leachate head, h_o, through Equation 4, and the virtual leachate thickness t_o is greater than the thickness of the leachate collection layer:

$$t_o > t_{LCL} \tag{13}$$

The surface area of the vertical cross section of the flow in the leakage collection layer (Figure 5) is expressed by:

$$S = \frac{D_o^2}{\tan\beta} - \frac{(D_o - D_{LCL})^2}{\tan\beta} = \frac{D_{LCL}(2D_o - D_{LCL})}{\tan\beta} \tag{14}$$

where D_{LCL} is the depth of the leakage collection layer.

The depth is measured vertically whereas the thickness is measured perpendicularly to the slope, hence, in accordance with Equation 3:

$$t_{LCL} = D_{LCL}\cos\beta \tag{15}$$

Using the demonstration presented in Section 2.2, i.e. combining Equations 4, 5, 7, 8, 14 and 15, gives:

$$Q = k\, t_{LCL}(2t_o - t_{LCL}) \tag{16}$$

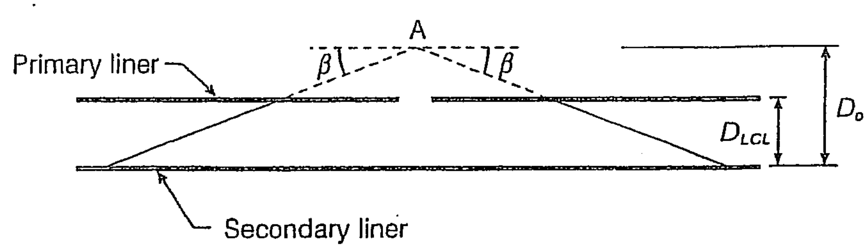

Figure 5. Vertical cross section of the assumed phreatic surface in the leakage collection layer in the case where the leakage collection layer is filled with leachate in a certain area around the primary liner defect.

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JOB NO. 1356-06-825
SHEET NO. 1 / 7
DATE 3/3/08
COMPUTED BY WMH
CHECKED BY KB

JOB NAME Duke Energy – Allen Steam Station Ash Landfill
SUBJECT Design Transmissivity

COMPUTATIONS BY: Signature [signature] Date 3/4/08

Name William Harrison, E.I.

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Title Staff Professional

REVIEWED BY: Signature [signature] Date 3-7-08

Name Jack Amar, P.E.

Title Vice President

REVIEW NOTES / COMMENTS:

OBJECTIVE:

Evaluate the design transmissivity of the geocomposite drainage layer used for the leachate collection system (LCS) and leak detection system (LDS) of the liner system for the proposed retired ash basin (RAB) ash landfill.

METHOD:

Develop a geocomposite drainage layer design transmissivity as described by Giroud et al. (2000) to account for in service reductions in flow capacity. Design transmissivity values were calculated for three operational conditions: Case 1, liner system with 2' operational cover; Case 2, liner system with 2' operational cover, 10'-80' compacted waste and 6" daily cover; and Case 3, closed landfill.

CALCULATIONS:

Drainage Layer Transmissivity Design Values

Transmissivity is calculated using the following equation:

$$\theta = kt \quad \text{(Equation 1)}$$

Where:

Θ=hydraulic transmissivity (cm^2/sec);

k=hydraulic conductivity (cm/sec); and

t=drainage layer thickness (0.69cm).

Use the following equations to estimate the appropriate geocomposite drainage layer design transmissivity value:

$$\theta_{LTIS} = \frac{\theta_{measured}}{\prod(RF)} = \frac{\theta_{measured}}{RF_{IMCO} * RF_{IMIN} * RF_{CR} * RF_{IN} * RF_{CD} * RF_{PC} * RF_{CC} * RF_{BC}} \quad \text{(Equation 2)}$$

$$\theta_{Design} = \frac{\theta_{LTIS}}{FS} \quad \text{(Equation 3)}$$

Where

Θ_{LTIS}=long term in-situ soil hydraulic transmissivity of the geocomposite;

