ATTACHMENT A
WIND-WAVE ANALYSIS FOR SEDIMENT CAP ARMOR LAYER DESIGNS – EXAMPLE CALCULATION

PROJECT: Onondaga Lake	CALC NO. 1	SHEET 1 of 13
SUBJECT: Attachment A – Wind-Wave Analysis for Sediment Cap Armor Layer Designs - Example Calculation		

Objective: To determine the 100-year design wave for each of Onondaga Lake's Remediation Areas and the resultant particle size(s) necessary for stability of the sediment cap.

This document presents an example calculation for Remediation Area E as well as the results of the analysis for each Remediation Area.

References:

Dean, R.G. and R.A. Dalrymple. 1991. *Water Wave Mechanics for Engineers and Scientists*. World Scientific.

Maynord, S. 1998. *Appendix A: Armor Layer Design for the Guidance for In-Situ Subaqueous Capping of Contaminated Sediment*. Prepared for the U.S. Environmental Protection Agency (USEPA).

U.S. Army Corps of Engineers (USACE). 1992. *Automated Coastal Engineering System (ACES).* Technical Reference by D.E. Leenknecht, A. Szuwalski, and A.R. Sherlock, Coastal Engineering Center, Department of the Army, Waterways Experiment Station, Vicksburg, MS.

USACE. 2006. *Coastal Engineering Manual*. Engineering Manual EM 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).

Vanoni, V.A. 1975. *Sedimentation Engineering*. ASCE Manuals and Reports on Engineering Practice – No. 54, 730 pp.

You. 2000. "A simple model of sediment initiation under waves." *Coastal Engineering* 41 (2000). pp 399-412

Computation of 100-year design wave and resultant particle size(s): The following presents a detailed summary and example calculation for the Onondaga Lake wind-wave analysis. The numbered list below outlines the general approach used for the calculation and defines specific parameters used in the calculations. To efficiently facilitate computations for multiple cases, all calculations were carried out using a spreadsheet and the *Automated Coastal Engineering System (ACES)* software. Subsequent sections below illustrate a step-by-step calculation for the example case of Remediation Area E.

1. Estimate the 15-minute averaged 100-year return interval wind speed

For the 68-years of one-hour averaged wind data, only the winds blowing from 280 to 340 degrees (clockwise from North) were considered for this Remediation Area. These are the winds blowing primarily toward the shoreline for this Remediation Area (i.e., along the possible fetch radials). The first step in computing the 15-minute averaged 100-year return interval wind speed was to determine the wind speed at an elevation of 10-meters above the ground (U_{10}) for each measurement. Equation II-2-9 from USACE (2006) was used:

$$U_{10} = U_z \left(\frac{10}{z} \right)^{\frac{1}{7}}$$

For example, wind speeds were measured at 21 feet (6.4 meters) above the ground from 1963 to 2009. Thus, for a one-hour averaged wind speed of 55.3 miles per hour (24.7 meters per second), the wind speed at 10-meters would be:

$$U_{10} = 24.7 \text{ m/s} \left(\frac{10 \text{ m}}{6.4 \text{ m}} \right)^{\frac{1}{7}} = 26.3 \text{ m/s} = 58.9 \text{ mph}$$

Figure A-1 was used to determine the estimated time to achieve fetch-limited conditions as a function of wind speed and fetch length. For a wind speed of 58.9 mph (26.3 m/s) and a fetch length of 4.66 miles (7.4 kilometers) for Remediation Area E, the time to achieve fetch-limited conditions is approximately 60-minutes. Therefore, using 15-minute averaged wind speeds would be conservative.

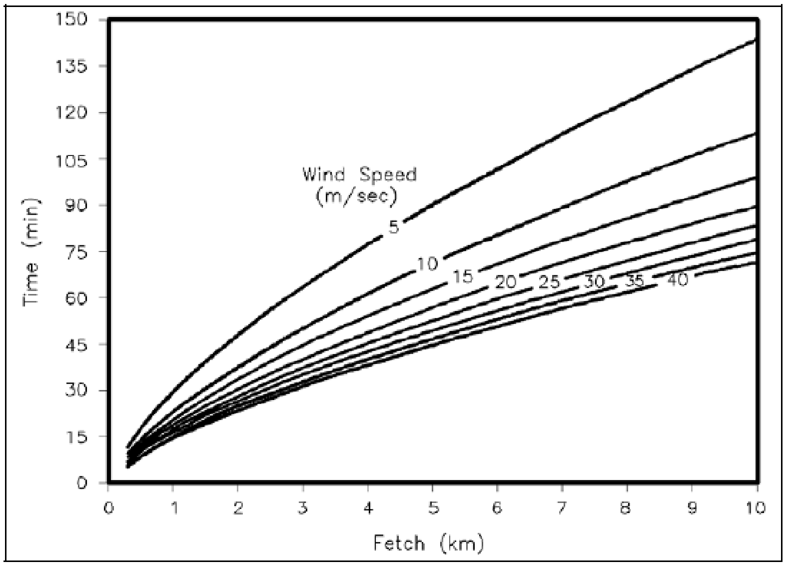

Figure A-1. Equivalent Duration for Wave Generation as a Function of Fetch and Wind Speed (adapted from Figure II-2-3 from USACE 2006)

After converting all of the maximum annual one-hour averaged wind data into winds speed at the 10-meter elevation, the wind data were converted to 15-minute averaged intervals (U_{900}) using Figure A-2.

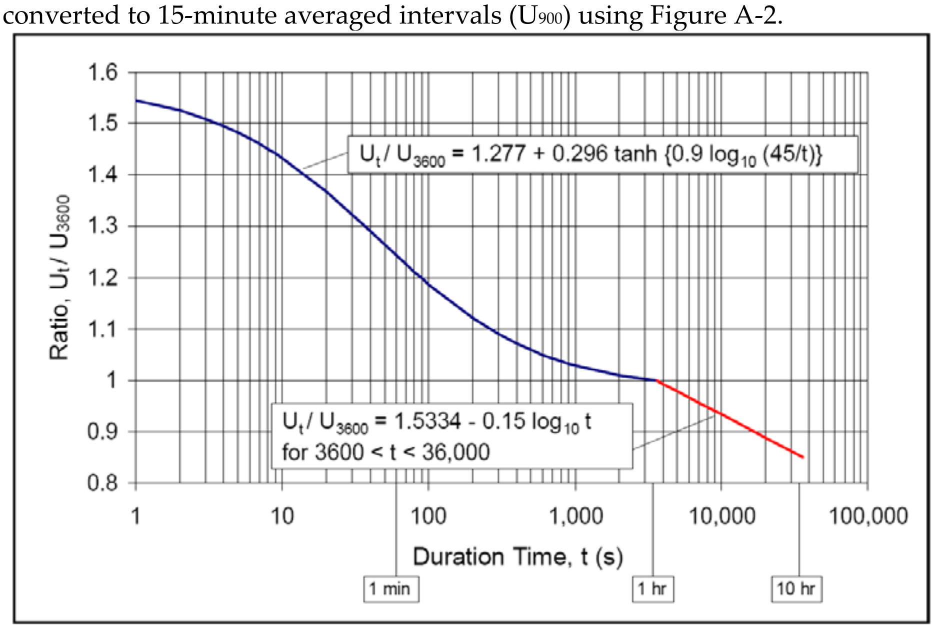

Figure A-2. Ratio of Wind Speed of any Duration U_t to the 1-hr wind speed U_{3600} (adapted from Figure II-2-1 from USACE 2006)

Using the above figure:

$$U_{900} = 1.03(58.9 \text{ mph}) = 60.6 \text{ mph}$$

The maximum annual 15-minute averaged wind speeds were analyzed using the ACES *Extremal Analysis Module* to estimate the various return periods. A review of the ACES results indicated that a Weibull Distribution (k=1) was found to be the best fit for the wind records from Remediation Area E. Figure A-3 shows the plot of computed return interval wind speeds based on Weibull Distribution.

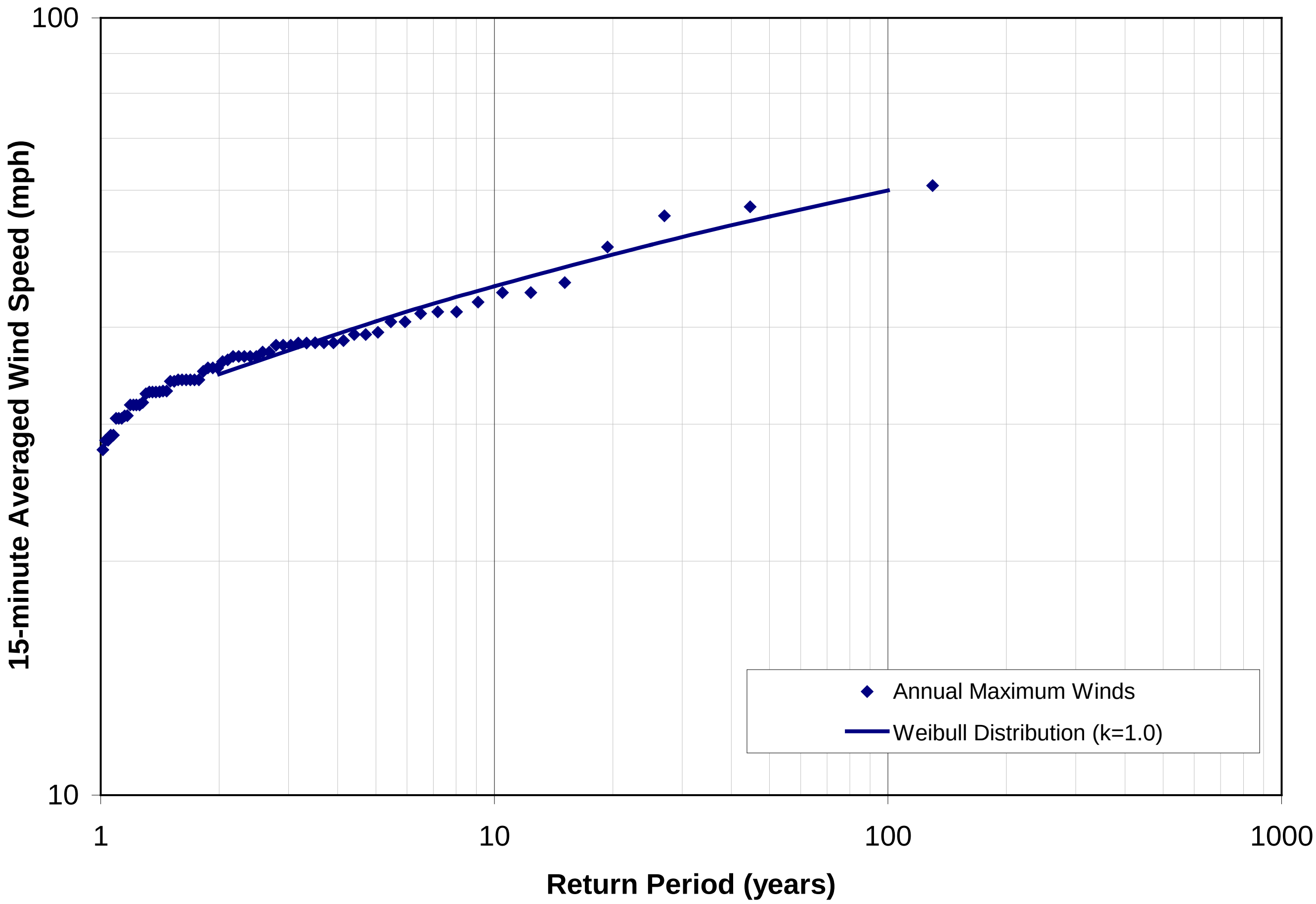

Figure A-3. Computed Return Interval Wind Speeds for Remediation Area E

Table A-1 shows the computed 15-minute averaged return interval wind speeds used for the sediment cap design.

Table A-1
Return Interval Wind Speeds for Remediation Area E

Return Period (years)	15-minuted Average Wind Speed (mph)
2	34.8
5	40.7
10	45.2
25	51.1
50	55.5
100	60.0

Therefore, the 100-year return interval wind speed was **60.0 mph**.

The analysis for Remediation Areas A, B, C and D followed a similar approach (i.e., use of the ACES *Extremal Analysis Module*). However, a review of the corresponding ACES results indicated that the Fisher - Tippet Type I Distribution was found to be the best fit for the wind records from A and C, while the Weibull Distribution (k=1.4) was found to be the best fit for B and D. Figures A-4 through A-7 shows the plots of computed return interval wind speeds based on for A, B, C, and D, respectively.

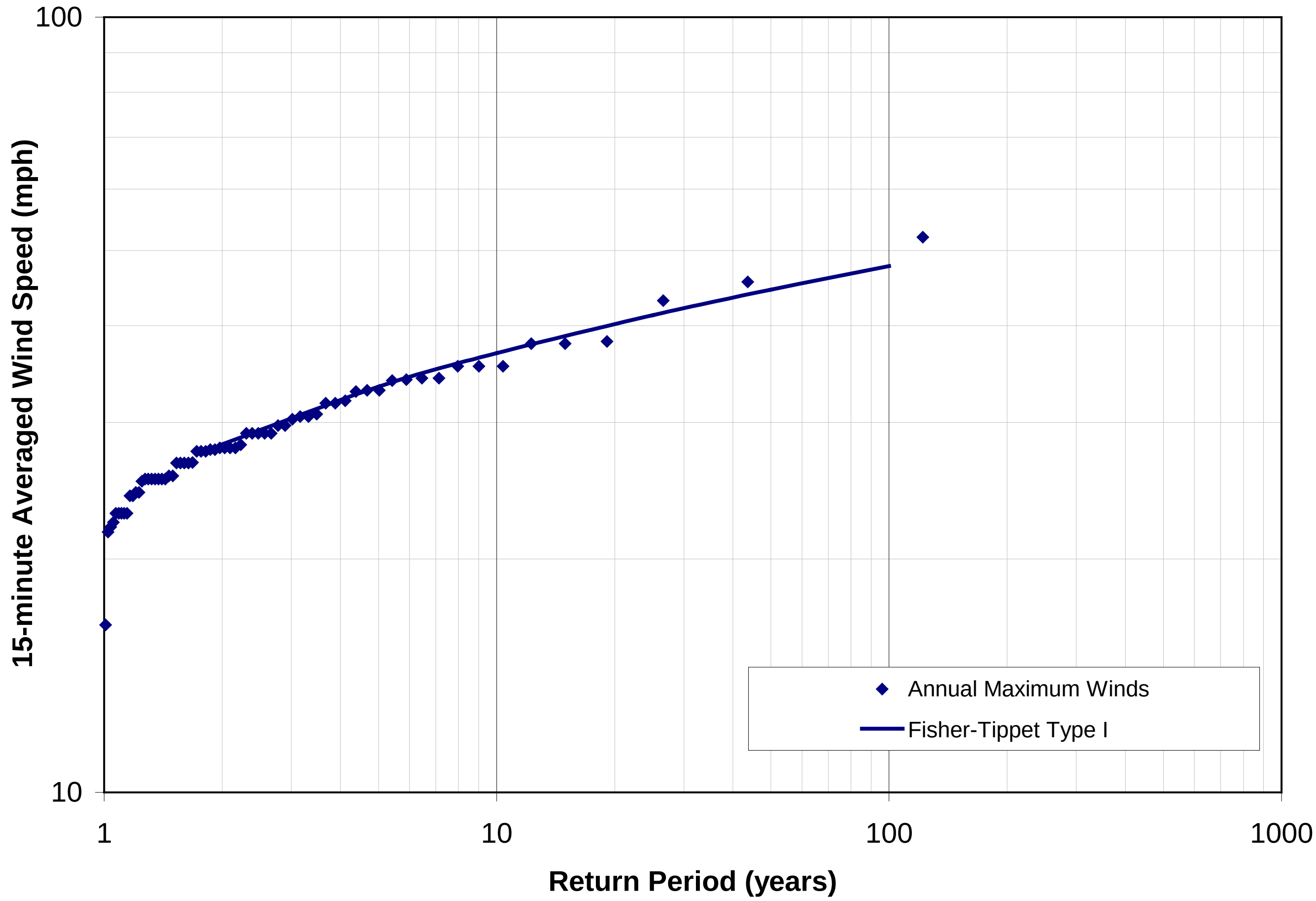

Figure A-4. Computed Return Interval Wind Speeds for Remediation Area A

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SUBJECT:	Wind-Wave Analysis for Sediment Cap Armor Layer Designs - Example Calculation						

