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ENVIRONMENTAL SCIENTISTS AND ENGINEERS

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Hydraulic Properties of LEHR/UC Davis Soil Samples

Prepared for
Battelle PNL/ITEH
Davis, California

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Summary

The Hydrologic Testing Laboratory at Daniel B. Stephens & Associates, Inc. (DBS&A) has completed laboratory tests on LEHR/UC Davis soil samples as specified by Ms. Dawn Mitchell and summarized in Table 1. Tables 2 through 6 give the results of the specified analyses. Raw laboratory data and graphical plots of data (where appropriate) are contained in Appendices A through E. Appendix F lists the methods used in these analyses. A detailed description of each method is available upon request.

The samples were removed from their packaging, cut to consistent dimensions, and immediately weighed for determination of initial moisture content. The GEO1 sample was disturbed from either shipping or sampling and was repacked to the bulk density of the original sample. We tested an undisturbed portion of the sample to determine bulk density and then repacked the sample to that density. After all other testing had been completed, the samples were oven dried for 24 hours to determine dry weights for calculation of dry bulk densities.

Saturated hydraulic conductivity was measured using constant and falling head permeameters. Falling head permeameters are used to determine saturated hydraulic conductivity on low permeability materials. The permeabilities ranged from 4.7×10^{-3} to 1.1×10^{-8} cm/s. All samples, except the GEO1 sample, were tested using falling head permeameters.

Moisture characteristics were determined using hanging column, pressure plate, and thermocouple psychrometer analysis. The samples were saturated by placing them in pans and slowly adding degassed water until the water level was even with the top of the sample. Using degassed water and wetting the samples from the bottom reduces the amount of entrapped gas in the samples. Unsaturated hydraulic parameters were determined by curve fitting the moisture retention data with the RETC code for determination of hydraulic parameters of unsaturated soils (van Genuchten, 1991).

Particle densities were determined using water pycnometers. Measured particle densities were used to calculate the total porosity of each sample.

Overall, the results appear reasonable and internally consistent. However, DBS&A cannot guarantee that these results are representative of the undisturbed materials at the field site, nor can we assume any responsibility for interpretations or analyses based on these data. We recommend that careful evaluation of these laboratory results be made for your particular application.

Table 1. Summary of Tests Performed

Laboratory Sample Number	Initial Moisture Content	Dry Bulk Density	Calculated Porosity	Saturated Hydraulic Conductivity	Moisture Characteristics			Unsaturated Hydraulic Conductivity	Particle Density
					Hanging Column	Pressure Plate	Thermocouple Psychrometer		
GEO1	X	X	X	X	X	X	X	X	X
GEO2	X	X	X	X	X	X	X	X	X
GEO3	X	X	X	X	X	X	X	X	X
GEO4	X	X	X	X	X	X	X	X	X
GEO5	X	X	X	X	X	X	X	X	X
GEO6	X	X	X	X	X	X	X	X	X
GEO7	X	X	X	X	X	X	X	X	X
GEO8	X	X	X	X	X	X	X	X	X
GEO9	X	X	X	X	X	X	X	X	X

Table 2. Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density, and Calculated Porosity

Sample Number	Initial Moisture Content Gravimetric (%, g/g)	Initial Moisture Content Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
GEO1	2.2	4.2	1.92	1.96	29.3
GEO2	17.8	29.9	1.68	1.98	37.1
GEO3	13.2	24.0	1.81	2.05	32.7
GEO4	23.8	36.1	1.51	1.87	43.6
GEO5	21.5	34.3	1.60	1.94	40.6
GEO6	19.3	31.8	1.65	1.96	39.3
GEO7	14.9	27.3	1.84	2.11	30.8
GEO8	17.7	30.1	1.70	2.00	37.9
GEO9	13.3	23.4	1.76	1.99	33.9

SB-5 48.62' Above MSL

SB-6 49.57' Above MSL

Table 3. Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K_{sat} (cm/sec)	Method of Analysis	
		Constant Head	Falling Head
GEO1	4.7E-03	X	
GEO2	6.7E-05		X
GEO3	1.4E-08		X
GEO4	6.4E-05		X
GEO5	1.0E-08		X
GEO6	5.8E-08		X
GEO7	3.1E-08		X
GEO8	1.1E-08		X
GEO9	5.6E-08		X

Table 4. Summary of Moisture Characteristics of the Initial Drainage Curve

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
GEO1	1	28.8
	9	24.5
	29	12.9
	78	8.0
	204	5.3
	2448	5.1
	20192	3.1
GEO2	1	35.6
	17	33.1
	50	30.8
	151	28.3
	510	25.6
	1020	24.1
	14073	17.4
GEO3	1	38.2
	55	37.1
	120	36.8
	1020	33.1
	3161	32.0
	5099	29.1
	18050	23.6
GEO4	1	48.0
	21	46.7
	55	45.0
	154	42.4
	510	39.0
	1020	36.9
	12034	22.8

Table 4. Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
GEO5	1	42.7
	51	42.2
	102	41.9
	1020	37.0
	3671	31.0
	4793	27.4
	13257	25.0
GEO6	1	38.9
	55	38.9
	106	38.7
	1019	35.1
	2550	31.6
	5303	28.5
	16929	20.5
GEO7	1	36.1
	54	33.9
	107	33.6
	1020	29.5
	3875	24.1
	5609	23.3
	14481	20.0
GEO8	1	43.6
	54	43.6
	119	43.6
	1020	41.8
	3977	37.0
	5915	33.9
	12238	30.4

Table 4. Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
GEO9	1	39.5
	54	39.5
	113	39.2
	1020	35.6
	2651	32.2
	5201	28.2
	15195	23.5

Table 5. Summary of Unsaturated Hydraulic Properties (Calculated)

Sample Number	α (cm^{-1}) Calculated Value	α 95% Confidence Limits Lower	α 95% Confidence Limits Upper	N (dimensionless) Calculated Value	N 95% Confidence Limits Lower	N 95% Confidence Limits Upper	θr (%)	θs (%)
GEO1	0.0852	0.0556	0.1149	1.9072	1.6210	2.1933	3.1	28.8
GEO2	0.0326	-0.0087	0.0739	1.3252	1.1404	1.5101	17.4	35.6
GEO3	0.0011	-0.0007	0.0029	1.6083	0.9361	2.2804	23.6	38.2
GEO4	0.0043	-0.0017	0.0102	1.5079	1.0069	2.0090	22.8	48.0
GEO5	0.0010	0.0005	0.0015	2.0480	1.4904	2.6056	25.0	42.7
GEO6	0.0005	-0.0007	0.0018	1.7676	1.2803	2.2549	20.5	38.9
GEO7	0.0019	-0.0008	0.0046	1.7045	1.0837	2.3252	20.0	36.1
GEO8	0.0003	0.0002	0.0005	2.8519	1.4239	4.2799	30.4	43.6
GEO9	0.0007	0.0003	0.0010	2.0018	1.4192	2.5844	23.5	39.5

Table 6. Summary of Particle Density Tests

Sample Number	Particle Density (g/cm^3)
GEO1	2.71
GEO2	2.68
GEO3	2.69
GEO4	2.68
GEO5	2.69
GEO6	2.71
GEO7	2.66
GEO8	2.74
GEO9	2.66

Appendix A

Initial Moisture Content, Bulk Density, and Porosity

Summary of Initial Moisture Content, Dry Bulk Density Wet Bulk Density, and Calculated Porosity

Sample Number	Initial Moisture Content Gravimetric (%, g/g)	Initial Moisture Content Volumetric (%, cm^3/cm^3)	Dry Bulk Density (g/cm^3)	Wet Bulk Density (g/cm^3)	Calculated Porosity (%)
GEO1	2.2	4.2	1.92	1.96	29.3
GEO2	17.8	29.9	1.68	1.98	37.1
GEO3	13.2	24.0	1.81	2.05	32.7
GEO4	23.8	36.1	1.51	1.87	43.6
GEO5	21.5	34.3	1.60	1.94	40.6
GEO6	19.3	31.8	1.65	1.96	39.3
GEO7	14.9	27.3	1.84	2.11	30.8
GEO8	17.7	30.1	1.70	2.00	37.9
GEO9	13.3	23.4	1.76	1.99	33.9

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	BATTELLE	
Job Number:	6908	
Sample Number:	GEO1	
Ring Number:	GEO1	
Depth:		
Field weight of sample (w/pan and ring):	328.21	(g)
Tare weight, ring:	58.59	(g)
Tare weight, plate:	83.28	(g)
Sample volume:	95.19	(cm^3)
Dry weight of sample:	182.32	(g)
Wet bulk density:	1.96	(g/cm^3)
Dry bulk density:	1.92	(g/cm^3)
Particle density:	2.71	(g/cm^3)
Calculated Porosity:	29.3	(% vol)
Initial Moisture Content (Volumetric):	4.2	(% vol)
Initial Moisture Content (Gravimetric):	2.2	(% g/g)
Percent Saturation:	14.4	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	BATTELLE	
Job Number:	6908	
Sample Number:	GEO2	
Ring Number:	GEO2	
Depth:		
Field weight of sample (w/pan and ring):	215.78	(g)
Tare weight, ring:	31.45	(g)
Tare weight, plate:	83.28	(g)
Sample volume:	50.94	(cm^3)
Dry weight of sample:	85.80	(g)
Wet bulk density:	1.98	(g/cm^3)
Dry bulk density:	1.68	(g/cm^3)
Particle density:	2.68	(g/cm^3)
Calculated Porosity:	37.1	(% vol)
Initial Moisture Content (Volumetric):	29.9	(% vol)
Initial Moisture Content (Gravimetric):	17.8	(% g/g)
Percent Saturation:	80.6	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	BATTELLE	
Job Number:	6908	
Sample Number:	GEO3	
Ring Number:	GEO3	
Depth:		
Field weight of sample (w/pan and ring):	246.02	(g)
Tare weight, ring:	36.66	(g)
Tare weight, plate:	88.28	(g)
Sample volume:	59.06	(cm^3)
Dry weight of sample:	106.93	(g)
Wet bulk density:	2.05	(g/cm^3)
Dry bulk density:	1.81	(g/cm^3)
Particle density:	2.69	(g/cm^3)
Calculated Porosity:	32.7	(% vol)
Initial Moisture Content (Volumetric):	24.0	(% vol)
Initial Moisture Content (Gravimetric):	13.2	(% g/g)
Percent Saturation:	73.3	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	BATTELLE	
Job Number:	6908	
Sample Number:	GEO4	
Ring Number:	GEO4	
Depth:		
Field weight of sample (w/pan and ring):	210.88	(g)
Tare weight, ring:	52.96	(g)
Tare weight, plate:	0.00	(g)
Sample volume:	84.30	(cm^3)
Dry weight of sample:	127.52	(g)
Wet bulk density:	1.87	(g/cm^3)
Dry bulk density:	1.51	(g/cm^3)
Particle density:	2.68	(g/cm^3)
Calculated Porosity:	43.6	(% vol)
Initial Moisture Content (Volumetric):	36.1	(% vol)
Initial Moisture Content (Gravimetric):	23.8	(% g/g)
Percent Saturation:	82.8	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	BATTELLE	
Job Number:	6908	
Sample Number:	GEO5	
Ring Number:	GEO5	
Depth:		
Field weight of sample (w/pan and ring):	239.31	(g)
Tare weight, ring:	37.37	(g)
Tare weight, plate:	83.29	(g)
Sample volume:	61.10	(cm^3)
Dry weight of sample:	97.69	(g)
Wet bulk density:	1.94	(g/cm^3)
Dry bulk density:	1.60	(g/cm^3)
Particle density:	2.69	(g/cm^3)
Calculated Porosity:	40.6	(% vol)
Initial Moisture Content (Volumetric):	34.3	(% vol)
Initial Moisture Content (Gravimetric):	21.5	(% g/g)
Percent Saturation:	84.6	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	BATTELLE	
Job Number:	6908	
Sample Number:	GEO6	
Ring Number:	GEO6	
Depth:		
Field weight of sample (w/pan and ring):	242.95	(g)
Tare weight, ring:	37.60	(g)
Tare weight, plate:	83.29	(g)
Sample volume:	62.17	(cm^3)
Dry weight of sample:	102.29	(g)
Wet bulk density:	1.96	(g/cm^3)
Dry bulk density:	1.65	(g/cm^3)
Particle density:	2.71	(g/cm^3)
Calculated Porosity:	39.3	(% vol)
Initial Moisture Content (Volumetric):	31.8	(% vol)
Initial Moisture Content (Gravimetric):	19.3	(% g/g)
Percent Saturation:	80.9	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	BATTELLE	
Job Number:	6908	
Sample Number:	GEO7	
Ring Number:	GEO7	
Depth:		
Field weight of sample (w/pan and ring):	246.22	(g)
Tare weight, ring:	36.74	(g)
Tare weight, plate:	83.26	(g)
Sample volume:	59.72	(cm^3)
Dry weight of sample:	109.89	(g)
Wet bulk density:	2.11	(g/cm^3)
Dry bulk density:	1.84	(g/cm^3)
Particle density:	2.66	(g/cm^3)
Calculated Porosity:	30.8	(% vol)
Initial Moisture Content (Volumetric):	27.3	(% vol)
Initial Moisture Content (Gravimetric):	14.9	(% g/g)
Percent Saturation:	88.7	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

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Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	BATTELLE	
Job Number:	6908	
Sample Number:	GEO8	
Ring Number:	GEO8	
Depth:		
Field weight of sample (w/pan and ring):	256.12	(g)
Tare weight, ring:	39.75	(g)
Tare weight, plate:	88.29	(g)
Sample volume:	63.92	(cm^3)
Dry weight of sample:	108.84	(g)
Wet bulk density:	2.00	(g/cm^3)
Dry bulk density:	1.70	(g/cm^3)
Particle density:	2.74	(g/cm^3)
Calculated Porosity:	37.9	(% vol)
Initial Moisture Content (Volumetric):	30.1	(% vol)
Initial Moisture Content (Gravimetric):	17.7	(% g/g)
Percent Saturation:	79.5	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Data for Initial Moisture Content, Bulk Density, Porosity, and Percent Saturation

Job Name:	BATTELLE	
Job Number:	6908	
Sample Number:	GEO9	
Ring Number:	GEO9	
Depth:		
Field weight of sample (w/pan and ring):	215.89	(g)
Tare weight, ring:	30.41	(g)
Tare weight, plate:	88.29	(g)
Sample volume:	48.76	(cm^3)
Dry weight of sample:	85.77	(g)
Wet bulk density:	1.99	(g/cm^3)
Dry bulk density:	1.76	(g/cm^3)
Particle density:	2.66	(g/cm^3)
Calculated Porosity:	33.9	(% vol)
Initial Moisture Content (Volumetric):	23.4	(% vol)
Initial Moisture Content (Gravimetric):	13.3	(% g/g)
Percent Saturation:	69.2	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Appendix B

Saturated Hydraulic Conductivity

Summary of Saturated Hydraulic Conductivity Tests

Sample Number	K_{sat} (cm/sec)	Method of Analysis	
		Constant Head	Falling Head
GEO1	4.7E-03	X	
GEO2	6.7E-05		X
GEO3	1.4E-08		X
GEO4	6.4E-05		X
GEO5	1.0E-08		X
GEO6	5.8E-08		X
GEO7	3.1E-08		X
GEO8	1.1E-08		X
GEO9	5.6E-08		X

Saturated Hydraulic Conductivity
Constant Head Method

Job name: BATTELLE
Job number: 6908
Sample number: GEO1
Ring number: GEO1
Depth:
Type of water used: TAP
Collection vessel tare: 10.70 g
Sample length: 5.11 cm
Sample diameter: 4.87 cm
Sample cross-sectional area: 18.63 cm3

Date	*Time*	*Temp (C)*	*Head (cm)*	*Q + Tare (g)*	*Q (cm^3)*	*Elapsed time (sec)*	*K_{sat} (cm/sec)*	*K_{sat} @ 20 C (cm/sec)*
Test # 1:								
12-Sep-96	09:36:00	23.0	4.1	27.0	16.3	210	5.2E-03	4.9E-03
12-Sep-96	09:39:30							
Test # 2:								
12-Sep-96	16:15:15	23.0	4.2	22.7	12.0	165	4.7E-03	4.4E-03
12-Sep-96	16:18:00							
Test # 3:								
13-Sep-96	09:08:57	22.0	4.2	23.8	13.1	175	4.9E-03	4.7E-03
13-Sep-96	09:11:52							

Average Ksat: 4.7E-03 cm/sec

Comments:

Laboratory analysis by: C. Wolf
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Saturated Hydraulic Conductivity
Falling Head Method

Job name: BATTELLE
Job number: 6908
Sample number: GEO2
Ring number: GEO2
Permeameter type
Standard = 1, Double =2: 1
Depth:
Type of water used: TAP
Sample length: 2.78 cm
Sample cross-sectional area: 18.32 cm2
Reservoir cross-sectional area: 0.70 cm2
Offset: 0 cm

Date	Time	Temp. (C)	Reservoir head (cm)	Corrected head (cm)	Elapsed time (sec)	K_{sat} (cm/sec)	K_{sat} @ 20 C (cm/sec)
Test # 1:							
12-Sep-96	12:35:25	20.0	77.0	77.0			
12-Sep-96	13:01:45	20.0	28.0	28.0	1580	6.8E-05	6.8E-05
Test# 2:							
12-Sep-96	16:35:31	20.5	75.0	75.0			
12-Sep-96	17:05:25	20.5	25.0	25.0	1794	6.5E-05	6.4E-05
Test # 3:							
13-Sep-96	11:46:50	20.0	75.0	75.0			
13-Sep-96	11:58:40	20.0	47.1	47.1	710	7.0E-05	6.9E-05

Average Ksat: 6.7E-05 cm/sec

Comments:

Laboratory analysis by: B. Hovda
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Saturated Hydraulic Conductivity
Falling Head Method

Job name: BATTELLE
Job number: 6908
Sample number: GEO3
Ring number: GEO3
Permeameter type Standard = 1, Double =2: 1
Depth:
Type of water used: TAP
Sample length: 3.21 cm
Sample cross-sectional area: 18.40 cm2
Reservoir cross-sectional area: 0.70 cm2
Offset: 0 cm

Date	Time	Temp. (C)	Reservoir head (cm)	Corrected head (cm)	Elapsed time (sec)	K_{sat} (cm/sec)	K_{sat} @ 20 C (cm/sec)
Test # 1:							
12-Sep-96	12:23:00	20.0	76.9	76.9			
13-Sep-96	11:39:40	20.0	76.0	76.0	83800	1.7E-08	1.7E-08
Test# 2:							
13-Sep-96	11:39:40	20.0	76.0	76.0			
14-Sep-96	13:14:15	20.0	75.3	75.3	92075	1.2E-08	1.2E-08
Test # 3:							
16-Sep-96	15:34:06	20.0	74.3	74.3			
17-Sep-96	08:44:00	20.0	73.8	73.8	61794	1.3E-08	1.3E-08

Average Ksat: 1.4E-08 cm/sec

Comments:

Laboratory analysis by: C. Wolf
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Saturated Hydraulic Conductivity
Falling Head Method

Job name: BATTELLE
Job number: 6908
Sample number: GEO4
Ring number: GEO4
Permeameter type
Standard = 1, Double =2: 1
Depth:
Type of water used: TAP
Sample length: 4.62 cm
Sample cross-sectional area: 18.25 cm2
Reservoir cross-sectional area: 0.70 cm2
Offset: 0 cm

Date	*Time*	*Temp. (C)*	*Reservoir head (cm)*	*Corrected head (cm)*	*Elapsed time (sec)*	*K_{sat} (cm/sec)*	*K_{sat} @ 20 C (cm/sec)*
Test # 1:							
12-Sep-96	12:24:06	19.5	66.0	66.0			
12-Sep-96	13:00:46	19.5	29.0	29.0	2200	6.6E-05	6.7E-05
Test# 2:							
12-Sep-96	16:20:11	20.5	68.0	68.0			
12-Sep-96	17:03:57	20.5	26.0	26.0	2626	6.5E-05	6.4E-05
Test # 3:							
13-Sep-96	11:41:21	20.0	78.0	78.0			
13-Sep-96	11:58:00	20.0	55.4	55.4	999	6.1E-05	6.1E-05

Average Ksat: 6.4E-05 cm/sec

Comments:

Laboratory analysis by: B. Hovda
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Saturated Hydraulic Conductivity
Falling Head Method

Job name: BATTELLE
Job number: 6908
Sample number: GEO5
Ring number: GEO5
Permeameter type
Standard = 1, Double =2: 1
Depth:
Type of water used: TAP
Sample length: 3.24 cm
Sample cross-sectional area: 18.86 cm2
Reservoir cross-sectional area: 0.70 cm2
Offset: 1.5 cm

Date	*Time*	*Temp. (C)*	*Reservoir head (cm)*	*Corrected head (cm)*	*Elapsed time (sec)*	*K_{sat} (cm/sec)*	*K_{sat} @ 20 C (cm/sec)*
Test # 1:							
25-Sep-96	17:01:36	20.0	782.7	781.2			
26-Sep-96	11:01:09	19.5	777.6	776.1	64773	1.2E-08	1.2E-08
Test# 2:							
26-Sep-96	11:01:09	19.5	777.6	776.1			
01-Oct-96	08:00:00	20.0	751.7	750.2	421131	9.7E-09	9.7E-09
Test # 3:							
01-Oct-96	08:00:00	20.0	751.7	750.2			
01-Oct-96	10:37:20	20.0	751.2	749.7	9440	8.5E-09	8.5E-09

Average Ksat: 1.0E-08 cm/sec

Comments:

Laboratory analysis by: C. Wolf
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Saturated Hydraulic Conductivity
Falling Head Method

Job name: BATTELLE
Job number: 6908
Sample number: GEO6
Ring number: GEO6
Permeameter type
Standard = 1, Double =2: 1
Depth:
Type of water used: TAP
Sample length: 3.27 cm
Sample cross-sectional area: 19.01 cm2
Reservoir cross-sectional area: 0.70 cm2
Offset: 0 cm

Date	*Time*	*Temp. (C)*	*Reservoir head (cm)*	*Corrected head (cm)*	*Elapsed time (sec)*	*K_{sat} (cm/sec)*	*K_{sat} @ 20 C (cm/sec)*
Test # 1:							
16-Sep-96	15:33:23	20.0	67.4	67.4			
17-Sep-96	08:42:43	20.0	65.4	65.4	61760	5.9E-08	5.9E-08
Test# 2:							
17-Sep-96	08:42:43	20.0	65.4	65.4			
17-Sep-96	14:38:58	20.0	64.7	64.7	21375	6.1E-08	6.0E-08
Test # 3:							
17-Sep-96	14:38:58	20.0	64.7	64.7			
18-Sep-96	12:31:14	19.5	62.4	62.4	78736	5.5E-08	5.6E-08

Average Ksat: 5.8E-08 cm/sec

Comments:

Laboratory analysis by: C. Wolf
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Saturated Hydraulic Conductivity
Falling Head Method

Job name: BATTELLE
Job number: 6908
Sample number: GEO7
Ring number: GEO7
Permeameter type
Standard = 1, Double =2: 1
Depth:
Type of water used: TAP
Sample length: 3.18 cm
Sample cross-sectional area: 18.78 cm2
Reservoir cross-sectional area: 0.70 cm2
Offset: 0 cm