$\Theta_{measured}$=value of hydraulic transmissivity obtained after laboratory testing;

Π (RF) = product of all reduction factors;

RF_{IMCO}=reduction factor for immediate compression;

RF_{IMIN}=reduction factor for immediate intrusion;

RF_{cr}=creep reduction factor;

RF_{in}=intrusion reduction factor;

RF_{cd}=chemical clogging/degradation reduction factor;

RF_{PC}= particulate clogging reduction factor;

RF_{cc}=chemical clogging reduction factor;

RF_{bc}=biological clogging reduction factor;

Θ_{design}=geocomposite transmissivity appropriate for use in design;

FS= factor of safety.

Evaluation of $\theta_{measured}$

- For Cases 1, 2 and 3 laboratory transmissivity tests were performed in accordance with ASTM D 4716. Test parameters replicating operational conditions of the LCS and LDS, including seating times of 100 hrs under normal stresses of 250 and 7,200 psf were used. Furthermore, sample profiles were arranged to replicate geocomposite contact conditions for LCS and LDS. These profiles consisted of a sand/geocomposite/HDPE geomembrane profile for the LCS and a HDPE geomembrane/geocomposite/ HDPE geomembrane profile for the LDS. Laboratory testing was performed by TRI/Environmental, Inc. of Austin, Texas. Lab test results are reported in Attachment 1.
- GSE Permanet TRx, a triaxial drainage net, was selected due to the products sustained flow capacity under high normal load.

LCS Reduction Factors

Reduction factors used to evaluate LCS geocomposite drainage layer design transmissivity values are presented in Table 1. As discussed in the preceding section, site specific operational conditions of the LCS geocomposite drainage layer were replicated during laboratory transmissivity testing. This allowed for minimization of several of the reduction factors.

Table 1: LCS Reduction Factors

		Range of Values		**Operating Conditions**			
		LINER	**COVER**	**Case 1 (No Waste)**	**Case 2 (10'-80' Waste)**	**Case 3 (Closed Landfill Liner)**	**Case 3 (Closed Landfill Cover)**
RF_{IMCO}	Reduction factor for immediate compression	1.0	1.0	1.0	1.0	1.0	1.0
RF_{IMIN}	Reduction factor for immediate intrusion	1.5	1.0	1.0	1.0	1.0	1.0
RF_{CR}	Reduction factor for creep	1.4-2.0[1]	1.1-1.4[1]	1.4	1.4	1.4	1.1
RF_{IN}	Reduction factor for delayed intrusion	1.0-1.2[1]	1.0-1.2[1]	1.1	1.0	1.0	1.0
RF_{CD}	Reduction factor for chemical degradation	1.5	1.2	1.0	1.0	1.0	1.0
RF_{PC}	Reduction factor for particulate clogging	1.2	1.2	1.0	1.2	1.2	1.2
RF_{CC}	Reduction factor for chemical clogging	1.5-2.0[1]	1.0-1.2[1]	1.0	1.0	1.0	1.0
RF_{BC}	Reduction factor for biological clogging	1.5-2.0[1]	1.2-1.5[1]	1.0	1.0	1.5	1.2
	Overrall Reduction Factors =	RF		**1.54**	**1.68**	**2.52**	**1.58**

[1] Published Values from Giroud et al. (2000) and Qian et al. (2002)

LDS Reduction Factors

Reduction factors used to evaluate the LDS geocomposite drainage layer design transmissivity values are presented in Table 2. Again, the replication of site specific operational conditions of the LDS geocomposite drainage layer during laboratory transmissivity testing allowed for minimization of several of the reduction factors.

