Appendix D

Laboratory Physical Soils Testing

This appendix material was developed in draft form by Hart Crowser for the 1994 Draft RI (Hart Crowser 1994d). For completeness, it is retained here as it was developed. It includes references to all sampling conducted as specified in the RI/FS Management Plan (Hart Crowser 1992a). As a result, it refers to locations sampled outside the Consent Decree Boundary that will be the subject of additional reports.

The Hart Crowser soils laboratory conducted mechanical (sieve) and hydrometer analyses to provide grain size distributions for aquifer and aquitard materials, respectively. In addition, flexible-wall permeability tests were conducted to estimate vertical hydraulic conductivity of the aquitard material.

Mechanical Analyses. The Hart Crowser soils laboratory conducted mechanical grain size analyses using standard sieve sizes in accordance with ASTM D 422. The wet sieve analyses were performed to determine the size distribution greater than the No. 200 mesh sieve. Figure 1 presents the classification system used for the grain size analyses. The results of the tests are presented as curves in Figures 2 through 12, plotting percent finer against grain size.

Hydrometer Analyses. Samples of the Kitsap Aquitard material were analyzed using the hydrometer method, or a combined analysis (mechanical plus hydrometer), to determine the size distribution smaller than the No. 200 mesh sieve (i.e., determine percent silt and percent clay). The hydrometer testing was conducted in accordance with ASTM D 422. The results of the tests are presented as curves in Figures 2 and 4.

Laboratory Vertical Hydraulic Conductivity Testing. Testing of vertical hydraulic conductivity was conducted on two undisturbed samples of the Kitsap Aquitard material.

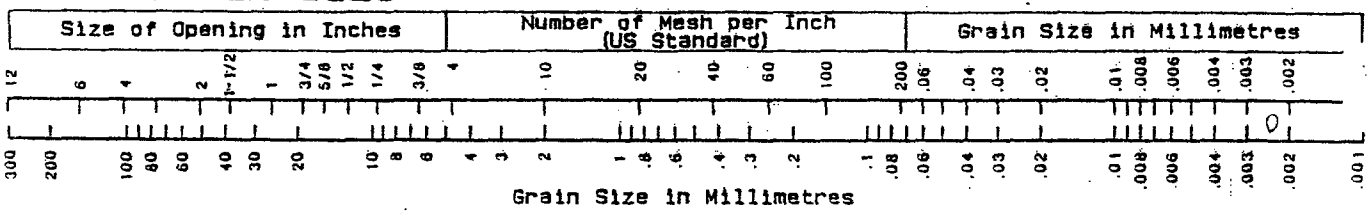
The tests were performed in a triaxial cell using "flexible wall" permeameter techniques, which allowed application of confining stresses approximately equal to the in situ effective overburden stresses. The sample was oriented in its stratigraphically correct position (up versus down) and flow was directed vertically downward through the sample using falling head techniques. The tests were run until steady state conditions were established. The results of the vertical hydraulic conductivity testing are presented in Table 1.

Table 1
Summary of Laboratory Vertical Hydraulic Conductivity (K) Results for Kitsap Aquitard Samples

Sample No.	Sample Description	Estimated Vertical K in cm/sec
MW-20, S-24E	Slightly clayey, sandy SILT	8×10^{-7}
MW-23, S-25A	Very sandy SILT with trace peat and sand partings	1×10^{-7}
	Geometric Mean:	3×10^{-7} cm/sec

Unified Soil Classification (USC) System

Soil Grain Size



COBBLES	GRAVEL	SAND	SILT and CLAY
Coarse-Grained Soils			Fine-Grained Soils

Coarse-Grained Soils

G W	G P	G M	G C	S W	S P	S M	S C
Clean GRAVEL <5% fines	*	GRAVEL with >12% fines		Clean SAND <5% fines	*	SAND with >12% fines	
GRAVEL >50% coarse fraction larger than No. 4				SAND >50% coarse fraction smaller than No. 4			
Coarse-Grained Soils >50% larger than No. 200 sieve							

G W and S W $\left(\frac{D_{60}}{D_{10}}\right) > 4$ for G W, > 6 for S W & $1 \leq \left(\frac{(D_{30})^2}{D_{10} \times D_{60}}\right) \leq 3$

G P and S P Clean GRAVEL or SAND not meeting requirements for G W and S W

G M and S M Atterberg limits below A Line with PI <4

G C and S C Atterberg limits above A Line with PI >7

* Coarse-grained soils with percentage of fines between 5 and 12 are considered borderline cases requiring use of dual symbols.

D_{10}, D_{30}, and D_{60} are the particle diameter of which 10, 30, and 60 percent, respectively, of the soil weight are finer.

Fine-Grained Soils

M L	C L	O L	M H	C H	O H	Pt
SILT	CLAY	Organic	SILT	CLAY	Organic	Highly Organic Soils
Soils with Liquid Limit <50%			Soils with Liquid Limit >50%			
Fine-Grained Soils >50% smaller than No. 200 sieve						