Date	*Time*	*Temp. (C)*	*Reservoir head (cm)*	*Corrected head (cm)*	*Elapsed time (sec)*	*K_{sat} (cm/sec)*	*K_{sat} @ 20 C (cm/sec)*
Test # 1:							
12-Sep-96	12:55:10	20.0	79.4	79.4			
12-Sep-96	16:58:00	20.5	79.1	79.1	14570	3.1E-08	3.1E-08
Test# 2:							
13-Sep-96	14:11:40	20.5	78.1	78.1			
14-Sep-96	13:34:30	20.0	76.4	76.4	84170	3.1E-08	3.1E-08
Test # 3:							
16-Sep-96	15:34:29	20.0	73.9	73.9			
17-Sep-96	08:52:49	20.0	72.7	72.7	62300	3.1E-08	3.1E-08

Average Ksat: 3.1E-08 cm/sec

Comments:

Laboratory analysis by: B. Hovda
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Saturated Hydraulic Conductivity
Falling Head Method

Job name: BATTELLE
Job number: 6908
Sample number: GEO8
Ring number: GEO8
Permeameter type
Standard = 1, Double =2: 1
Depth:
Type of water used: TAP
Sample length: 3.46 cm
Sample cross-sectional area: 18.47 cm2
Reservoir cross-sectional area: 0.70 cm2
Offset: 0 cm

Date	Time	Temp. (C)	Reservoir head (cm)	Corrected head (cm)	Elapsed time (sec)	K_{sat} (cm/sec)	K_{sat} @ 20 C (cm/sec)
Test # 1:							
12-Sep-96	12:51:35	20.0	76.3	76.3			
13-Sep-96	11:52:00	20.0	75.7	75.7	82825	1.2E-08	1.2E-08
Test# 2:							
13-Sep-96	11:52:00	20.0	75.7	75.7			
14-Sep-96	13:30:00	20.0	75.2	75.2	92280	9.4E-09	9.4E-09
Test # 3:							
14-Sep-96	13:30:00	20.0	75.2	75.2			
16-Sep-96	15:42:13	20.0	74.1	74.1	180733	1.1E-08	1.1E-08

Average Ksat: 1.1E-08 cm/sec

Comments:

Laboratory analysis by: C. Wolf
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Saturated Hydraulic Conductivity
Falling Head Method

Job name: BATTELLE
Job number: 6908
Sample number: GEO9
Ring number: GEO9
Permeameter type
Standard = 1, Double =2: 1
Depth:
Type of water used: TAP
Sample length: 2.65 cm
Sample cross-sectional area: 18.40 cm2
Reservoir cross-sectional area: 0.70 cm2
Offset: 0 cm

Date	*Time*	*Temp. (C)*	*Reservoir head (cm)*	*Corrected head (cm)*	*Elapsed time (sec)*	*K_{sat} (cm/sec)*	*K_{sat} @ 20 C (cm/sec)*
Test # 1:							
12-Sep-96	12:20:30	20.0	77.3	77.3			
12-Sep-96	16:21:40	20.5	76.7	76.7	14470	5.4E-08	5.4E-08
Test# 2:							
12-Sep-96	16:21:40	20.5	76.7	76.7			
13-Sep-96	14:18:50	20.5	73.1	73.1	79030	6.1E-08	6.1E-08
Test # 3:							
13-Sep-96	14:18:50	20.5	73.1	73.1			
14-Sep-96	13:10:30	20.0	69.9	69.9	82300	5.5E-08	5.4E-08

Average Ksat: 5.6E-08 cm/sec

Comments:

Laboratory analysis by: B. Hovda
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Appendix C

Moisture Characteristics

Summary of Moisture Characteristics of the Initial Drainage Curve

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
GEO1	1	28.8
	9	24.5
	29	12.9
	78	8.0
	204	5.3
	2448	5.1
	20192	3.1
GEO2	1	35.6
	17	33.1
	50	30.8
	151	28.3
	510	25.6
	1020	24.1
	14073	17.4
GEO3	1	38.2
	55	37.1
	120	36.8
	1020	33.1
	3161	32.0
	5099	29.1
	18050	23.6
GEO4	1	48.0
	21	46.7
	55	45.0
	154	42.4
	510	39.0
	1020	36.9
	12034	22.8

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
GEO5	1	42.7
	51	42.2
	102	41.9
	1020	37.0
	3671	31.0
	4793	27.4
	13257	25.0
GEO6	1	38.9
	55	38.9
	106	38.7
	1019	35.1
	2550	31.6
	5303	28.5
	16929	20.5
GEO7	1	36.1
	54	33.9
	107	33.6
	1020	29.5
	3875	24.1
	5609	23.3
	14481	20.0
GEO8	1	43.6
	54	43.6
	119	43.6
	1020	41.8
	3977	37.0
	5915	33.9
	12238	30.4

Summary of Moisture Characteristics of the Initial Drainage Curve (Continued)

Sample Number	Pressure Head (-cm water)	Moisture Content (%, cm^3/cm^3)
GEO9	1	39.5
	54	39.5
	113	39.2
	1020	35.6
	2651	32.2
	5201	28.2
	15195	23.5

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ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: Battelle
Job Number: 6908
Sample Number: GEO1
Ring Number: GEO1
Depth: NA
Sample Volume: 95.18 (cm^3)

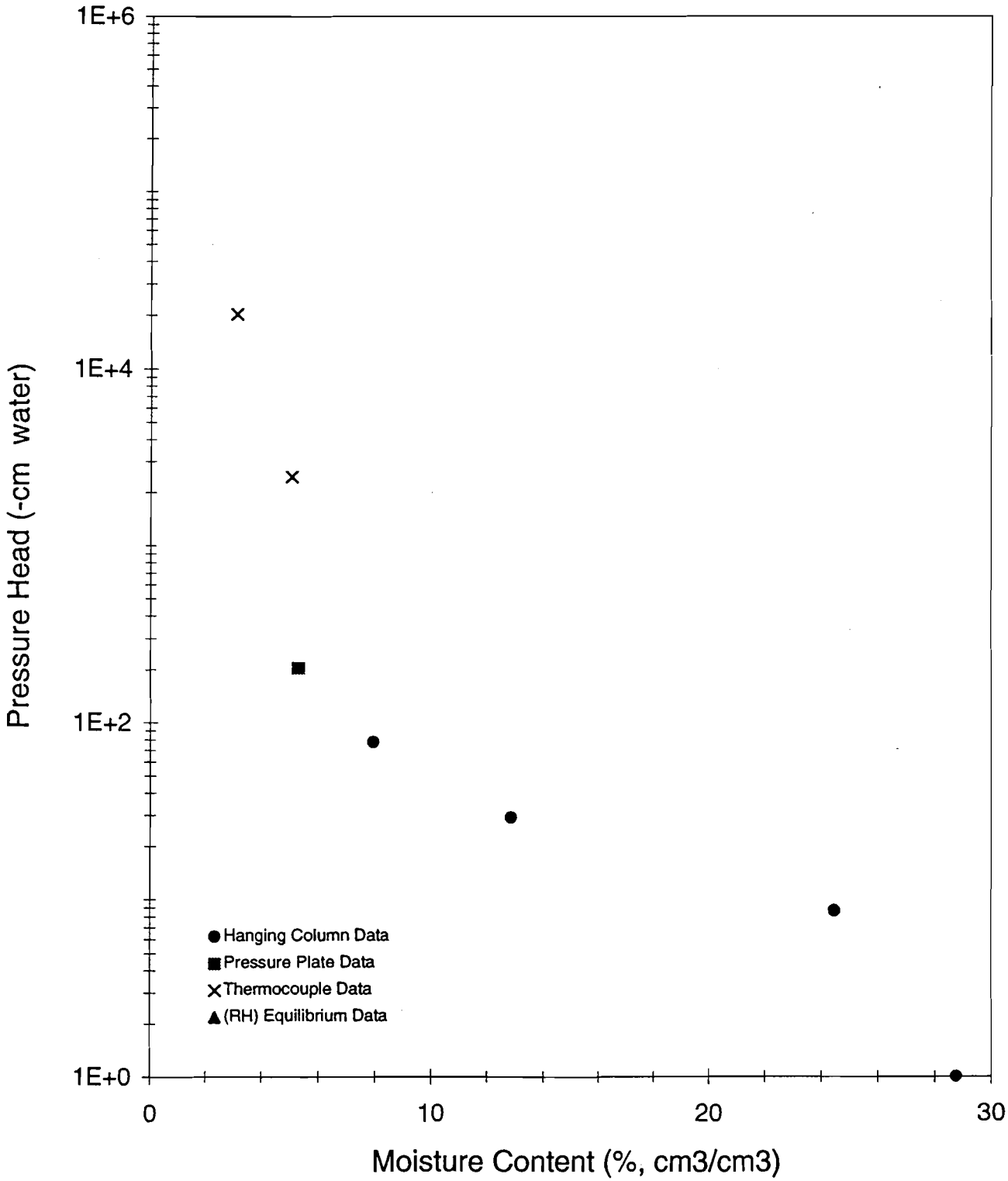
Saturated weight at 0 cm tension(with cap and ring): 291.44 (g)
Tare Ring: 58.58 (g)
Tare Other: 0.00 (g)
Tare Weight of Screen And Clamp: 23.16 (g)
Dry Weight of Sample: 182.32 (g)
Saturated Moisture Content: 28.77 (% vol)
Volume of Water in Saturated Sample: 27.38 (cm^3)

Date (1996)	*Time*	*Method*	*Matric Potential*	*Weight W/Ring (g)*	*Weight Change (g)*	*Total Weight Change (g)*	*Moisture Content (% vol)*
9/13	1135	1	0	291.44	0.00	0.00	28.77
9/16	1458	1	8.6	287.35	4.09	4.09	24.47
9/18	1457	1	29.0	276.30	11.05	15.14	12.86
9/20	1453	1	77.6	271.63	4.67	19.81	7.95
9/27	800	2	0.2	269.10	2.53	22.34	5.30
9/27	1353	3	2.4	268.88	0.22	22.56	5.06
9/27	1641	3	19.8	267.02	1.86	24.42	3.11

Comments: Assumed density of water is 1.0 g/cm

Method 1= Hanging Column Analysis (-cm water)
Method 2= Pressure Plate Analysis (-bars)
Method 3= Thermocouple Analysis (-bars)
Method 4= (RH) Equilibrium Analysis (-bars)

Laboratory Analysis Performed by: P. Prieksat
Calculations performed by: M. Prieksat
Checked by: M. Ankeny



Sample Number: GEO1

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Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: Battelle
Job Number: 6908
Sample Number: GEO2
Ring Number: GEO2
Depth: NA
Sample Volume: 50.94 (cm^3)

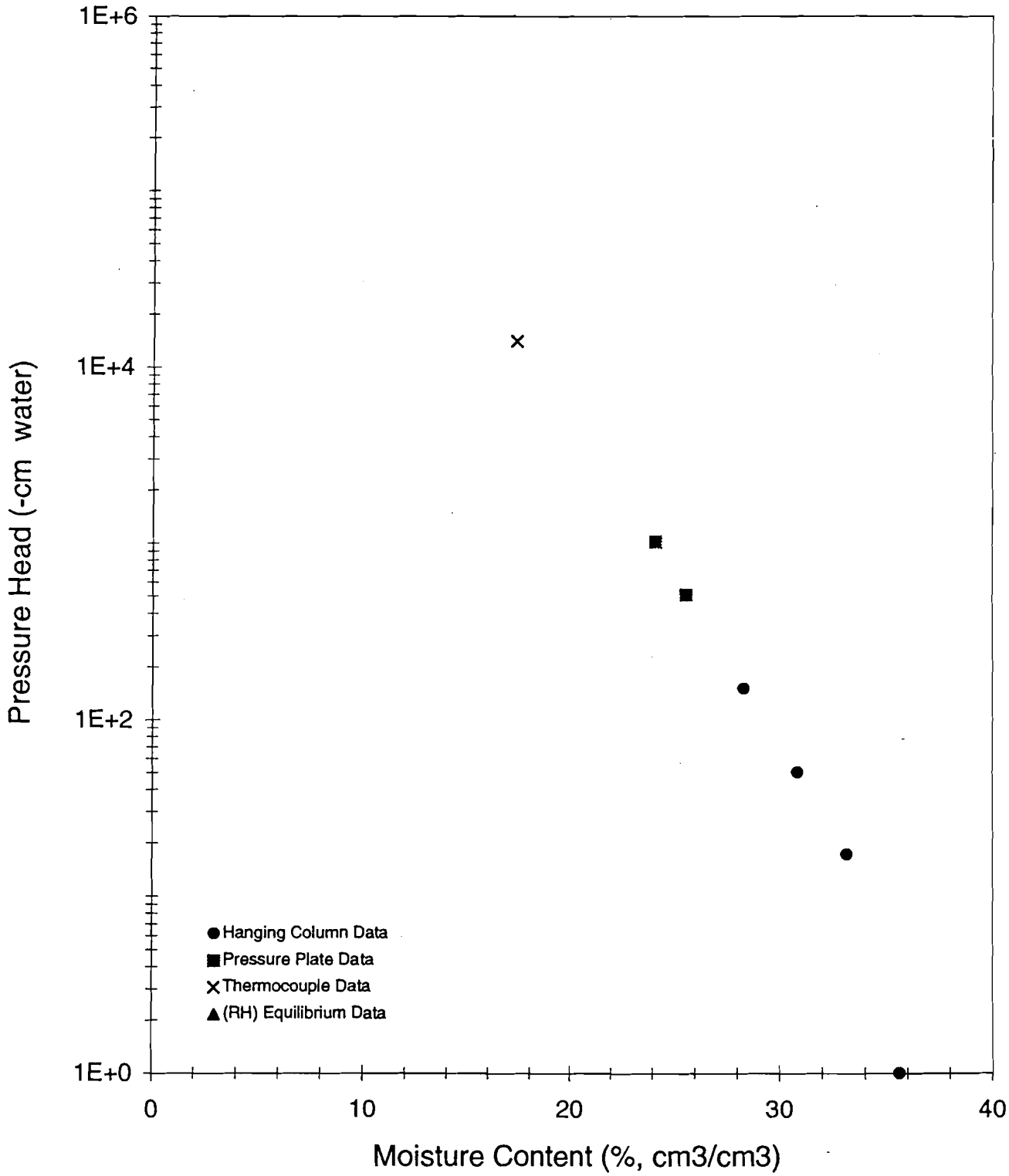
Saturated weight at 0 cm tension(with cap and ring): 163.06 (g)
Tare Ring: 34.15 (g)
Tare Other: 0.00 (g)
Tare Weight of Screen And Clamp: 24.97 (g)
Dry Weight of Sample: 85.80 (g)
Saturated Moisture Content: 35.61 (% vol)
Volume of Water in Saturated Sample: 18.14 (cm^3)

Date (1996)	*Time*	*Method*	*Matric Potential*	*Weight W/Ring (g)*	*Weight Change (g)*	*Total Weight Change (g)*	*Moisture Content (% vol)*
9/17	1312	1	0	163.06	0.00	0.00	35.61
9/20	1400	1	17.3	161.79	1.27	1.27	33.12
9/23	820	1	50.3	160.62	1.17	2.44	30.82
9/26	930	1	151.2	159.33	1.29	3.73	28.29
9/30	1035	2	0.5	157.96	1.37	5.1	25.60
10/7	917	2	1.0	157.22	0.74	5.84	24.15
10/8	912	3	13.8	153.76	3.46	9.30	17.36

Comments: Assumed density of water is 1.0 g/cm

Method 1= Hanging Column Analysis (-cm water)
Method 2= Pressure Plate Analysis (-bars)
Method 3= Thermocouple Analysis (-bars)
Method 4= (RH) Equilibrium Analysis (-bars)

Laboratory Analysis Performed by: P. Prieksat
Calculations performed by: M. Prieksat
Checked by: M. Ankeny



Sample Number: GEO2

Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: Battelle
Job Number: 6908
Sample Number: GEO3
Ring Number: GEO3
Depth: NA
Sample Volume: 59.06 (cm^3)

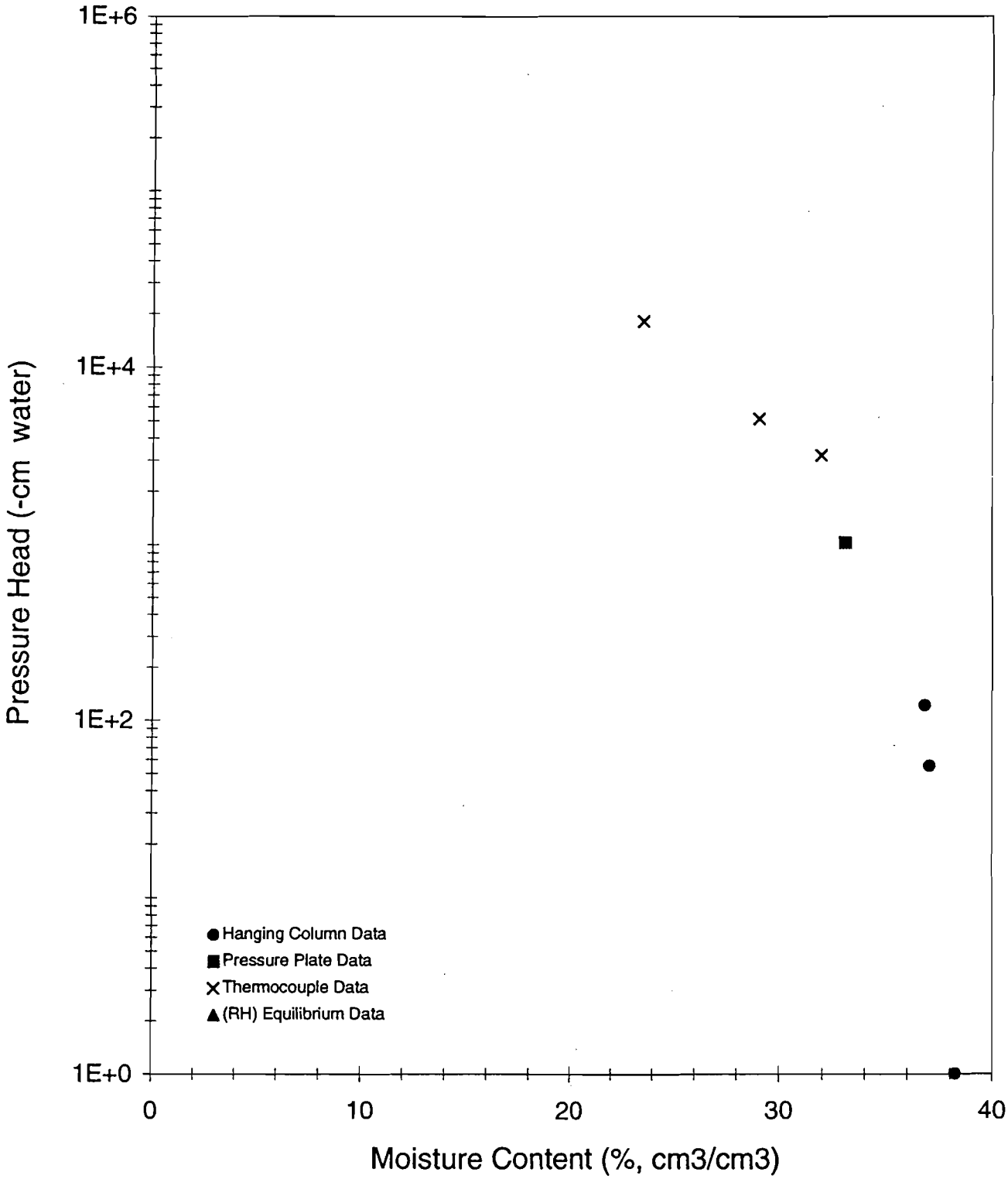
Saturated weight at 0 cm tension(with cap and ring): 189.49 (g)
Tare Ring: 36.66 (g)
Tare Other: 0.00 (g)
Tare Weight of Screen And Clamp: 23.31 (g)
Dry Weight of Sample: 106.93 (g)
Saturated Moisture Content: 38.25 (% vol)
Volume of Water in Saturated Sample: 22.59 (cm^3)

Date (1996)	*Time*	*Method*	*Matric Potential*	*Weight W/Ring (g)*	*Weight Change (g)*	*Total Weight Change (g)*	*Moisture Content (% vol)*
9/17	1312	1	0	189.49	0.00	0.00	38.25
9/20	1400	1	54.6	188.79	0.70	0.70	37.06
9/23	820	1	120.3	188.66	0.13	0.83	36.84
9/30	930	2	1	186.44	2.22	3.05	33.09
10/1	1035	3	3.1	185.79	0.65	3.7	31.98
10/1	917	3	5.0	184.09	1.70	5.40	29.11
10/3	912	3	17.7	180.83	3.26	8.66	23.59

Comments: Assumed density of water is 1.0 g/cm

Method 1= Hanging Column Analysis (-cm water)
Method 2= Pressure Plate Analysis (-bars)
Method 3= Thermocouple Analysis (-bars)
Method 4= (RH) Equilibrium Analysis (-bars)

Laboratory Analysis Performed by: P. Prieksat
Calculations performed by: M. Prieksat
Checked by: M. Ankeny



Sample Number: GEO3

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Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: Battelle
Job Number: 6908
Sample Number: GEO4
Ring Number: GEO4
Depth: NA
Sample Volume: 84.30 (cm^3)

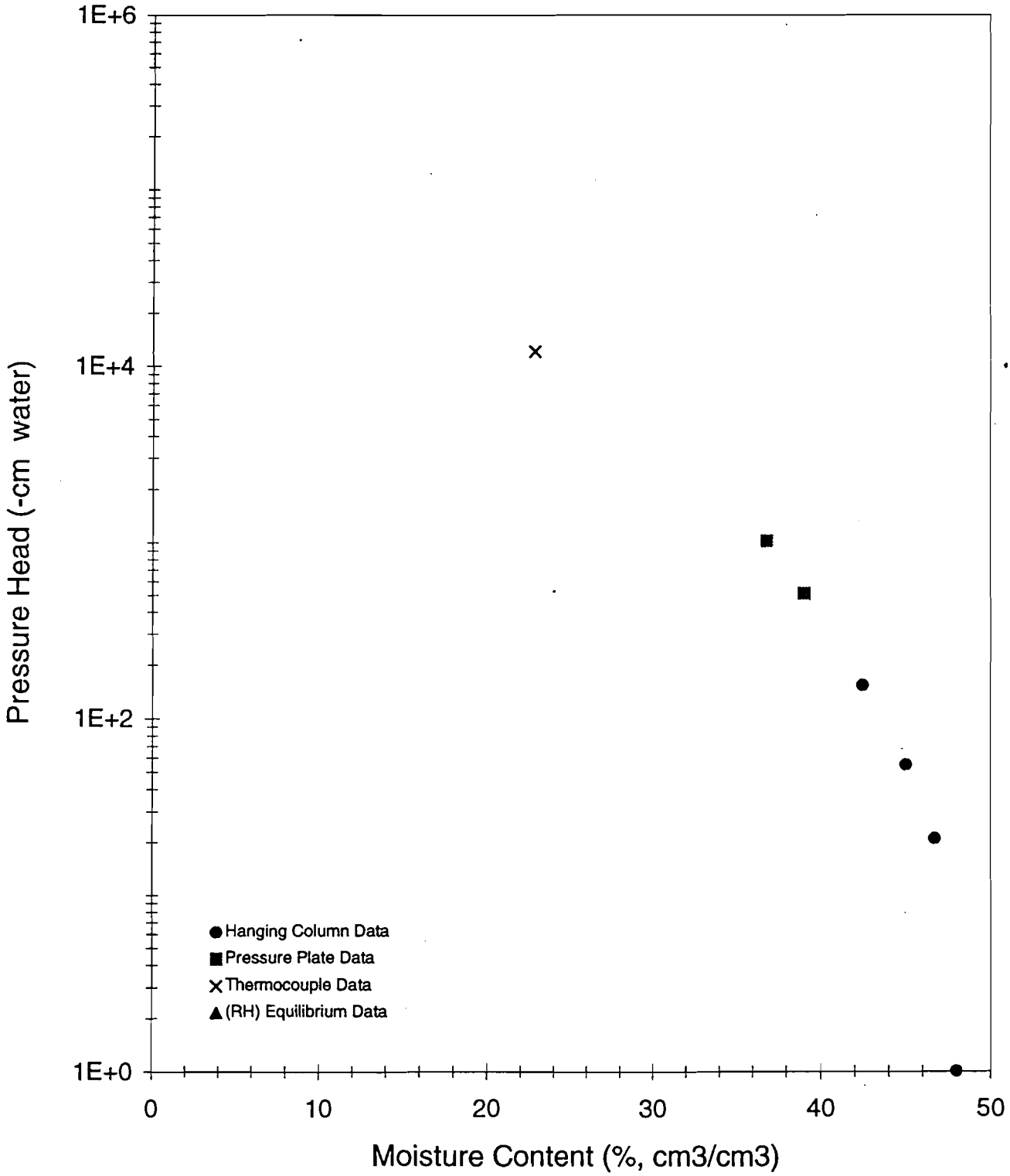
Saturated weight at 0 cm tension(with cap and ring): 244.17 (g)
Tare Ring: 52.96 (g)
Tare Other: 0.00 (g)
Tare Weight of Screen And Clamp: 23.21 (g)
Dry Weight of Sample: 127.52 (g)
Saturated Moisture Content: 48.02 (% vol)
Volume of Water in Saturated Sample: 40.48 (cm^3)