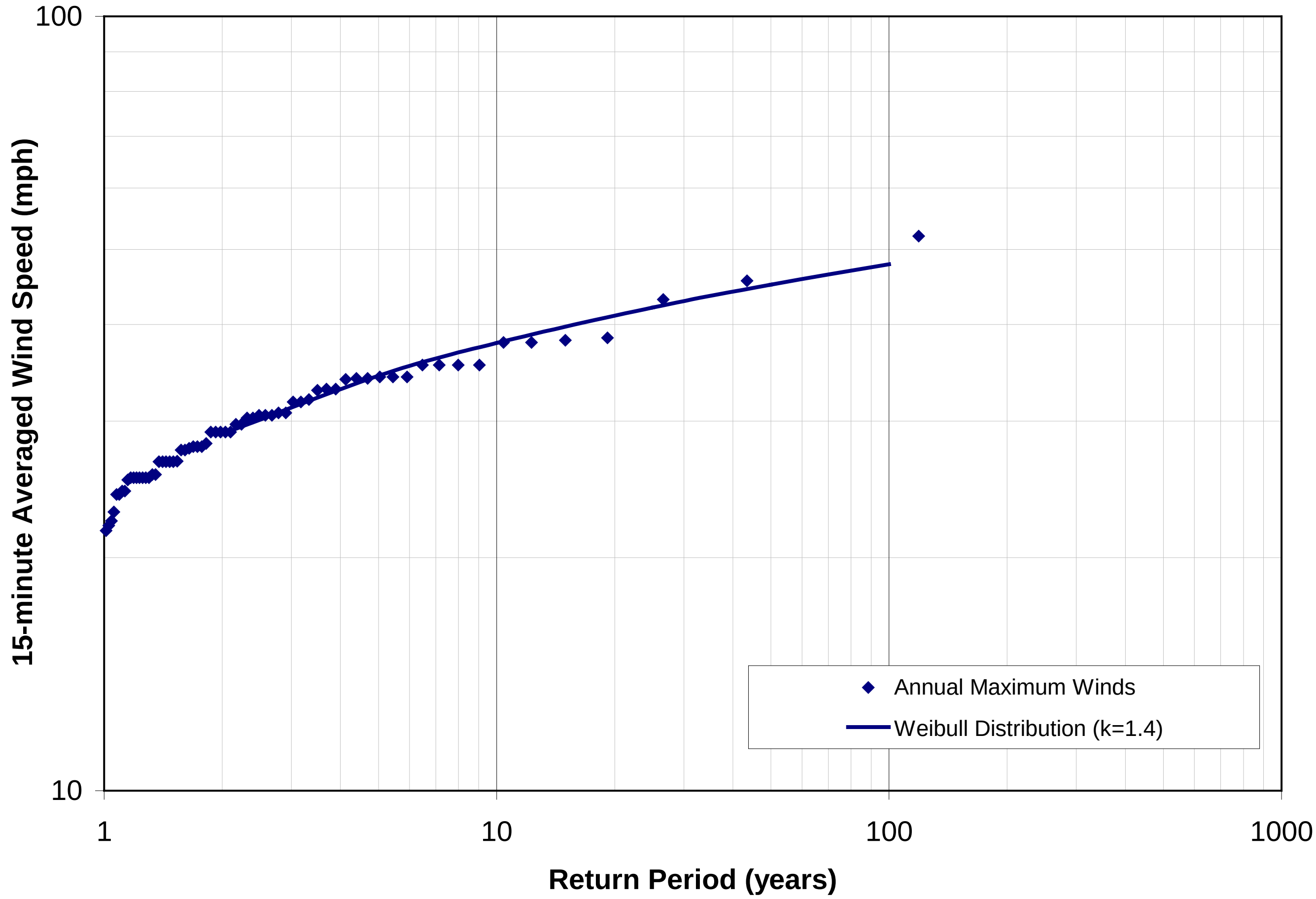

Figure A-5. Computed Return Interval Wind Speeds for Remediation Area B

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SUBJECT:	Wind-Wave Analysis for Sediment Cap Armor Layer Designs - Example Calculation				

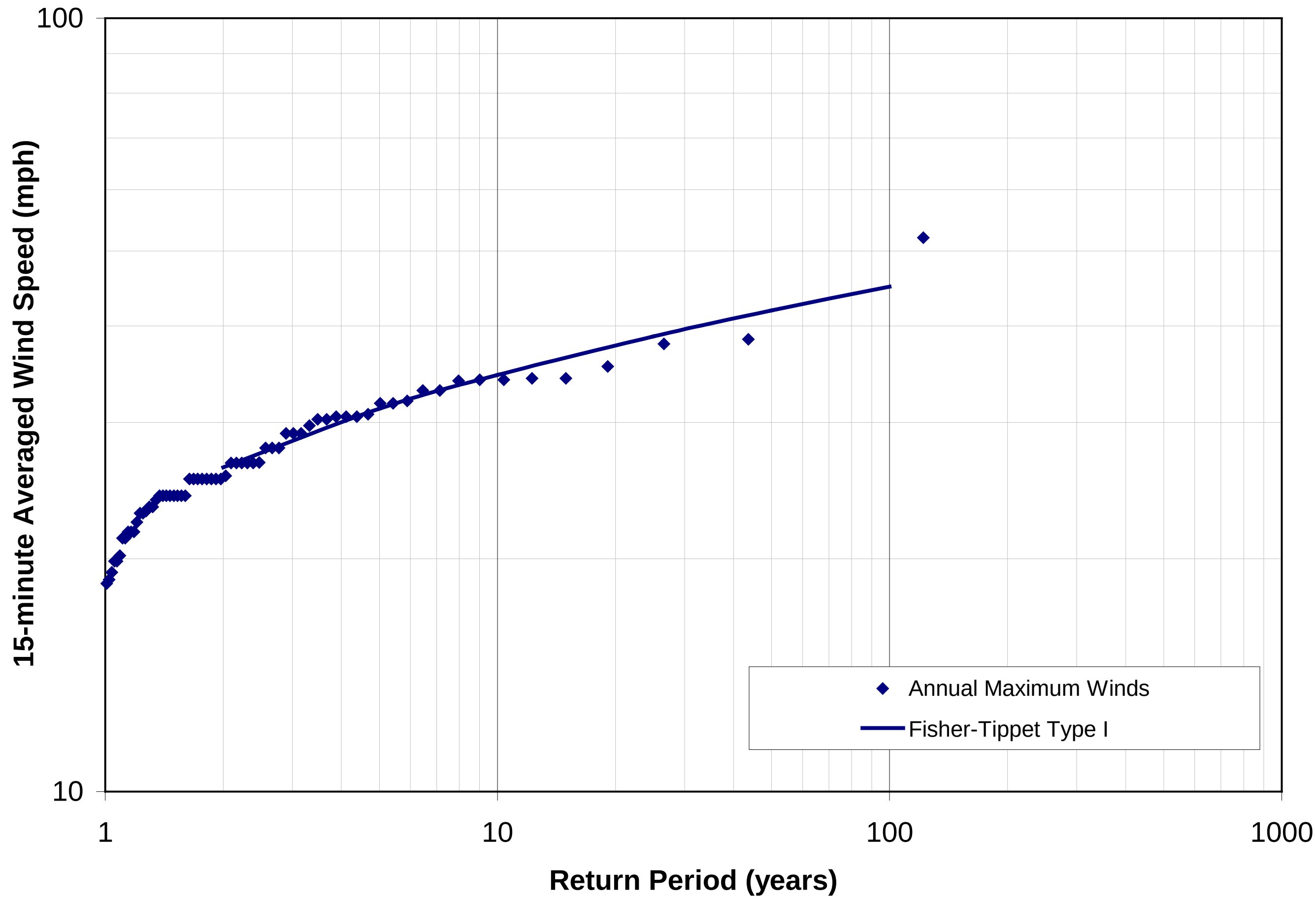

Figure A-6. Computed Return Interval Wind Speeds for Remediation Area C

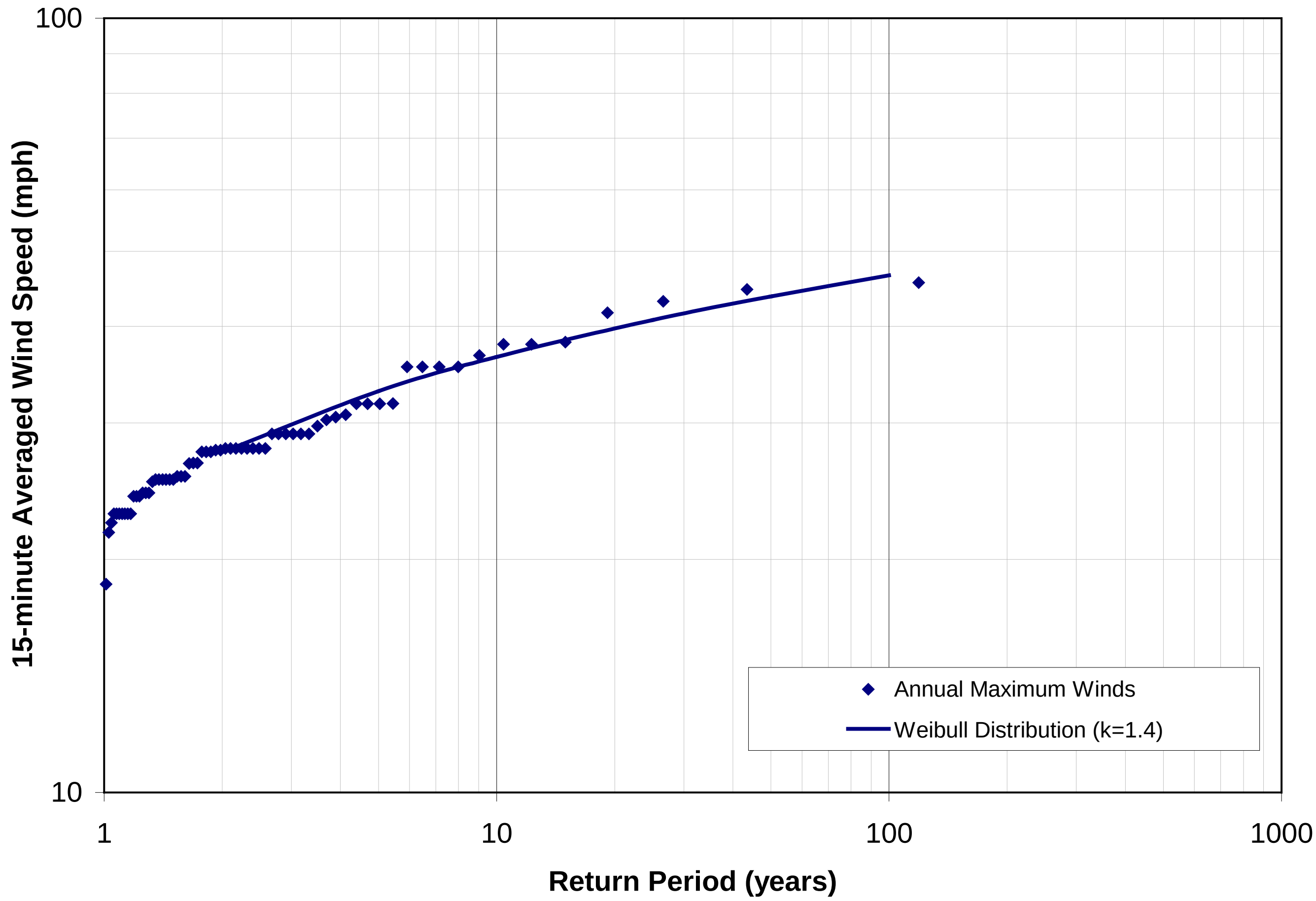

Figure A-7. Computed Return Interval Wind Speeds for Remediation Area D

2. Estimate the 100-year return interval significant wave height and period

For Remediation Area E, the longest fetch distance is 4.66 miles. The 100-year return interval wind speed was applied along this fetch using the *Wave Prediction Module* in ACES with the following parameters:

- 15-minute 100-year Return Interval Wind Speed = 60.0 mph (computed above)
- Wind Fetch Length = 4.66 miles (longest fetch distance)
- Fetch Depth = 65 feet (which is the maximum depth along the 4.66 mile fetch transect, and thus conservative)

Using the shallow openwater wind fetch method in the *Wave Prediction Module*, the significant wave height (H_s) and period (T_p) were:

H_s = 5.2 feet
T_p = 3.9 seconds

Sensitivity analyses:
A sensitivity analysis was performed on the Air-Water Temperature Difference. The Air-Water Temperature Difference in the calculation above was 0 degrees Celsius (^{0}C) (0 degrees Fahrenheit [^{0}F]). The Air-Water Temperature Difference was varied between -4 ^{0}C and 4 ^{0}C (-39.2 to 39.2 ^{0}F). The computed wave heights and periods varied from 5.4 feet and 4.0 seconds to 5.1 feet and 3.9 seconds. Therefore, it is evident that the wave heights for Onondaga Lake are not extremely sensitive to the Air-Water Temperature Difference. Thus, a design wave height of 5.2 feet and period of 3.9 seconds was selected for this analysis.

3. Compute the Stable Sediment Sizes at Various Depths Outside of the Surf Zone

The *Linear Wave Theory/Snell's Law Wave Transformation Module* in ACES was used to estimate wave shoaling, bottom orbital velocities at different depths, and the breaking wave height and depth using the cotangent of the nearshore slope = 45.5 and a crest angle of 0 degrees. Maximum bottom orbital velocities were computed using the *Linear Wave Theory Module* in ACES and the results are presented in Table A-2.