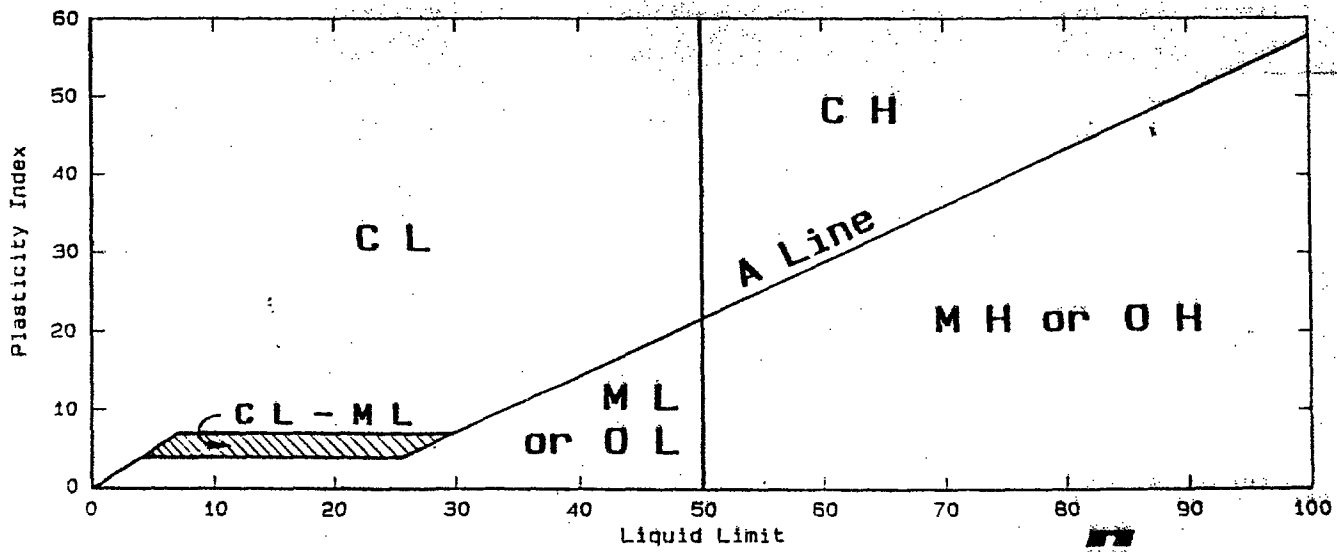


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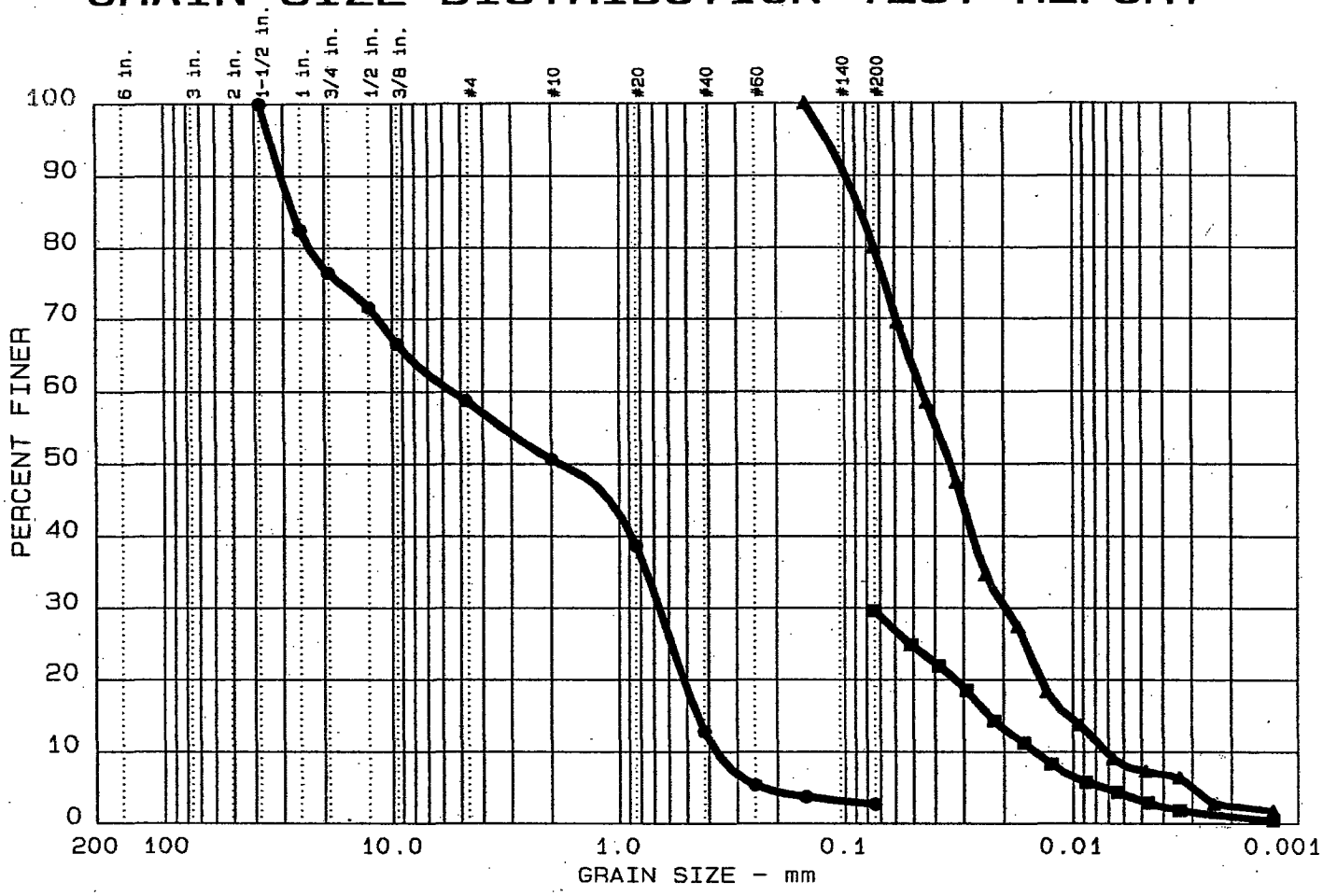
Figure 1

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	41.2	56.1	2.7	
▲	0.0	0.0	20.0	72.6	7.4
■	0.0	0.0	70.4	26.4	3.2

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			27.23	5.43	1.78	0.661	0.4513	0.3711	0.22	14.6
▲			0.08		0.03	0.019	0.0104	0.0071	1.17	6.3
■					0.07	0.074	0.0231	0.0146	5.07	5.1

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Very gravelly SAND	SP	10%
▲ Slightly clayey, sandy SILT (Kitsap Aquitard)	ML	42%
■ Very silty SAND (Kitsap Aquitard)	SM	26%

Remarks:

Project: Weyco Dupont

● Location: MW-20, S-17, Depth: 85.0' - 86.5'

▲ Location: MW-20, S-24E, Depth: 135.0'-135.5'

■ Location: MW-20, S-24D, Depth: 135.5'-136.0'

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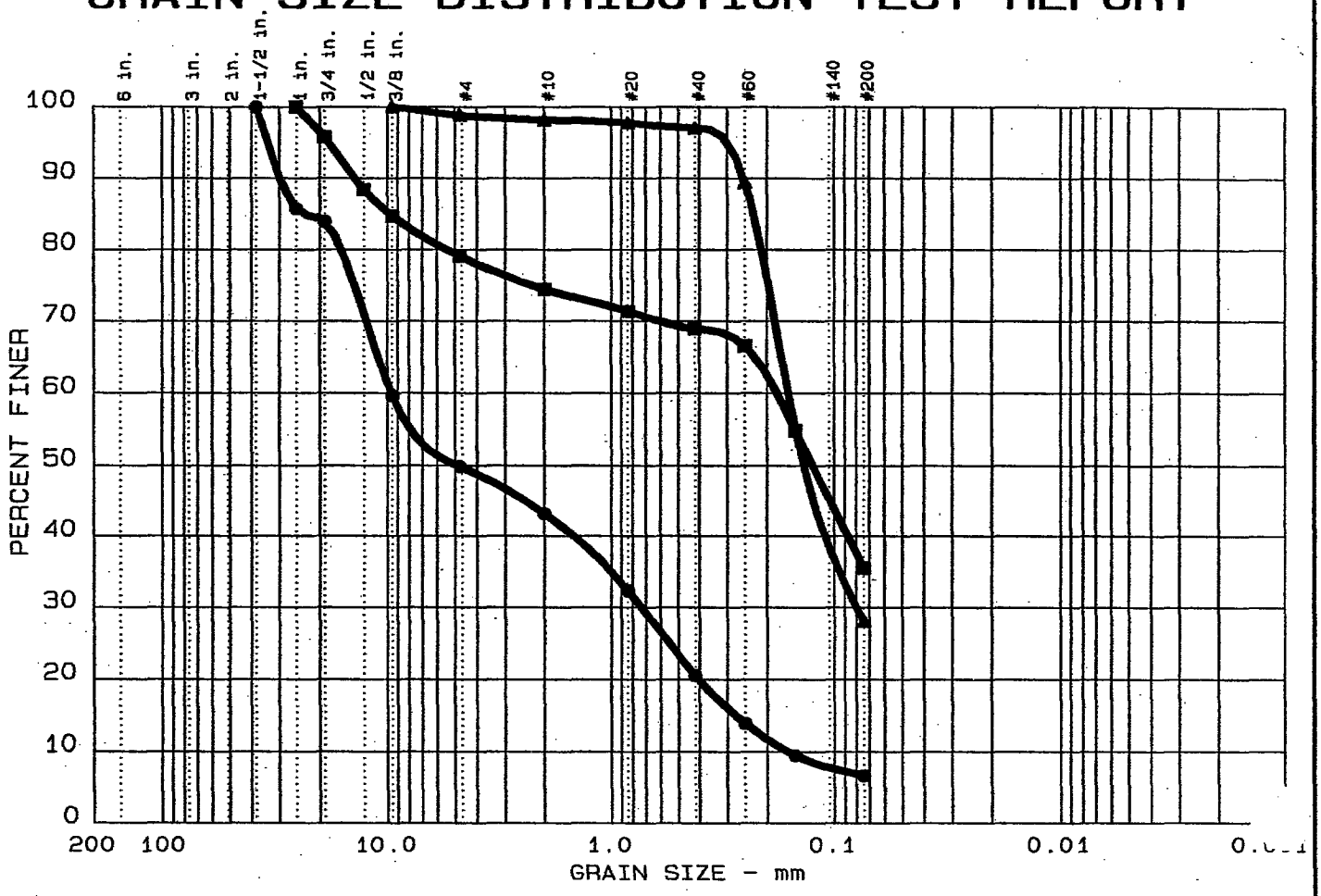
Figure 2

