WESTINGHOUSE SAVANNAH RIVER COMPANY
INTER-OFFICE MEMORANDUM **SRT-ESS-96-453**

October 10, 1996

To: Distribution

From: Mark A. Phifer, 773-42A
Environmental Sciences Section

ESS Borehole Flowmeter Capability

The Savannah River Technology Center (SRTC) Environmental Sciences Section (ESS) has the capability to perform Borehole Flowmeter tests, which measure horizontal hydraulic conductivity on a 1 to 2 foot resolution. The following provides information on borehole flowmeter tests in general and on a test conducted by ESS adjacent to the D-Area Coal Pile Runoff Basin (CPRB).

General

A borehole flowmeter test of a well screen zone in conjunction with a standard aquifer pump test provides a methodology to obtain the hydraulic conductivity profile of the aquifer over the screened zone (both confined and unconfined aquifers). The highest quality data is produced from a naturally packed, fully penetrating well. The vertical flow rate within the well is measured at a set interval under both ambient and steady state pumping rate conditions. The pumping vertical flow rate minus the ambient vertical flow rate equal the net pumping vertical flow rate. The differential net pumping vertical flow rate over the set interval is equal to the flow rate entering the screen over that interval due to pumping. The vertical distribution of flow entering the well screen is proportional to the vertical distribution of the horizontal hydraulic conductivity. Equation 3.1 is the equation of proportionality:

Equation 3.1:
$$\frac{K_i}{K_a} = \frac{(\Delta Q_i - \Delta q_i) / \Delta z_i}{Q_p / b}$$

where: K_i = horizontal conductivity of ith layer
K_a = average horizontal conductivity over the screen (saturated portion)
Q_p = pumping rate
$\Delta Q_i - \Delta q_i$ = differential net pumping vertical flow rate over interval i
b = screen length (saturated portion)
Δz_i = interval length

The actual horizontal hydraulic conductivity of the ith layer is determined by multiplying the average aquifer hydraulic conductivity by the dimensionless conductivity (right side of equation 3.1) for the ith layer. (Molz, 1990)

D-Area Coal Pile Runoff Basin Borehole Flowmeter Test

A standard aquifer test of DCB-25 was performed on July 18, 1996. The standard aquifer test was conducted at an average flow rate of 5 gpm (0.67 cfm) and three observation wells were utilized. Analysis of the data produced an average horizontal hydraulic conductivity of 5.0E-4 cm/s, and an average vertical hydraulic conductivity of 5.0E-5 cm/s ($K_v / K_h = 0.10$).

A borehole flowmeter test of DCB-25 was performed on July 30 and 31, 1996. The borehole flowmeter utilized was a patented, prototype, downhole, one inch orifice, electromagnetic (EM) borehole flowmeter (TISCO, Inc.). Ambient conditions were on a one foot interval before and after pumping. Steady state pumping rate conditions were measured on a one foot interval during pumping at an average rate of 2.58 gpm (0.3443 cfm).

The differential ambient flow condition is shown in Figure 1. Positive differential ambient flows represent flow into the screen at that elevation; negative flows represent flow out of the screen at that elevation. Groundwater is entering the well in the bottom 25 feet of the screen (elevation 70 to 95 ft-msl), and it is exiting over a 10 ft upper central section of the screen (elevation 100 to 110 ft-msl). This indicates that there is an upward gradient from the bottom half of the water table aquifer to the upper central part of the water table aquifer. The hydraulic conductivity profile produced from analysis of the data produced during the test is provided in Figure 2, along with the results of the DCB-25 standard aquifer pump test. As can be seen both sets of hydraulic conductivity data correlate well. The borehole flowmeter results produced a range of hydraulic conductivities from 2.2E-5 to 3.4E-3 cm/s. The areas of high differential ambient flow (Figure 1) correspond to the areas of high hydraulic conductivity (Figure 2), and both correspond to the areas of lower natural gamma readings. This data demonstrates that the water table aquifer is anisotropic and heterogeneous. It has high conductive zones (sands) interbedded in low conductive zones (clays) with greater than two orders of magnitude difference in hydraulic conductivities. Finally, it demonstrates that an upward gradient exists from the bottom half of the aquifer.

Conclusions

Borehole flowmeter tests provide the ability to identify preferential pathways within an aquifer and produce a hydraulic conductivity profile of that aquifer. Additionally within an area of an aquifer it may be possible to correlate borehole flowmeter results to gamma logs; thereby increasing the ability to determine spatial variations in hydraulic conductivity and map preferential flow paths. This data is invaluable for more accurate groundwater and contaminant transport modeling and for the design of recovery/injection wells and situ treatment systems.

ESS is prepared to offer this service to Environmental Restoration (ER), and would like to do so on a case by case basis through a funded WAD.

If you need additional information, please contact me at 725-5222 or Joette Sonnenberg at 725-5190.