Table A-2
Design Wave Heights and Bottom Orbital Velocities at Various Depths for Remediation Area E

Water Depth (feet)	Wave Height (feet)	Maximum Orbital Velocity (feet per second)	Notes
40	5.2	0.33	Computed in Step 2
30	5.1	0.71	
20	4.9	1.5	
15	4.8	2.1	
10	4.8	3.1	
8	4.8	3.8	
6.7	5.3	Wave Breaking	Wave Breaking Depth

The stable sediment size under a progressive wave was estimated using the following three methods, for comparative purposes:

- Equation 5 from Appendix A – Armor Layer Design from the Guidance for In-Situ Subaqueous Capping of Contaminated Sediments (Maynord 1998).
- Shields Diagram (Vanoni 1975) (see Figure A-8)
- You (2000)

Using Equation 5 from Maynord (1998) for waves at a water depth of 10 feet, the D_{50} is approximately 0.75 inches (1.9 mm):

$$D_{50} = \frac{\left(\frac{V}{C_3}\right)^2}{g\left(\frac{\gamma_s - \gamma_w}{\gamma_w}\right)} = \frac{\left(\frac{3.1\,\text{ft/s}}{1.7}\right)^2}{32.2\,\text{ft/s}^2\left(\frac{165 - 62.4\,\text{lbs/ft}^3}{62.4\,\text{lbs/ft}^3}\right)} = 0.063\,\text{ft} = 19\,\text{mm}$$

Where,

V = maximum horizontal bottom velocity from the wave
C_3 = 1.7 for orbital velocities beneath waves (page A- 13 from Maynord 1998)
γ_s = unit weight of stone = 165 lbs/ft^3 (page A-6 of Maynord 1998)
γ_w = unit weight of water = 62.4 lbs/ft^3
g = 32.2 ft/s^2

Using the Shields Diagram, the D_{50} is approximately 0.5 inches (13 mm).

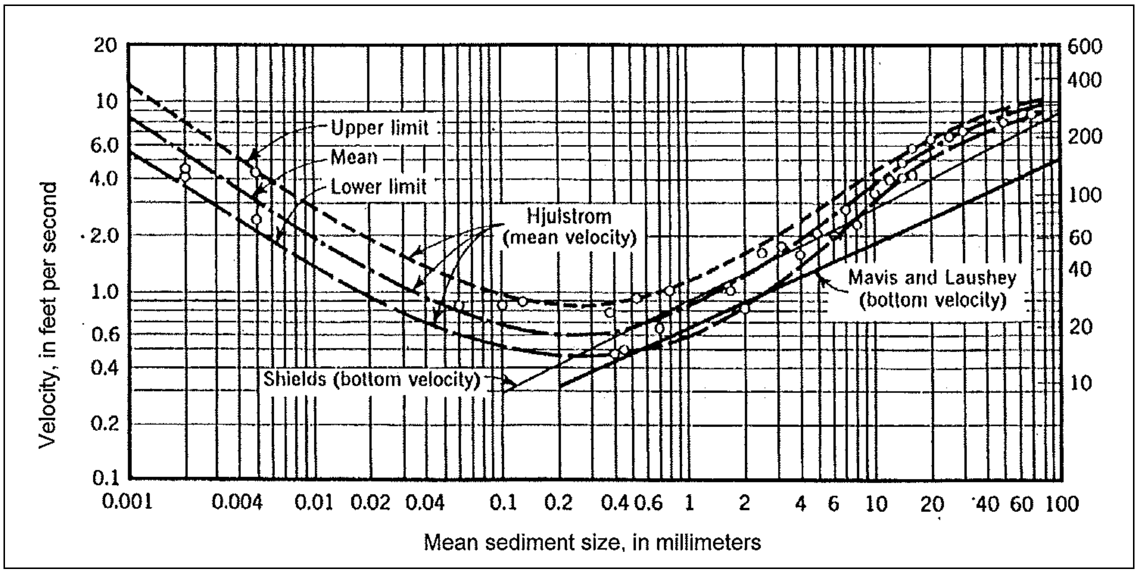

Figure A-8. Shields Diagram for Initiation of Cap Material Movement (from Vanoni 1975)

Using Equations 20 and 6 from You (2000), the D_{50} is approximately 0.4 inches (11 mm):

$$U_{max} = 3.97\sqrt{(s-1)gd}\,s_*^{-0.08}$$

Where,

U_{max} = nearbed wave orbital velocity from the wave for sediment onset velocity
s = particle specific gravity = 2.65 for sands
g = 9.81 m/s^2
d = particle diameter

and

$$s_* = \frac{d\sqrt{(s-1)gd}}{4\nu}$$

ν = kinematic viscosity of water = 1.139 x10^{-6} m^2/s at 15^0C (59 ^{0}F)

For a given nearbed wave orbital velocity, compute the stable particle size d using simple iteration (Solver in Microsoft Excel was used in this application). For U_{max} = 3.1 fps, d is approximately = 11 mm (10.5 mm):

$$s_* = \frac{d\sqrt{(s-1)gd}}{4\nu} = \frac{0.0105m\sqrt{(2.65-1)(9.81m/s^2)(0.0105m)}}{4(1.139x10^{-6}m^2/s)} = 950$$

$$U_{max} = 3.97\sqrt{(2.65-1)(9.81m/s^2)(0.0105m)}(950)^{-0.08} = 0.95m/s = 3.1\,fps$$

The results for selected water depths are summarized in Table A-3 below.

Table A-3
Armor Layer Size Calculations at Various Depths in Remediation Area E

Water Depth (ft)	Wave Height (ft)	Maximum Orbital Velocity (ft/s)	D_{50} (Maynord) (mm)	D_{50} (Shield's) (mm)	D_{50} (You) (mm)	Design D_{50} (mm)	Design D_{50} (inches)	Sediment Type
40	5.2	0.33	0.22	0.15	0.1	0.2	0.008	FINE SAND
30	5.1	0.71	1	0.6	0.2	1	0.04	MEDIUM SAND
20	4.9	1.5	4	3	2	4	0.2	FINE GRAVEL
15	4.8	2.1	9	5	4	9	0.4	FINE GRAVEL
10	4.8	3.1	19	13	11	19	0.75	COARSE GRAVEL
8	4.8	3.8	29	19	18	29	1.1	COARSE GRAVEL
6.7	5.3	*Wave Breaking **						

** see Section 4 below for Armor design for the Surf Zone (i.e., breaking wave condition)*

The results for selected water depths for A, B, and C and D are summarized in Tables A-4 to A-6 below.

Table A-4
Armor Layer Size Calculations at Various Depths in Remediation Area A

Water Depth (ft)	Wave Height (ft)	Maximum Orbital Velocity (ft/s)	D_{50} (Maynord) (mm)	D_{50} (Shield's) (mm)	D_{50} (You) (mm)	Design D_{50} (mm)	Design D_{50} (inches)	Sediment Type
30	2.6	0.038	0.003	0.1	0.1	0.1	0.004	FINE SAND
20	2.6	0.21	0.09	0.1	0.1	0.1	0.004	FINE SAND
15	2.5	0.45	0.4	0.3	0.1	0.4	0.02	FINE SAND
10	2.4	1.0	2	1	0.6	2	0.08	MEDIUM SAND
8	2.4	1.3	3	3	1	3	0.1	COARSE SAND
6	2.4	1.8	7	5	3	7	0.3	FINE GRAVEL
4	2.4	2.6	13	8	7	13	0.51	FINE GRAVEL
3.4	2.6	*Wave Breaking*						

Table A-5
Armor Layer Size Calculations at Various Depths in Remediation Area B

Water Depth (ft)	Wave Height (ft)	Maximum Orbital Velocity (ft/s)	D_{50} (Maynord) (mm)	D_{50} (Shield's) (mm)	D_{50} (You) (mm)	Design D_{50} (mm)	Design D_{50} (inches)	Sediment Type
30	2.8	0.076	0.01	0.1	0.1	0.1	0.004	FINE SAND
20	2.8	0.32	0.21	0.13	0.1	0.2	0.008	FINE SAND
15	2.7	0.63	0.79	0.55	0.2	0.8	0.03	MEDIUM SAND
10	2.6	1.2	3	2	1	3	0.1	COARSE SAND
8	2.6	1.6	5	3.5	2	5	0.2	FINE GRAVEL
6	2.6	2.1	9	5	4	9	0.4	FINE GRAVEL
4	2.6	3.0	17	12	10	17	0.67	FINE GRAVEL
3.6	2.9	*Wave Breaking*						

Table A-6
Armor Layer Size Calculations at Various Depths in Remediation Areas C and D

Water Depth (ft)	Wave Height (ft)	Maximum Orbital Velocity (ft/s)	D_{50} (Maynord) (mm)	D_{50} (Shield's) (mm)	D_{50} (You) (mm)	Design D_{50} (mm)	Design D_{50} (inches)	Sediment Type
40	3.2	0.052	0.01	0.1	0.1	0.1	0.004	FINE SAND
30	3.2	0.17	0.06	0.1	0.1	0.1	0.004	FINE SAND
20	3.1	0.54	0.57	0.35	0.1	0.6	0.02	FINE SAND
15	3.0	0.95	2	1	0.4	2	0.08	MEDIUM SAND
10	2.9	1.6	5	4	2	5	0.2	FINE GRAVEL
8	2.9	2.0	8	5	3	8	0.3	FINE GRAVEL
6	3.0	2.6	13	8	7	13	0.52	FINE GRAVEL
4.2	3.3	*Wave Breaking*						

4. Compute the Armor Stone Size within the Surf Zone

The *Rubble Mound Revetment Design Module* in ACES was used to compute the required armor layer size (gradation and thickness) in the surf zone to resist the forces generated by turbulence from breaking waves. The following parameters were used in the computation:

- Significant wave height = 5.2 feet (computed above)
- Significant wave period = 3.9 seconds (computed above)
- Breaking criteria = 0.78 (Dean and Dalrymple 1991)
- Water depth at toe of the structure = 10 feet (used a water depth slightly deeper than the beginning of the surf zone depth of 6.7 feet in E)
- Cotangent of nearshore slope = 45.5 (the slope of the bed offshore of the surf zone in Remediation Area E)
- Unit weight of rock = 165 lbs/ft^3 (page A-6 of Maynord 1998)
- Permeability coefficient = 0.4 (Figure 4-4-2b of USACE 1992)
- Cotangent of structure (revetment) slope = 50 (restored slope in surf zone for Remediation Area E)
- Minor Displacement Level (S) = 3 (from Table VI-5-21 of USACE 2006 and Table 4-4-1 of USACE 1992)

Table A-7 presents the armor layer gradation results for the minor displacement level for a 50H:1V slope computed by ACES.

Table A-7
Cap Armor Gradation for Minor Displacement for Remediation Area E

Gradation and Thickness	Stone Size (inches) for Minor Displacement (S=3)
D_0	1.4
D_{15}	2.2
D_{50}	3.0
D_{85}	3.7
D_{100}	4.7
Thickness of Armor Layer	6

Sensitivity analyses:
A sensitivity analysis was performed on the permeability coefficient. Variations in water depth at the toe of the structure and breaking criteria do not affect the armor stone size or gradation just the wave runup distance. In Onondaga Lake, the sediment cap is always submerged and does not extend above the lake surface; thus the wave run-up estimate in the revetment design methodology is not used. The permeability coefficient was varied between 0.6 (a homogeneous structure, consisting only of armor stones as shown in Figure 4-4-2d of USACE 1992) and 0.5 (two-diameter-thick armor layer on a permeable core with a ratio of armor/core stone diameter was 3.2 as shown on Figure 4-4-2c). The median stone size varied between 2.8 inches for P=0.6 and 2.9 inches for P=0.5. Therefore, the approach presented above and summarized in Table A-7 (i.e., a P=0.4) was used in this design.

Table A-8 presents the armor layer gradation results for the minor displacement level for a 50H:1V slope computed by ACES for the other Remediation Areass.

Table A-8
Cap Armor Gradation for Minor Displacement for Remediation Areas

Gradation and Thickness	Particle Size (inches)			
	A	B	C and D	E
D_0	0.7	0.8	1.0	1.5
D_{15}	1.1	1.2	1.4	2.2
D_{50}	1.5	1.7	1.9	3.0
D_{85}	1.8	2.1	2.4	3.8
D_{100}	2.3	2.6	3.0	4.8
Minimum Thickness of Armor Layer	3	3.5	4	6

DESIGNER: KDP/MRH	DATE: 6-01-09	CALC. NO.: 1	REV.NO.: 1
PROJECT: Onondaga Lake		CHECKED BY: RKM	CHECKED DATE: 6-08-09
SUBJECT: Wind-Wave Analysis for Sediment Cap Armor Layer Designs - Example Calculation			

RECORD OF REVISIONS

NO.	REASON FOR REVISION	BY	CHECKED	APPROVED/ ACCEPTED	DATE
1	Revise the calculation to include wind data from 2007 to 2009 and to address NYSDEC's comments	MRH	RKM		

ATTACHMENT B
COMPARATIVE MONTHLY AVERAGE WIND SPEEDS (IN MPH) FOR SYRACUSE AIRPORT, WASTEBED 13 SITE, AND LAKESHORE SITE – DECEMBER 2006 THROUGH FEBRUARY 2009

Comparative Monthly Average Wind Speeds (in mph) for Syracuse Airport, Wastebed 13 Site, and Lakeshore Site - December 2006 through February 2009

Month	Syracuse Hancock Int'l Airport	WB13	Lake Shore
January	11.1	8.3	8.2
February	11.7	9.3	8.5
March	11.4	8.3	7.5
April	10.9	8.0	7.4
May	8.6	6.1	6.0
June	8.5	5.5	5.8
July	7.6	5.2	5.4
August	8.0	5.1	5.4
September	7.8	5.2	5.3
October	8.8	6.5	6.0
November	9.5	6.5	6.9
December	11.4	8.5	8.4

Comparative Monthly Maximum Wind Speeds (in mph) for Syracuse Airport, Wastebed 13 Site, and Lakeshore Site - December 2006 through February 2009

Month	Syracuse Hancock Int'l Airport	WB13	Lake Shore
January	46	30	26
February	33	35	24
March	34	30	22
April	37	26	25
May	28	19	19
June	33	19	19
July	29	17	14
August	33	16	14
September	34	29	29
October	28	27	18
November	33	26	24
December	66.7*	25	23

Note:

* The maximum value of 66.7 mph for December measured at Syracuse Airport may have been an anomalous or erroneous measurement. This maximum value occurred on December 19, 2008. The maximum wind was 66.7 mph blowing from the southwest (200 degrees). At the same day and hour, the maximum winds at WB13 and the Lakeshore were both 9.0 mph and from the east. At the airport, the wind speed one hour before and one hour after this measurement were 17 and 16 mph respectively, and from the east (100 degrees). Therefore, this value appears inconsistent with other measurements. The maximum windspeed for December excluding this value is 40.3 mph.

ATTACHMENT C
TRIBUTARY ANALYSIS FOR SEDIMENT CAP ARMOR LAYER DESIGNS – EXAMPLE CALCULATION

CALCULATION COVER SHEET

PROJECT: Onondaga Lake	**CALC NO. 1**	**SHEET** 1 of 7
SUBJECT: Attachment C – Tributary Analysis for Sediment Cap Armor Layer Designs - Example Calculation		

Objective: To determine the particle size necessary to prevent erosion of sediment cap due to the 100-year flood flows from tributaries to Onondaga Lake. This document presents an example calculation for Onondaga Creek as well as the results of the analysis for Ninemile Creek.

References:

Effler, S. 1996 Limnological and Engineering Analysis of a Polluted Urban Lake: Prelude to Environmental Management of Onondaga Lake, New York. Springer-Verlag, New York.

Maynord, S. 1998. *Appendix A: Armor Layer Design for the Guidance for In-Situ Subaqueous Capping of Contaminated Sediment*. Prepared for the U.S. Environmental Protection Agency (USEPA).