Table 2: LDS Reduction Factors

		Operating Conditions			
		Range of Values **LINER**	**Case 1 (No Waste)**	**Case 2 (10'-80' Waste)**	**Case 3 (Closed Landfill Liner)**
RF_{IMCO}	Reduction factor for immediate compression	1.0	1.0	1.0	1.0
RF_{IMIN}	Reduction factor for immediate intrusion	1.5	1.0	1.0	1.0
RF_{CR}	Reduction factor for creep	1.4-2.0[(1)]	1.4	1.4	1.4
RF_{IN}	Reduction factor for delayed intrusion	1.0-1.2[(1)]	1.0	1.0	1.0
RF_{CD}	Reduction factor for chemical degradation	1.5	1.0	1.0	1.0
RF_{PC}	Reduction factor for particulate clogging	1.2	1.0	1.0	1.0
RF_{CC}	Reduction factor for chemical clogging	1.5-2.0[(1)]	1.0	1.0	1.0
RF_{BC}	Reduction factor for biological clogging	1.5-2.0[(1)]	1.0	1.0	1.0
	Overall Reduction Factor =	RF	**1.4**	**1.4**	**1.4**

[(1)] Published Values from Giroud et al. (2000) and Qian et al. (2002)

RESULTS:

Design transmissivity values were calculated for three operational conditions: Case 1, liner system with 2' operational cover; Case 2, liner system with 2' operational cover, 10'-80' compacted waste and 6" daily cover; and Case 3, closed landfill.

LCS Design Transmissivity and Hydraulic Conductivity

The estimated LCS geocomposite drainage layer design transmissivity values for operational conditions are presented in Table 3.

Table 3: LCS Design Transmissivity and Hydraulic Conductivity

Operation Conditions	$\Theta_{measured}$ (m^2/s)	Θ_{LTIS}	k_{design} (cm/s)
Case 1	5.53E-03	3.59E-03	52
Case 2	3.36E-03	2.00E-03	29
Case 3	3.36E-03	1.33E-03	19

Please note that a hand calculation verifying the k_{design} is provided in Attachment 2.

LDS Design Transmissivity and Hydraulic Conductivity

The estimated LDS geocomposite drainage layer design transmissivity values for operational conditions are presented in Table 4. These values will be used to evaluate the LDS performance and action leakage rate (ALR).

Table 4: LDS Design Transmissivity and Hydraulic Conductivity

Operation Conditions	$\Theta_{measured}$ (m^2/s)	Θ_{LTIS}	k_{design} (cm/s)
Case 1	5.77E-03	4.12E-03	60
Case 2	4.45E-03	3.18E-03	46
Case 3	4.45E-03	3.18E-03	46

S&ME

JOB NO.	1356-06-825
SHEET NO.	7 / 7
DATE	2/26/08
COMPUTED BY	WMH
CHECKED BY	KB

JOB NAME Duke Energy – Allen Steam Station Ash Landfill

SUBJECT Design Transmissivity

REFERENCE:

1. J. P. Giroud, J. G. Zornberg and A. Zhao (2000) "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers". *Geosynthetics International*, Vol. 7, Nos 4-5.
2. X. Qian, R. M. Koerner and D. H. Gray (2002) "Geotechnical Aspects of Landfill Design and Construction" Prentice Hall, Inc. Upper Saddle River , New Jersey 07458
3. Geosynthetics Specifiers Guide 2008. Vol. 25, Number 6

Design Transmissivity: Attachment 2

LCS geocomposite drainage layer design transmissivity:

Case 1 (No Waste Present):

$\theta_{measured} = 5.53 \cdot 10^{-3}\ m^2/s$

$RF = 1.54$

$\theta_{LTIS} = \frac{5.53 \cdot 10^{-3}\ m^2/s}{1.54} = 3.59 \cdot 10^{-3}\ m^2/s$ ✓ vmf

$K = \frac{\theta}{t} = \frac{3.59 \cdot 10^{-3}\ m^2/s}{(.0069\ m)} = 52\ cm/s$ ✓ vmf

February 11, 2008

Mail To:

Mr. Wiliam M. Harrison
S & ME
9751 Southern Pine Blvd.
Charlotte, NC 28273-5560

email:Wharrison@smeinc.com
phone: 704-523-4726
Fax: 704-525-3953

Bill To:

<= Same (Proj. Number: 1356-06-825)

Dear Mr. Harrison:

Thank you for consulting TRI/Environmental, Inc. (TRI) for your geosynthetics testing needs. TRI is pleased to submit this final report for laboratory testing.