Date (1996)	*Time*	*Method*	*Matric Potential*	*Weight W/Ring (g)*	*Weight Change (g)*	*Total Weight Change (g)*	*Moisture Content (% vol)*
9/17	1154	1	0	244.17	0.00	0.00	48.02
9/20	1357	1	21.1	243.07	1.10	1.10	46.71
9/23	820	1	54.8	241.62	1.45	2.55	44.99
9/26	930	1	153.5	239.45	2.17	4.72	42.42
9/30	1035	2	0.5	236.58	2.87	7.59	39.02
10/7	917	2	1.0	234.76	1.82	9.41	36.86
10/8	1629	3	11.8	222.95	11.81	21.22	22.85

Comments: Assumed density of water is 1.0 g/cm

Method 1= Hanging Column Analysis (-cm water)
Method 2= Pressure Plate Analysis (-bars)
Method 3= Thermocouple Analysis (-bars)
Method 4= (RH) Equilibrium Analysis (-bars)

Laboratory Analysis Performed by: P. Prieksat
Calculations performed by: M. Prieksat
Checked by: M. Ankeny



Sample Number: GEO4

Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: Battelle
Job Number: 6908
Sample Number: GEO5
Ring Number: GEO5
Depth: NA
Sample Volume: 61.10 (cm^3)

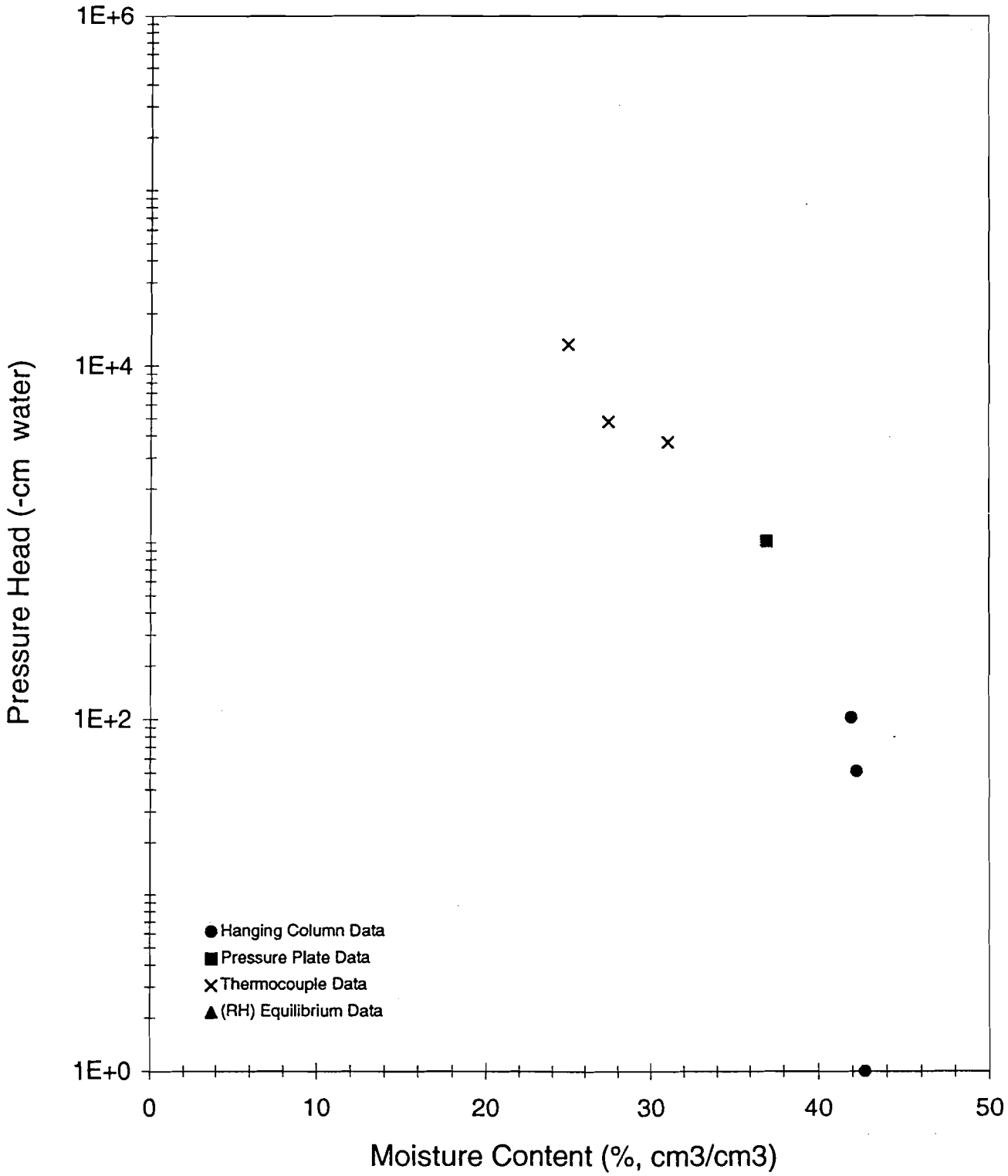
Saturated weight at 0 cm tension(with cap and ring): 186.90 (g)
Tare Ring: 37.37 (g)
Tare Other: 0.00 (g)
Tare Weight of Screen And Clamp: 25.74 (g)
Dry Weight of Sample: 97.69 (g)
Saturated Moisture Content: 42.72 (% vol)
Volume of Water in Saturated Sample: 26.10 (cm^3)

Date (1996)	*Time*	*Method*	*Matric Potential*	*Weight W/Ring (g)*	*Weight Change (g)*	*Total Weight Change (g)*	*Moisture Content (% vol)*
10/1	1106	1	0	186.9	0.00	0.00	42.72
10/4	1640	1	51.0	186.59	0.31	0.31	42.21
10/7	1004	1	102.2	186.41	0.18	0.49	41.92
10/14	1110	2	1	183.41	3	3.49	37.01
10/15	1015	3	3.6	179.77	3.64	7.13	31.05
10/15	925	3	4.7	177.56	2.21	9.34	27.43
10/15	1631	3	13.0	176.05	1.51	10.85	24.96

Comments: Assumed density of water is 1.0 g/cm

Method 1= Hanging Column Analysis (-cm water)
Method 2= Pressure Plate Analysis (-bars)
Method 3= Thermocouple Analysis (-bars)
Method 4= (RH) Equilibrium Analysis (-bars)

Laboratory Analysis Performed by: P. Prieksat
Calculations performed by: M. Prieksat
Checked by: M. Ankeny



Sample Number: GEO5

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Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: Battelle
Job Number: 6908
Sample Number: GEO6
Ring Number: GEO6
Depth: NA
Sample Volume: 62.17 (cm^3)

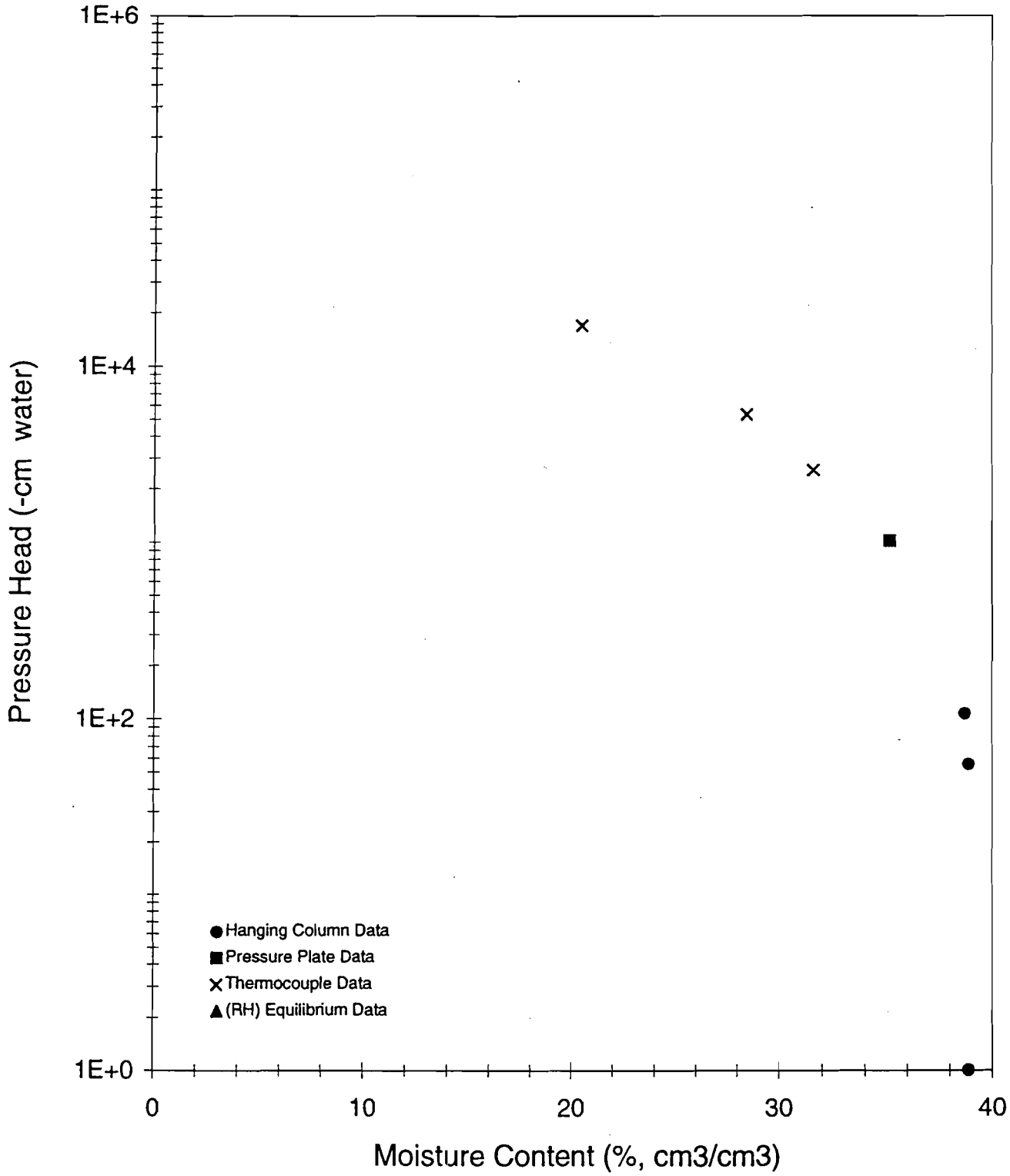
Saturated weight at 0 cm tension(with cap and ring): 188.79 (g)
Tare Ring: 37.62 (g)
Tare Other: 0.00 (g)
Tare Weight of Screen And Clamp: 24.71 (g)
Dry Weight of Sample: 102.29 (g)
Saturated Moisture Content: 38.88 (% vol)
Volume of Water in Saturated Sample: 24.17 (cm^3)

Date (1996)	*Time*	*Method*	*Matric Potential*	*Weight W/Ring (g)*	*Weight Change (g)*	*Total Weight Change (g)*	*Moisture Content (% vol)*
9/19	1715	1	0	188.79	0.00	0.00	38.88
9/23	817	1	55.2	188.79	0.00	0.00	38.88
9/26	930	1	106.1	188.69	0.1	0.1	38.72
10/1	1619	2	0.999	186.47	2.22	2.32	35.15
10/3	1106	3	2.5	184.27	2.2	4.52	31.61
10/3	928	3	5.2	182.31	1.96	6.48	28.46
10/4	1128	3	16.6	177.38	4.93	11.41	20.53

Comments: Assumed density of water is 1.0 g/cm

Method 1= Hanging Column Analysis (-cm water)
Method 2= Pressure Plate Analysis (-bars)
Method 3= Thermocouple Analysis (-bars)
Method 4= (RH) Equilibrium Analysis (-bars)

Laboratory Analysis Performed by: P. Prieksat
Calculations performed by: M. Prieksat
Checked by: M. Ankeny



Sample Number: GEO6

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: Battelle
Job Number: 6908
Sample Number: GEO7
Ring Number: GEO7
Depth: NA
Sample Volume: 59.72 (cm^3)

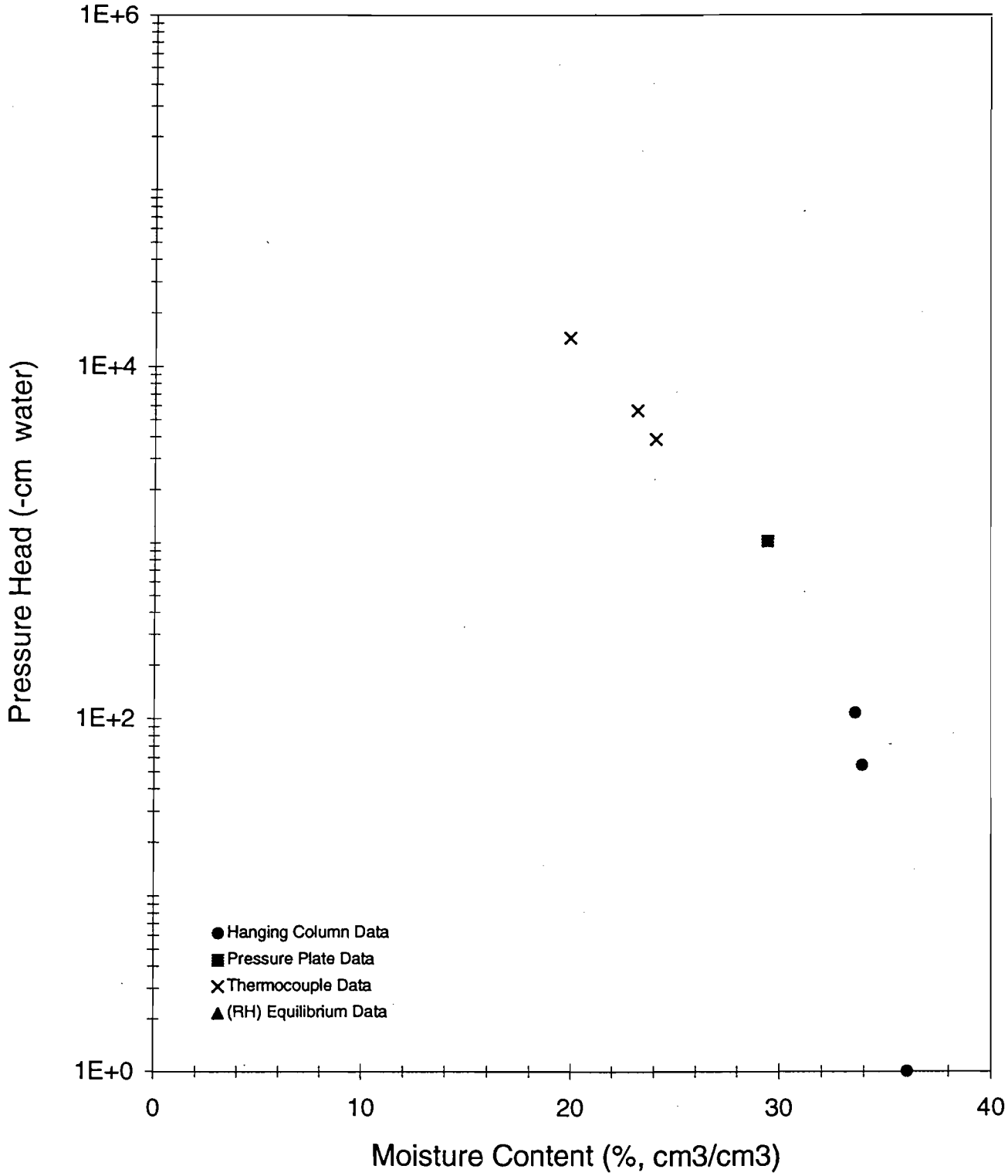
Saturated weight at 0 cm tension(with cap and ring): 191.42 (g)
Tare Ring: 36.74 (g)
Tare Other: 0.00 (g)
Tare Weight of Screen And Clamp: 23.25 (g)
Dry Weight of Sample: 109.89 (g)
Saturated Moisture Content: 36.07 (% vol)
Volume of Water in Saturated Sample: 21.54 (cm^3)

Date (1996)	*Time*	*Method*	*Matric Potential*	*Weight W/Ring (g)*	*Weight Change (g)*	*Total Weight Change (g)*	*Moisture Content (% vol)*
9/17	1425	1	0	191.42	0.00	0.00	36.07
9/20	1347	1	54.1	190.14	1.28	1.28	33.92
9/23	850	1	107.1	189.94	0.2	1.48	33.59
9/30	856	2	1	187.49	2.45	3.93	29.49
10/1	1513	3	3.8	184.29	3.2	7.13	24.13
10/1	1133	3	5.5	183.77	0.52	7.65	23.26
10/1	1027	3	14.2	181.82	1.95	9.60	19.99

Comments: Assumed density of water is 1.0 g/cm

Method 1= Hanging Column Analysis (-cm water)
Method 2= Pressure Plate Analysis (-bars)
Method 3= Thermocouple Analysis (-bars)
Method 4= (RH) Equilibrium Analysis (-bars)

Laboratory Analysis Performed by: P. Prieksat
Calculations performed by: M. Prieksat
Checked by: M. Ankeny



Sample Number: GEO7

DANIEL B. STEPHENS & ASSOCIATES, INC.

ENVIRONMENTAL SCIENTISTS AND ENGINEERS

Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: Battelle
Job Number: 6908
Sample Number: GEO8
Ring Number: GEO8
Depth: NA
Sample Volume: 63.92 (cm^3)

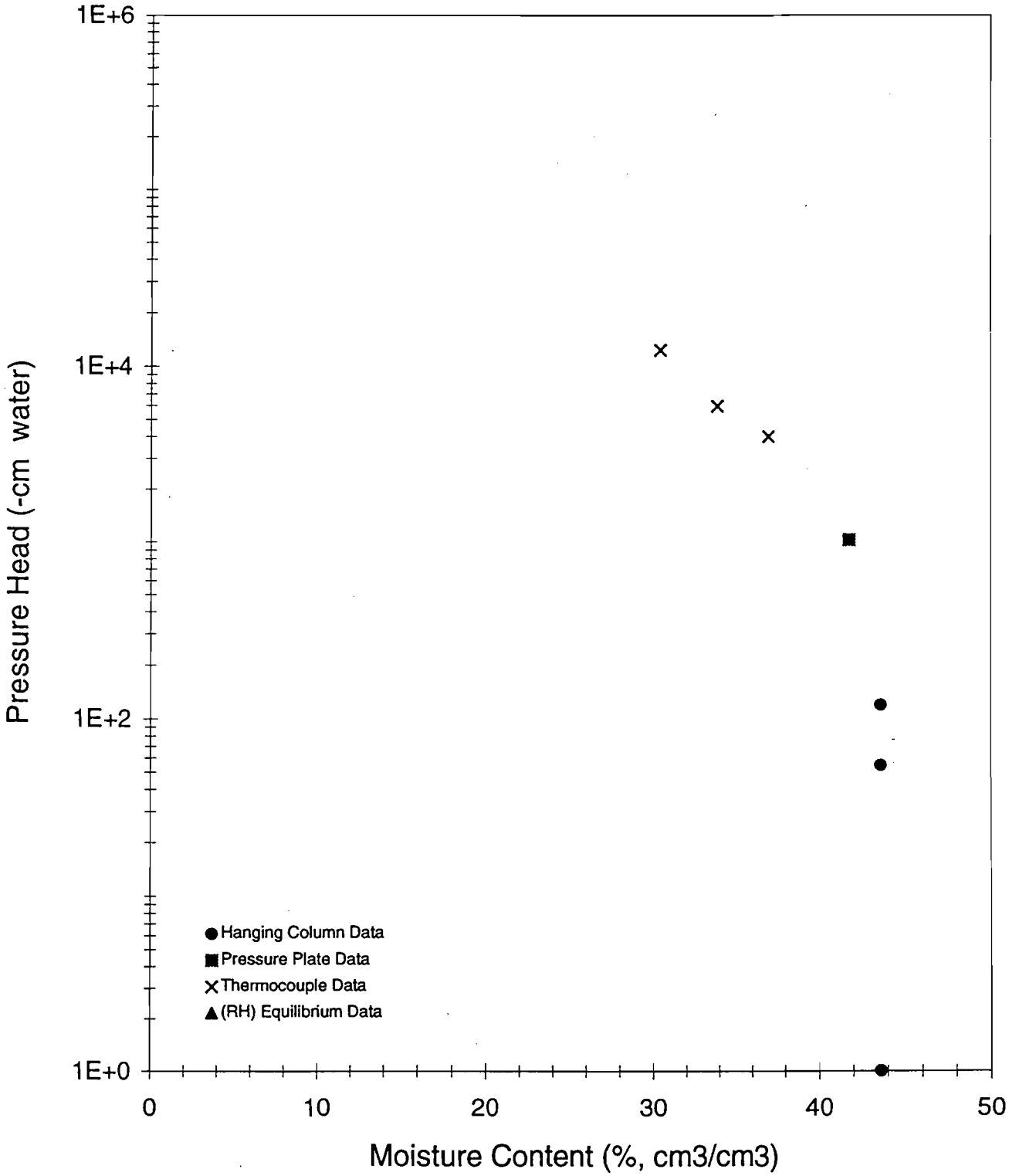
Saturated weight at 0 cm tension(with cap and ring): 202.08 (g)
Tare Ring: 39.75 (g)
Tare Other: 0.00 (g)
Tare Weight of Screen And Clamp: 25.62 (g)
Dry Weight of Sample: 108.84 (g)
Saturated Moisture Content: 43.60 (% vol)
Volume of Water in Saturated Sample: 27.87 (cm^3)

Date (1996)	*Time*	*Method*	*Matric Potential*	*Weight W/Ring (g)*	*Weight Change (g)*	*Total Weight Change (g)*	*Moisture Content (% vol)*
9/20	1155	1	0	202.08	0.00	0.00	43.60
9/23	814	1	54.1	202.08	0.00	0.00	43.60
9/26	930	1	118.5	202.08	0	0	43.60
10/1	1618	2	1	200.9	1.18	1.18	41.75
10/3	1100	3	3.9	197.86	3.04	4.22	37.00
10/3	921	3	5.8	195.87	1.99	6.21	33.89
10/3	1400	3	12.0	193.67	2.20	8.41	30.44