U.S. Army Corps of Engineers (USACE). 1994. *Hydraulic Design for Flood Control Channels* EM1110-2-1601

USACE. 1996. Users Guide to RMA2 Version 4.3, U.S. Army Corps of Engineers – Waterways Experiment Station Hydraulics Laboratory. (June 1996).

United States Geological Survey (USGS). 2006. Magnitude and Frequency of Floods in New York. Scientific Investigations Report 2006-5112.

Vanoni, V.A. 1975. *Sedimentation Engineering*. ASCE Manuals and Reports on Engineering Practice – No. 54, 730 pp.

Computation of 100-year flood flows for tributaries and resultant particle size(s): The following presents a detailed summary and example calculation for the Onondaga Lake tributary analysis. The numbered list below outlines the general approach used for the calculation and defines specific parameters used in the calculations. Subsequent sections below illustrate a step-by-step calculation for the example case of Onondaga Creek.

1. Estimate the 100-year return interval flood flow

Estimation of peak discharge for the 100-year return interval flood flow was based on three different methods/sources. These values were reviewed and compared and the most conservative value was recommended for utilization in the design. The methods/sources included:

- Fitting a Log-Pearson Type III (LP3) probability distribution to the data and estimating the return flow based on the expected value of the distribution at the 99% exceedance level.
- Using the United States Geological Survey (USGS) flood frequency analysis PeakFQ program (also based on the LP3 method).
- Obtaining 100-year flood flow estimates from a USGS report of flood flows for streams in New York State (USGS 2006).

2. Predict velocity flow fields using USACE's RMA2

The velocity fields generated by the 100-year flows from Onondaga Creek were modeled using the USACE hydrodynamic model, RMA-2. The RMA2 model is a 2-dimensional, depth-averaged (i.e., the model computes lateral, not vertical variations in flows), finite element, hydrodynamic numerical model routinely used by the USACE for hydrodynamic studies. The RMA2 model was used in conjunction with the Surface Water Modeling System (SMS) for RMA2, which is a pre- and post-processor that includes a graphical interface for display of inputs and results. A detailed description of the model input parameters is provided in Section 6 of Appendix D.

Current velocities along the centerline of the tributary discharge were extracted from the model and used for determination of stable particle size. Table C-1 presents the computed velocities along the centerline of the Onondaga Creek.

Table C-1
Predicted Velocities along the Discharge Centerline from Onondaga Creek

Distance Offshore (feet)	Computed Velocity (fps)
0	2.7
206	2.1
382	1.9
744	1.5
1100	1.3
1785	0.9
1990	0.8
2590	0.7

Notes:
a. Sediment cap extends approximately 1,840 feet offshore from Onondaga Creek (indicated with shading).
b. fps = feet per second

The analysis for Ninemile Creek followed a similar approach (i.e., use of the RMA2 model). Table C-2 presents the computed velocities along the centerline of the Ninemile Creek

Table C-2
Predicted Velocities along the Discharge Centerline from Ninemile Creek

Distance Offshore (feet)	Computed Velocity (fps)
0	3.8
79	3.4
251	2.8
363	2.3
551	1.9
749	1.4
1038	1.1
1466	0.7
1529	0.7
1922	0.6

Notes:
a. Sediment cap extends approximately 1,450 feet offshore from Ninemile Creek (indicated with shading).
b. fps = feet per second

3. Compute the Stable Sediment Sizes at Various Depths along the Centerline Discharge of the Tributary

The stable sediment size for maximum current velocities or a flood flow was estimated using the following two methods, for comparative purposes:

- Equation 2 from Appendix A – Armor Layer Design from the Guidance for In-Situ Subaqueous Capping of Contaminated Sediments (Maynord 1998).
- Shields Diagram (Vanoni 1975) (see Figure C-1).

Using Equation 2 from Maynord (1998) for a current velocity of 0.9 fps at a water depth of 32 feet located approximately 1,800 feet offshore, the D_{50} is approximately 0.02 inches (0.51 mm):

$$D_{50} = S_f C_s C_v C_T C_G d\left[\left(\frac{\gamma_w}{\gamma_s - \gamma_w}\right)^{1/2} \frac{V}{\sqrt{K_1 g d}}\right]$$

$$D_{50} = 1.1 * 0.375 * 1.25 * 1 * 1.52 * 32\,ft\left[\left(\frac{62.4\frac{ft}{s^3}}{165\frac{ft}{s^3} - 62.4\frac{ft}{s^3}}\right)^{1/2} \frac{0.9\frac{ft}{s}}{\sqrt{0.99 * 32.2\frac{ft}{s^2} * 32\,ft}}\right]^{2.5}$$

$$D_{50} = 0.002\ ft = 0.02\ inches$$

Where,

S_f = safety factor = 1.1 (page A-6 from Maynord 1998)
C_s = stability coefficient for incipient failure = 0.375 for rounded rock (page A-6 from Maynord 1998)
C_V = velocity distribution coefficient = 1.25 (page A-6 from Maynord 1998)
C_T = blanket thickness coefficient (typically 1 for flood flows)
C_G = gradation coefficient = $(D_{85}/D_{15})^{1/3}$
D_{85}/D_{15} = gradation uniformity coefficient (typical range = 1.8 to 3.5) = 3.5 (page A-6 from Maynord 1998)
d = depth = 32 feet
γ_s = unit weight of stone = 165 lbs/ft^3 (page A-6 of Maynord 1998)
γ_w = unit weight of water = 62.4 lbs/ft^3
V = maximum depth-averaged velocity = 0.9 fps
K_1 = side slope correction factor = $\sqrt{1 - \frac{\sin^2\theta}{\sin^2\phi}}$ (page 3-7 from USACE 1994)

Where,
Θ = angle of side slope with horizontal = 50 horizontal:1 vertical for restored slopes
ϕ = angle of repose of riprap material (normally 40 deg) (page 3-7 from USACE 1994)

g = 32.2 ft/s^2

Using the Shields Diagram, the D_{50} is approximately 0.04 inches (1 mm).

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PROJECT:	Onondaga Lake			CHECKED BY:	MRH	CHECKED DATE:	12-14-10
SUBJECT:	Tributary Analysis for Sediment Cap Armor Layer Designs - Example Calculation						

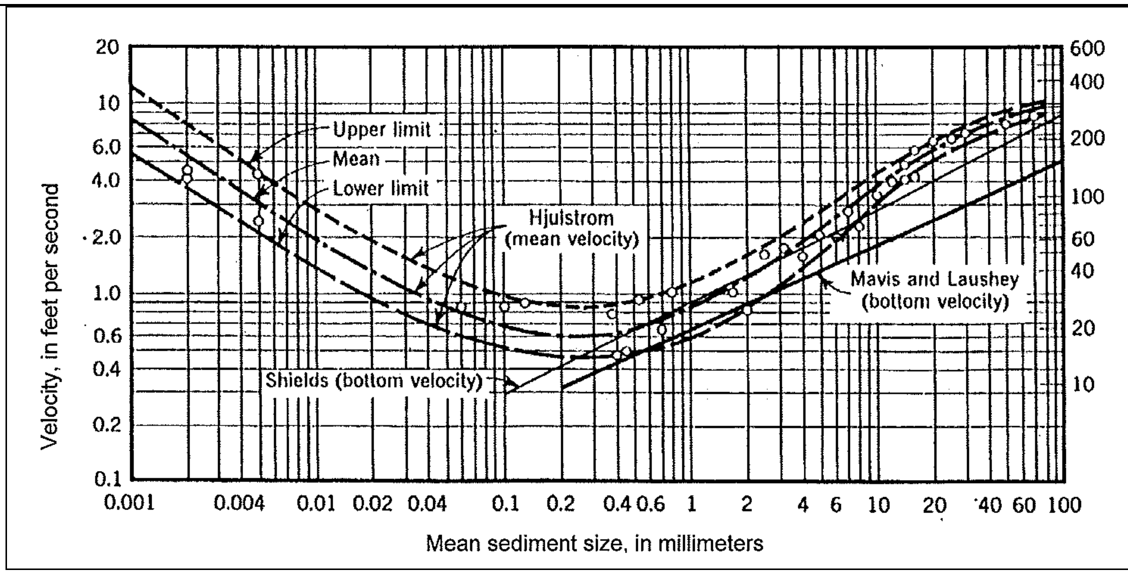

Figure C-1. Shields Diagram for Initiation of Cap Material Movement (from Vanoni 1975)

The results for the discharge along the centerline are presented in Table C-3 below.

Table C-3
Stable Particle Sizes along the Discharge Centerline from Onondaga Creek

Distance Offshore (feet)	Computed Velocity (fps)	Median Particle Diameter (inches)		Design Median Particle Size (inches)	Design Median Particle Size (mm)	Sediment Type
		Maynord (1998)	Vanoni (1975)			
0	2.7	0.36	0.33	0.36	9.2	fine gravel
206	2.1	0.19	0.24	0.24	6.0	fine gravel
382	1.9	0.14	0.18	0.18	4.5	coarse sand
744	1.5	0.09	0.11	0.11	2.8	coarse sand
1100	1.3	0.06	0.08	0.08	2.0	medium sand
1785	0.9	0.02	0.04	0.04	1.0	medium sand
1990	0.8	0.02	0.03	0.03	0.8	medium sand
2590	0.7	0.01	0.02	0.02	0.6	medium sand

Notes:

a. Sediment cap extends approximately 1,840 feet offshore from Onondaga Creek (indicated with shading).

b. Sediment type was classified using the Unified Soil Classification System.

The results for the discharge along the centerline of Ninemile Creek are presented in Table C-4 below.

Table C-4
Stable Particle Sizes along the Discharge Centerline from Ninemile Creek

Distance Offshore (feet)	Computed Velocity (fps)	Median Particle Diameter (inches)		Design Median Particle Size (inches)	Design Median Particle Size (mm)	Sediment Type
		Maynord (1998)	Vanoni (1975)			
0	3.8	1.00	0.71	1.00	25.5	coarse gravel
79	3.4	0.77	0.59	0.77	19.5	coarse gravel
251	2.8	0.52	0.35	0.52	13.2	fine gravel
363	2.3	0.30	0.28	0.30	7.7	fine gravel
551	1.9	0.19	0.18	0.19	4.8	coarse sand
749	1.4	0.08	0.08	0.08	2.2	coarse sand
1038	1.1	0.05	0.06	0.06	1.6	medium sand
1466	0.7	0.01	0.02	0.02	0.6	medium sand
1529	0.7	0.01	0.02	0.02	0.6	medium sand
1922	0.6	0.01	0.02	0.02	0.4	fine sand

Notes:
a. Sediment cap extends approximately 1,450 feet offshore from Ninemile Creek (indicated with shading).
b. Sediment type was classified using the Unified Soil Classification System.

Additionally, the stable particle size to resist current velocities in Onondaga Lake under typical weather conditions were assessed using current velocities reported in Effler (1996). The results are presented in Table C-5.

Table C-5
Stable Particle Sizes for Typical Onondaga Lake Current Velocities

Measured Velocity (fps)[a]	Median Particle Diameter (inches)		Design Median Particle Size (inches)	Sediment Type
	Maynord (1998)	Vanoni (1975)		
0.17	<0.001	<0.004	0.004	fine sand
0.02	<0.001	<0.004	0.004	fine sand
0.25	0.001	<0.004	0.004	fine sand
0.04	<0.001	<0.004	0.004	fine sand
0.18	<0.001	<0.004	0.004	fine sand
0.03	<0.001	<0.004	0.004	fine sand

Notes:
a. Measured velocities include values reported by Effler (1996) in the littoral zone (<9 meters).
b. Sediment type was classified using the Unified Soil Classification System.

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NO.	REASON FOR REVISION	BY	CHECKED	APPROVED/ ACCEPTED	DATE
1	Updated post-remediation bathymetry	KDP	MRH		11-24-09
2	Updated post-remediation bathymetry in Remediation Area A	KDP	MRH		12-14-10

ATTACHMENT D
PROPELLER WASH ANALYSIS FOR SEDIMENT CAP ARMOR LAYER DESIGNS – EXAMPLE CALCULATION

Objective: To determine the propeller wash velocities from commercial and recreational vessels that may operate in Onondaga Lake's Remediation Areas and the resultant particle size(s) necessary for stability of the sediment cap subject to these propeller wash flows.

This document presents an example calculation for a commercial and recreational vessel.

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Computation of commercial vessel propeller wash and resultant particle size(s): The following presents a detailed example calculation for a commercial vessel operating on Onondaga Lake. The numbered list below outlines the general approach used for the calculation and defines specific parameters used in the calculations. Subsequent sections below illustrate a step-by-step calculation for the example case. The example calculation is provided for the *Mavret H* tugboat operating in 14 ft of water at 25 percent of the installed engine power.

1. Select representative vessel for analysis

The *Mavret H* tugboat was the example vessel used in the calculation to represent tugboats operating on the Lake. Based on previous discussions with the vessel owner, the tugboat has the following characteristics:

- Number of engines: One
- Propeller shaft depth: 3 feet (ft)
- Total installed engine horsepower: 800 horsepower (hp)
- Propeller diameter: 4.67 ft
- Ducted propeller: Yes

2. Determine the maximum bottom velocities in the propeller wash of a maneuvering vessel

Equation 4 from Maynord (1998) is used to first determine the jet velocity exiting a propeller (U_0) in feet per second (fps):

$$U_0 = C_2\left(\frac{P_d}{D_p^{\,2}}\right)^{\frac{1}{3}}$$

where

C_2 = 7.68 for ducted propellers (page A-10 from Maynord 1998)
P_d = applied engine horsepower
D_p = Propeller diameter = 4.67 ft (from above)

Previous discussions with tug operators indicate that their vessels operate in the deeper portion of the Lake and use an average of 25 percent of their horsepower. For this example calculation, P_d = 0.25x800 hp = 200 hp. Therefore,

$$U_0 = C_2\left(\frac{P_d}{D_p^{\,2}}\right)^{\frac{1}{3}} = (7.68)\left(\frac{200}{4.67^2}\right)^{\frac{1}{3}} = 16.1\,\text{fps}$$

The resulting maximum bottom velocities, $V_{b(maximum)}$, in the propeller wash of a maneuvering vessel is computed using Equation 3 from Maynord (1998):

$$V_{b(maximum)} = C_1U_0D_p/H_p$$

where
C_1 = 0.30 for a ducted propeller
Hp = distance from propeller shaft to channel bottom in ft

In this example calculation, the tugboat operating in a depth of 14 ft of water is being evaluated. Therefore, Hp = 14 ft-3 ft = 11 ft. The maximum bottom velocity for this case is:

$$V_{b(maximum)} = C_1U_0D_p/H_p = 0.30(16.1)(4.67)/11 = 2.0\text{ fps}$$

3. Compute the Stable Sediment Sizes to resist the propeller wash of a maneuvering vessel

Equation 5 from Maynord (1998) is used to compute the Stable Sediment Sizes to resist the propeller wash of a maneuvering vessel:

$$V_{b(maximum)} = C_3\left[g\left(\frac{\gamma_s - \gamma_w}{\gamma_w}\right)D_{50}\right]^{\frac{1}{2}}$$

where

C_3 = 0.7 for small transport (page A-10 from Maynord 1998)
D_{50} = median particle size
γ_s = unit weight of stone = 165 pounds per cubic foot (lbs/ft^3) (page A-6 of Maynord 1998)
γ_w = unit weight of water = 62.4 lbs/ft^3

Solving for D_{50}:

$$D_{50} = \frac{\left(\frac{2.0}{0.7}\right)^2}{32.2\left(\frac{165-62.4}{62.4}\right)} = 0.15\text{ ft} = 1.9\text{ inches}$$

The computed particle size for the *Mavret H* operating in 14 ft of water at 25 percent power is **1.9 inches** (coarse gravel). It should be noted that this method provides a conservative estimate of stable particle size for the low bottom velocities when compared with other methods used to compute a representative particle size to resist erosion associated with current velocities. For example, the stable particle size to resist a 2 fps bottom current velocity using Shields diagram presented in Vanoni (1975) is 0.2 inches (5 millimeters).