Project:	**Ash Landfill**
TRI Job Reference Number:	E2302-57-06
Material(s) Tested:	4 GSE Permanet TRx -2-8oz Double Sided Geocomposite(s)
Test(s) Requested:	Transmissivity (ASTM D 4716)

If you have any questions or require any additional information, please call us at 1-800-880-8378.

Sincerely,

MPatel

Dr. Mansukh Patel
Sr. Laboratory Coordinator
Geosynthetic Services Division
www.GeosyntheticTesting.com

cc: Sam R. Allen, Vice President and Division Manager

GEOCOMPOSITE TEST RESULTS

TRI Client: S & ME
Project: Ash Landfill

Material: Double Sided Geocomposite
Sample Identification: 109195134
TRI Log #: E2302-57-06

PARAMETER	TEST REPLICATE NUMBER										MEAN	STD. DEV.
	1	2	3	4	5	6	7	8	9	10		

Hydraulic Transmissivity (ASTM D 4716)

Direction Tested: Machine Direction

Normal Load (psf):	250
Hydraulic Gradient:	0.03
Test Length (in)	12
Test Width (in)	12

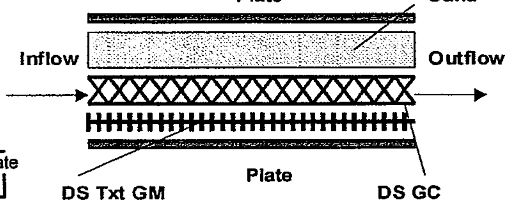

Plate / Ottawa Sand / Sample / 60 mil Textured HDPE Geomembrane / Plate

Seat Time (hours)		Specimen	1		MEAN	STD. DEV.
	Volume (cc)	762	769	767		
	Time (s)	15.09	15.20	15.15		
100	Flow Rate (GPM/ft width)	0.80	0.80	0.80	0.80	0.00
	Transmissivity (m^2/s)	5.52E-03	5.53E-03	5.54E-03	5.53E-03	7.36E-06
	Test Temp (C)		20.0			
	Temp. Corr. Factor		1.000			

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9063 Bee Caves Road / Austin, TX 78733 / 512 263 2101 / fax 512 263 2558

GEOCOMPOSITE TEST RESULTS

TRI Client: S & ME
Project: Ash Landfill

Material: Double Sided Geocomposite
Sample Identification: 109195134
TRI Log #: E2302-57-06

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	6	7	8	9	10	MEAN	STD. DEV.
Hydraulic Transmissivity (ASTM D 4716)												

Direction Tested: Machine Direction

Normal Load (psf):	7,200
Hydraulic Gradient:	0.03
Test Length (in)	12
Test Width (in)	12

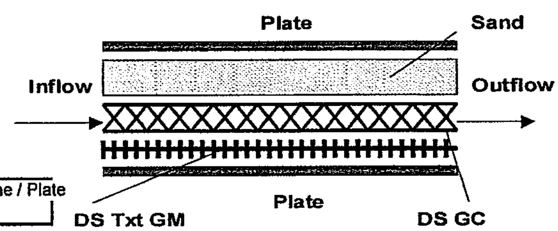

Plate / Ottawa Sand / Sample / 60 mil Textured HDPE Geomembrane / Plate

Seal Time (hours)		Specimen	1		MEAN	STD. DEV.
	Volume (cc)	623	621	628		
	Time (s)	20.27	20.26	20.44		
100	Flow Rate (GPM/ft width)	0.49	0.49	0.49	0.49	0.00
	Transmissivity (m^2/s)	3.36E-03	3.35E-03	3.36E-03	3.36E-03	4.96E-06
	Test Temp (C)		20.0			
	Temp. Corr. Factor		1.000			

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GEOCOMPOSITE TEST RESULTS

TRI Client: S & ME
Project: Ash Landfill

Material: Double Sided Geocomposite
Sample Identification: 109195134
TRI Log #: E2302-57-06