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	50.2	43.2	6.6	
▲	0.0	1.2	70.7	28.1	
■	0.0	20.9	43.6	35.5	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			23.71	9.63	4.77	0.730	0.2745	0.1616	0.34	59.6
▲			0.23	0.16	0.14	0.079				
■			9.77	0.18	0.12					

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Slightly silty, very sandy GRAVEL	GP-GM	9%
▲ Silty, fine SAND	SM	29%
■ Gravelly, very silty, medium to fine SAND	SM	22%

Remarks:

Project: Weyco DuPont

● Location: MW-21, S-17, Depth: 85.0' - 86.0'

▲ Location: MW-21, S-23, Depth: 148.0'- 149.0'

■ Location: MW-21, S-26, Depth: 165.0'- 165.5'

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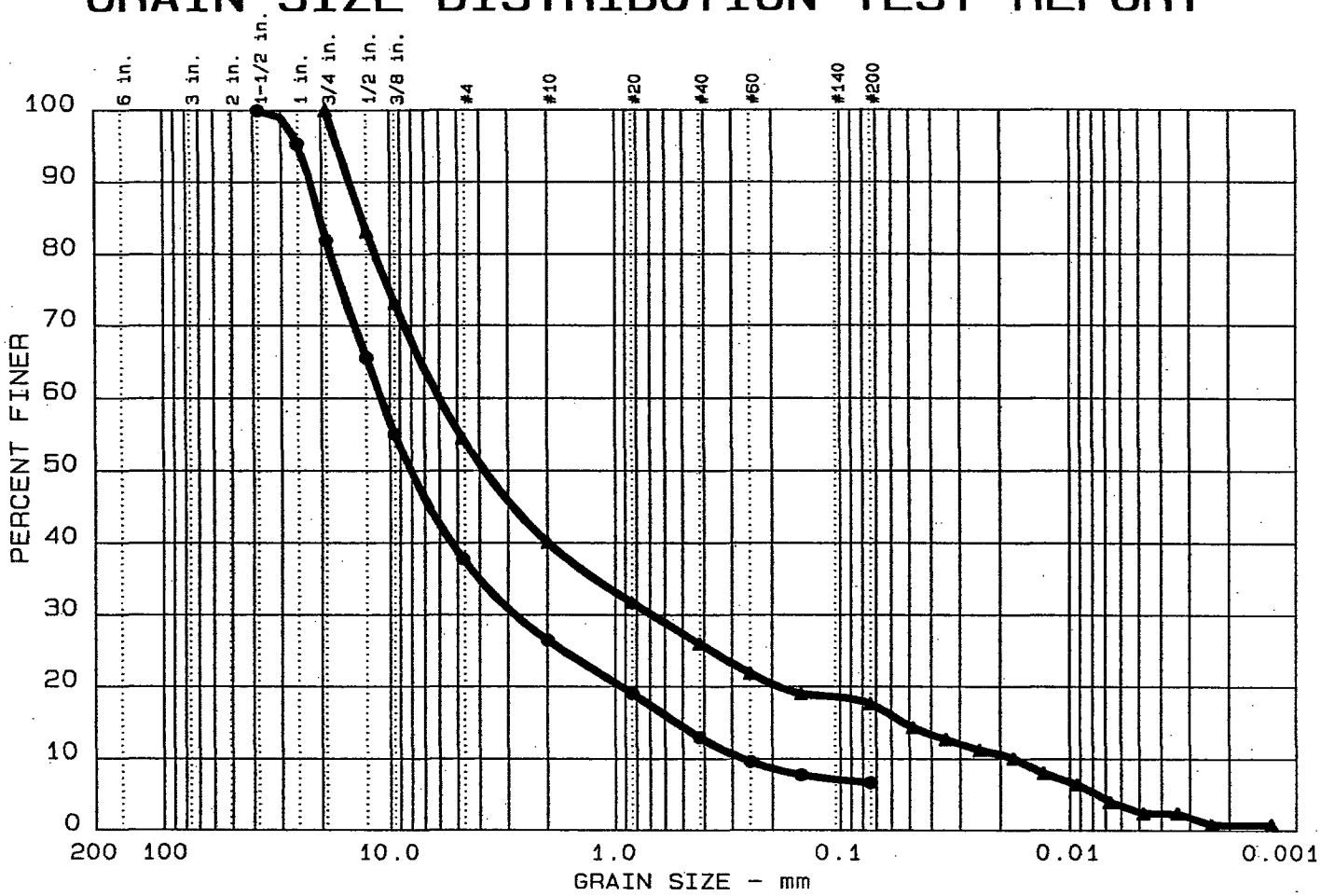
Figure 3

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75 mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	62.2	31.2	6.6	
▲	0.0	45.5	36.9	15.0	2.6

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			20.28	10.89	8.07	2.767	0.5272	0.2642	2.66	41.2
▲			13.34	6.01	3.79	0.682	0.0524	0.0175	4.42	342.8

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Slightly silty, very sandy GRAVEL	GW-GM	9%
▲ Silty, sandy GRAVEL (Kitsap Aquitard)	GM	8%

Remarks:

Project: Weyco DuPont

● Location: MW-22, S-20, Depth: 109.5'- 111.0'

▲ Location: MW-22, S-21B, Depth: 121.0'-122.0'