Computation of recreational vessel propeller wash and resultant particle size(s): The following presents a detailed example calculation for a recreational vessel operating on Onondaga Lake at high speeds in shallow water. This approach for evaluating the propeller wash from recreational vessels involved adapting the predictive equations developed for the larger vessels (based on Maynord 1998) to address smaller recreational vessels under moving conditions. The refinements were based, in part, on results of a field study where bottom-mounted current meters were used to measure actual bottom velocities of maneuvering and passing recreational vessels in the Fox River (Wisconsin). This refined approach was successfully applied and accepted by USEPA (Region V) for the design of the Lower Fox River remediation to evaluate the effects of propeller wash for the design of the armor layer of a sediment isolation cap (Shaw and Anchor 2007).

The example calculation is provided for the Triumph 191 FS boat operating at 50 percent power at 5 ft above the sediment cap armor layer.

1. Select representative vessel for analysis

The Triumph 191 FS boat was the example vessel used in the calculation to represent ski and fishing boats operating on Onondaga Lake. Based on discussions with and specifications provided by the manufacturers and boat dealers, the

Triumph 191 FS has the following characteristics:

- Number of engines: One
- Propeller shaft depth: 2.5 ft
- Total installed engine horsepower: 150 hp
- Propeller diameter: 1.33 ft (16 inches)
- Ducted propeller: No

2. Compute jet velocity for the moving vessel

The thrust, T, generated by the propeller is computed based on the applied engine horsepower at a given time during the start-up (e.g., period during which vessel accelerates from a stand still). A relationship between engine power and thrust (T in pounds force [lb_f]) for a range of applied power was previously compiled and presented in Shaw and Anchor (2007) and is utilized to compute the thrust for this example as follows:

$$T[lb_f] = 10.3(P_d) + 370$$

Blaauw and van de Kaa (1978) is used to first determine the jet velocity exiting a propeller (U_0) in meters per second (m/s) based on the thrust:

$$U_0 = \frac{1.6}{D_p}\left(\frac{T}{\rho_w}\right)^{1/2}$$

Where ρ_w = density of water (in slugs per cubic foot)

For this example, the maximum applied engine power is assumed to be 50 percent of 150 hp (or 75 hp). The applied engine power is assumed to increase linearly between zero at t=0 and 75 hp at the end of the engine power dwell time. The engine power dwell time ranges between approximately 1 and 3 seconds (Shaw and Anchor 2007). A value of 3 seconds was used in this analysis. Therefore, the power applied at time t = 1 second, would be the final applied power of 75 hp divided by engine power dwell time (i.e., 25 hp). Similarly, 50 hp would be applied at time t=2 seconds.

For the Triumph 191 FS operating at 50 percent power at 0.5 seconds after start-up:

$$T = 10.3\left(0.5 \times 150 \times \frac{0.5}{3}\right) + 370 = 498.8\text{ lbf} = 2219\text{ Newtons (N)}$$

$$U_0 = \frac{1.6}{1.33}\left(\frac{498.8}{1.94}\right)^{1/2} = 19.3\text{ fps (in English Units) or}$$

$$U_0 = \frac{1.6}{0.406}\left(\frac{2219}{1000}\right)^{1/2} = 5.87\text{ meters per second (in SI Units)}$$

This jet velocity behind the stationary propeller is converted to a velocity for the moving vessel relative to a fixed point using the boat speed, as described below.

The increase in boat speed during start-up conditions is assumed to be linear from zero at time zero (t=0) to maximum speed at the end of the boat speed dwell time. For the Onondaga Lake propeller wash evaluation, it was assumed that maximum boat speed will be dependent on propulsion parameters (e.g. applied engine power). The maximum boat speed, $V_{w(max)}$, for use in calculating the speed at each time step for a given set of operating conditions is estimated using a regression equation developed from values for boat speed (in miles per hour) and applied engine power (in hp) from field measurements reported by engine manufacturers (Shaw and Anchor 2007):

$$V_{w(\max)} = 2.0229(P_d)^{0.4568}$$

The boat speed dwell time is assumed to be 1.5 x engine power dwell time (Shaw and Anchor 2007). Therefore , $t_{(max)}$ is defined as follows

$t_{(max)}$ = 1.5 x engine power dwell time

Based on the assumed linear increase in boat speed between t=0 and $t_{(max)}$, the boat speed at time t, $V_{w(t)}$, is computed as follows:

$$V_{w(t)} = V_{w(\max)}\left(\frac{t}{t_{(\max)}}\right)$$

For the example calculation at time t=0.5 seconds:

$$V_{w(\max)} = 2.0229(0.5\times 150)^{0.4568} = 14.5 \text{ mph}$$

$$t_{(max)} = 1.5 \times 3 = 4.5 \text{ seconds}$$

$$V_{w(t)} = 14.5\left(\frac{0.5}{4.5}\right) = 1.61 \text{ mph} = 2.36 \text{ fps}$$

The method used to compute the relative near bottom velocity from a moving vessel is to first compute the jet velocity exiting a propeller (U_0) and the subtract the vessel speed from U_0. The adjusted X is then used to compute the near bottom velocity. For this example, the jet velocity exiting a propeller (U_0) for the moving vessel relative to a fixed point is

U_0 = 19.3 fps – 2.36 fps = 16.9 fps

The instantaneous fluid velocity (V_x) at a given point in the velocity jet relative to the propeller is computed using the Equation 6 from Maynord (1998) but modified to include the effects of propeller pitch (i.e. jet angle with respect to horizontal):

$$V_x = 2.78 \times U_0 \times \frac{D_0}{x}\exp\left(-15.43\left(\frac{z}{x}\right)^2\right) + V_\theta$$

where

V_x = Instantaneous fluid velocity at coordinate x and z in fps

X = Horizontal distance aft of propeller in ft

Z = Radial distance from axis of propeller in ft (see attached sketch)

$D_0 = 0.71\, D_p$ for non-ducted propeller

V_θ = Velocity adjustment at point of calculation to account for jet angle with respect to horizontal. Note: this velocity adjustment is included in the computation of the radial distance from the jet centerline to the point of interest, z_r (see Figure D-1)

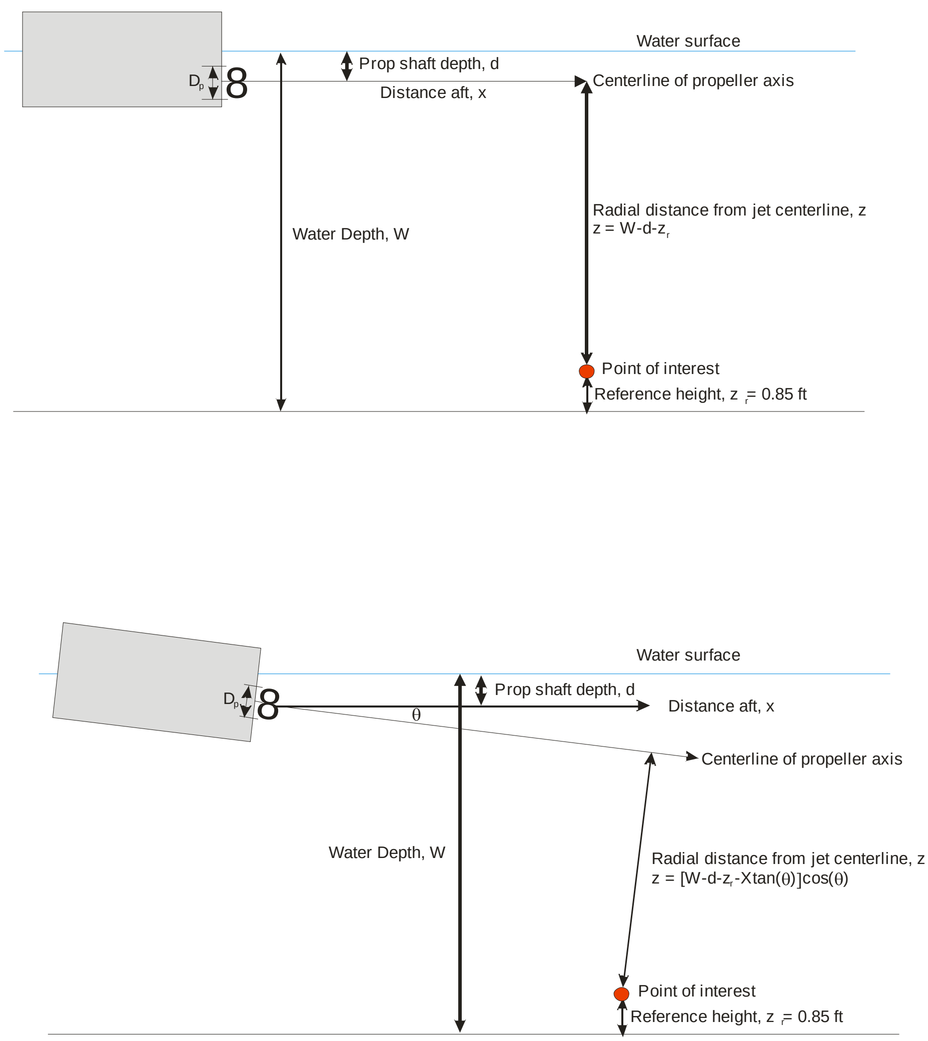

Figure D-1. Illustration of factors accounted for in V_θ

The flow pattern behind a stationary propeller is typically divided into a zone of flow establishment and a zone of established flow (Albertson et al. 1948). The zone of flow establishment typically occupies the distance 4 propeller diameters downflow from the propeller (Francisco 1995). Within the zone of flow establishment, momentum has not diffused away from the jet to the extent of affecting the core velocity, and bottom velocities are less than at the same elevation at the start of the zone of established flow. Therefore, for this evaluation, the horizontal distance, x, is selected as multiples of the propeller diameter beginning at a distance of 4Dp. The peak bottom velocities can occur at a distance greater than $4D_P$. Based on discussions with boat representatives and manufacturers, a propeller pitch angle of 7.5 degrees was used for this analysis for recreational boats.

For example, for $x = 5D_P = 5(1.33) = 6.65$ ft

$$z = [5 - 2.5 - 0.85 - 6.65 \times \tan(7.5)]\cos(7.5) = 0.77 \text{ ft}$$

$$V_x = 2.78 \times 16.9 \times \frac{0.71 \times 1.33}{6.65} \exp\left(-15.43 \left(\frac{0.77}{6.65} \right)^2 \right) = 5.42 \text{ fps}$$

Figure D-2 presents the instantaneous fluid velocity (Vx) relative to the propeller for this example.

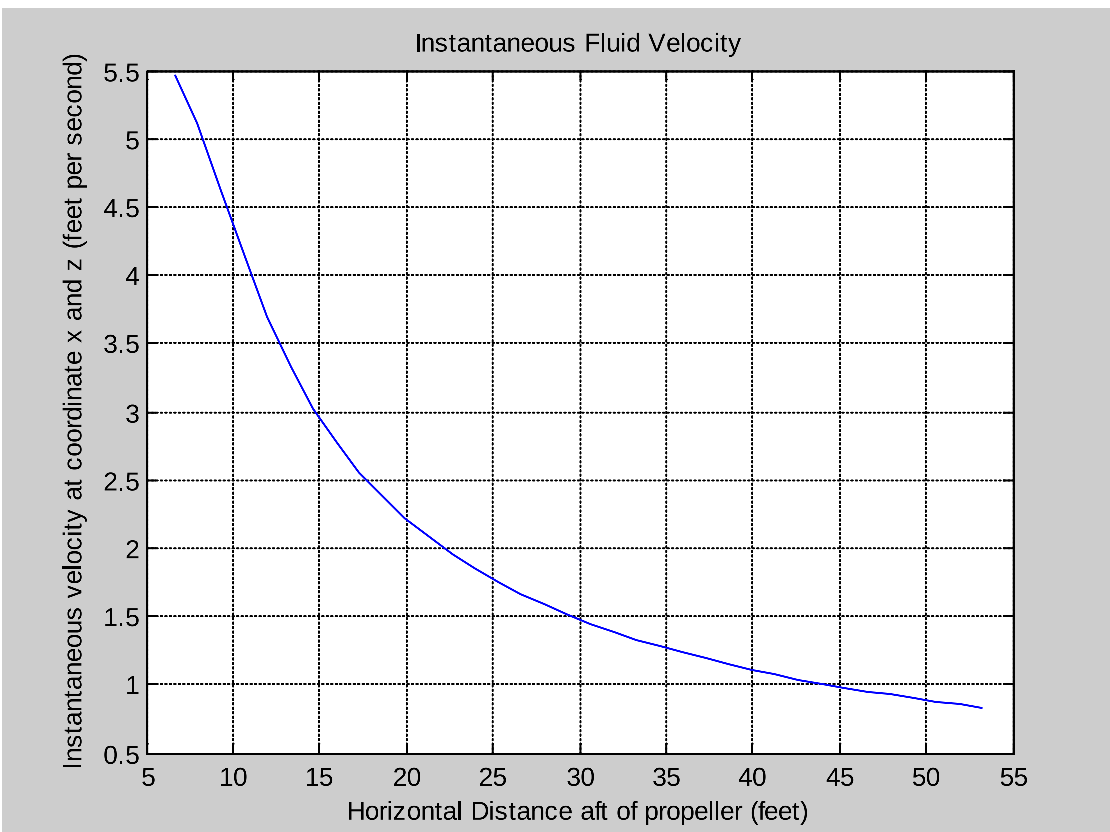

Figure D-2. Instantaneous fluid velocity (Vx) relative to the propeller

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SUBJECT:	Propeller Wash Analysis for Sediment Cap Armor Layer Designs - Example Calculation						

3. Compute propeller wash time series for a moving vessel

The velocity pattern at the reference height above the bottom (0.85 ft) behind the stationary propeller is converted to a time series of velocity for the moving vessel relative to a fixed point using the boat speed computed above. The reference height of 0.85 feet was selected as it corresponds to the minimum height above the bottom at which reliable measurements could reasonably be collected during previous field experiments. Previous propeller wash evaluations and particle sizes at the threshold of motion were compared to field measurements of velocities collected at this elevation (Shaw and Anchor 2007). To do so, the velocity vs. distance values (Figure D-2) are "translated" using the speed of the boat for the time step of interest. For example:

$$T = \frac{x}{V_{w(t)}} = \frac{6.65\,ft}{2.36\,fps} = 2.82\,\text{sec}$$

For the cases where the peak of the relative velocity time series is not well defined, the time T for x=0 is computed as one half of the time computed for the peak velocity. Figure D-3 presents the propeller wash time series for this example.