Comments: Assumed density of water is 1.0 g/cm

Method 1= Hanging Column Analysis (-cm water)
Method 2= Pressure Plate Analysis (-bars)
Method 3= Thermocouple Analysis (-bars)
Method 4= (RH) Equilibrium Analysis (-bars)

Laboratory Analysis Performed by: P. Prieksat
Calculations performed by: M. Prieksat
Checked by: M. Ankeny



Sample Number: GEO8

Moisture Retention Data

Hanging Column/Pressure Plate/Thermocouple

(Main Drainage Curve)

Job Name: Battelle
Job Number: 6908
Sample Number: GEO9
Ring Number: GEO9
Depth: NA
Sample Volume: 48.76 (cm^3)

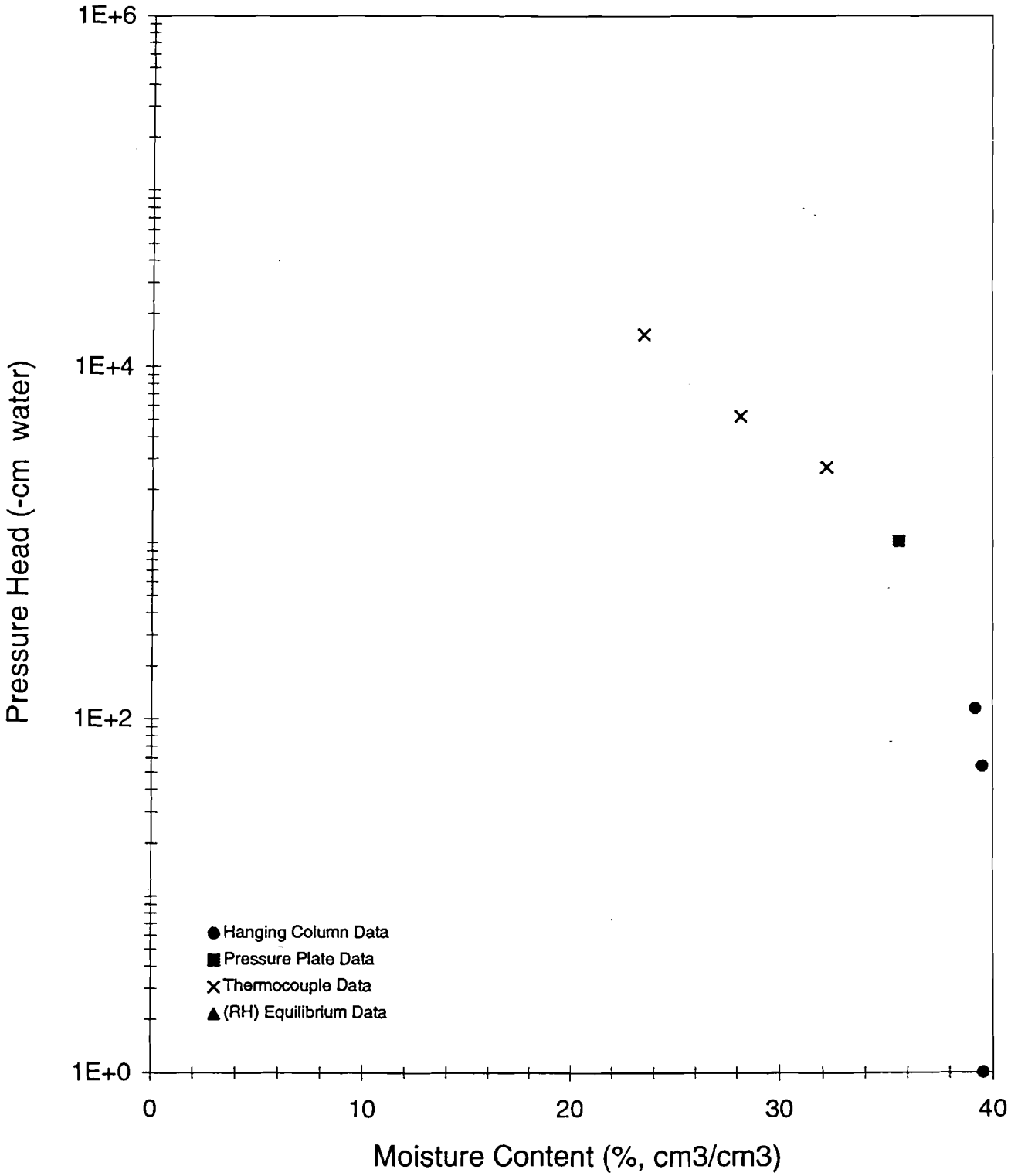
Saturated weight at 0 cm tension(with cap and ring): 160.85 (g)
Tare Ring: 30.41 (g)
Tare Other: 0.00 (g)
Tare Weight of Screen And Clamp: 25.39 (g)
Dry Weight of Sample: 85.77 (g)
Saturated Moisture Content: 39.54 (% vol)
Volume of Water in Saturated Sample: 19.28 (cm^3)

Date (1996)	*Time*	*Method*	*Matric Potential*	*Weight W/Ring (g)*	*Weight Change (g)*	*Total Weight Change (g)*	*Moisture Content (% vol)*
9/17	1125	1	0	160.85	0.00	0.00	39.54
9/20	1338	1	53.5	160.84	0.01	0.01	39.52
9/25	829	1	113.0	160.67	0.17	0.18	39.17
9/30	849	2	1	158.93	1.74	1.92	35.61
10/1	1634	3	2.6	157.26	1.67	3.59	32.18
10/1	1501	3	5.1	155.31	1.95	5.54	28.18
10/1	1015	3	14.9	153.05	2.26	7.80	23.55

Comments: Assumed density of water is 1.0 g/cm

Method 1= Hanging Column Analysis (-cm water)
Method 2= Pressure Plate Analysis (-bars)
Method 3= Thermocouple Analysis (-bars)
Method 4= (RH) Equilibrium Analysis (-bars)

Laboratory Analysis Performed by: P. Prieksat
Calculations performed by: M. Prieksat
Checked by: M. Ankeny



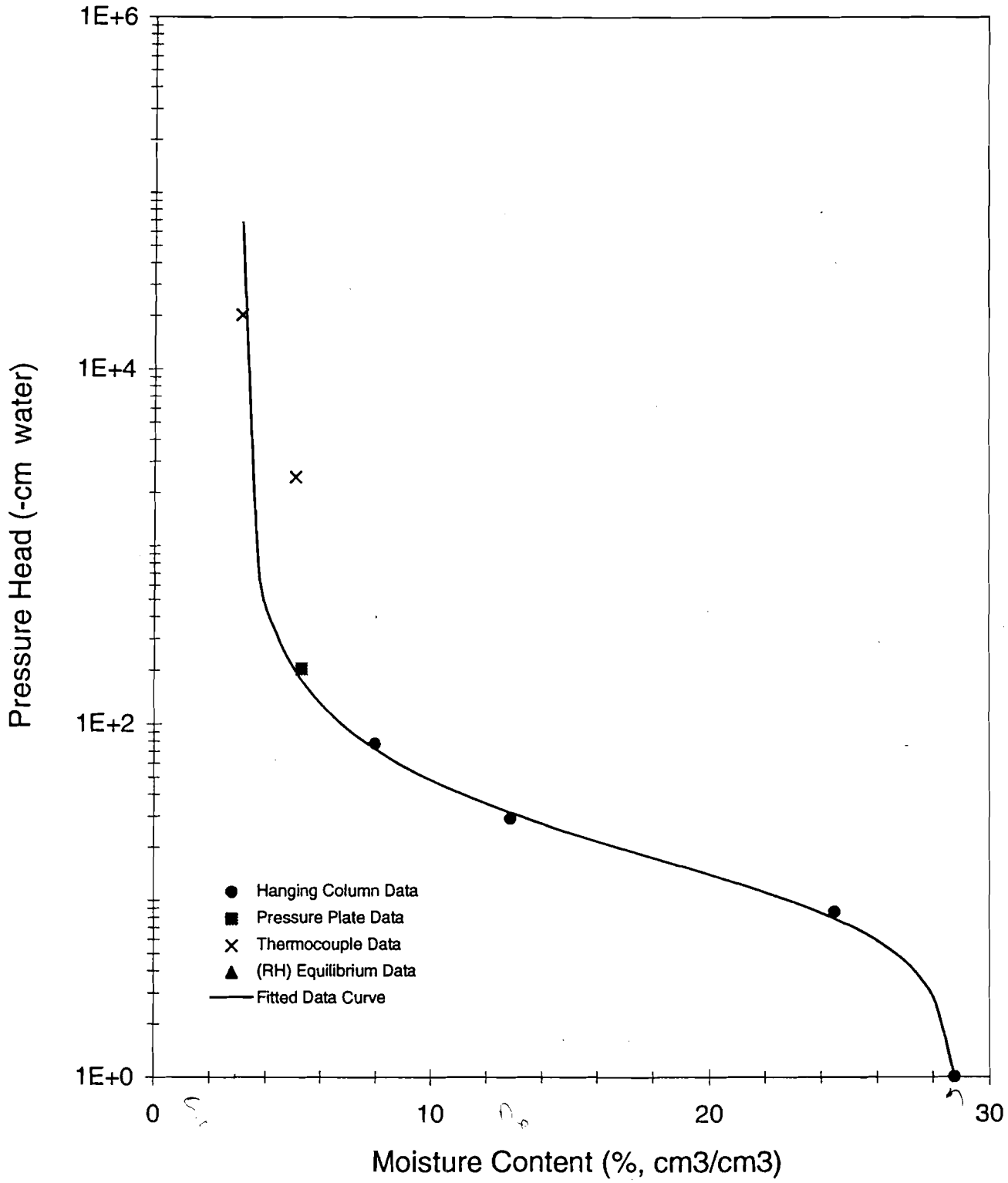
Sample Number: GEO9

Appendix D

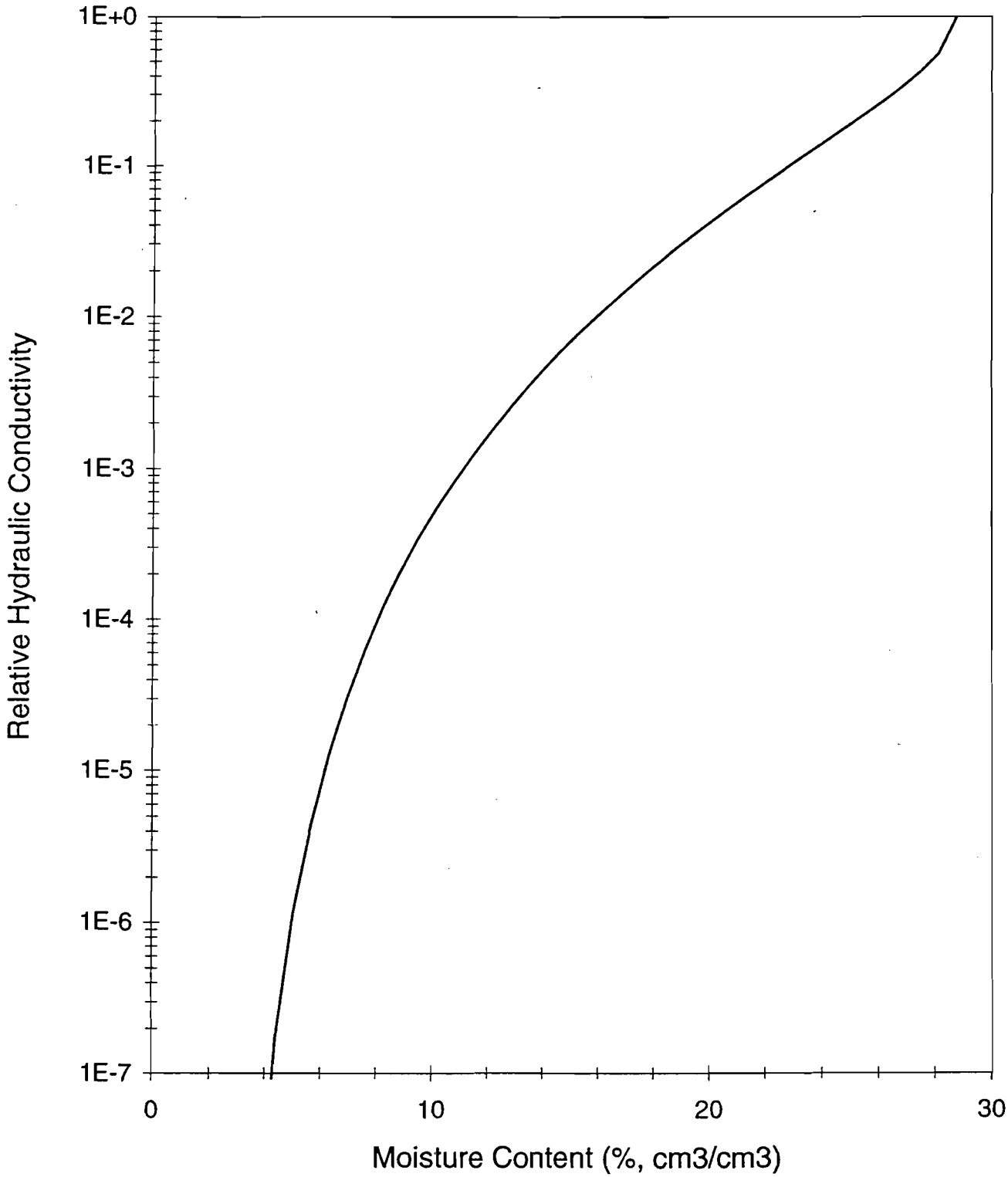
Unsaturated Hydraulic Properties

Summary of Unsaturated Hydraulic Properties (Calculated)

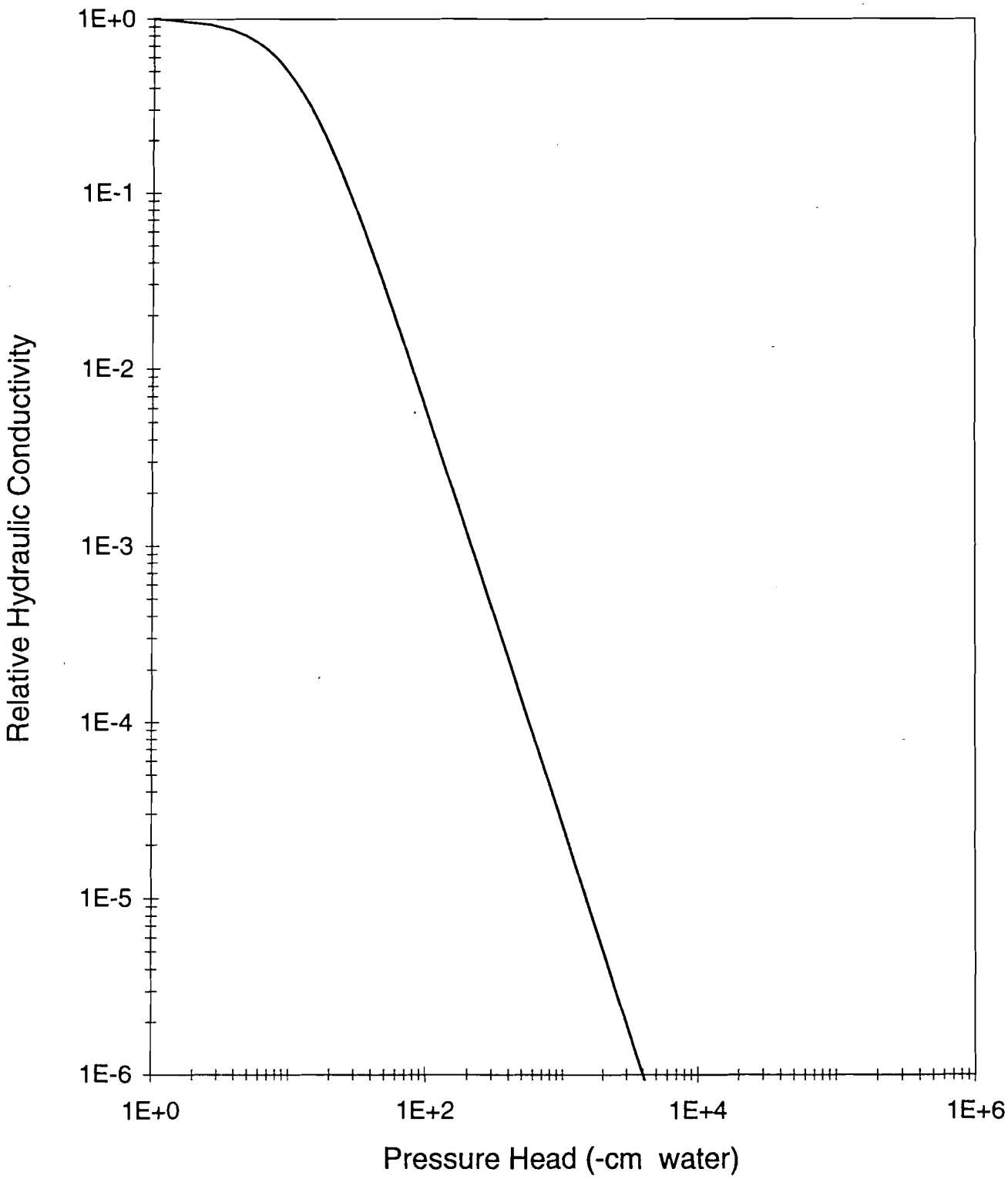
Sample Number	α (cm^{-1}) Calculated Value	α 95% Confidence Limits Lower	α 95% Confidence Limits Upper	N (dimensionless) Calculated Value	N 95% Confidence Limits Lower	N 95% Confidence Limits Upper	θr (%)	θs (%)
GEO1	0.0852	0.0556	0.1149	1.9072	1.6210	2.1933	3.1	28.8
GEO2	0.0326	-0.0087	0.0739	1.3252	1.1404	1.5101	17.4	35.6
GEO3	0.0011	-0.0007	0.0029	1.6083	0.9361	2.2804	23.6	38.2
GEO4	0.0043	-0.0017	0.0102	1.5079	1.0069	2.0090	22.8	48.0
GEO5	0.0010	0.0005	0.0015	2.0480	1.4904	2.6056	25.0	42.7
GEO6	0.0005	-0.0007	0.0018	1.7676	1.2803	2.2549	20.5	38.9
GEO7	0.0019	-0.0008	0.0046	1.7045	1.0837	2.3252	20.0	36.1
GEO8	0.0003	0.0002	0.0005	2.8519	1.4239	4.2799	30.4	43.6
GEO9	0.0007	0.0003	0.0010	2.0018	1.4192	2.5844	23.5	39.5