PARAMETER	TEST REPLICATE NUMBER										MEAN	STD. DEV.
	1	2	3	4	5	6	7	8	9	10		
Hydraulic Transmissivity (ASTM D 4716)												

Direction Tested: Machine Direction

Normal Load (psf):	250
Hydraulic Gradient:	0.03
Test Length (in)	12
Test Width (in)	12

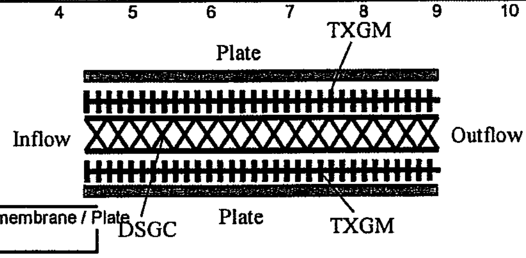

Plate / 60 mil TX HDPE Geomembrane / Sample / 6 mil TX HDPE Geomembrane / Plate

Seat Time (hours)		Specimen	1			MEAN	STD. DEV.
	Volume (cc)	806	805	814			
	Time (s)	15.29	15.27	15.41			
100	Flow Rate (GPM/ft width)	0.84	0.84	0.84		0.84	0.00
	Transmissivity (m^2/s)	5.76E-03	5.77E-03	5.78E-03		5.77E-03	6.75E-06
	Test Temp (C)		20.0				
	Temp. Corr. Factor		1.000				

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GEOCOMPOSITE TEST RESULTS

TRI Client: S & ME
Project: Ash Landfill

Material: Double Sided Geocomposite
Sample Identification: 109195134
TRI Log #: E2302-57-06

PARAMETER	TEST REPLICATE NUMBER 1	2	3	4	5	6	7	8	9	10	MEAN	STD. DEV.

Hydraulic Transmissivity (ASTM D 4716)

Direction Tested: Machine Direction	
Normal Load (psf):	7,200
Hydraulic Gradient:	0.03
Test Length (in)	12
Test Width (in)	12

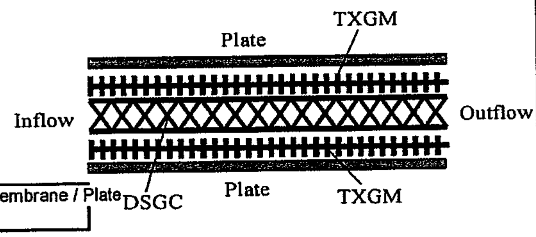

Plate / 60 mil TX HDPE Geomembrane / Sample / 6 mil TX HDPE Geomembrane / Plate

Seat Time (hours)		Specimen		1		MEAN	STD. DEV.
	Volume (cc)		612	613	615		
	Time (s)		15.07	15.09	15.10		
	Flow Rate (GPM/ft width)		0.64	0.64	0.65	0.64	0.00
100	Transmissivity (m^2/s)		4.44E-03	4.44E-03	4.45E-03	4.45E-03	7.09E-06
	Test Temp (C)			20.0			
	Temp. Corr. Factor			1.000			

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction: of this report, except in full, without prior approval of TRI.

Periodic equipment maintenance shall be performed as recommended by the manufacturer. Equipment maintenance will consist of checking equipment for corrosion, leakage, wear, scale build-up, improper functioning, and other improper operations. Appropriate corrective measures shall be taken when equipment is not operating properly.

Each LCS sump shall be equipped with a dedicated pump system. The pump system shall operate automatically based on level switches. The LCS sumps will have a low level cutoff at 0.5 ft and a high level run-start at 1.5 ft. Additionally, a visual and audible high level alarm shall be in place which will activate at 2 ft. The LCS system control panels will be equipped with audible and visual alarms programmed to identify sump liquid levels. LCS audible and visual alarms will be checked and tested for proper function weekly.

Records shall be maintained documenting the amounts of leachate generated and disposed of at the active ash basin.