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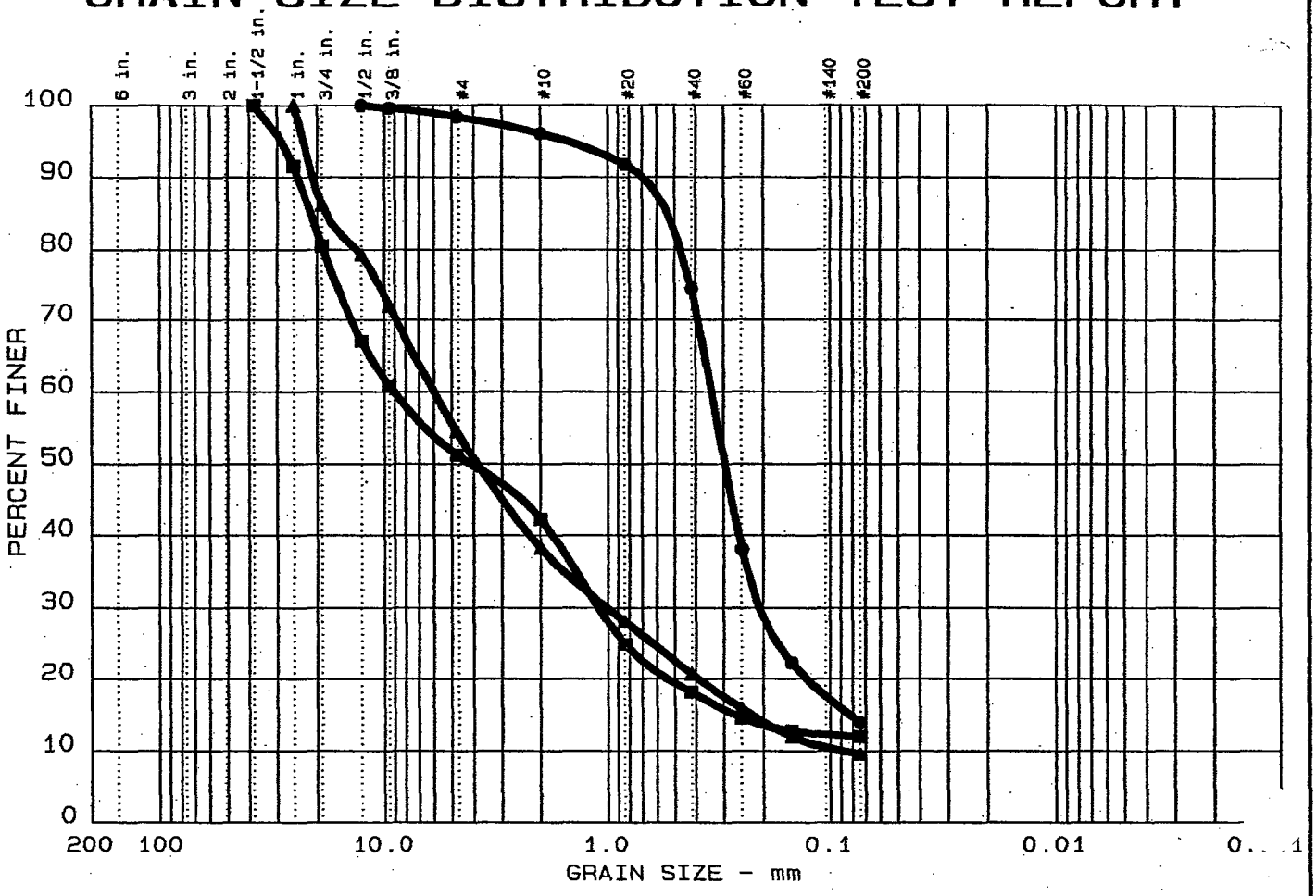
Figure 4

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	1.6	84.6	13.8	
▲	0.0	45.5	45.0	9.5	
■	0.0	48.8	39.3	11.9	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			0.54	0.34	0.30	0.209	0.0821			
▲			18.34	6.00	3.83	0.997	0.2257	0.0888	1.86	67.6
■			21.28	9.08	4.15	1.102	0.2642			

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Silty, medium to fine SAND	SM	25%
▲ Slightly silty, very sandy GRAVEL	GW-GM	9%
■ Slightly silty, very sandy GRAVEL	GP-GM	7%

Remarks:

Project: Weyco DuPont

● Location: MW-23, S-23, Depth: 119.0'- 120.5'

▲ Location: MW-24, S-11, Depth: 25.0' - 26.5'

■ Location: MW-27, S-08, Depth: 39.0' - 40.5'

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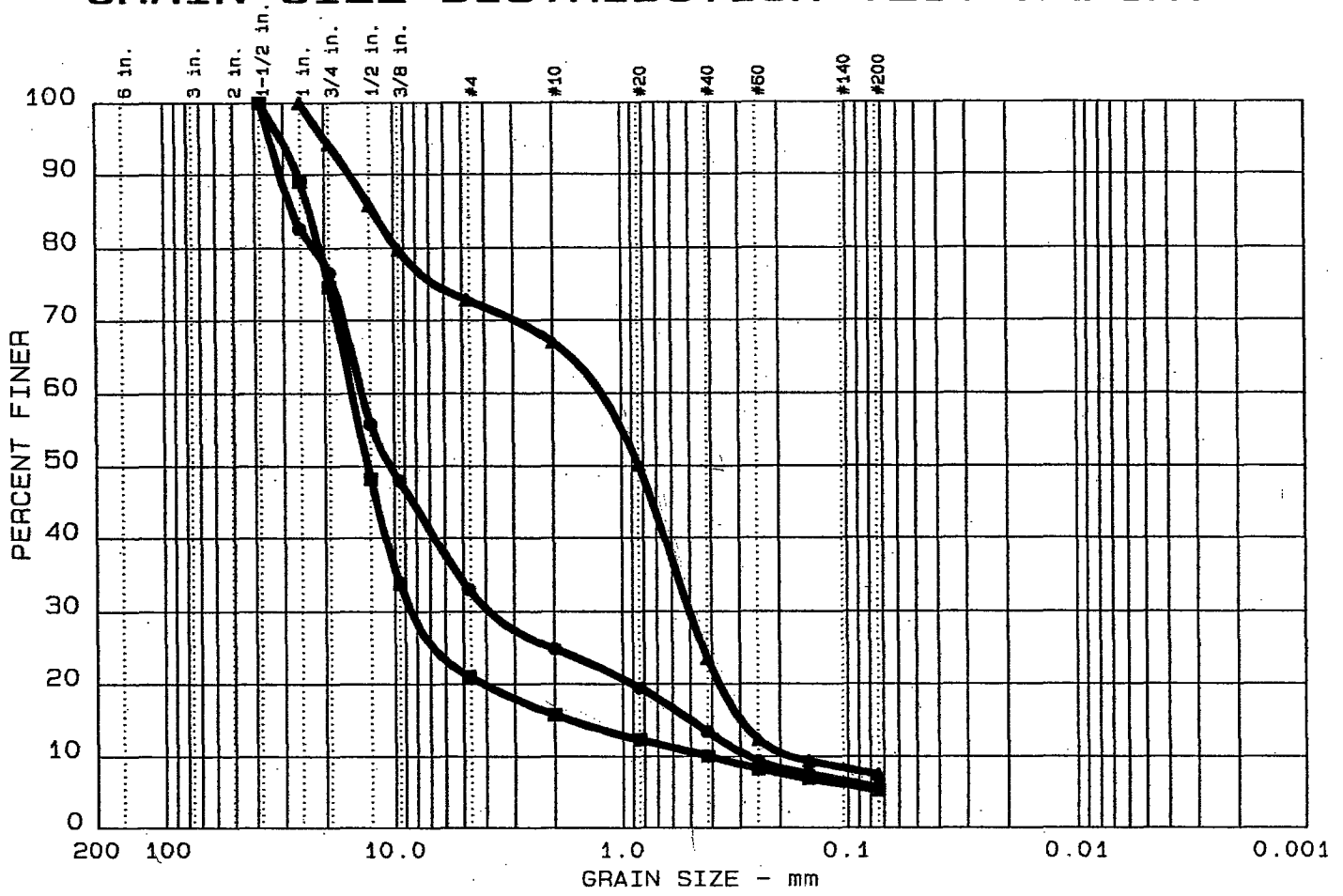
Figure 5