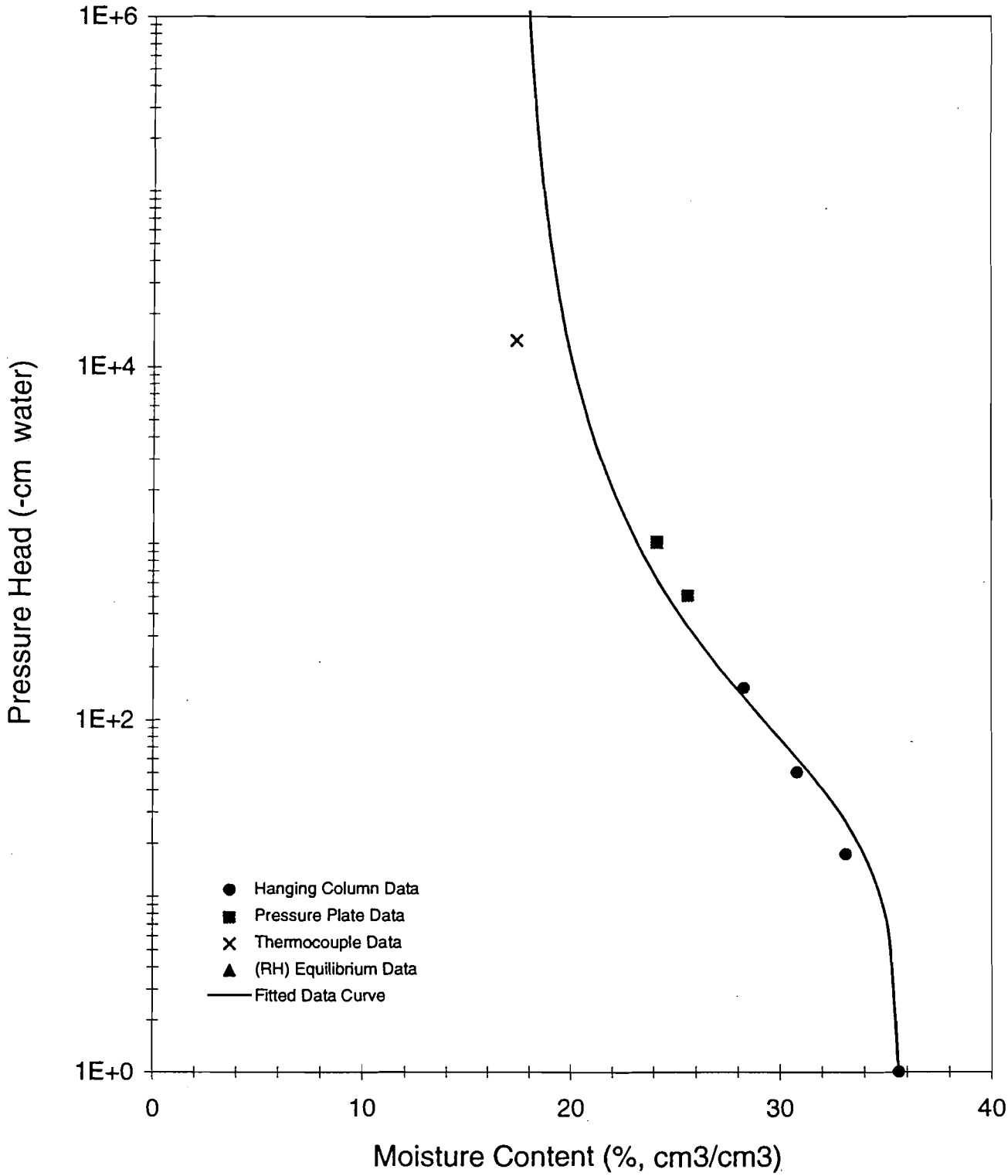
Sample Number: GEO1



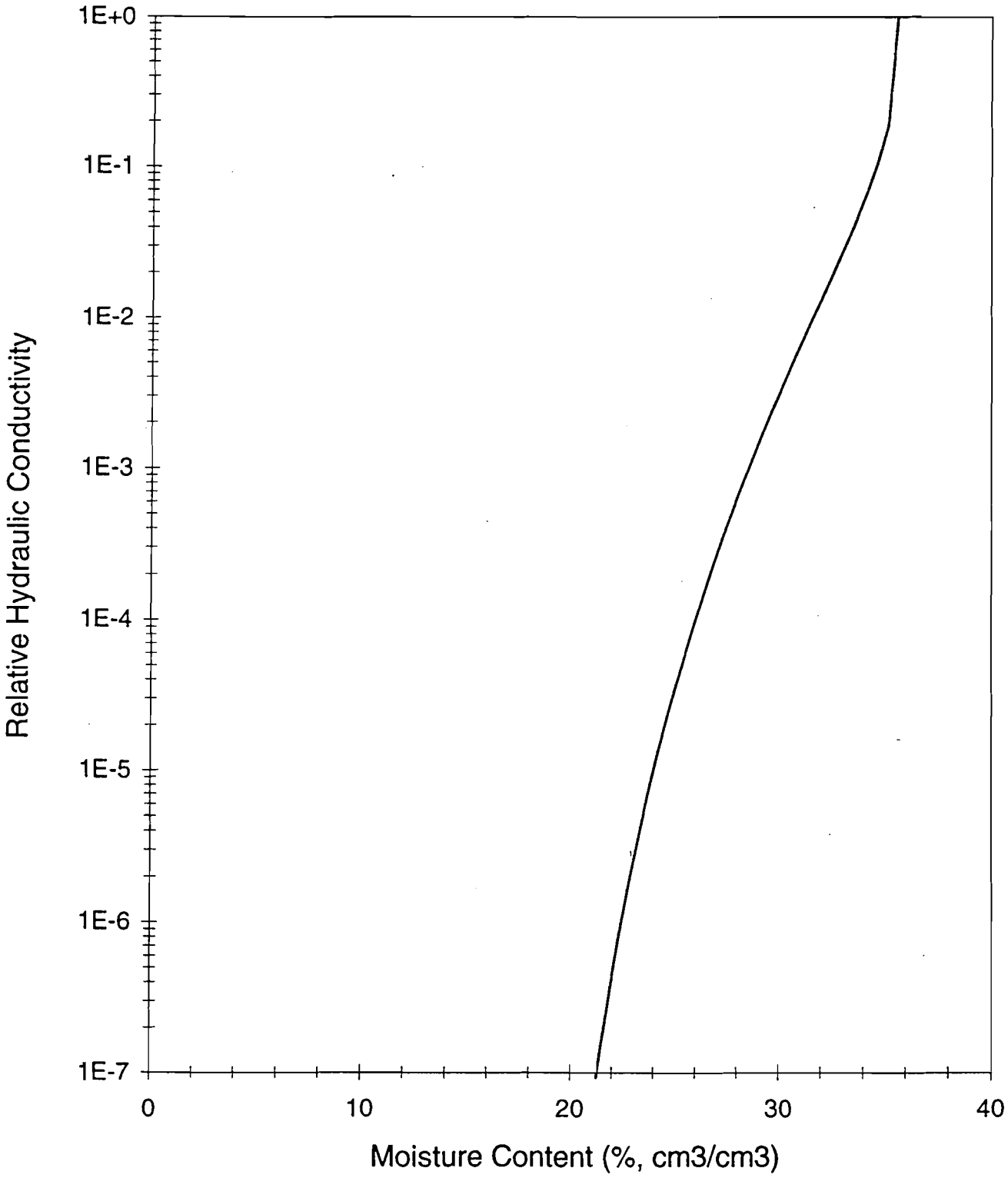
Sample Number: GEO1



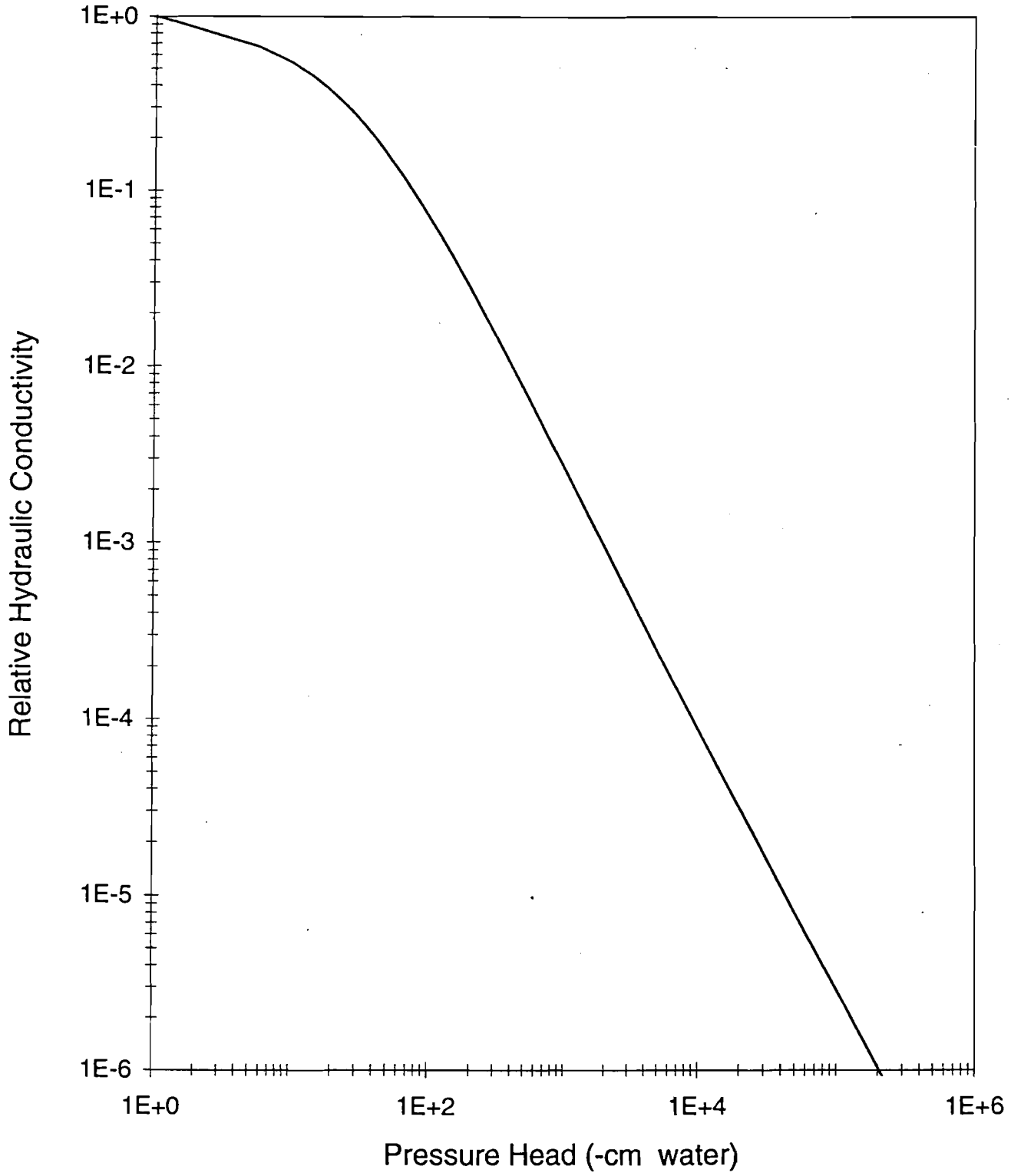
Sample Number: GEO1



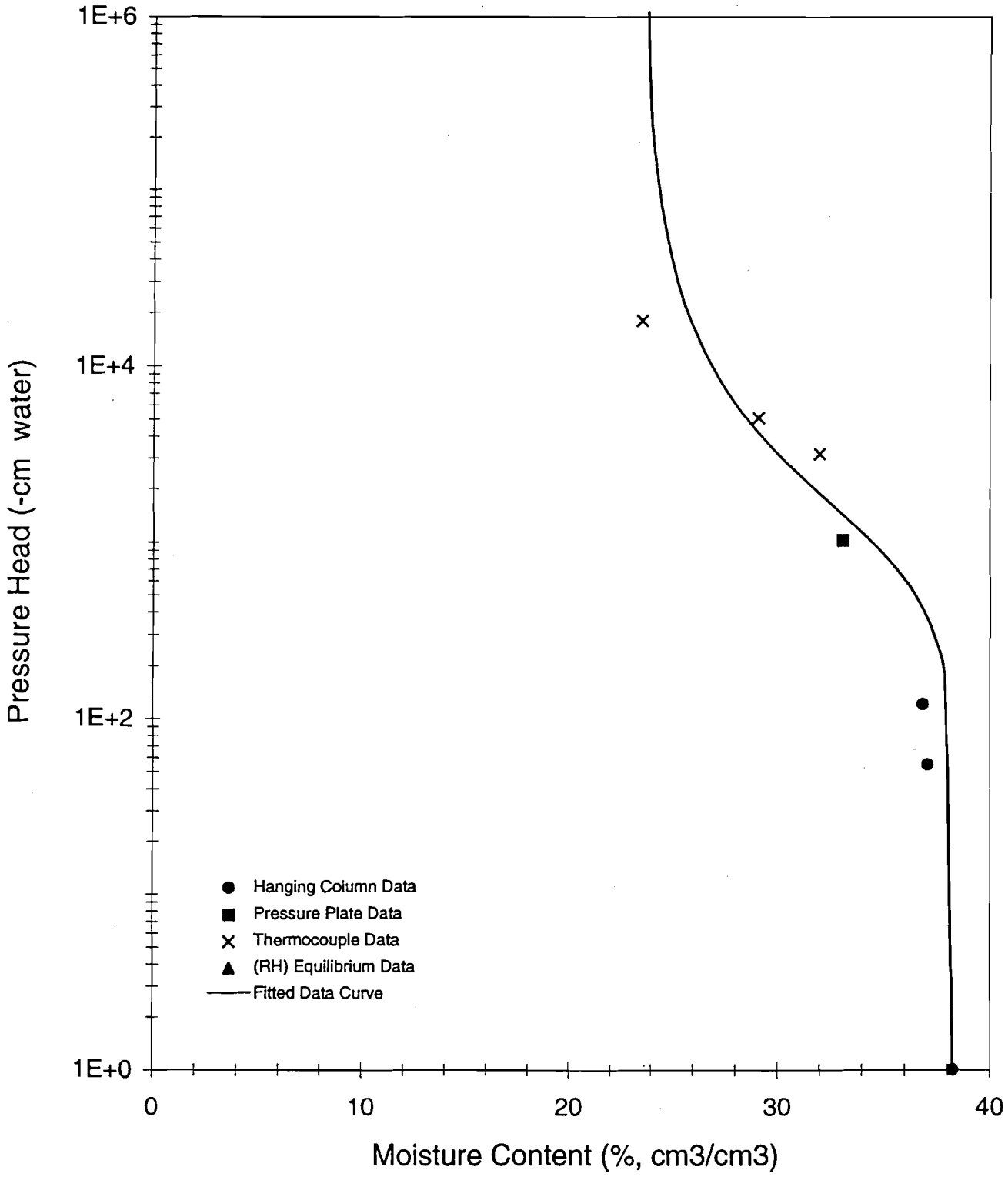
Sample Number: GEO2



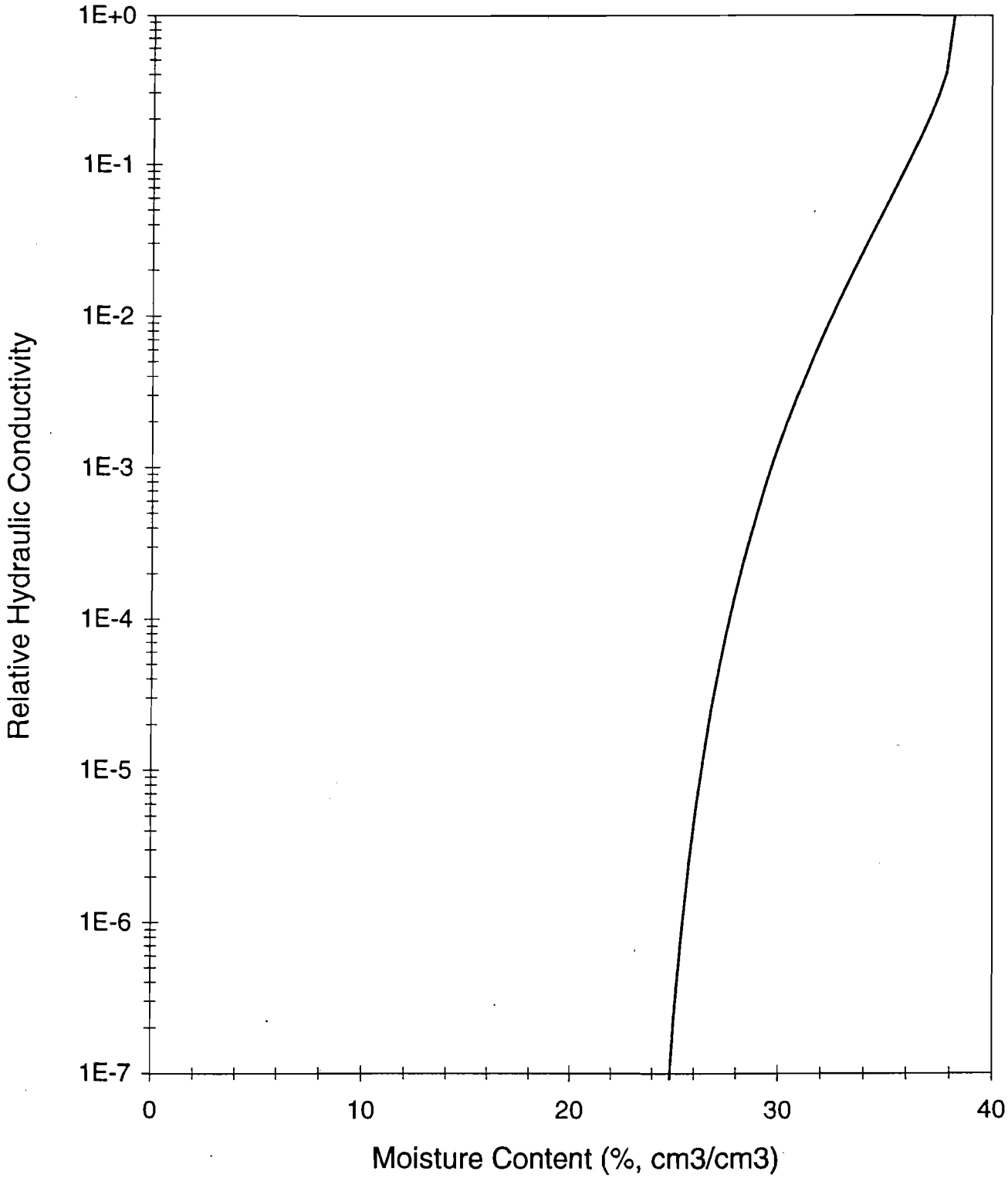
Sample Number: GEO2



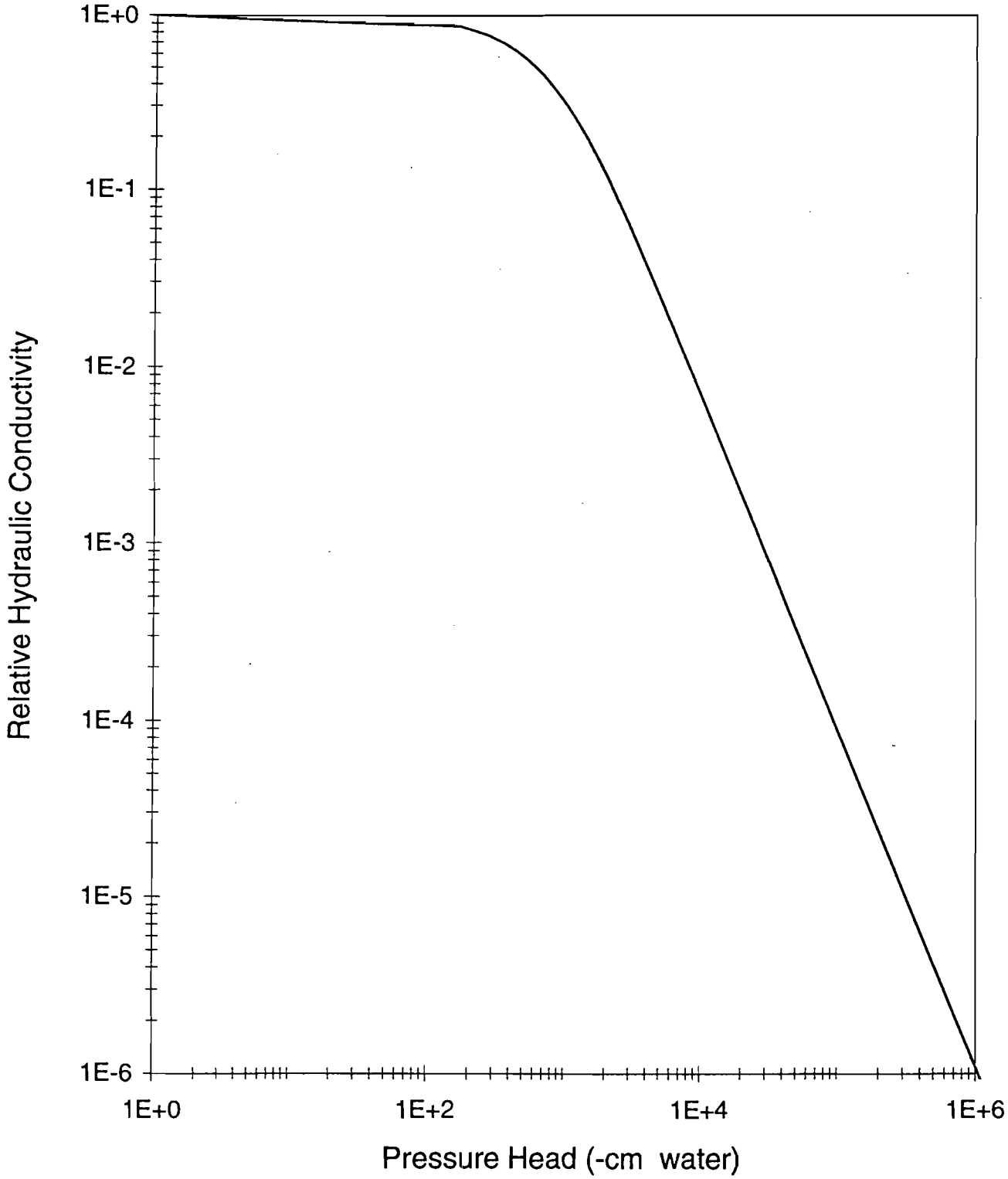
Sample Number: GEO2



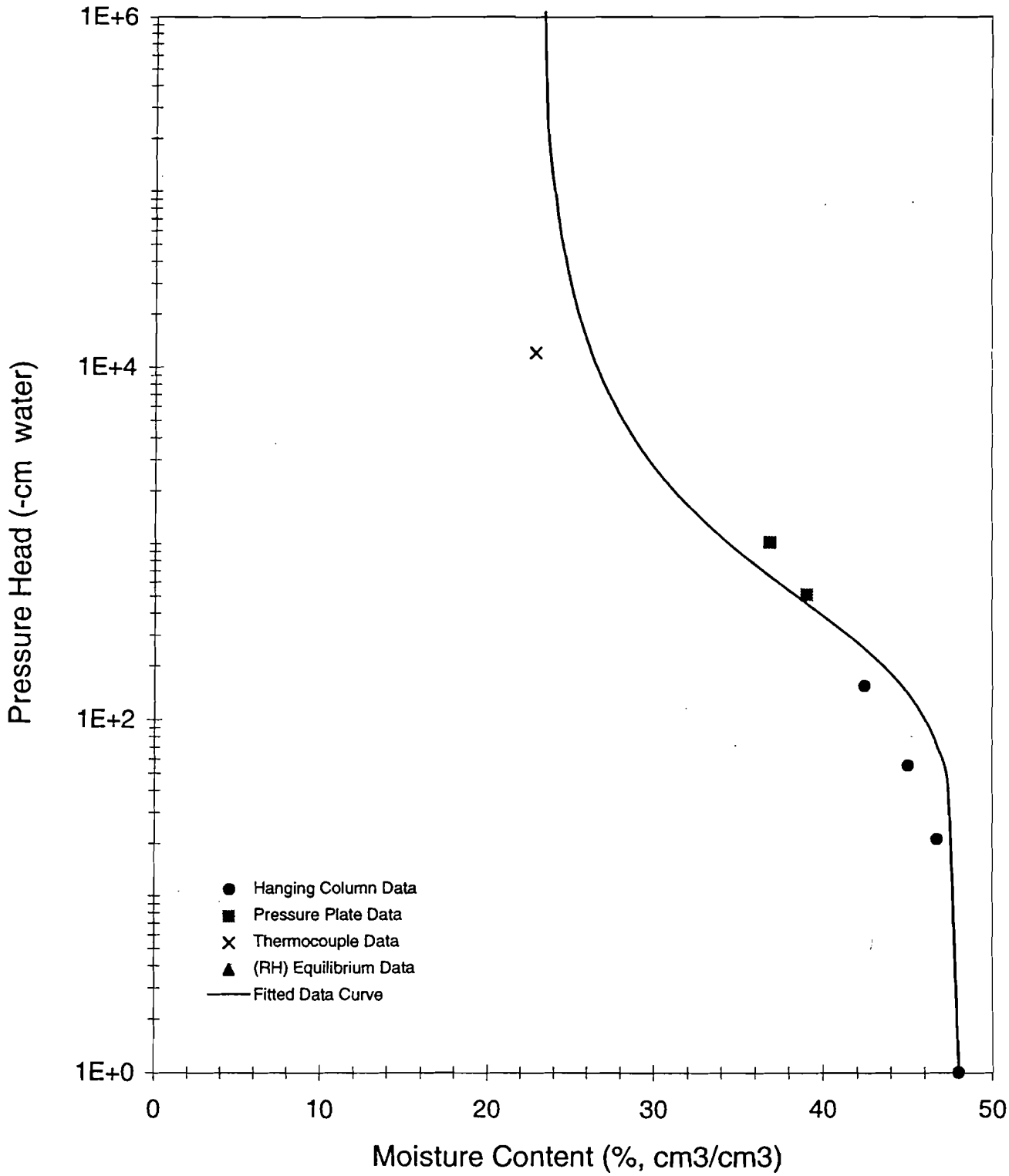
Sample Number: GEO3



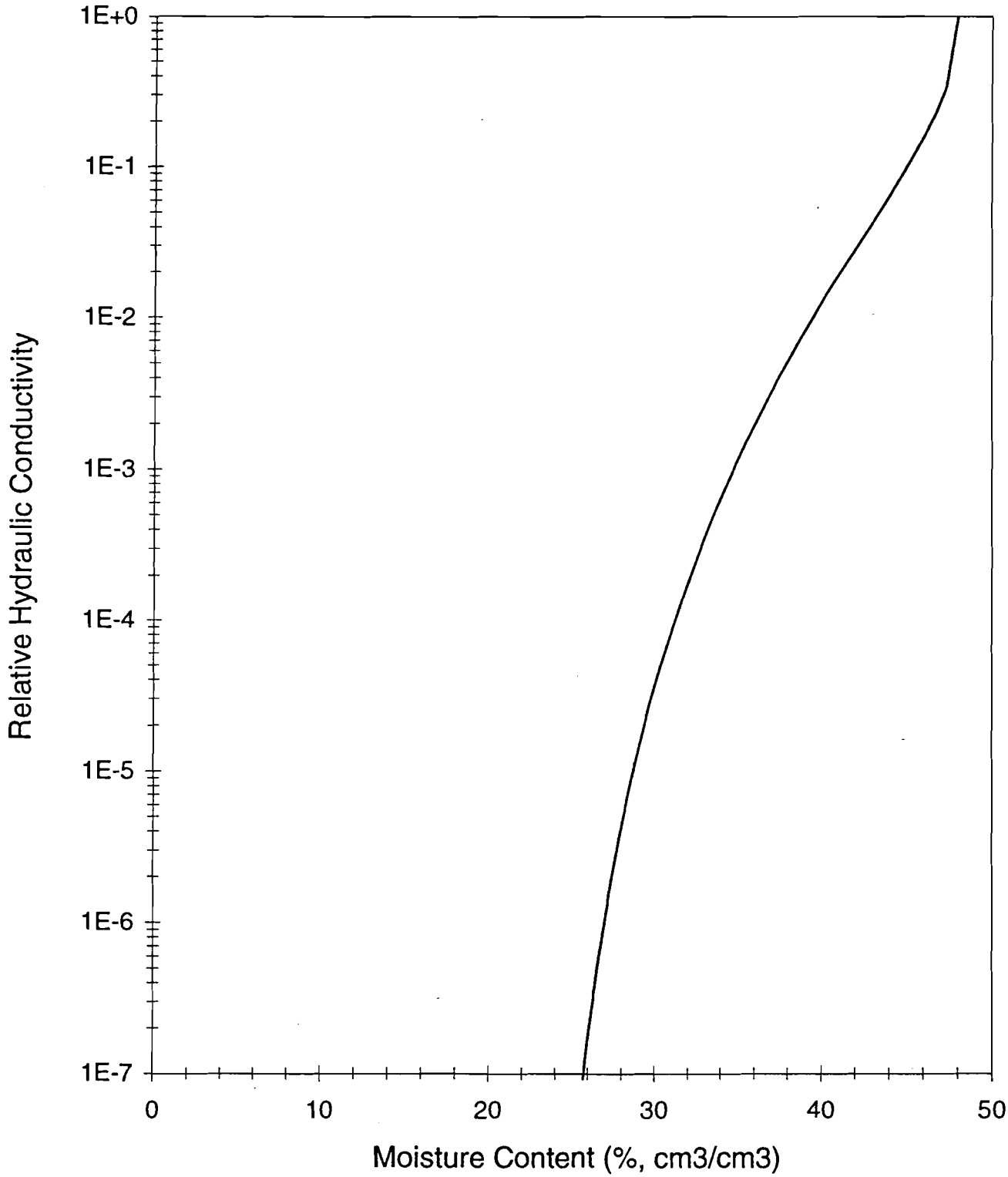
Sample Number: GEO3



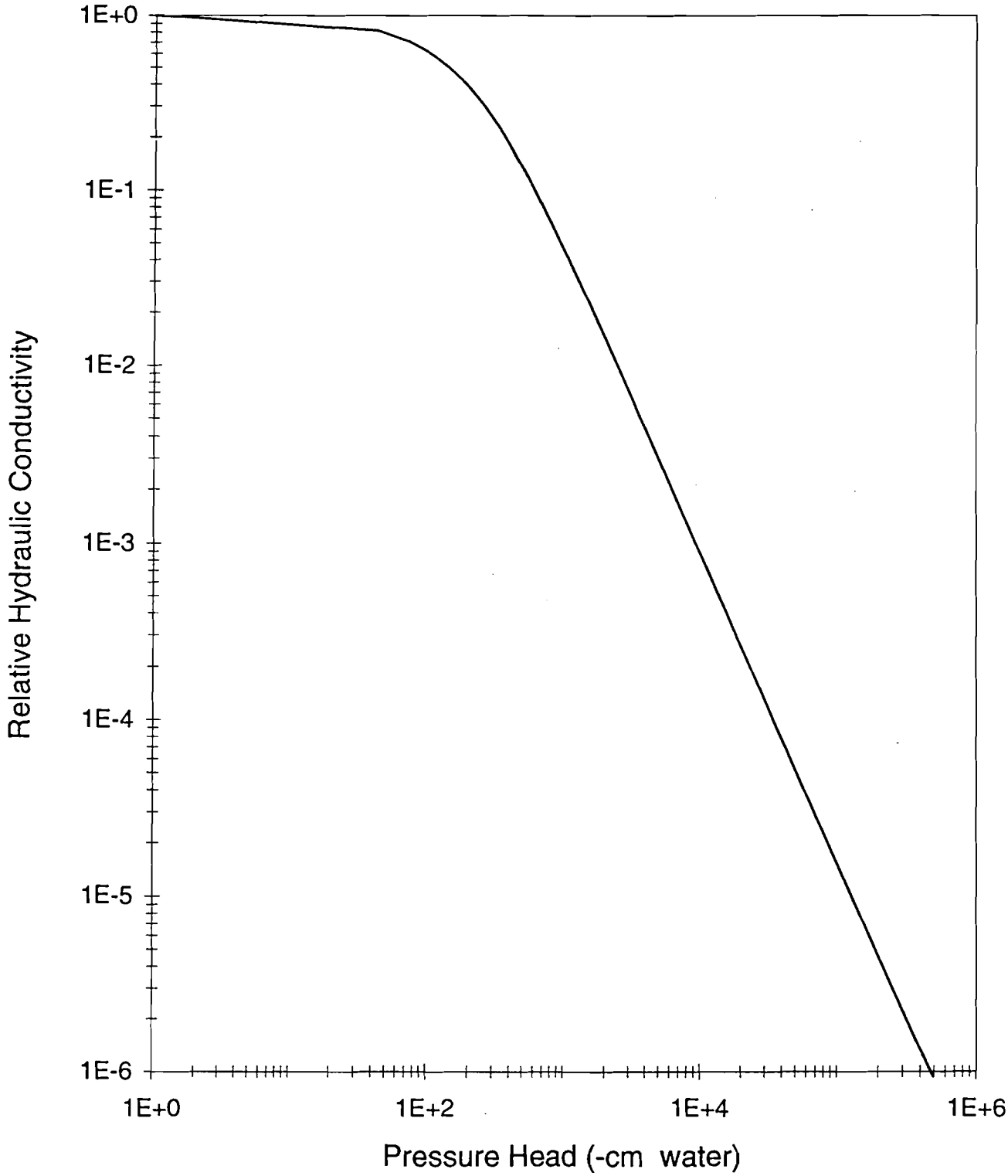
Sample Number: GEO3



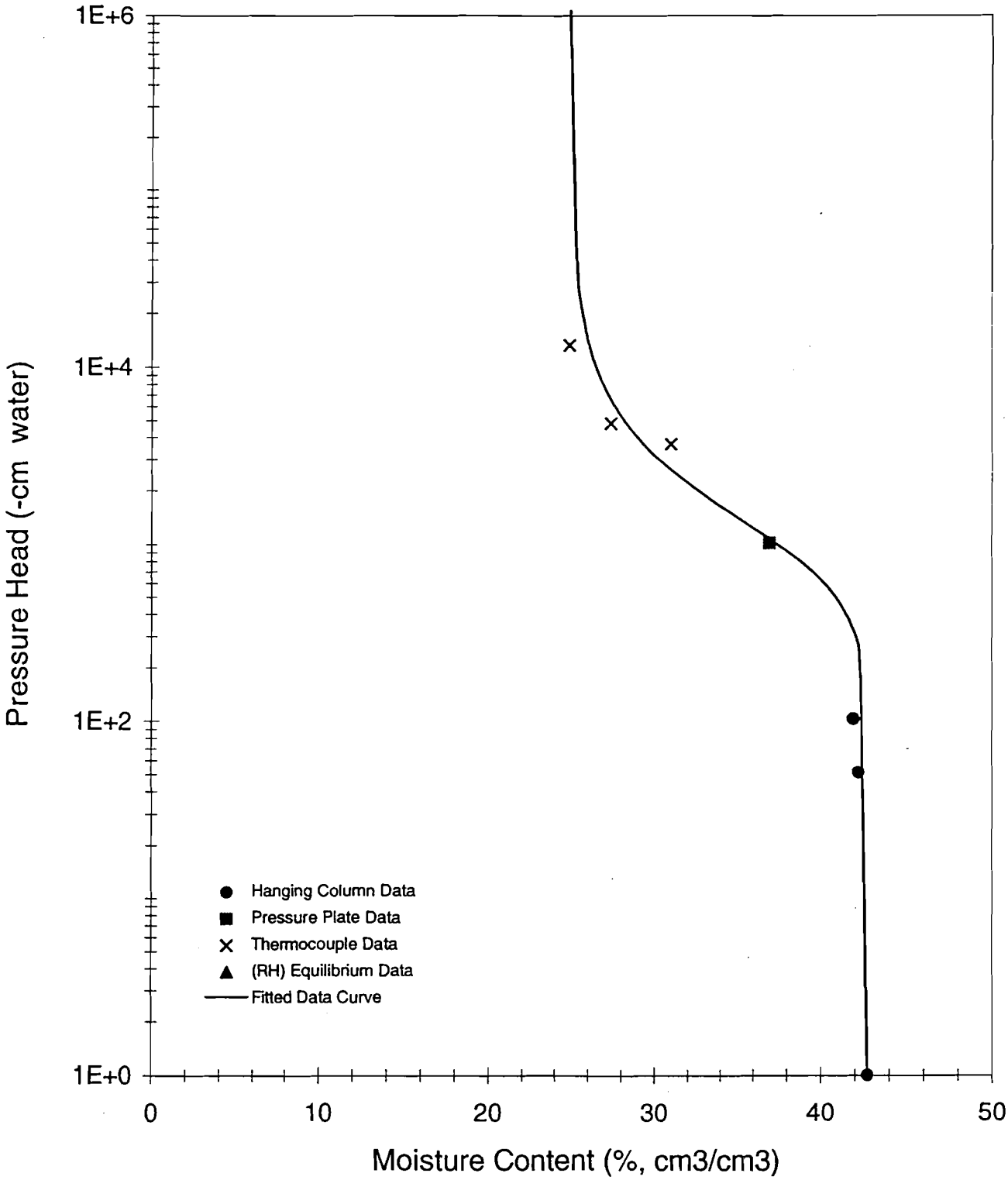
Sample Number: GEO4



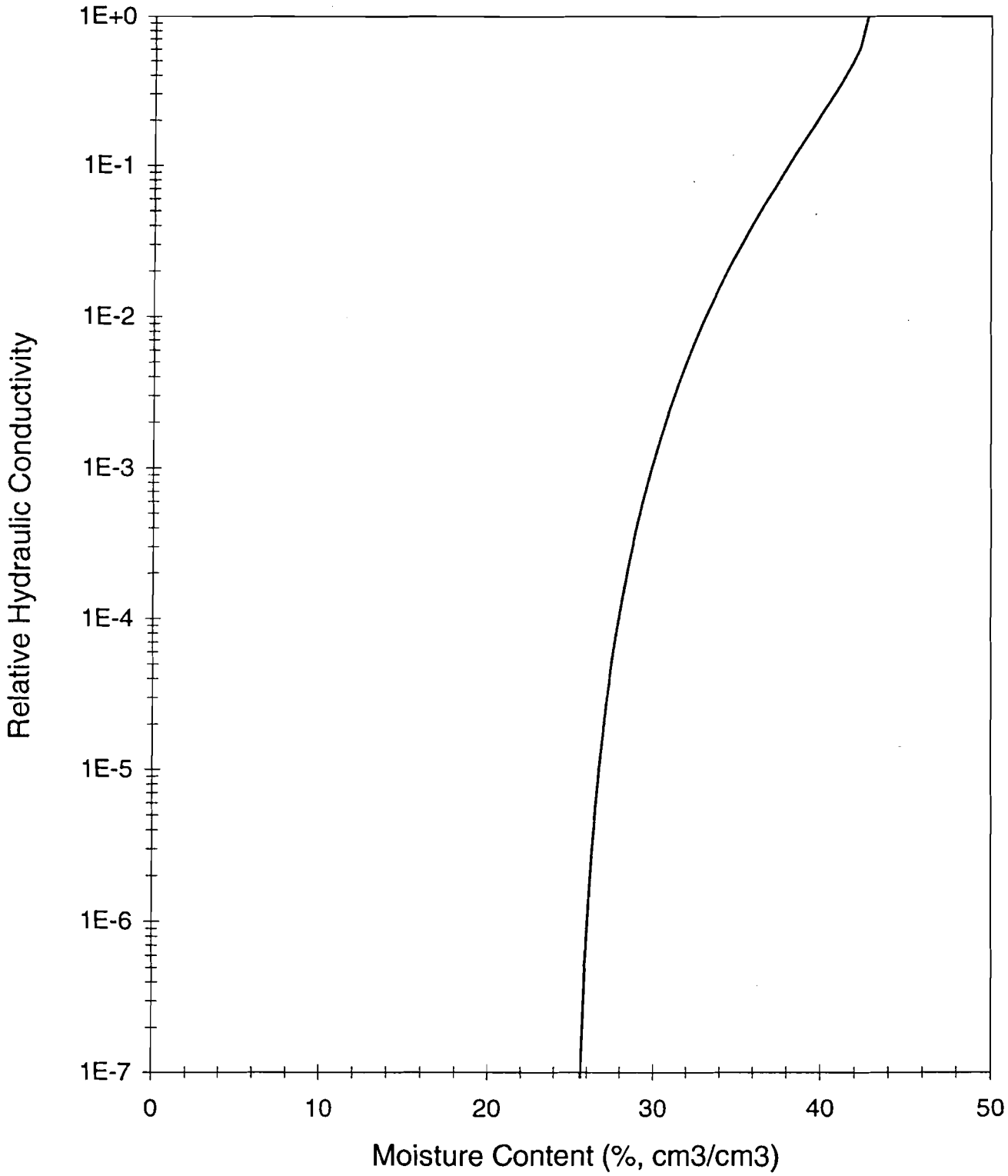
Sample Number: GEO4



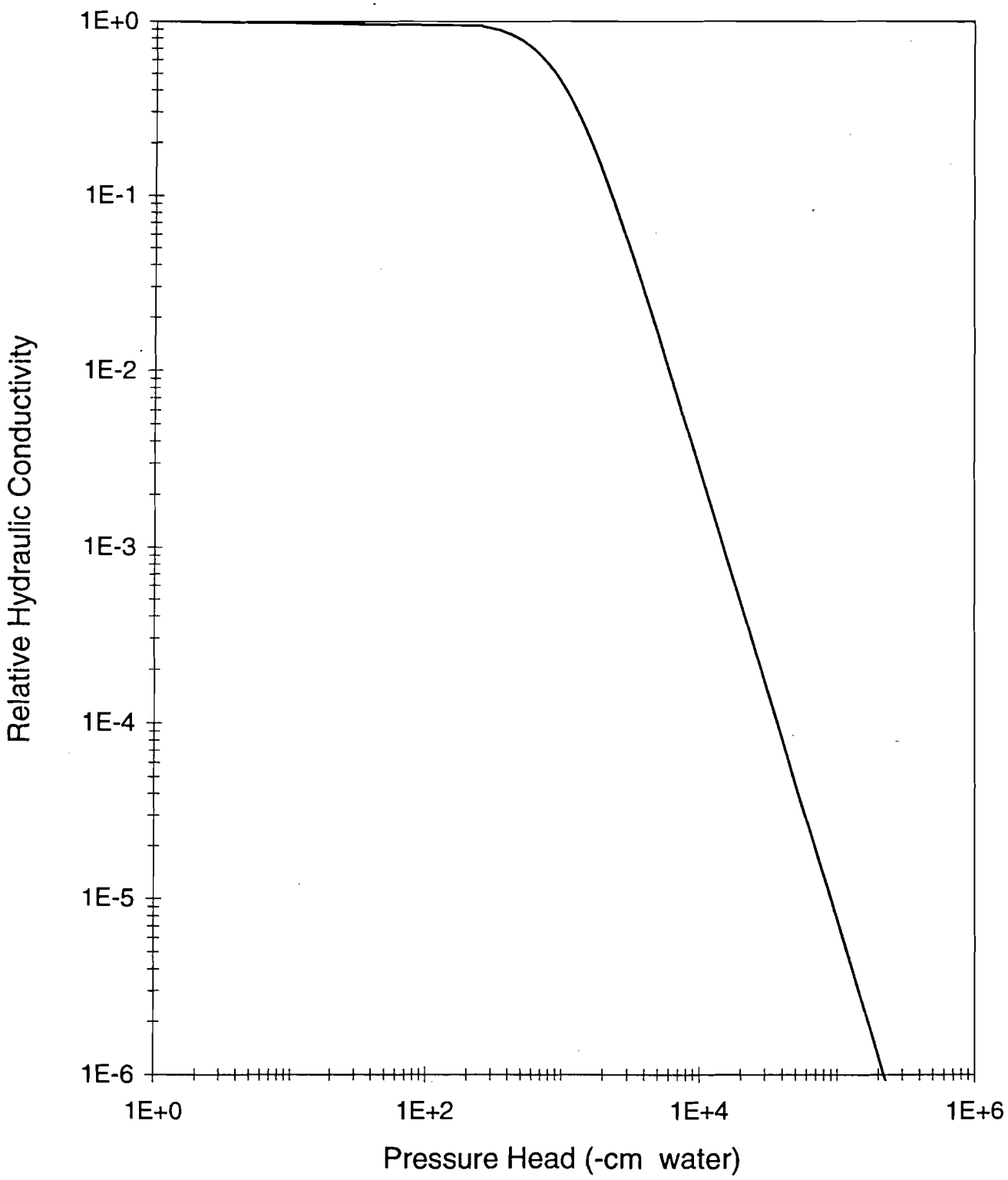
Sample Number: GEO4



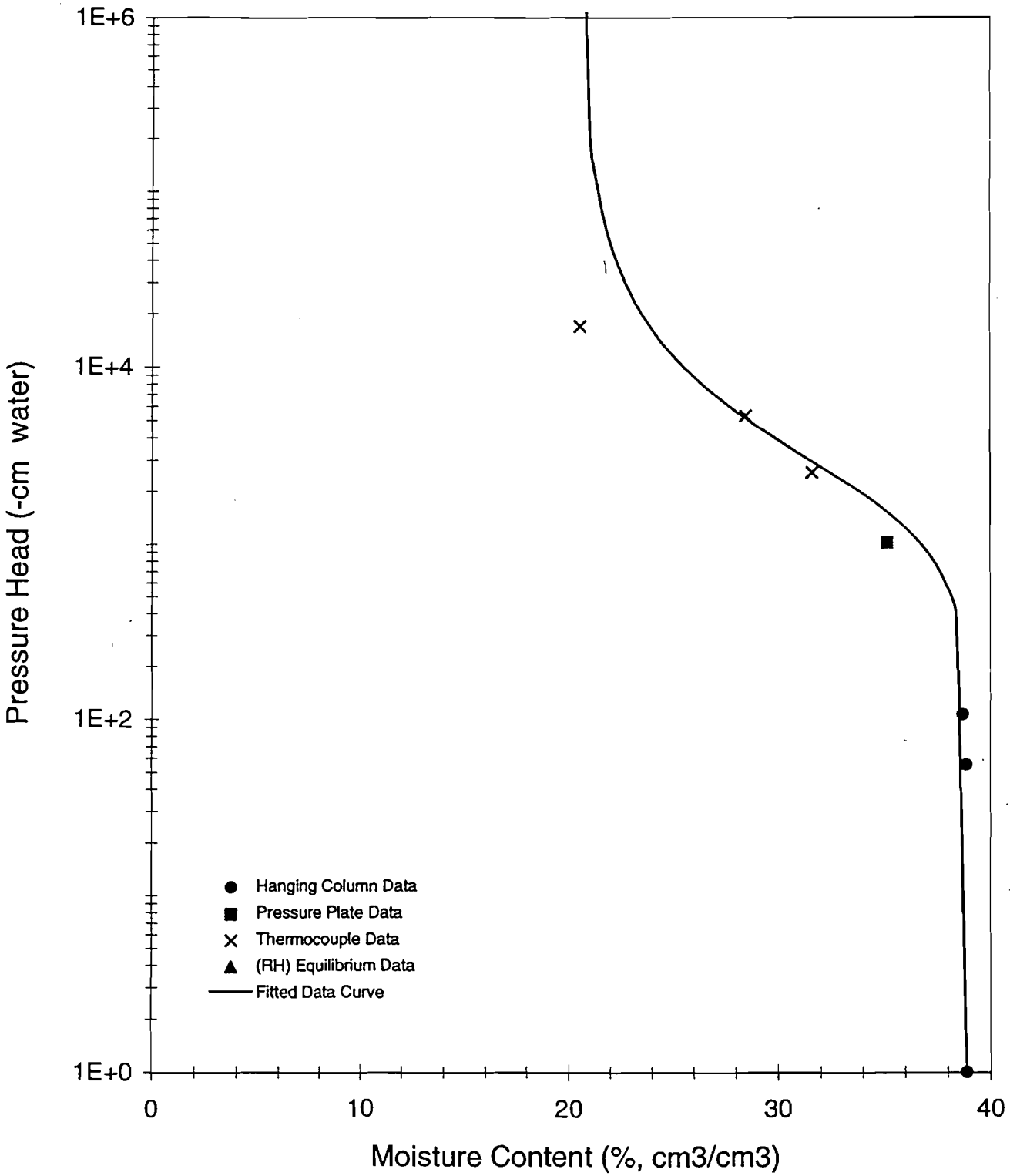
Sample Number: GEO5



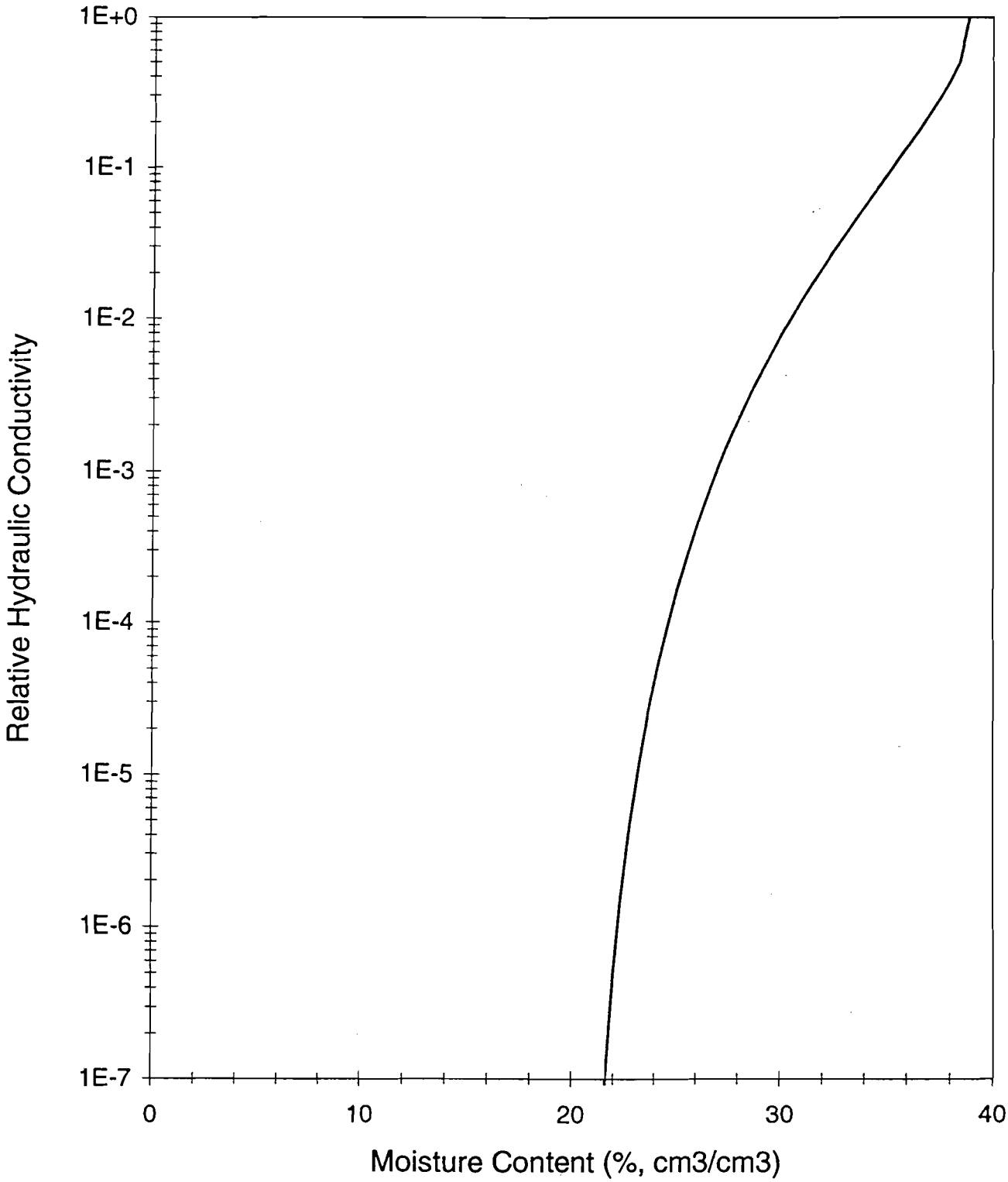
Sample Number: GEO5



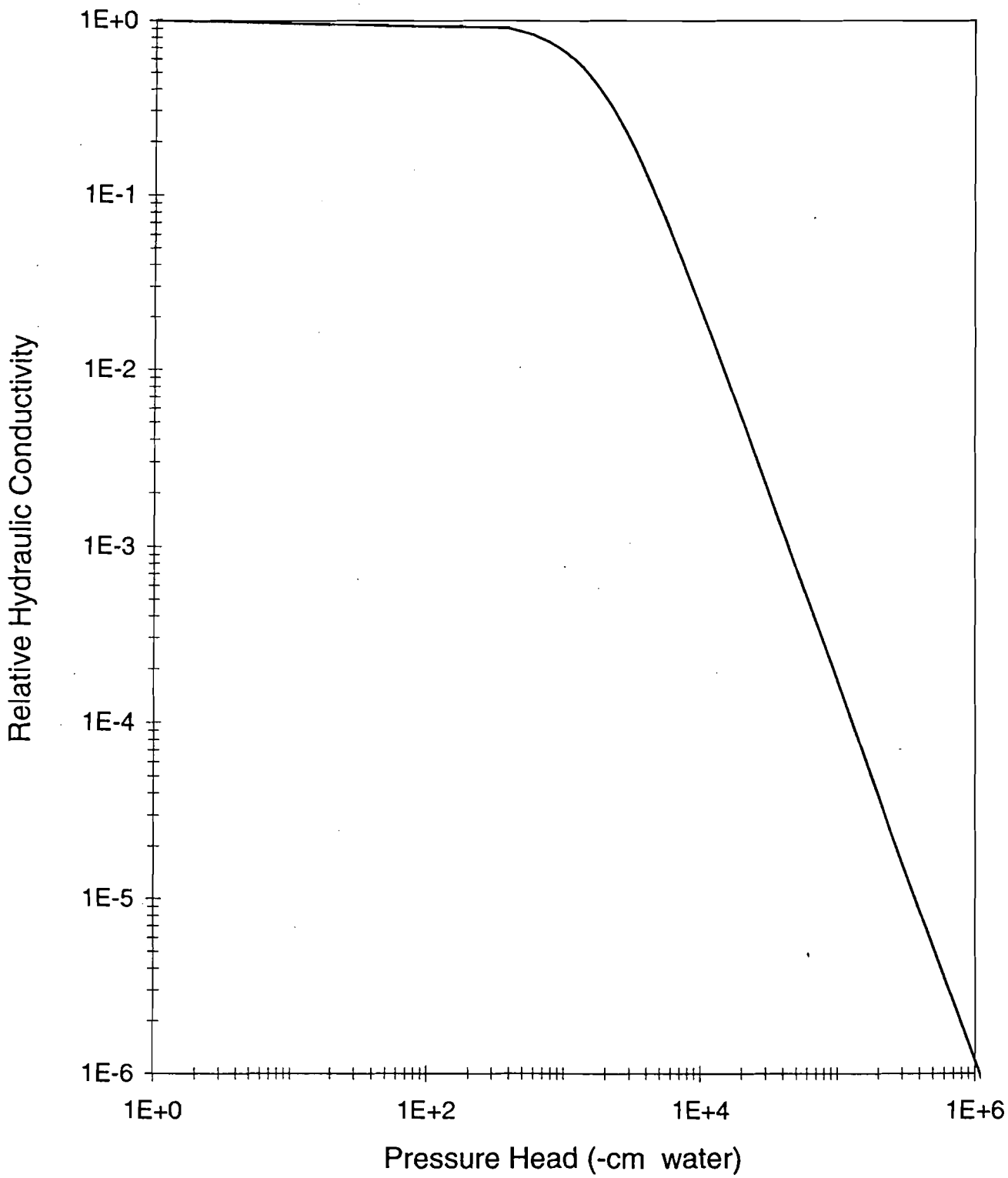
Sample Number: GEO5



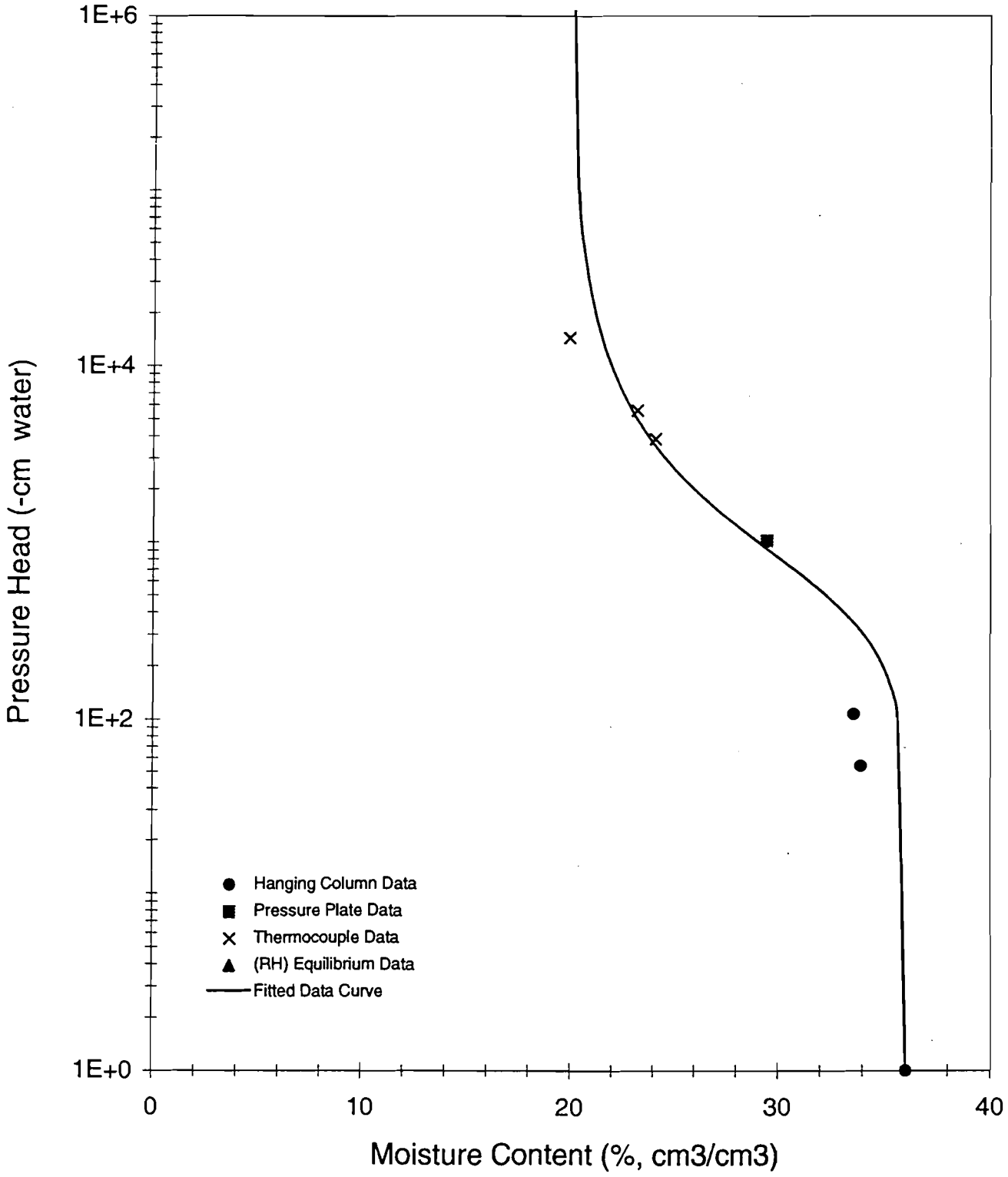
Sample Number: GEO6



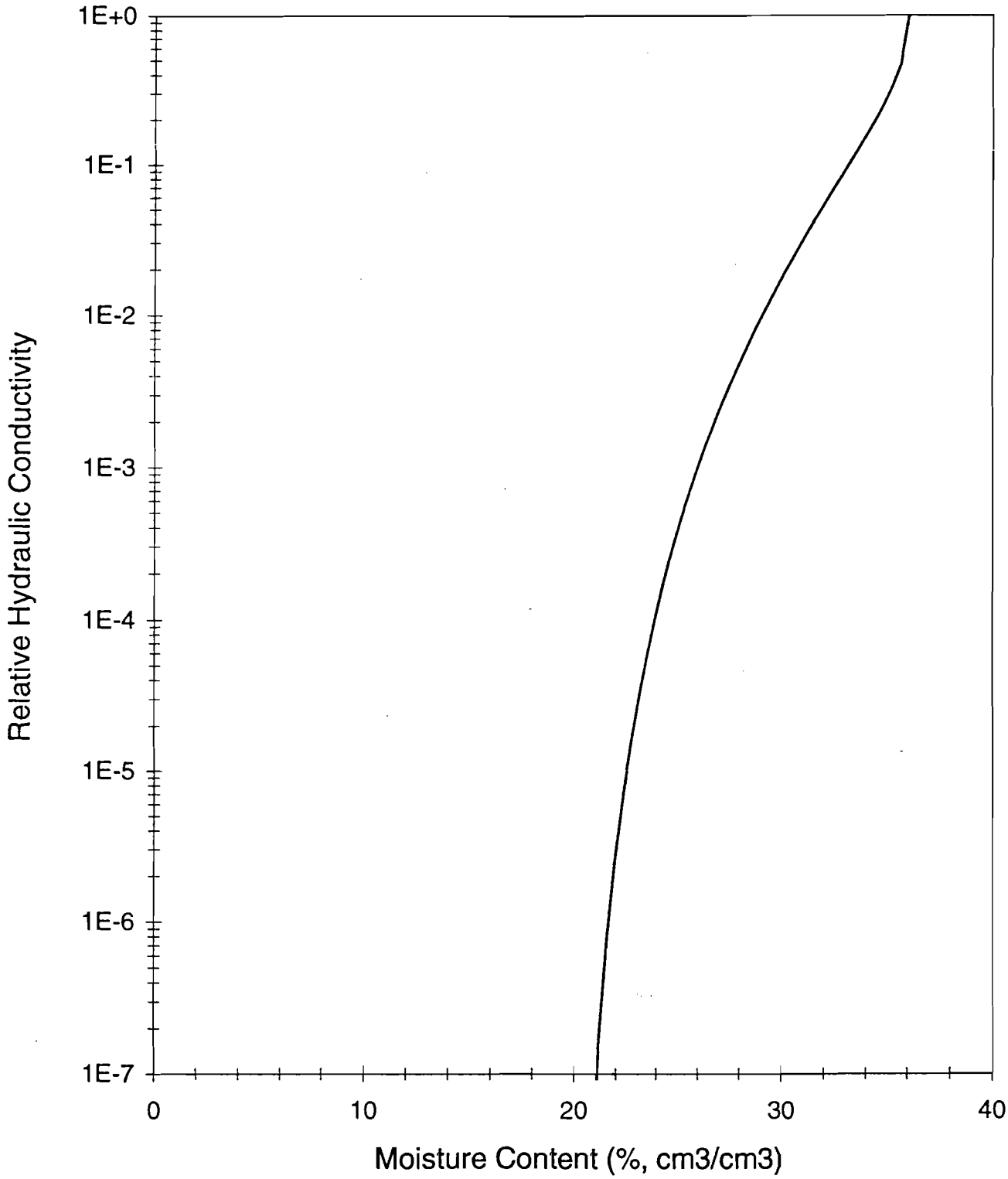
Sample Number: GEO6



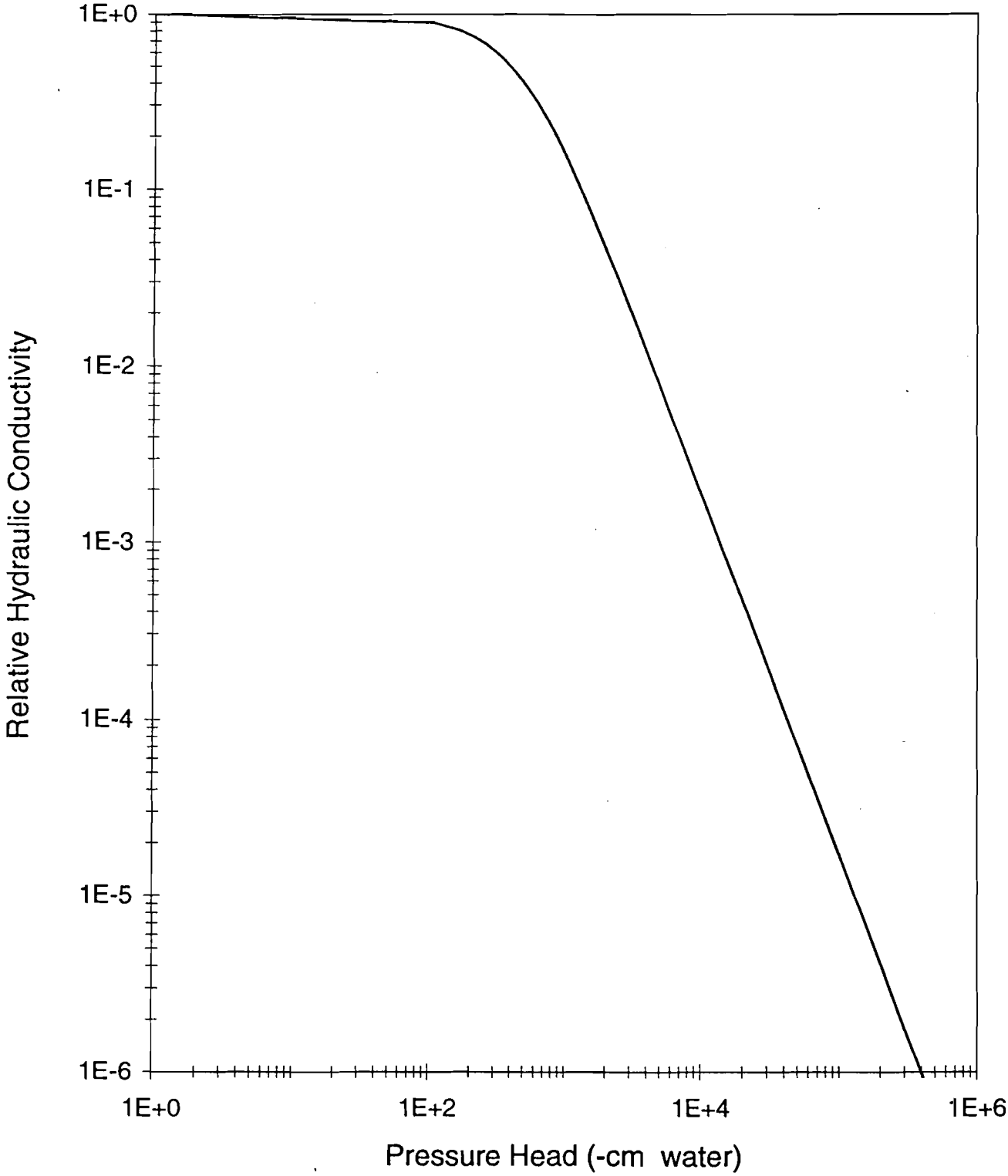
Sample Number: GEO6



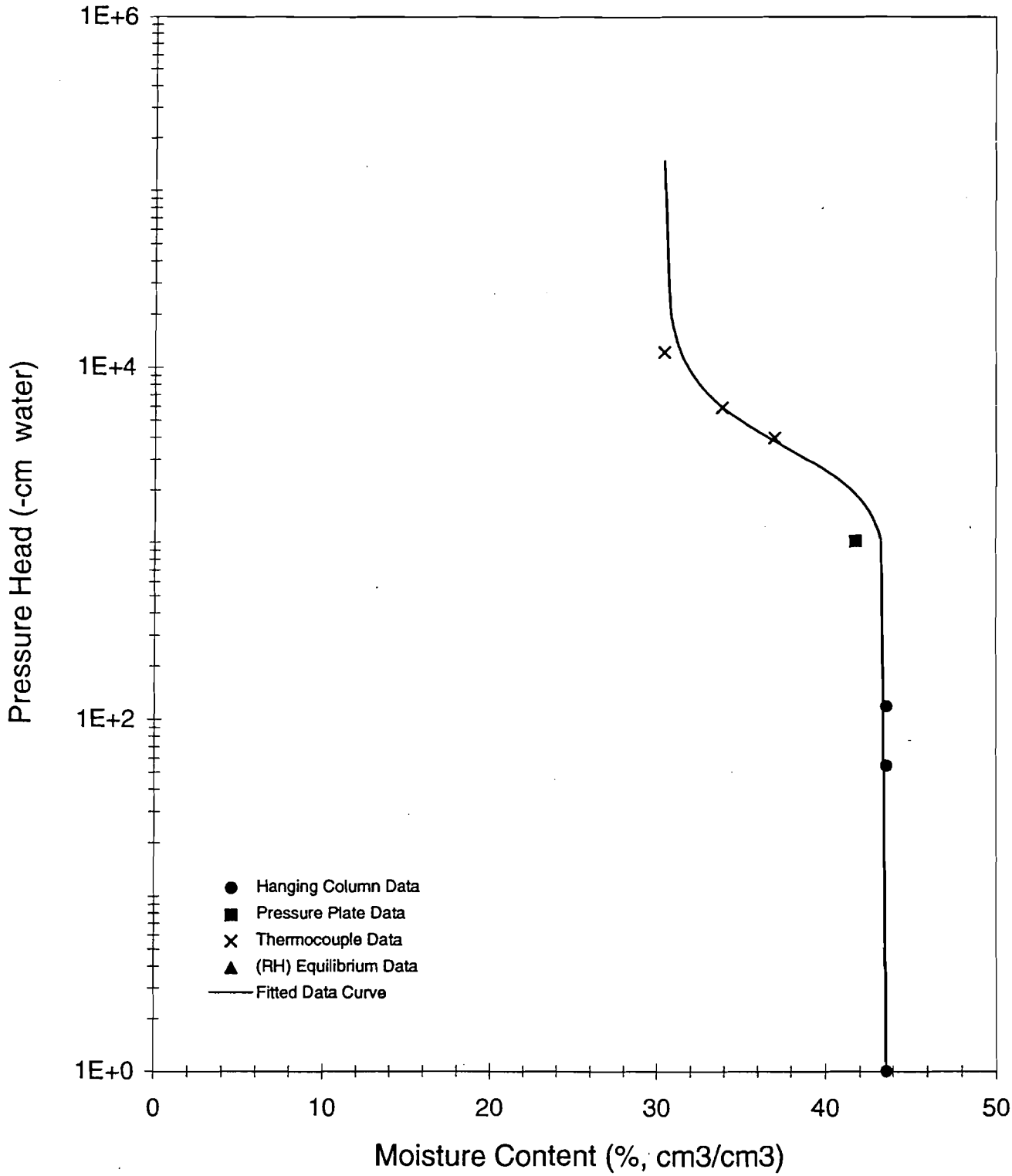
Sample Number: GEO7



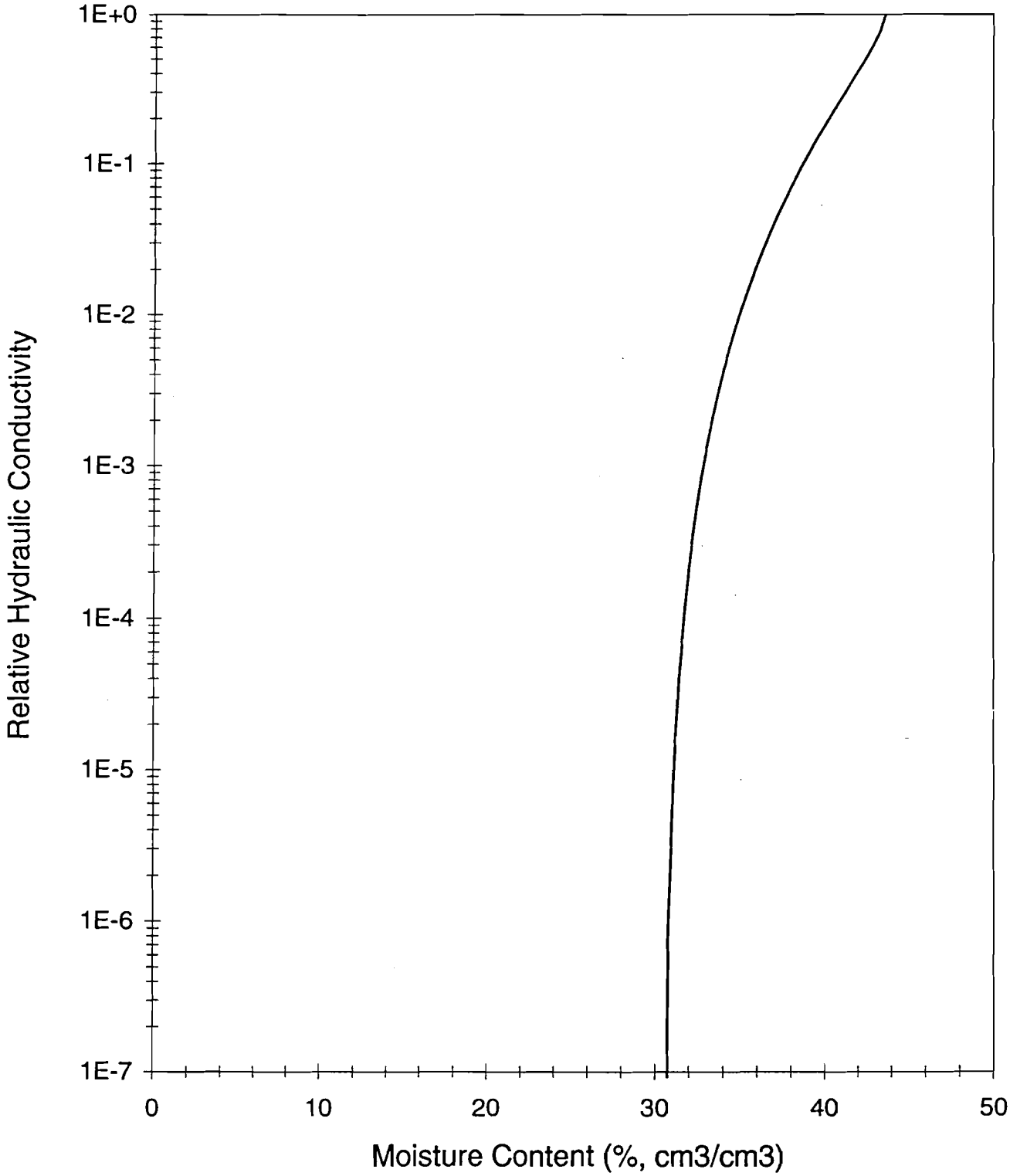
Sample Number: GEO7



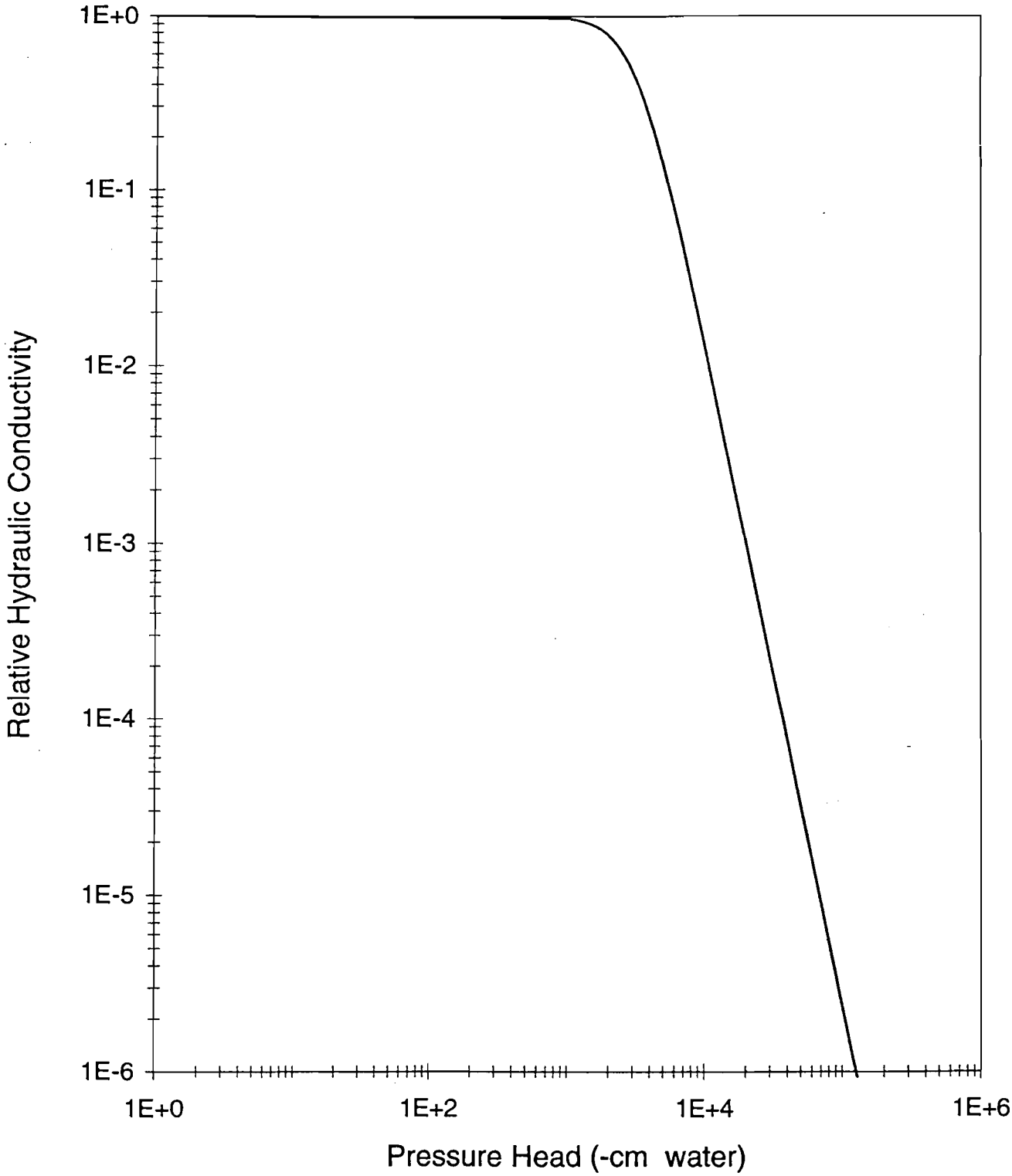
Sample Number: GEO7



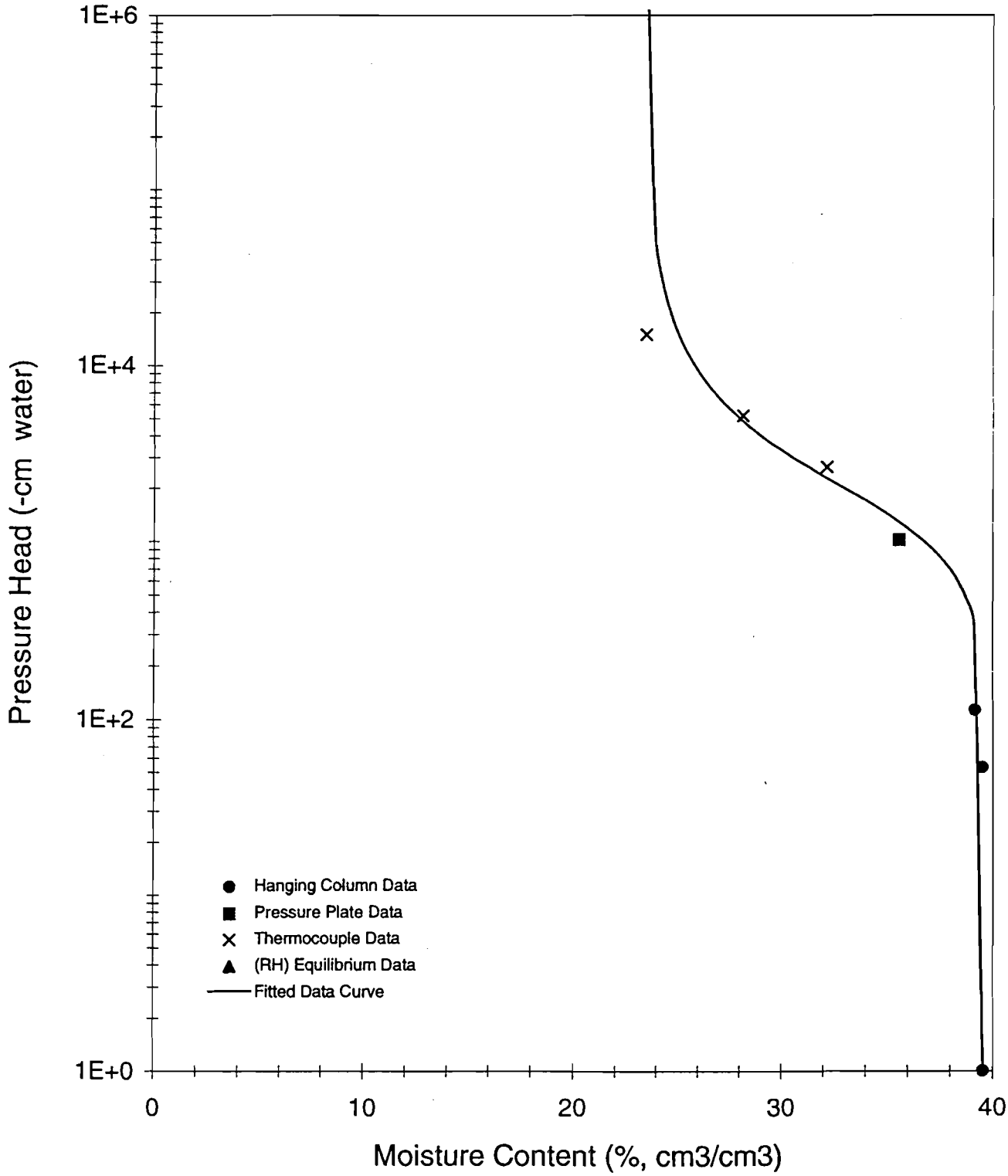
Sample Number: GEO8



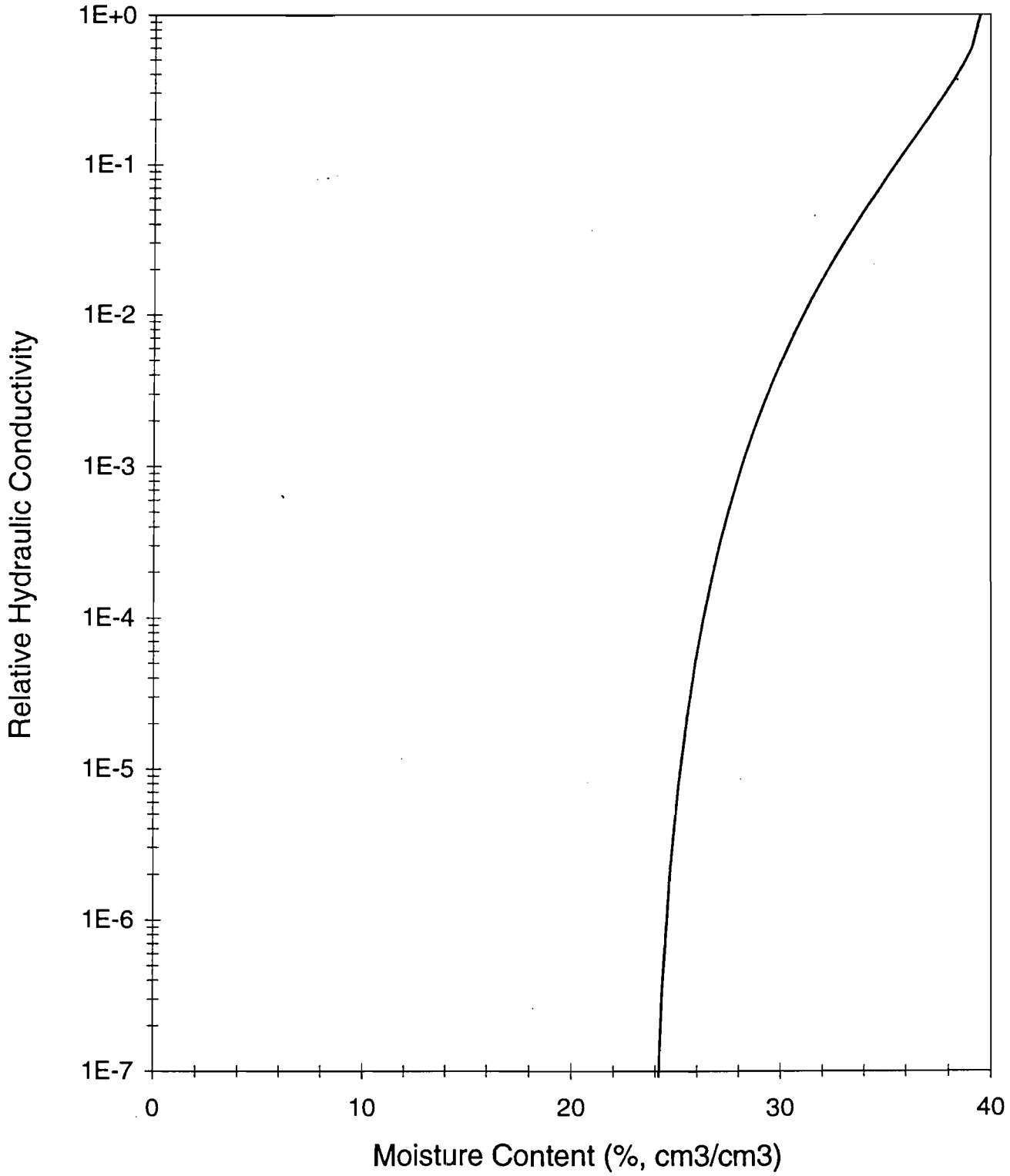
Sample Number: GEO8



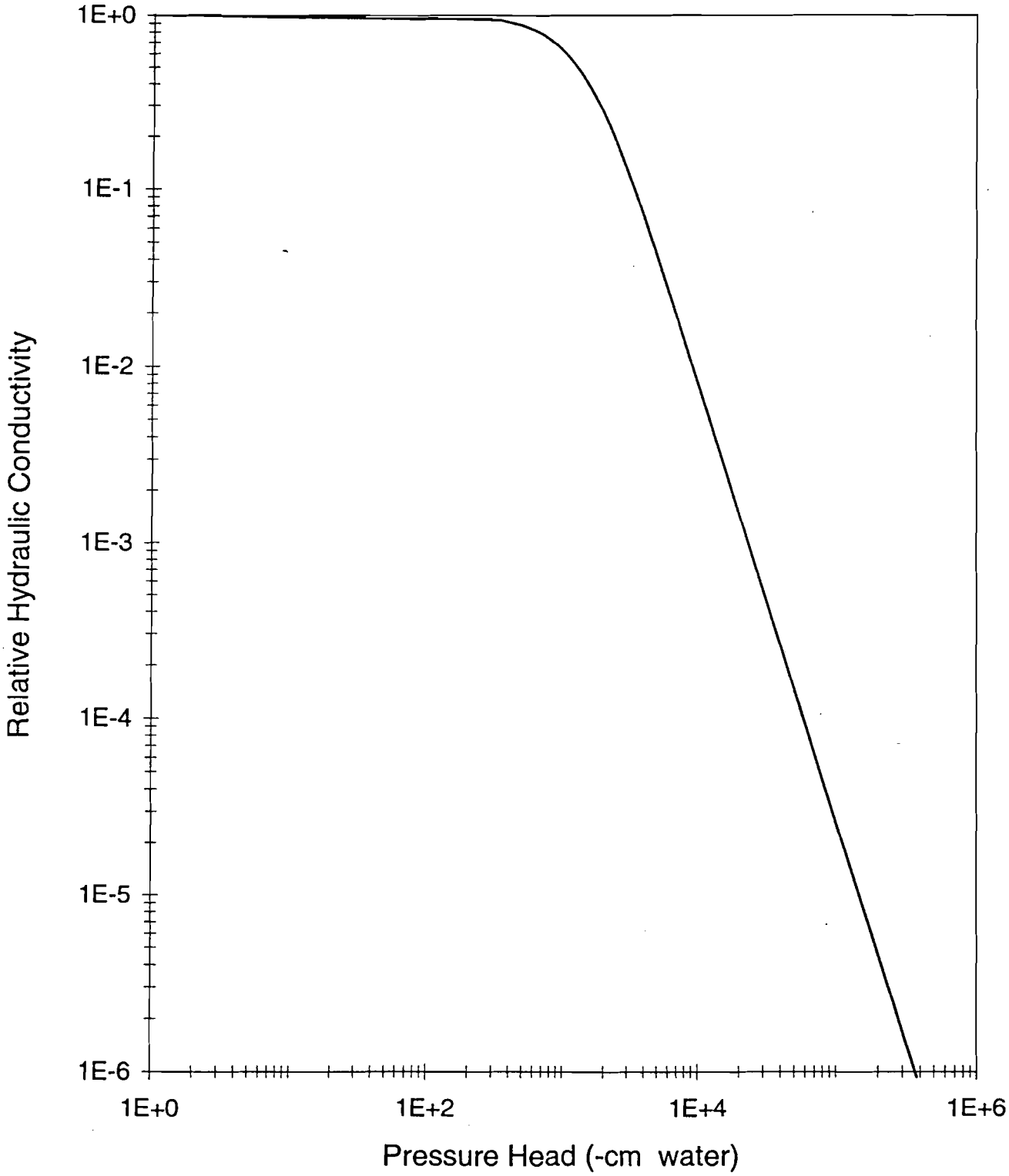
Sample Number: GEO8



Sample Number: GEO9



Sample Number: GEO9



Sample Number: GEO9

Appendix E

Particle Density

Summary of Particle Density Tests

Sample Number	Particle Density (g/cm^3)
GEO1	2.71
GEO2	2.68
GEO3	2.69
GEO4	2.68
GEO5	2.69
GEO6	2.71
GEO7	2.66
GEO8	2.74
GEO9	2.66

Particle Density

Job Name: BATTELLE
Job Number; 6908
Sample Number: GEO1
Depth:

	TRIAL 1	TRIAL 2
Weight of pycnometer filled w/air (g):	94.43	94.43
Weight of pycnometer filled w/soil (g):	151.13	151.01
Weight of pycnometer filled w/soil & water (g):	379.17	378.68
Weight of pycnometer filled w/water (g):	343.31	343.03