Leachate from the LCS system shall be sampled in accordance with the approved monitoring plan. Leachate will be sampled semiannually from dedicated sample ports located on the LCS system. Leachate quality will be analyzed and reported consistent with the requirements of the approved monitoring plan. The following constituents will be analyzed for semi-annually:

Temperature	Arsenic	Barium
Boron	Cadmium	Chloride
Chromium	Copper	Fluoride
Iron	Lead	Manganese
Mercury	Nickel	Nitrate
pH	Selenium	Silver
Sulfate	Zinc	Total Dissolved Solids

3.2.2 Contingency Plan

In the unlikely event that leachate can not be pumped to the active ash basin (i.e. a power outage), leachate flow will be temporally stored within the landfill until such time that pumping operations to the active ash basin can be restored. Note that the design provides for redundant electrical supply from the power plant, such that the system will switch to the backup power supply line in the event that primary power is lost. In such an event, the Division shall be notified in writing, within 30 days, about the events and corrective actions taken.

3.3 Leak Detection System (LDS)

A leak detection system (LDS) has been incorporated into the design of the RAB ash landfill. The LDS consists of a secondary 60 mil HDPE liner system overlain by a secondary geocomposite drainage layer connected to LDS sumps. To aid in determining the location of a possible leak source and to reduce the likelihood of premature closure of an entire landfill cell as a consequence of excessive leakage, the LDS of each landfill cell is subdivided into two subcells, each with a dedicated LDS sump. Flow collected in the sumps will be transferred to the active ash basin via the leachate force main.

Each LDS sump shall be equipped with a dedicated pump system. The pump system shall operate automatically based on level switches. The LDS sumps will have a low level cutoff at 0.5 ft and a high level run-start at 1.5 ft. Additionally, a visual and audible high level alarm shall be in place which will activate at 2 ft.

The LDS has been designed with an initial response leakage rate (IRLR) of XXXX gallons per acre per day and an action leakage rate (ALR) of 500 gallons per acre per day. Should fluid collected in the LDS exceed the IRLR or ALR based on routine flow meter readings, the owner or operator shall take steps as indicated in the facility's Response Action Plan presented in Section 3.3.3.

The management of the leak detection system's physical facilities (consisting of piping and flow meters) and records of monitoring will be performed by or under the direct supervision of Duke Energy.

3.3.1 LDS Maintenance

Periodic equipment maintenance shall be performed as recommend by the manufacturer. Equipment maintenance will consist of checking equipment for corrosion, wear, scale build-up, improper functioning, and other improper operations. Appropriate corrective measures shall be taken when equipment is not operating properly. The LDS system control panels will be equipped with audible and visual alarms programmed to identify sump liquid levels. LCS sump controls will be checked and tested for proper function weekly.

3.3.2 Record Keeping and Monitoring

Flow will be measured at the discharge of each LDS sump by a totalizing flow meter. The facility shall maintain records of monthly flow rate data from each LDS sump from the activation of the cell drainage system and until the waste height reaches approximately 40 ft. From that point, flow rate data shall be collected on a quarterly basis until landfill closure.

During the post-closure care period, semiannual monitoring is required. If the liquid levels in the sumps stay below the pump high level run-start (no pump flow) for more than 1 year, then flow rates can be recorded annually. However, if at any time during post-closure care the pump high level run-start is exceeded on the semi-annual or annual schedules, the facility must return to monthly monitoring, until such time as the liquid level remains below the pump high-level run start for two consecutive months.

The purpose of LDS monitoring is to monitor if the leakage rates have been exceeded. Specific leakage rates are identified in Section 3.3. To determine if exceedances of the leakage rates have occurred, the facility must convert monitored data to an average daily flow rate for each sump (gallons per acre per day). If a leakage rate is exceeded, then the

Division must be notified as set forth in the Response Action Plan presented in Section 3.3.3.

3.3.3 Response Action Plan

The purpose of the response action plan is to describe the necessary course of action in the event the initial response leakage rate (IRLR) and/or the action leakage rate (ALR) are exceeded. If the IRLR is exceeded, steps 1 through 4 will be followed. Should the ALR also be exceeded steps 1 through 6 will be followed. The IRLR and ALR are referenced collectively as "leakage rates" in the following response action plan steps.