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	66.9	27.4	5.7	
▲	0.0	27.2	65.4	7.4	
■	0.0	78.9	15.8	5.3	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			27.54	13.80	10.47	3.846	0.4955	0.2786	3.85	49.5
▲			12.27	1.21	0.84	0.502	0.2992	0.1762	1.18	6.9
■			23.12	15.22	13.08	8.521	1.7002	0.4126	11.56	36.9

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Slightly silty, sandy, GRAVEL	GP-GM	16.5%
▲ Slightly silty, gravelly, SAND	SW-SM	14.7%
■ Slightly silty, sandy, GRAVEL	GP-GM	27.2%

Remarks:

Project: Weyco/DuPont

● Location: LR-17, Depth 0"-6"

▲ Location: LR-20, Depth 0"-6"

■ Location: LR-59, Depth 0"-6"

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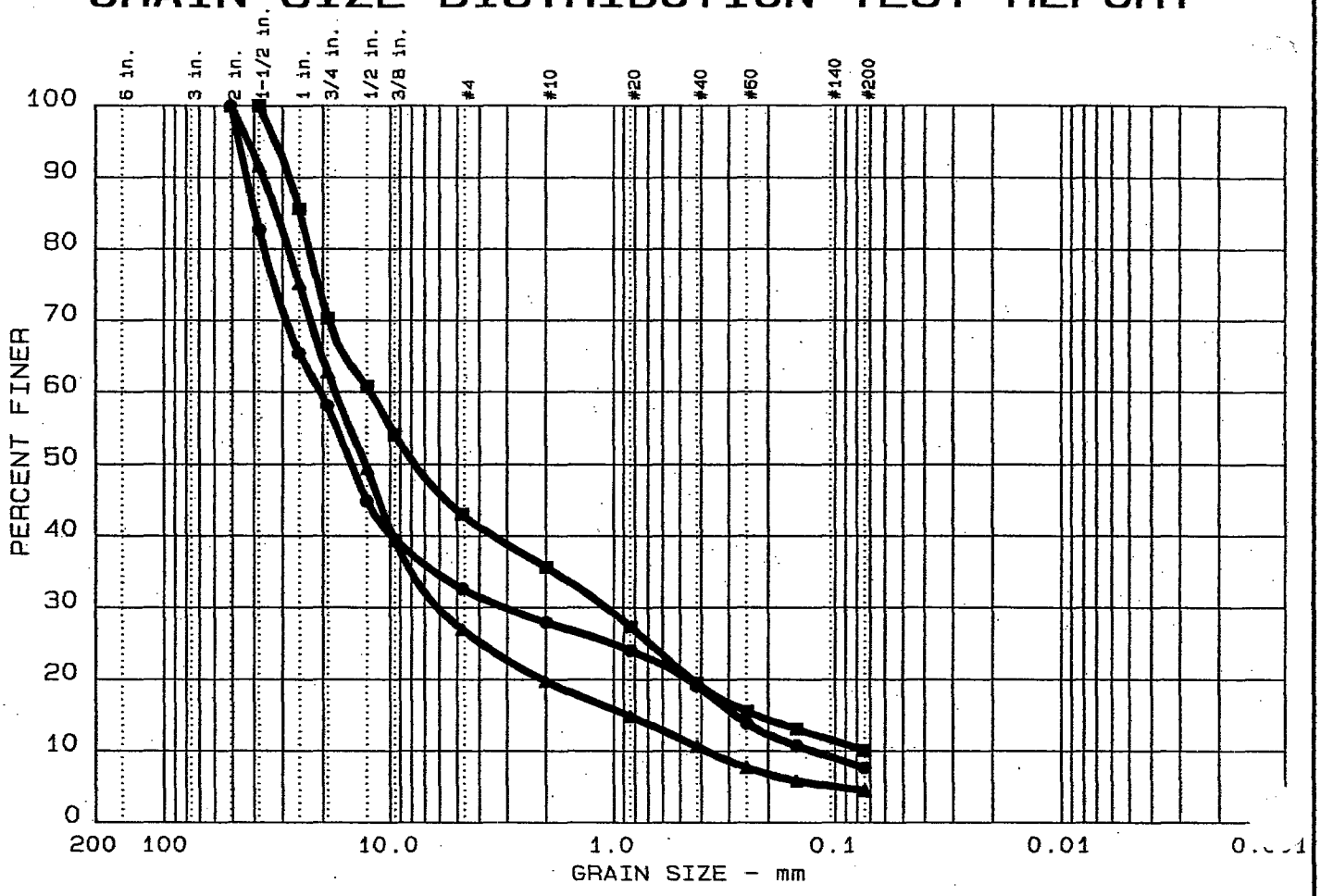
Figure 6

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	67.4	25.0	7.6	
▲	0.0	73.0	22.5	4.5	
■	0.0	56.9	33.0	10.1	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			39.67	20.35	14.91	2.975	0.2809	0.1269	3.43	160.3
▲			31.88	17.68	12.91	6.109	0.8630	0.3724	5.67	47.5
■			25.09	12.15	7.75	1.070	0.2211			

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Slightly silty, sandy GRAVEL	GP-GM	17%
▲ Sandy, GRAVEL	GP	15%
■ Slightly silty, very sandy, GRAVEL	GP-GM	18%

Remarks:

Project: Weyco/DuPont
● Location: LR-60, Depth 0"-6"
▲ Location: LR-68, Depth 0"-6"
■ Location: LR-91, Depth 0"-6"