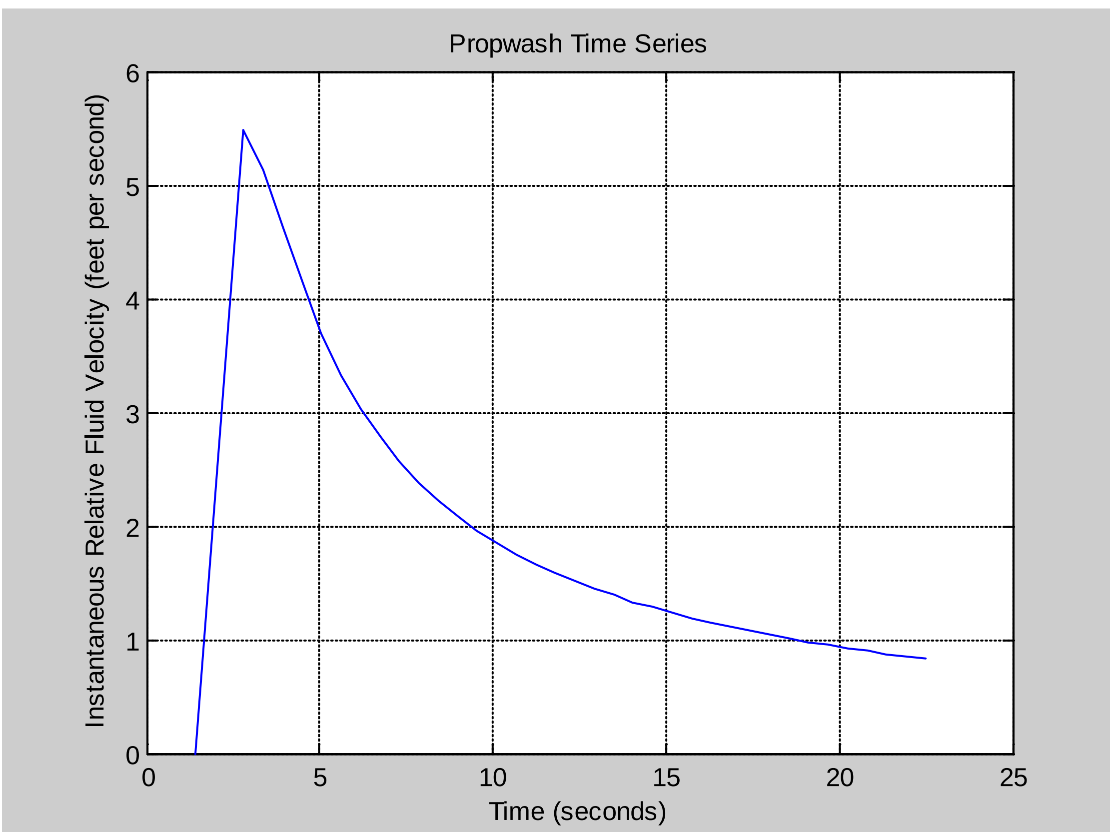

Figure D-3. Propeller Wash Time Series

Instantaneous velocities are calculated at intermediate points by linear interpolation between the points defining the curve in Figure D-3 using the procedures described in (Shaw and Anchor 2007). The effective velocity at each step in the velocity time series is computed as the average of a given instantaneous velocity and the peak instantaneous velocity. The duration corresponding to this effective velocity (ΔT) is conservatively assumed to be equal to the duration at the given instantaneous velocity:

$$\Delta T_{(VR)} = T_{2(VR)} - T_{1(VR)}$$

where

$\Delta T_{(VR)}$ = duration of time for which fluid velocity exceeds a given instantaneous relative velocity. Computed by interpolating between points on the velocity time series

$T_{1(VR)}$ = time within propeller wash time series that given instantaneous relative velocity is first exceeded (see Figure D-3)

$T_{2(VR)}$ = time within propeller wash time series that given instantaneous relative velocity is no longer exceeded (see Figure D-3)

For example, for the peak instantaneous relative velocity = 5.42 fps from Figure D-3 and for V_x = 3.0 fps:

$$V_{eff} = \frac{3.0 + 5.42}{2} = 4.2\ fps$$

$$\Delta T_{(3\ fps)} = 6.25 - 2.17 = 4.08 \text{ sec}$$

4. Compute Particle Size at Threshold of Motion

This step presents the estimation of particle size at threshold of motion using two methods, including a momentum based approach that considers both duration and magnitude of the flow as well as empirical data presented by Neill (1973) for a duration unlimited case as an upper bound of particle instability. The methods presented in the USEPA guidance (Maynord 1998) and technical literature (Blaauw and van de Kaa 1978) are based on large ocean-going vessels operating at very slow speeds (e.g., maneuvering operations), and therefore are not fully applicable to the smaller, fast-moving recreational vessels that typically operate in the shallower waters of Onondaga Lake. Specifically, the model does not properly consider the angle of the propeller (the propeller angling downward toward the bed as the boat is starting up) or the transient (i.e., moving vessel) nature characteristic of recreational propeller wash. In addition, as shown above, the USEPA guidance provides a conservative estimate of stable particle size for the low bottom velocities.

The threshold particle size was computed using the following equation that considers of both velocity and duration (Shaw and Anchor 2007).

$$D_{50} = \frac{3}{4} C_D \frac{V_{eff}^{\ 2}}{\frac{\rho_s}{\rho_{fluid}}\left(gC_F + \frac{\alpha V_{eff}}{\Delta t}\right) - gC_F}$$

where

ρ_{fluid} = fluid density in lbs/ft^3 = 62.4 lbs/ft^3

$\rho_{sediment}$ = particle density in lbs/ft^3 = 165 lbs/ft^3

C_D = Drag and lift combined coefficient. The lift and drag coefficients empirically account for two forces, lift and drag, that are exerted on a particle resting on the bed as a result of passing flow and contribute to the initiation of motion of the particle. The drag and lift coefficient of 0.35 is used in this analysis based on a review of published literature (van Rijn 1993; Saffman 1965, 1968; and others).

V_{eff} = effective fluid velocity in fps

C_F = Coefficient of friction (tan ϕ). The coefficient of friction here relates to a combination of friction (resistance to movement) forces acting on a single particle on a horizontal bottom, stochastically bounded with other particles. The friction angle of 45.67 degrees is used in this analysis based on a range of values reported in literature (Middleton and Southard 1984).

α = ratio of particle speed to fluid speed at initial motion. A value of 0.86 was used in this analysis (based on van Rijn 1984).

D_{50} = particle diameter, in ft

For the effective velocity of 4.2 fps and ΔT= 4.08 sec:

$$D_{50} = \frac{3}{4}(0.35)\frac{4.2^2}{\frac{165}{62.4}\left((32.2)\tan 45.67 + \frac{(0.86)(4.2)}{4.08}\right) - (32.2)\tan 45.67} = 0.082\,ft = 0.98\,inches$$

The threshold particle size was also computed for each effective velocity value assuming a duration unlimited condition according to the following relationship based on Neill (1973).

$$D_{50} = (V_{eff})^{3.5432} \times 0.002$$

where

D_{50} = median particle size in inches at threshold of motion

V_{eff} = velocity specific to reference point of interest, z_r (0.85 ft)

$$D_{50} = (4.2)^{3.5432} \times 0.002 = 0.32\,inches$$

Both threshold particle size curves are plotted on Figure D-4. The particle size at threshold of motion is selected as the peak of the momentum equation curve if that peak plots to the right of (or below) the Neill curve. If the peak of the momentum equation curve plots to the left the Neill curve, the particle size at threshold of motion is defined as the intersection point of the momentum equation curve and the Neill curve.

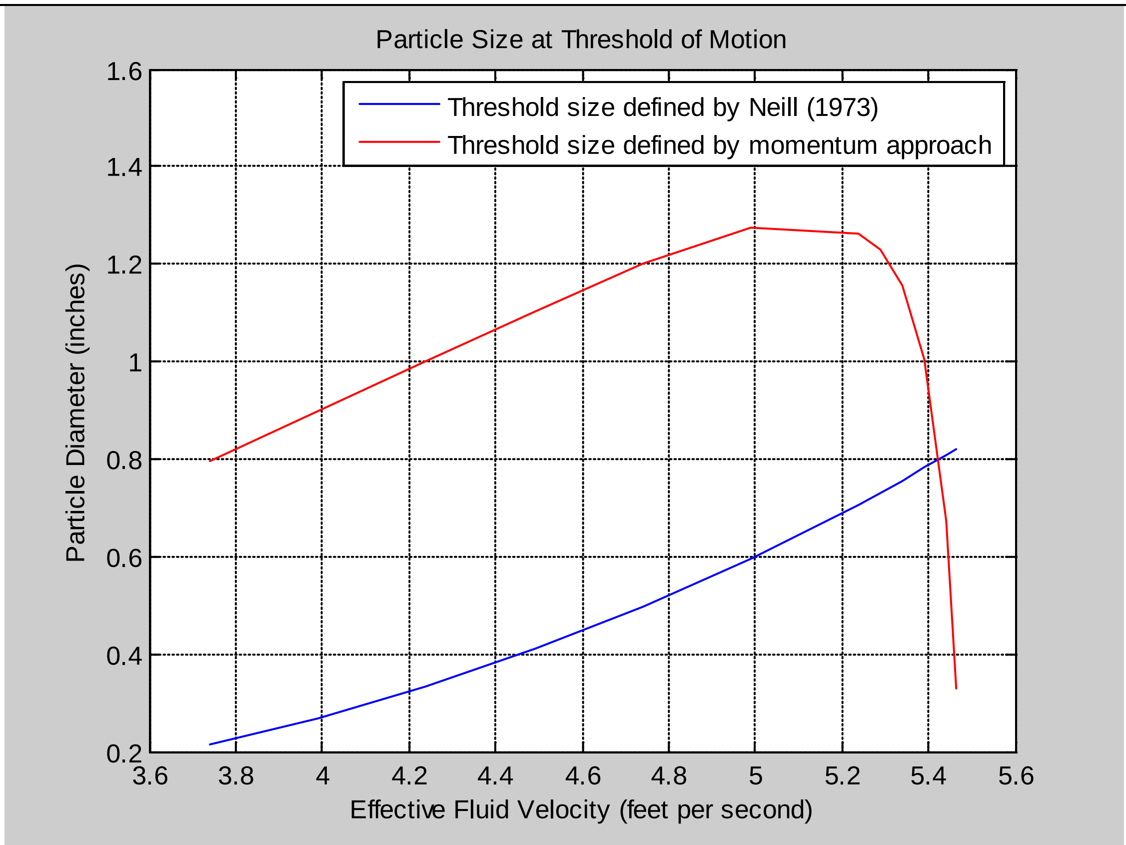

Figure D-4. Particle Size at Threshold of Motion

In this case, the peak of the momentum equation curve plots to the left the Neill curve, so the particle size at threshold of motion is defined as the intersection point of the momentum equation curve and the Neill curve. Therefore, the stable particle size for a Triumph 191 FS boat operating at 50 percent power 5 feet above the sediment cap armor layer is **0.8 inches** (coarse gravel).

RECORD OF REVISIONS

NO.	REASON FOR REVISION	BY	CHECKED	APPROVED/ ACCEPTED	DATE

ATTACHMENT E
VESSEL WAKE ANALYSIS FOR ARMOR LAYER DESIGNS – EXAMPLE CALCULATION

CALCULATION COVER SHEET

PROJECT: Onondaga Lake	**CALC NO. 1**	**SHEET** 1 of 6
SUBJECT: Attachment E – Vessel Wake Analysis for Armor Layer Designs - Example Calculation		

Objective: To determine the wave height and period generated by a vessel traveling through Onondaga Lake's Remediation Areas.

References:

Bhowmik, N.G., Soong, T.W., Reichelt, W.F., and Seddik, N. M. L. 1991. *Waves generated by recreational traffic on the Upper Mississippi River System*. Research Report 117, Department of Energy and Natural Resources, Illinois State Water Survey, Champaign, IL.

Sorensen, R., 1997. *Prediction of Vessel-Generated Waves with Reference to Vessels Common to the Upper Mississippi River System.* Lehigh University and Coastal Hydraulics Laboratory of the US Army Engineer Waterways Experiment Station. ENV Report 4. December.

Weggel, J.R. and R.M. Sorensen. 1986. "Ship wave prediction for port and channel design." Proceedings of the Ports '86 Conference, Oakland, CA, May 19-21, 1986. Paul H. Sorensen, ed., American Society of Civil Engineers, New York, pp. 797-814.

Sorensen, R.M. and J.R. Weggel. 1984. "Development of ship wave design information." Proceedings of the 19th Conference of Coastal Engineering, Houston, Texas, September 3-7, 1984., Billy Ledge, ed., American Society of Civil Engineers, New York, III, pp 3227-43.

Determination of wake wave height and period for a tugboat: The following presents a detailed summary and example calculation to determine the wave height and period of a wake wave generated by a tugboat traversing Onondaga Lake. The approach was developed by Weggel and Sorensen (1986) and Sorensen and Weggel (1984). The numbered list below outlines the general approach used for the calculation and defines specific parameters used in the calculations.

1. Obtain vessel characteristics (model input parameters) for the vessel in question, in this case the *Mavret H*, a tugboat. Also, determine water depth and distance to sailing line, where wave characteristics will be assessed. These parameters are provided in the following table:

Table A-1
Vessel Characteristics and Input Parameters (Tugboat)

Parameter	Value	Units
Length	70	feet
Vessel Displacement	24	metric tons
Vessel Speed	10	mph
Water Depth	14	feet

2. Relating maximum wave height, H_m, to the vessel speed, distance from the sailing line, water depth, and the vessel displacement yields four dimensionless variables (equations 1 through 4) with their corresponding values for this calculation:

$$F = \frac{V}{\sqrt{gd}}$$

$$x^* = \frac{x}{W^{0.33}}$$

$$d^* = \frac{d}{W^{0.33}}$$

$$H_m^* = \frac{H_m}{W^{0.33}}$$

where

F = Froude number
V = vessel speed
g = acceleration of gravity
d = water depth
x* = dimensionless distance from vessel sailing line to point of interest
x = distance from vessel sailing line to point of interest measured perpendicular to the sailing line
W = vessel displacement = 24 metric tons x 2,204 lbs/metric ton/62.4 lbs of water per ft^3 = 850 ft^3
H_m^* = dimensionless maximum wave height
H_m = maximum wave height in a vessel wave record
d* = dimensionless water depth

3. The basic initial model, in terms of these dimensionless variables, is given by (equation 5):

$$H_m^* = \alpha (x^*)^n$$

Where α and n are a function of the Froude number and dimensionless depth as follows (equation 6):

$$n = \beta (d^*)^\delta$$

Where (equation 7):

$\beta = -0.342 \quad 0.55 < F < 0.8$
$\beta = -0.225\, F^{-0.699} \quad 0.2 < F < 0.55$

$\delta = -0.146 \quad 0.55 < F < 0.8$
$\delta = -0.118\, F^{-0.356} \quad 0.2 < F < 0.55$

and (equation 8):

$$log(\alpha) = a + b \log(d^*) + c(\log(d^*))^2$$

where (equation 9):

$$a = \frac{-0.6}{F}$$

$$b = 0.75F^{-1.125}$$

$$c = 2.653F - 1.95$$

4. Using Equations 5 through 9, H_m can be determined given the vessel speed, displacement, water depth, and distance from the sailing line. These equations are valid for vessel Froude numbers from 0.2 to 0.8, which are common for most vessel operations, and in this case is 0.69 as defined in equation 1 above (and shown in the calculation below).