Observed temperature(°C)	27.0	31.0
Density of water at observed temperature (g/cm^3):	0.9965	0.9954
Particle Density (g/cm^3):	2.71	2.69
Correction factor, K:	0.9983	0.9972
Particle Density at 20°C (g/cm^3):	2.72	2.70
Average Particle Density (g/cm^3):	2.71	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Particle Density

Job Name: BATTELLE
Job Number; 6908
Sample Number: GEO2
Depth:

	TRIAL 1	TRIAL 2
Weight of pycnometer filled w/air (g):	99.08	99.60
Weight of pycnometer filled w/soil (g):	159.92	168.09
Weight of pycnometer filled w/soil & water (g):	386.15	391.39
Weight of pycnometer filled w/water (g):	347.84	348.62
Observed temperature(°C)	26.0	26.0
Density of water at observed temperature (g/cm^3):	0.9968	0.9968
Particle Density (g/cm^3):	2.69	2.65
Correction factor, K:	0.9986	0.9986
Particle Density at 20°C (g/cm^3):	2.70	2.66
Average Particle Density (g/cm^3):	2.68	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Particle Density

Job Name: BATTELLE
Job Number; 6908
Sample Number: GEO3
Depth:

	TRIAL 1	TRIAL 2
Weight of pycnometer filled w/air (g):	99.37	95.48
Weight of pycnometer filled w/soil (g):	156.00	147.11
Weight of pycnometer filled w/soil & water (g):	383.36	375.90
Weight of pycnometer filled w/water (g):	347.71	343.50
Observed temperature(°C)	32.0	36.0
Density of water at observed temperature (g/cm^3):	0.9951	0.9937
Particle Density (g/cm^3):	2.69	2.67
Correction factor, K:	0.9969	0.9955
Particle Density at 20°C (g/cm^3):	2.69	2.68
Average Particle Density (g/cm^3):	2.69	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Particle Density

Job Name: BATTELLE
Job Number; 6908
Sample Number: GEO4
Depth:

	TRIAL 1	TRIAL 2
Weight of pycnometer filled w/air (g):	100.81	100.95
Weight of pycnometer filled w/soil (g):	162.32	155.28
Weight of pycnometer filled w/soil & water (g):	387.94	383.53
Weight of pycnometer filled w/water (g):	349.31	349.48
Observed temperature(°C)	32.0	32.0
Density of water at observed temperature (g/cm^3):	0.9951	0.9951
Particle Density (g/cm^3):	2.68	2.67
Correction factor, K:	0.9969	0.9969
Particle Density at 20°C (g/cm^3):	2.68	2.67