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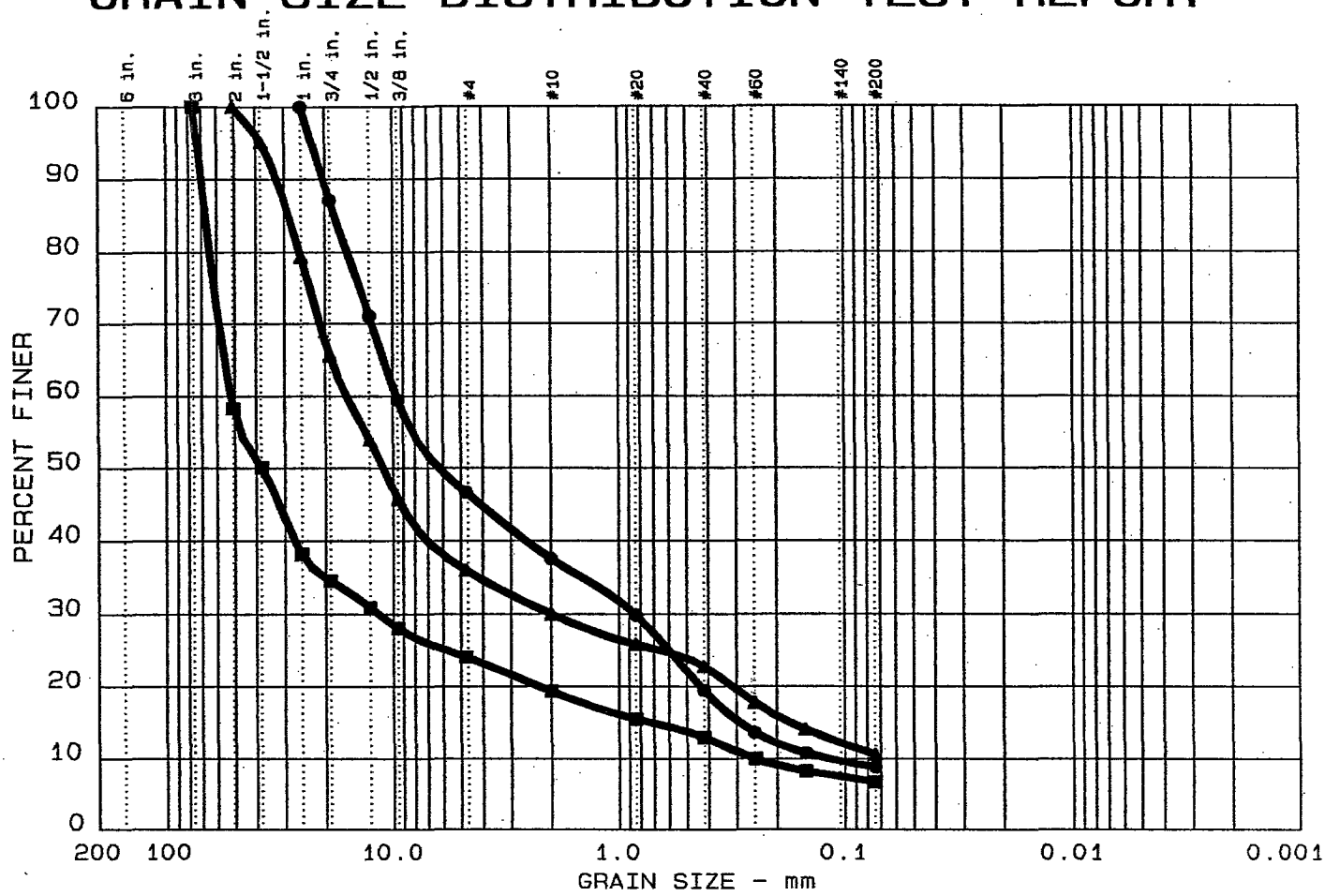
Figure 7

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	53.3	37.9	8.8	
▲	0.0	63.9	25.5	10.6	
■	0.0	75.9	17.3	6.8	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			18.07	9.67	6.24	0.842	0.2887	0.1176	0.62	82.2
▲			28.67	16.07	11.08	1.970	0.1736			
■			67.45	52.18	37.80	11.548	0.7203	0.2526	10.12	206.5

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● slightly silty, very sandy, GRAVEL	GP-GM	11.1%
▲ Slightly silty, sandy, GRAVEL	GP-GM	19.1%
■ Slightly silty, sandy, GRAVEL	GP-GM	13.2%

Remarks:

Project: Weyco/DuPont

● Location: LR-104, Depth 0"-6"

▲ Location: LR-126, Depth 0"-6"

■ Location: LR-130, Depth 0"-6"

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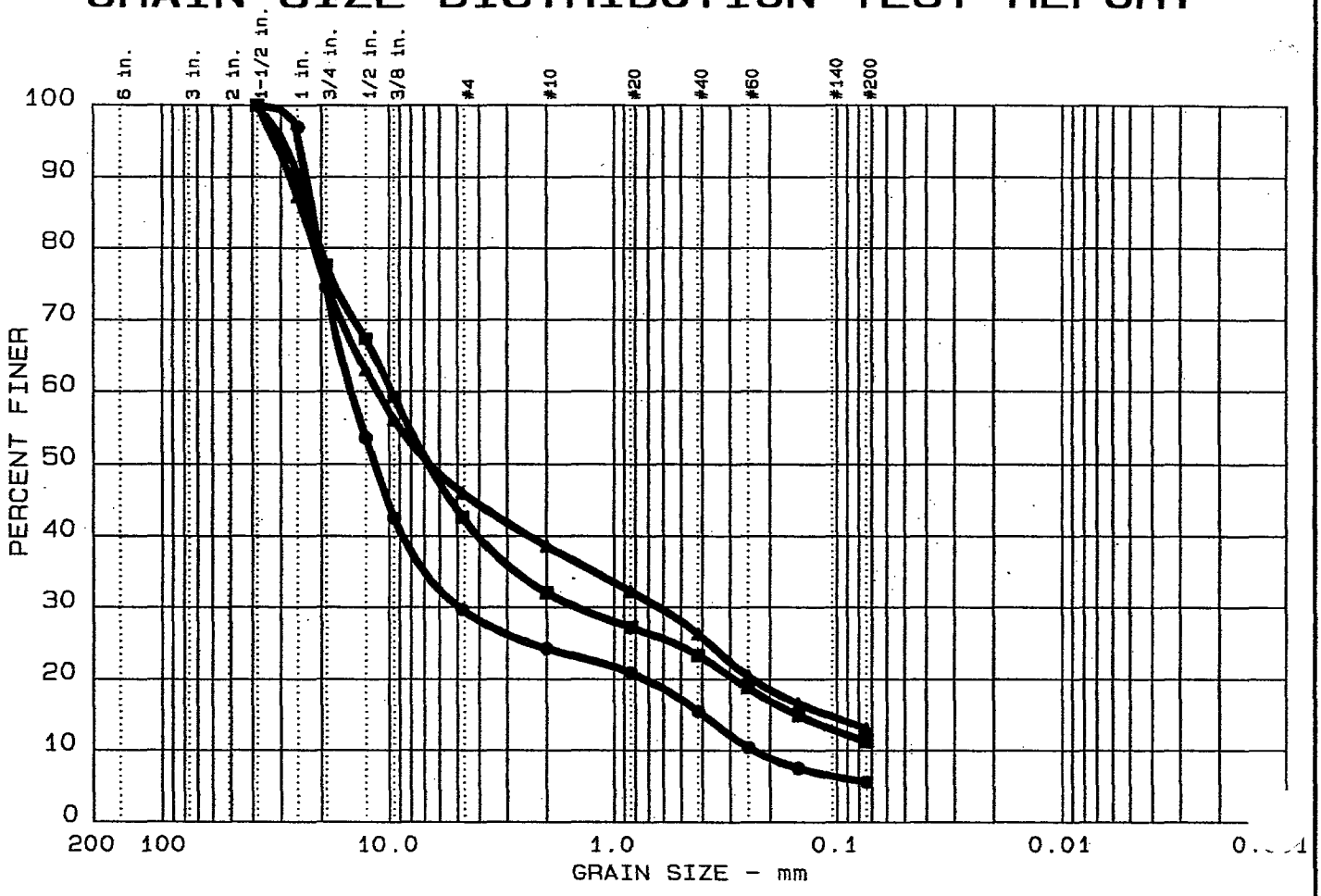
Figure 8

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75 mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	70.3	24.1	5.6	
▲	0.0	53.9	33.0	13.1	
■	0.0	57.3	31.5	11.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			21.88	14.79	11.61	4.898	0.3981	0.2371	6.84	62.4
▲			23.99	11.22	6.68	0.624	0.1109			
■			22.49	9.77	6.74	1.457	0.1508			