Distribution:

C. L. Bergren, 730-2B
R. S. Van Pelt, 730-2B
G. H. Golshir, 730-2B
J. A. Adams, 730-2B
R. H. Sentelle, 730-2B
G. C. Blount, 730-2B
J. E. Sciarro, 730-2B
W. C. Miles, 730-2B
J. E. Cardoso-Neto, 730-2B
R. Malanowski, 730-2B
C. M. Lewis, 730-2B
E. Topp, 730-2B
W. W. Pidcoe, 730-2B
T. F. Gaughan, 730-2B
M. B. Amidon, 730-2B
R. S. Aylward, 730-2B
A. Suer, 730-2B
D. B. Moore-Shedrow, 773-A
J. G. Sonnenberg, 773-42A
R. L. Nichols, 773-42A
G. P. Flach, 773-42A
D. G. Jackson, 773-42A
F. C. Sappington, 704-D
R. N. Strom, 773-42A
M. K. Harris, 773-42A
ESS files

Figure 1

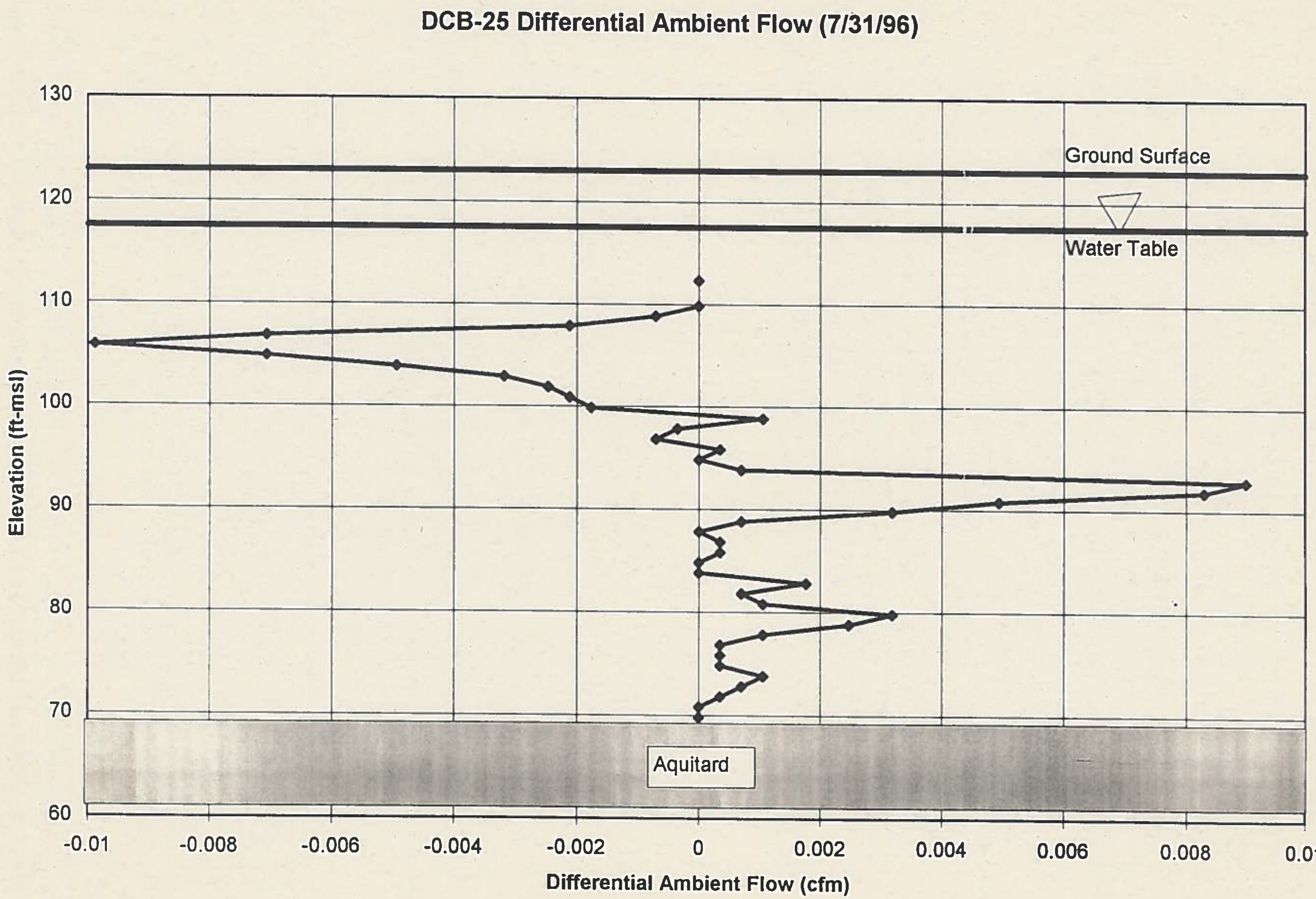
DCB-25 Differential Ambient Flow (7/31/96)
Ground Surface
Water Table
Aquitard
Elevation (ft-msl)
130
120
110
100
90
80
70
60
-0.01
-0.008
-0.006
-0.004
-0.002
0
0.002
0.004
0.006
0.008
0.01
Differential Ambient Flow (cfm)

Figure 2

DCB-25 Hydraulic Conductivity Profile