Average Particle Density (g/cm^3):	2.68	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Particle Density

Job Name: BATTELLE
Job Number: 6908
Sample Number: GEO5
Depth:

	TRIAL 1	TRIAL 2
Weight of pycnometer filled w/air (g):	102.73	100.82
Weight of pycnometer filled w/soil (g):	152.76	151.27
Weight of pycnometer filled w/soil & water (g):	382.81	380.90
Weight of pycnometer filled w/water (g):	351.32	349.22
Observed temperature(°C)	30.0	33.0
Density of water at observed temperature (g/cm^3):	0.9957	0.9947
Particle Density (g/cm^3):	2.69	2.67
Correction factor, K:	0.9975	0.9965
Particle Density at 20°C (g/cm^3):	2.69	2.68
Average Particle Density (g/cm^3):	2.69	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Particle Density

Job Name: BATTELLE
Job Number; 6908
Sample Number: GEO6
Depth:

	TRIAL 1	TRIAL 2
Weight of pycnometer filled w/air (g):	98.76	99.59
Weight of pycnometer filled w/soil (g):	155.93	154.43
Weight of pycnometer filled w/soil & water (g):	383.04	382.46
Weight of pycnometer filled w/water (g):	346.80	348.00
Observed temperature(°C)	35.5	34.5
Density of water at observed temperature (g/cm^3):	0.9941	0.9944
Particle Density (g/cm^3):	2.72	2.68
Correction factor, K:	0.9959	0.9962
Particle Density at 20°C (g/cm^3):	2.73	2.69
Average Particle Density (g/cm^3):	2.71	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Particle Density

Job Name: BATTELLE
Job Number; 6908
Sample Number: GEO7
Depth:

	TRIAL 1	TRIAL 2
Weight of pycnometer filled w/air (g):	97.43	99.37
Weight of pycnometer filled w/soil (g):	155.20	159.50
Weight of pycnometer filled w/soil & water (g):	381.90	385.11
Weight of pycnometer filled w/water (g):	345.72	347.59
Observed temperature(°C)	33.5	33.5
Density of water at observed temperature (g/cm^3):	0.9947	0.9947
Particle Density (g/cm^3):	2.66	2.65
Correction factor, K:	0.9965	0.9965
Particle Density at 20°C (g/cm^3):	2.67	2.65
Average Particle Density (g/cm^3):	2.66	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Particle Density

Job Name: BATTELLE
Job Number; 6908
Sample Number: GEO8
Depth:

	TRIAL 1	TRIAL 2
Weight of pycnometer filled w/air (g):	95.50	100.95