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● slightly silty, sandy, GRAVEL	GP-GM	13.7%
▲ Slightly silty, very sandy, GRAVEL	GM	22.9%
■ Slightly silty, very sandy, GRAVEL	GP-GM	23.3%

Remarks:

Project: Weyco/DuPont
● Location: LR-154, Depth 0"-6"
▲ Location: LR-158, Depth 0"-6"
■ Location: LR-223, Depth 0"-6"

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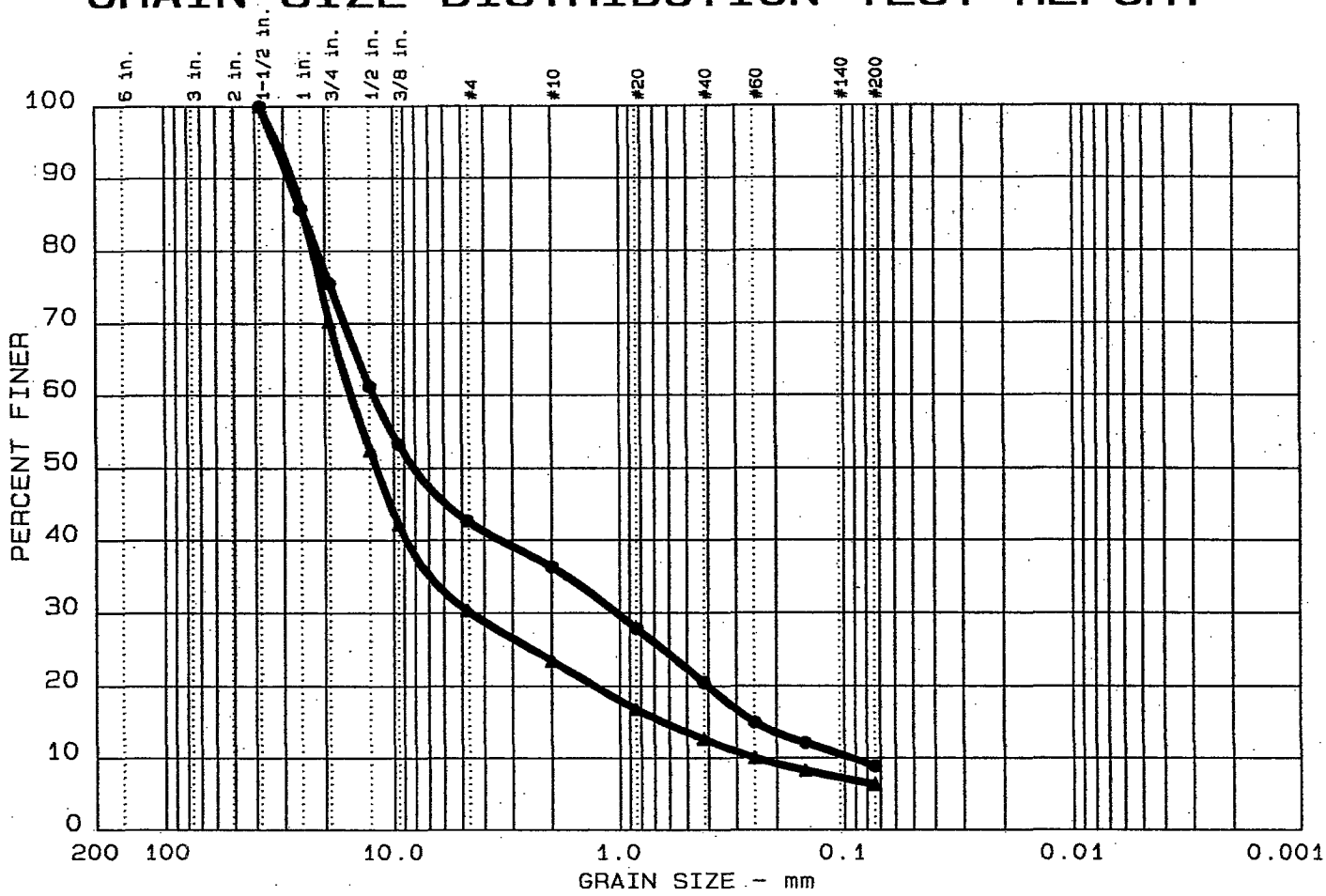
Figure 9

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	57.3	33.9	8.8	
▲	0.0	69.7	24.1	6.2	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			24.83	12.16	8.13	1.023	0.2483	0.0933	0.92	130.3
▲			24.72	15.35	11.91	4.581	0.6324	0.2518	5.43	61.0

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Slightly silty, very sandy GRAVEL	GP-GM	26%
▲ Slightly silty, sandy GRAVEL	GP-GM	16%

Remarks:

Project: Weyco DuPont
● Location: LR-245, Depth 0"-6"
▲ Location: LR-715, Depth 0"-6"

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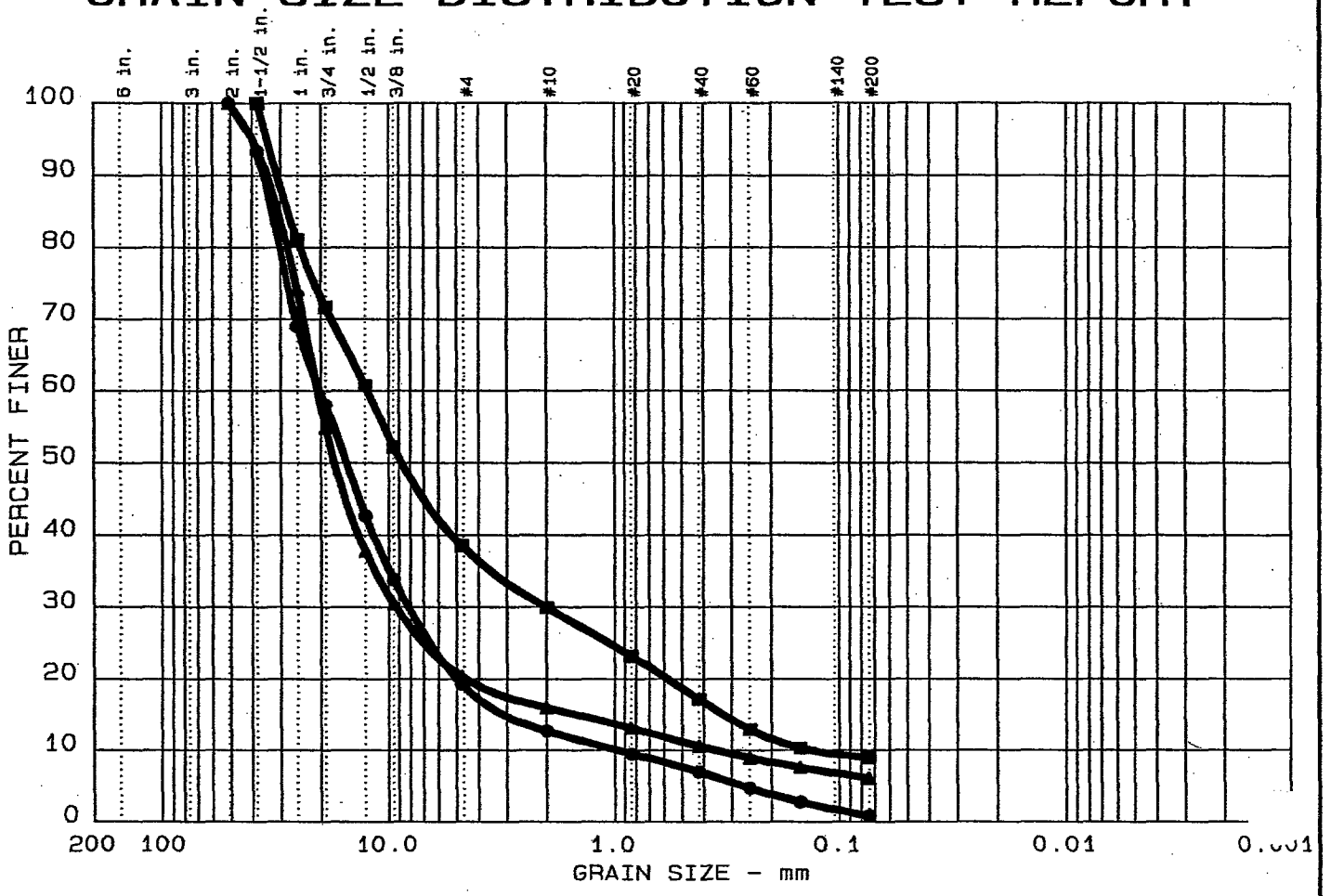
Figure 10