The IRLR is [redacted] gallons per acre per day
The ALR is 500 gallons per acre per day

The response action steps include:

Step 1 (IRLR and ALR):
Review physical equipment (pump and flow meter) function and data to confirm flow readings. Review operations to evaluate where operating equipment may have contacted the landfill liner or how landfill operations may have influenced the exceedance.

If the exceedance is confirmed, the cell LDS flow shall be recorded daily. Should the daily monitored LDS flow exceed the IRLR or ALR after the initial exceedance, operational responses may include: the reduction of active face area; grading to provide improved drainage; and/or, the addition of interim soil cover.

Step 2 (IRLR and ALR):
Within 14 days of identifying that a leakage rate has been exceeded, the facility shall contact the Division in writing. Daily LDS flow recording shall continue. Should none of the daily measured LDS flow rates exceed the leakage rate within 14 days of initial identification of the exceedance, monthly LDS flow averaging shall resume.

Step 3 (IRLR and ALR):
Within 30 days of identifying that a leakage rate has been exceeded, the facility shall submit to the Division a written preliminary assessment which shall include at a minimum:

- the amount of the liquid exceedance including initial measurement and daily measurements, if necessary, to date;
- likely sources of the liquids;
- the possible leak location;
- the possible leak size;
- the probable cause of the leak; and
- an outline of the short-term actions being taken and planned.

Step 4 (IRLR and ALR):

To the extent practicable, evaluate the location, size and cause of the leak; and assess the potential for escaping into the environment and its mobility. Leachate quality shall be sampled including a chemical analysis of LDS fluids to evaluate potential hazards (pH and RCRA metals).

Step 5 (ALR Only):

When the ALR is exceeded establish whether or not the unit should be closed or receipt of waste be curtailed; and conclude whether waste should be removed from the unit for inspection, engineered controls, or repair of the subcell liner and drainage system. Evaluate and prepare to implement what other short-term or long-term measures shall be taken to mitigate or stop any leaks according to the stage (early operations, middle operations, or closed) of landfill development, as detailed in Section 3.3.2, the discussion on LDS flow measurement.

Step 6(ALR Only):

Within 60 days of identifying that the ALR has been exceeded, submit to the Division the results of the evaluation performed in Step 4, any actions taken according to Step 5, and any further measures planned. For as long as there is an exceedance of the action leakage rate, the owner or operator shall submit monthly reports to the Division summarizing the results of the remedial actions taken and further actions planned.

3.4 Landfill Gas Management

Waste will consist of combustion products residuals including fly ash, bottom ash, boiler slag, mill rejects, and flue gas desulfurization (FGD) residue generated at the Allen Steam Station. The majority of the waste stream (approximately 95% or more) will consist of fly ash. A small portion of the remaining waste stream will consist of FGD residue. Based on the nature of the waste it is not anticipated that methane or hydrogen sulfide gas will be generated or that odor will be an issue. However, Duke Energy proposes to monitor for the presence of these gases throughout active landfill operations as summarized in the following sections.

3.4.1 Monitoring Program

Duke Energy will monitor for the presence of methane and hydrogen sulfide gas on an annual basis during landfill operations. Monitoring will be conducted by sampling/measuring within 12 to 24 inches of the landfill surface with a handheld gas meter. Monitoring shall be conducted continuously while traversing the landfill cell and active face on an approximate 100-foot wide grid pattern.

3.4.2 Record Keeping

Results of the gas monitoring program will be maintained in the operating record.

3.4.3 Contingency Plan

In the event that methane or hydrogen sulfide gases are detected appropriate actions will be taken. In the event that gases are regularly detected during active landfill operations, the final closure and post closure plan will be developed to address gas. It is anticipated that a minimum response will be to provide a passive gas venting system with the final closure. In the event that odor becomes a concern during operations, landfill operating procedures will be evaluated. Corrective measures may include reducing the active face area and placing additional or more frequent operational soil cover.