$$F = \frac{V}{\sqrt{gd}} = \frac{10\,\frac{\text{miles}}{\text{hr}} \times 5{,}280\,\frac{\text{ft}}{\text{mile}} \times \frac{1}{3{,}600}\,\frac{\text{hr}}{\text{sec}}}{\sqrt{32.2\,\frac{\text{ft}}{\text{s}^2} \times 14\text{ ft}}} = 0.69$$

Where,
F = Froude number
V = vessel speed = 10 miles per hour
g = 32.2 ft/s^2
d = water depth = 14 feet

Given F = 0.69, β = -0.342 and δ = -0.146 and the value of H_m = 1.5 ft

equation 2:

$$x^* = \frac{x}{W^{0.33}} = \frac{25\text{ ft}}{\left(850\text{ ft}^3\right)^{0.33}} = 2.7$$

equation 3:

$$d^* = \frac{d}{W^{0.33}} = \frac{14\text{ ft}}{\left(850\text{ ft}^3\right)^{0.33}} = 1.5$$

equation 4:

$$H_m^* = \frac{H_m}{W^{0.33}} \Rightarrow H_m = \left(H_m^*\right)\left(W^{0.33}\right) = 0.16 \times \left(850\text{ ft}^3\right)^{0.33} = 1.5\text{ ft}$$

equation 5:

$$H_m^* = \alpha(x^*)^n = 0.21 \times (2.7)^{-0.3} = 0.16$$

equation 6:

$$n = \beta (d^*)^{\delta} = -0.342 \times (1.5)^{-0.146} = -0.3$$

equation 8:

$$\log(\alpha) = a + b\log(d^*) + c\left(\log(d^*)\right)^2 = -0.87 + 1.1\log(1.5) + -0.12\left(\log(1.5)\right)^2 = -0.68$$

$$\alpha = 10^{-0.53} = 0.21$$

equation 9:

$$a = \frac{-0.6}{F} = \frac{-0.6}{0.69} = -0.87$$

$$b = 0.75F^{-1.125} = 0.75(0.69)^{-1.125} = 1.1$$

$$c = 2.653F - 1.95 = 2.653 \times 0.69 - 1.95 = -0.12$$

Where,
F = Froude number = 0.69 (per equation 1 above)
V = vessel speed = 10 miles per hour
g = acceleration of gravity = 32.2 ft/s^2
d = water depth = 14 feet
x* = Dimensionless distance from vessel sailing line to point of interest
x = Distance from vessel sailing line to point of interest measured perpendicular to the sailing line = 25 feet
W = vessel displacement = 850 ft^3
H_m* = Dimensionless maximum wave height
H_m = maximum wave height in a vessel wave record
d* = Dimensionless water depth

5. The wave height is subsequently adjusted by modifying the value of H_m by the following relationship (equation 10):

$$H_m = A' H_m - B' = 1.73 \times 1.5 \text{ ft} - 0.015 = 2.58 \text{ ft}$$

Where,
A' and *B'* = coefficients to account for hull geometry = 1.73 and 0.015 (Equation 14 and Table 2 of Weggel and Sorensen 1986)

6. In order to determine the wave period, the diverging wave direction is determined with respect to the sailing line, by the following equation (equation 15):

$$\theta = 35.27 - 35.27^{(12F-12)} \qquad F<1$$

$$\theta = a\sin\left(\frac{1}{F}\right) \qquad F>1$$

In this example calculation where F= 0.69:

$$\theta = 35.27 - 35.27^{(12*0.69-12)} = 34.4 \text{ degrees, or } 0.6 \text{ radians}$$

And the diverging wave celerity, *C* is determined by the following (equation 16):

$$C = V\cos(\theta) = 10\frac{\text{miles}}{\text{hr}} \times 5{,}280\frac{\text{ft}}{\text{mile}} \times \frac{1}{3{,}600}\frac{\text{hr}}{\text{sec}} \times \cos(0.6) = 12.1\frac{ft}{\text{sec}}$$

Where,
V = vessel speed = 10 mph

And the period is calculated as (equation 17):

$$T = 2\pi(C/g) \qquad \text{F<0.7}$$

$$T = \frac{L^*}{C} \qquad \text{F>0.7}$$

Where L* is determined through an iterative process, to match *C* with *C**, where C* is defined as (equation 18):

$$C^* = \frac{\sqrt{32.2 \times L^* \times 0.5}}{\pi \times \tanh\left(2\pi\frac{d}{L^*}\right)}$$

In this example F < 0.7, and the first part of equation 17 is used to determine T:

$$T = 2\pi\left(\frac{12.1\frac{ft}{\text{sec}}}{32.2\frac{ft}{\text{sec}^2}}\right) = 2.4\text{sec}$$

Determination of wake wave height and period for a ski and fishing boat: The following presents a detailed summary and example calculation to determine the wave height and period of a wake wave generated by a ski and fishing boat traversing Onondaga Lake. The approach was developed by Bhowmik et al. (1991). The numbered list below outlines the general approach used for the calculation and defines specific parameters used in the calculations.

1. Obtain vessel characteristics (model input parameters) for the vessel in question, in this case the *Triumph 191*, a ski and fishing boat. These parameters are provided in the following table:

Table A-2
Vessel Characteristics and Input Parameters (Ski and Fishing Boat)

Parameter	Value	Units
Length	18.5	feet
Draft	1.17	feet
Vessel Speed	8	mph

2. Compute maximum wave height, H_m, using vessel length, vessel draft, vessel speed, and distance from the sailing line using Bhowmik et al. (1991):

$$H_m = 0.537\,V^{-0.346} x^{-0.345} L_v^{\,0.56} D^{0.355}$$

$$H_m = 0.537\left(3.6\,\frac{\text{m}}{\text{s}}\right)^{-0.346}(7.6\text{ m})^{-0.345}(5.6\text{ m})^{0.56}(0.36)^{0.355} = 0.31\text{ m, or } 1\text{ foot}$$

Where,
V = vessel speed = 8 mph, or 3.6 m/s
x = Distance from vessel sailing line to point of interest measured perpendicular to the sailing line = 25 feet, or 7.6 meters
L_v = vessel length = 18.5 feet, or 5.6 meters
D = vessel draft = 1.17 feet, or 0.36 meters

RECORD OF REVISIONS

NO.	REASON FOR REVISION	BY	CHECKED	APPROVED/ ACCEPTED	DATE

ATTACHMENT F
SEDIMENT CAP BEARING CAPACITY ANALYSIS – EXAMPLE CALCULATION

CALCULATION COVER SHEET

PROJECT: Onondaga Lake	**CALC NO. 1**	**SHEET** 1 of 4
SUBJECT: Attachment F – Sediment Cap Bearing Capacity Analysis – Example Calculation		

Objective: To determine the factor of safety relative to bearing capacity for human foot traffic on the nearshore sediment caps.

References:

Das, B.M. 1999. *Shallow Foundations Bearing Capacity and Settlement*. CRC Press.

Das, B.M. 1990. *Principles of Geotechnical Engineering*. Second Edition. PWS-Kent Publishing Company.

Determination of bearing loads due to human foot traffic: The following presents a detailed summary and example calculation to determine the factor of safety relative to bearing capacity for human foot traffic on the nearshore sediment caps in Onondaga Lake. The calculation was performed by assuming human foot traffic is similar to a shallow foundation that rests on a layered material (the sand and gravel cap over the softer, fine grained sediments in Onondaga Lake). The Terzaghi-Meyerhof method was used to compute the general bearing capacity of the cap. The sediment cap (i.e. top layer) was conservatively assumed to be comprised of sand only with the following soil properties:

Cohesion (c) = 0 pounds per square foot (psf)
Soil friction angle (ϕ) = 32 degrees
Submerged unit weight (γ) = 125 pounds per cubic foot (pcf) for sand – 62.4 pcf for water = 62.6 pcf

The Bearing Capacity Factors for general shear failure are:

N_c = 35.49 (from Table 10.1 of Das 1990)
N_q = 23.18 (from Table 10.1 of Das 1990)
N_γ = 30.22 (from Table 10.1 of Das 1990)

Approximating a human foot as a rectangular footing with a width (B) of 4 inches (0.33 ft), a length (L) of 10 inches, (0.83 ft), and a footing depth (D_f) of 0 ft.

For the sediment cap, the general bearing capacity using Equation 10.37 from Das 1990 is:

$$q_n = cN_c + qN_q + \frac{1}{2}\gamma BN_\gamma = (0)(35.49) + 0 + \frac{1}{2}(62.6)(0.33)(30.22) = 312 \text{ psf}$$

Note: since the foot traffic is at the top of the cap, there is no surcharge contribution to the general bearing capacity.

The bottom layer (i.e. the native sediments below the sediment cap) is assumed to consist of cohesive, fine-grained sediments with the following properties:

Cohesion (c) = 25 psf (representing the softest sediments in the upper one foot)
soil friction angle (ϕ) = 0 degrees
Submerged unit weight (γ) = 30 pcf (an average value of the sediments based on Pre-Design Investigations)

The Bearing Capacity Factors for general shear failure are:

$N_c = 5.14$
$N_q = 1.00$
$N_\gamma = 0.00$

For the underlying sediments, the general bearing capacity using Equation 10.37 from Das 1990 is:

$$q_n = cN_c + qN_q + \frac{1}{2}\gamma BN_\gamma = (25)(5.14) + 0 + \frac{1}{2}(30)(0.33)(0.00) = 129 \text{ psf}$$

Equation 4.32 from Das (1999) was used to determine the ultimate bearing capacity (q_u). The subscript 1 refers to the sediment cap (the top layer) and the subscript 2 refers to the underlying, native sediments (bottom layer). The thickness (H) of the sediment caps in the nearshore region can range from 2.75 ft to 5 ft in thickness.

$$q_u = q_b + \left(\frac{2c_a H}{B}\right) + \left(\gamma_1 H^2\right)\left(1 + \frac{2D_f}{H}\right)\left(\frac{K_s \tan\phi_1}{B}\right) - \gamma_1 H$$

Equation 4.29 from Das (1999) was used to determine q_b:

$$q_b = c_2 N_{C2} + \gamma_1 \left(D_f + H\right) N_{q2} + \frac{1}{2}\gamma_2 BN_{\gamma 2} = (25)(5.14) + (62.6)(0 + 2.75)(1) + \frac{1}{2}(30)(0.33)(0) = 301 \text{ psf}$$

For a 5 ft thick cap, q_b = 442 psf.

K_s was determined from Figure 4.15 of Das (1999) below:

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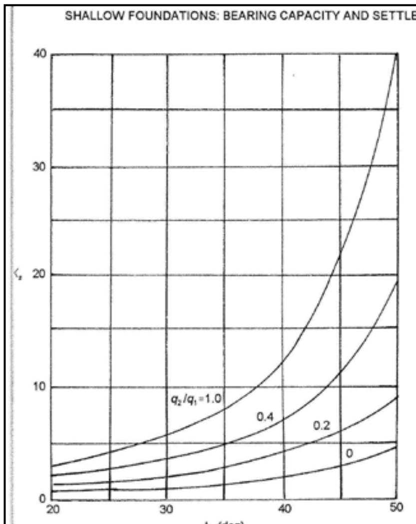

IGURE 4.15 Meyerhof and Hanna's theory — variation of K_s with ϕ_1 and q_2/q_1

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For $\phi_1 = 32$ degrees and $\frac{q_2}{q_1} = \frac{129}{312} = 0.41, K_s = 4$

c_a was estimated as 1 using Figure 4.23 from Das (1999) below:

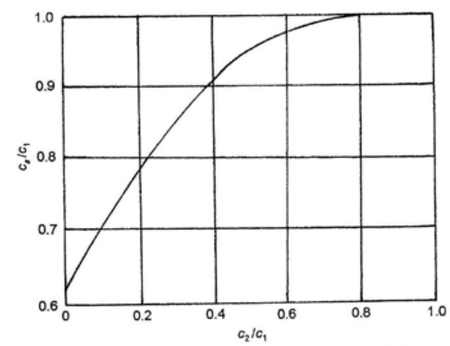

FIGURE 4.23 Analysis of Meyerhof and Hanna for the variation of c_a/c_1 with c_2/c_1

Since $\frac{c_2}{c_1} = \frac{25}{0}$, a value of 1 was selected for c_a

For a 2.75 thick nearshore cap:

$$q_u = 301 + \left(\frac{(2)(1)(2.75)}{0.33}\right) + (62.6)(2.75)^2\left(1 + \frac{2(0)}{2.75}\right)\left(\frac{4\tan 32}{0.33}\right) - (62.6)(2.75) = 3{,}730 \text{ psf}$$

For a 5 ft thick nearshore cap, q_u = 12,000 psf

The applied load for a 200 lb person on the cap is estimated as:

$$q = \frac{200}{(0.83)(0.33)} = 730 \text{ psf}$$

Note: this is conservative as it does not consider the submerged weight of the person.

Therefore, the Factors of Safety (FOS) for the 2.75- and 5-thick caps are:

$$FOS_{\text{2.75-ft thick cap}} = \frac{3{,}730}{730} = 5.11$$

$$FOS_{\text{5-ft thick cap}} = \frac{12{,}000}{730} = 16.4$$

RECORD OF REVISIONS

NO.	REASON FOR REVISION	BY	CHECKED	APPROVED/ ACCEPTED	DATE

ATTACHMENT G
ICE EFFECTS ON SEDIMENTS
ONONDAGA LAKE

ICE EFFECTS ON SEDIMENTS ONONDAGA LAKE

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March 2004

BACKGROUND

As part of the effort to assess remediation of contaminated sediments in Onondaga Lake in New York, there was concern as to whether or not ice effects would influence various remedies being proposed, in particular capping of the existing bottom sediments. This report discusses the nature of the ice cover on Onondaga Lake and associated ice processes that could conceivably interact with the sediments. The conclusions below are based on a site visit to Onondaga Lake on 18 November 2003, on published literature dealing with ice and sediments, and some 35 years of personal experience examining river and lake ice behavior.

ONONDAGA LAKE

Onondaga Lake is a small to medium-sized lake located near Syracuse, New York. It is approximately 5 miles long and 1 mile wide with an orientation in the NW to SE direction. For a lake of this size, it is fairly deep with maximum depth of about 20 meters. The near shore areas slope gradually in a terrace to about 4 meters depth and then more steeply to near the maximum depth. Typically the ice cover forms in late December to early January and melts out near the latter part of March or the first part of April. Because of its depth, the temperature cools beneath the maximum density temperature of 4º C but does not cool down to the freezing point, since the surface ice cover forms before that occurs. In the 2002-2003 winter the coldest temperature at 14 feet depth near the site was about 2º C. From a water temperature record provided by Tim Johnson of Parsons Company, it is estimated that the first substantial ice cover occurred about 15 January and disappeared about 2 April. The winter 2002-2003 was extremely cold in the northeastern U.S. and maximum level ice thicknesses in the lake, based on a degree-days freezing algorithm using an air temperature from the site, were between 12 and 16 inches. Most likely there are years in which complete freeze over does not occur, although the usual scenario is one in which the lake is more or less completely ice covered.