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	80.8	18.4	0.8	
▲	0.0	79.7	14.3	6.0	
■	0.0	61.4	29.7	8.9	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			32.70	20.16	15.38	8.166	3.1405	0.9817	3.37	20.5
▲			30.55	20.65	17.46	9.268	1.4028	0.3565	11.67	57.9
■			27.86	12.39	8.77	2.009	0.3258	0.1327	2.45	93.3

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Sandy, GRAVEL	GP	18.7%
▲ Slightly silty, sandy, GRAVEL	GP-GM	10.5%
■ Slightly silty, sandy, GRAVEL	GW-GM	20.9%

Remarks:

Project: Weyco/DuPont
● Location: 18R-10, Depth 0"-6"
▲ Location: 18R-15, Depth 0"-6"
■ Location: 18R-19 Depth 0"-6"

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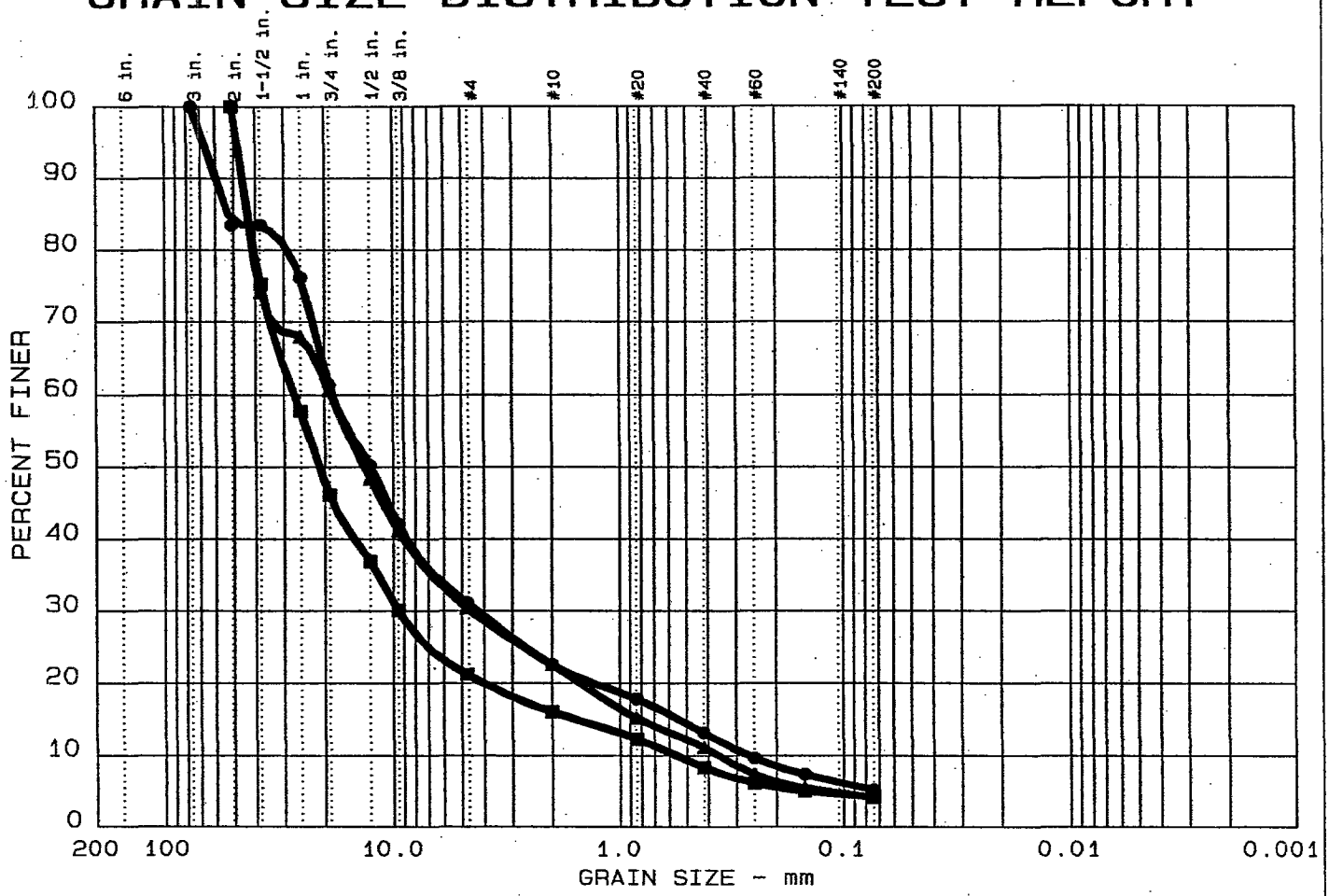
Figure 11

GRAIN SIZE DISTRIBUTION TEST REPORT



	%+75mm	% GRAVEL	% SAND	% SILT	% CLAY
●	0.0	68.8	26.0	5.2	
▲	0.0	69.6	26.3	4.1	
■	0.0	78.8	16.9	4.3	

	LL	PI	D_{85}	D_{60}	D_{50}	D_{30}	D_{15}	D_{10}	C_c	C_u
●			52.48	18.41	12.59	4.217	0.5370	0.2630	3.67	70.0
▲			43.90	18.69	13.38	4.534	0.8063	0.3602	3.05	51.9
■			43.15	26.92	21.09	9.419	1.5631	0.5546	5.94	48.5

MATERIAL DESCRIPTION	USCS	NAT. MOIST.
● Slightly silty, sandy, GRAVEL	GP-GM	6.2%
▲ Sandy, GRAVEL	GP	8.8%
■ Sandy, GRAVEL	GP	8.3%

Remarks:

Project: Weyco/DuPont
● Location: RR-502, Depth 0"-6"
▲ Location: RR-509, Depth 0"-6"
■ Location: RR-515, Depth 0"-6"

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Figure 12