Weight of pycnometer filled w/soil (g):	154.98	158.31
Weight of pycnometer filled w/soil & water (g):	382.03	386.08
Weight of pycnometer filled w/water (g):	344.11	349.78
Observed temperature(°C)	28.0	28.0
Density of water at observed temperature (g/cm^3):	0.9963	0.9963
Particle Density (g/cm^3):	2.75	2.71
Correction factor, K:	0.998	0.998
Particle Density at 20°C (g/cm^3):	2.75	2.72
Average Particle Density (g/cm^3):	2.74	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Particle Density

Job Name: BATTELLE
Job Number; 6908
Sample Number: GEO9
Depth:

	TRIAL 1	TRIAL 2
Weight of pycnometer filled w/air (g):	102.73	100.81
Weight of pycnometer filled w/soil (g):	156.03	155.81
Weight of pycnometer filled w/soil & water (g):	384.30	383.37
Weight of pycnometer filled w/water (g):	351.02	348.99
Observed temperature(°C)	34.0	36.0
Density of water at observed temperature (g/cm^3):	0.9944	0.9937
Particle Density (g/cm^3):	2.65	2.65
Correction factor, K:	0.9962	0.9955
Particle Density at 20°C (g/cm^3):	2.66	2.66
Average Particle Density (g/cm^3):	2.66	

Comments:

Laboratory analysis performed by: P. Prieksat
Calculations made by: M. Prieksat
Checked by: M. Ankeny

Appendix F

Laboratory Methods

SUMMARY OF LABORATORY METHODS

Methods	Reference
Moisture Content	ASTM D 2216-90
Bulk Density	Klute, 1986. Chp. 13, pp. 363-367
Porosity	Klute, 1986. Chp. 18, pp. 444-445
Saturated Hydraulic Conductivity	
Constant Head	ASTM D 2434-68(74)
Falling Head	Klute, 1986. Chp. 28, pp. 700-703
Moisture Retention Characteristics	
Hanging Column	Klute, 1986. Chp. 26, pp. 637-639
Pressure Plate Extractor	ASTM D 2325-68(81)
Thermocouple Psychrometer	Klute, 1986. Chp. 24, pp. 597-618 Operators Manual for the SC-10A Thermocouple Psychrometer Sample Chamber (manufactured by Decagon Devices, Inc., Pullman, WA)
Unsaturated Hydraulic Conductivity (Calculated from Moisture Retention Data)	Van Genuchten, M. 1980. A Closed Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils. *Soil Sci. Soc. Am. J.* 44:892-898.
Particle Density	ASTM D 854-91

* Klute, A. (ed.) 1986. *Methods of Soil Analysis, Part 1*, 2nd ed. American Society of Agronomy. Madison, WI.