ICE OBSERVATIONS

There are no known regular and/or historical ice thickness observations for Onondaga Lake. Onondaga County made almost daily observations of the extent of ice cover on the lake from the winter of 1987-88 through the winter of 2002-03. The lake was actively used in the late 1800's for iceboating which implies a more or less complete ice cover in most years. In an interview with Tim Johnson (Parsons), he suggested it is not used regularly by snowmobiles. In a telephone interview with Bob Halbritter of O'Brien and Gere, he stated that there are occasional ice pilings along the shore but these are of limited height (less than 5 feet) and were not considered severe. There are almost no residential or camp docks along the lake's shoreline and only a very small marina for boating access. Ordinarily damage (or not) to such docks provide indications of ice action. An inspection of the shoreline at several places by the writer showed no obvious signs of ice damage such as tree scars, except possibly some abrasion of shoreline trees at the very water's edge and at the water level. These abrasions could also have been caused by wave action on littoral debris near the shoreline.

The record of observations by Onondaga County was examined in detail. While providing a good record of surface ice coverage, measurements of ice thickness were infrequent. The surface ice coverage typically occurs in stages with initial ice formation along the shores and in protected inlets but eventually covering the entire lake. Often there are large open areas, particularly near the center of the lake. When the ice begins to melt, it first becomes clear of ice by enlargement of the open areas where tributaries enter, followed by an overall pattern that tends in most years to melt out the south basin first followed by the north basin. In those sixteen years of observation only two cases of shore ice piling was noted and they both occurred during the 1989-90 winter. On 1 February 1989 a photograph of thin ice piled on the eastern shore near French Fort was included with the caption stating "strong winds and temperatures that reached a high of 52 degrees combined to cause the ice to break up on Onondaga Lake. The ice was piled up in sheets on the eastern shore near the French Fort about 2:30 p.m. Tuesday." The ice appeared to consist of quite thin plates and no apparent damage could be observed from the photograph. On the calendar notes of that year for 19 January 1989 is a notation "heavy winds separated the South …pushed it ashore as shown (in cove near the south side of the lake).

Reported ice thicknesses were sparse in the record and rarely greater than 8 inches except for the years 1993-94 and 2002-03. During the 1993-94 year there are two notations: on 16 February 94: "+/- 20.5 inches at North Deep" and on 4 March 94: "+/-19.5 inches at North end." The month of January 1994 was the coldest of record for the Syracuse area, with an average air temperature of 12.6 °F. A degree-day calculation provided an estimate of expected thicknesses between 12 and 18 inches, so these two measurements are not inconsistent with the temperature record or other reported thicknesses that year. In the 2002-03 winter there were a series of thickness measurements with the maximum reported thickness 15 inches on 13 March 2003. The overall record that year is more detailed than usual and this thickness is consistent with other measurements through the season and a calculation based on freezing degree-days.

MECHANISMS OF ICE INTERACTION WITH BOTTOM SEDIMENTS

There are few studies of lake ice interaction with bottom sediments. However, several mechanisms of ice action are known and can be assessed for Onondaga Lake.

Frazil and Anchor Ice

Formation of frazil or anchor ice is not likely to occur at Onondaga lake due to the size of the lake and the low exposure to supercooling. Frazil is ice in very small crystals formed in supercooled (below 0º C) water. While in the supercooled matrix water it is adhesive to most materials. In some cases this frazil can adhere to the bottom sediments. When attached to the bottom, it is often termed anchor ice. When the water warms, or the deposit becomes large, the mass of frazil can rise and bring with it a quantity of sediment to which it had adhered.

Two conditions are necessary for this frazil formation at depth. They are cooling of the water to below 0º C and sufficient turbulent mixing to entrain the water and crystals to depth. In the Great Lakes both occur with the turbulent mixing due to both wind and current action, and the extended period of open water to achieve the necessary cooling associated with the difficulty in forming an intact ice cover over such a large surface area. In Onondaga Lake, neither condition occurs. The lake is not of sufficient size and exposure to develop large wind-driven currents, and it is doubtful that the majority of the lake becomes supercooled. There will be some limited supercooling of the top surface water during the time of initial ice formation but this will only occur in the absence of mixing with the warmer water below.

Wave Action

During the initial period of ice formation there may be very short periods when the wind and wave action will prevent an intact ice cover from forming. This will manifest itself in accumulations of very thin plates of ice accumulating in the surface waters at the downwind shorelines. This is expected to persist only until the winds subside. The interaction with the sediments below are considered to be equivalent to similar wave actions during open water periods with the exception that the surface layer of ice accumulation has a damping effect on the wave action.

Thermal Expansion

During the winter the ice cover expands and contracts in response to changes in air temperature. Associated with this expansion and contraction are formation and refreezing of cracks in the ice cover and the net effect usually is to push the ice edges in the shoreward direction. These pushes can move the top layers of the shoreline materials away from the lake. Personal observations of these by the writer suggests the disturbance to the top layers of soil are of limited depth, since the ice tends to “ride up” the shore. The forces, however, may be substantial and are limited by the strength of the ice.

Ice Ridging

Ice ridging of any significant degree is not expected to occur in Onondaga Lake due to its size. On the surface such ridges are easily observed because of their size. Descriptions of the ice cover of Onondaga Lake and other similar and even much larger lakes strongly suggest moving ice ridges do not occur. Undoubtedly there are smaller ridging features observed from time to time on Onondaga Lake but these are most likely due to local buckling resulting from thermal expansion and contraction, and are of limited vertical extent.

Shoreline Ice Piling

On large lakes such as the Great Lakes large ice pilings occur along the shorelines driven by winds and currents. On small lakes such as Onondaga Lake there is little literature and experience that quantifies such ice pilings, although it is well known that they often occur and cause damage to minor docks and similar relatively fragile shoreline installations. Documented cases for a lake much larger than Lake Onondaga (Tsang, 1975) were associated with formation of a wide open water gap along the shoreline followed by a reversal of strong winds that then drove the solid ice sheet towards the shoreline and resulted in ice pilings that were about 2 meters high and caused significant shoreline damage. The observations of interaction with the shoreline are instructive for the Onondaga Lake concerns. When the ice impacted an embankment or rock protection, it either flexured upwards and broke, or buckled upwards and failed. When it encountered a sloping shore it slid up the shore pushing a quantity of sediment ahead of it in a shallow "bulldozing" mode. Although the depth of excavation by the "bulldozing" was not measured, the diagram of the "bulldozing" mode suggested a depth of the excavation of about ½ or less than the thickness of the ice. It was also noted that extremely high winds earlier in the winter did not cause piling and led to the conclusion that the ice piling required a precedent condition of open water along the shoreline. Additionally these ice pilings had been observed often at the study site.

Lake Otsego, located about 85 miles ESE of Onondaga Lake, is similar to Onondaga Lake, although it is somewhat deeper. It has a long term record of ice-on and ice-off (beginning and ending dates of more-or-less complete ice cover) reported by Assel and Herche (1975). Lake Otsego average ice-on date is 12 January (standard deviation of 15 days) and ice-off is 13 April (standard deviation of 12 days) based on a record longer than 100 years. In Lake Otsego "shoreline alteration and damage of artificial structures on the shore (e.g. breakwaters) due to lake ice occurs in two ways: 1. by expansion and contraction associated with temperature changes through the winter and spring before breakup and 2. by moving ice during the meteorological events responsible for breakup of ice cover." (The State of Otsego Lake, 1936 – 1996, Biological Field Station, SUNY NY at Oneonta). That report goes on to state: "Most ice damage on Otsego Lake can be attributed to the former, which heaves rip-rap and breakwaters and often pushes natural unconsolidated beach materials into large berms parallel with the water. Ice breakup is usually not accompanied by extensive catastrophic change in the eulittoral environment because the ice is not often moved by wind until it is structurally weakened by warm spring weather. Upon coming in contact with the shore or any solid object, ice 12 cm or more in thickness will typically break up easily into pencil-shaped columnar crystals, If, however, the ice starts to move before its structural integrity has been weakened, extensive damage may occur in areas exposed to the prevailing winds." This report also noted "…in 1970-71, it (ice thickness) reached a thickness of about 30 cm, the thickest recorded."

Ice freezing to the bottom

Ice freezing to the bottom is expected in shallow water at the shoreline of Onondaga Lake. In such cases it is expected that the normal thickening of the ice will encounter the bed and freezing will continue. It is possible that with the rise of the ice cover associated with inflow to the lake from spring snowmelt, and this usually occurs prior to complete melting of lake ice covers, this ice could be raised and transported a short distance during the ice decay period. The maximum thickness of the ice-and-sediment layer can easily be estimated using straightforward algorithms using daily air temperatures through the winter. Where the water depth is less than the maximum ice thickness, the combined ice-sediment frozen thickness will be somewhat greater than the maximum ice thickness since there is less water to freeze in the sediment portion. This mode of sediment interaction is limited to those areas with depths of water less than the maximum ice thickness experienced and corresponds to water depths less than about 18 inches.

CONCLUSIONS

There are a number of mechanisms that could disturb the bottom sediments of Onondaga Lake as a result of ice action. They are: thermal expansion that would push the lake ice shoreward, shoreline ice piling as a result of wind action, and ice freezing to the bottom in very shallow areas. In the first two cases, the result would be shallow disturbance to the top layers of sediment in the very near shore areas and the adjacent land. In the third case, and limited to shallow areas with depths less than the maximum thickness of the ice, it is possible for the freezing process to entrain a top layer of sediment and, if the ice is then moved, to deposit it where it melts. Processes associated with ice ridging, and with frazil and anchor ice are not expected to occur in Onondaga Lake.

Armor is being considered as a design component for a cap on the sediments. In terms of ice action, the shallow freezing entrainment mode is limited to depths less than the maximum expected ice thickness of about 18 inches.

It is also noted that the occurrence of ice piling requires some meltout prior to ice piling, so selection of 18 inches for the ice thickness is conservative. To resist ice piling action with no displacement of riprap material, one detailed model study (Sodhi, 1996) suggested the maximum rock size (D100) should be twice the ice thickness for shallow slopes (1V:3H). This would correspond to 32 inches and be considerably larger than the size presently proposed for the armoring layer. Matheson (1988) suggested, from a survey of riprap performance on Canadian hydropower reservoirs, that damage occurs to riprap with D50 less than 0.4 m (16 inches) and this corresponds to experience with ice thicknesses quite a bit greater than that experienced on Onondaga Lake. This writer believes that riprap of a size greater than 16 inches is an extreme measure and that, since the occurrences of ice piling are considered infrequent and limited to only portions of the shoreline at any event occurrence, it would be preferable to replace those limited portions of the riprap protection after annual inspection. An alternative is to provide a sacrificial layer of smaller riprap that would be replenished as needed.

REFERENCES

Assel, R. A. and L. R. Herche, 1975. Ice-on, ice-off, and ice duration for lakes and rivers with long-term records, Proceedings 14th International Symposium on Ice, Potsdam, NY 27-31 July 1998, Potsdam, NY.

----Biological Field Station in Cooperstown, 1996. The State of Otsego Lake, 1936-1996, SUNY College at Oneonta.

Matheson, D. S. 1988. Performance of riprap in northern climates. Contract report to the Canadian Electrical Association, CEA No. 625 G 571, Acres International Limited, Winnipeg, Manitoba (cited in Wuebben, J.L. 1995, Ice effects on riprap, in River, Coastal and Shoreline Protection: Erosion Control using Riprap and Armourstone, J. Wiley and Sons.)

Tsang, G. 1975. A field study on ice piling on shores and the associated hydro-meteorological parameters, Third International Symposium on Ice Problems, Hanover, NH, pp. 93-110.

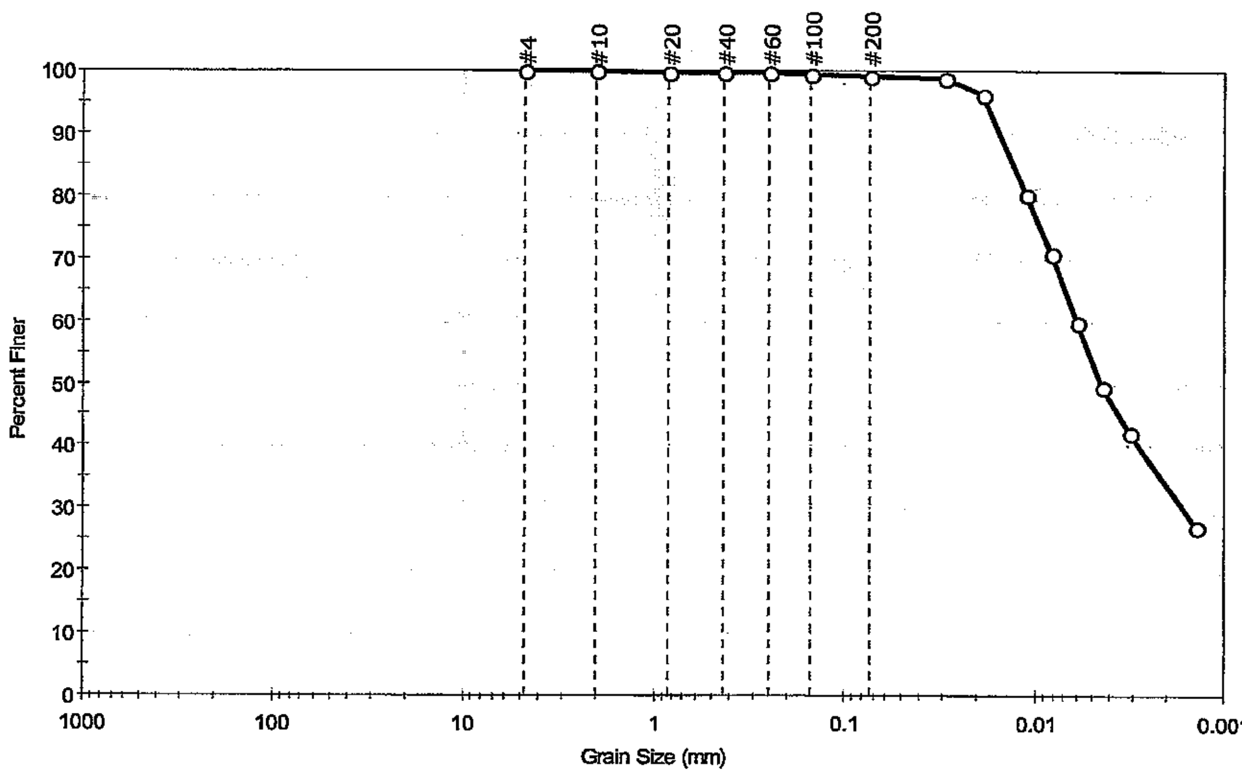
Sodhi, D.S., S. L. Borland, and J. M. Stanley, 1996. Ice action on riprap: Small-scale tests, CRREL Report 96-12, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, NH, 64 p.

ATTACHMENT H
PARTICLE SIZE ANALYSIS

GeoTesting express
a subsidiary of Geocomp Corporation

Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-40016	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0287-02	Test Date:	02/09/07	Checked By:	jdt
Depth :	9.9-13.2 ft	Test Id:	105918		
Test Comment:	---				
Sample Description:	Moist, olive brown silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.8	99.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	99		
—	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0293	99		
---	0.0190	96		
---	0.0113	80		
---	0.0082	71		
---	0.0060	60		
---	0.0044	50		
---	0.0031	42		
---	0.0014	27		

Coefficients

D_{85} = 0.0132 mm | D_{30} = 0.0016 mm
D_{60} = 0.0060 mm | D_{15} = N/A
D_{50} = 0.0044 mm | D_{10} = N/A
C_u = N/A | C_c = N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (76))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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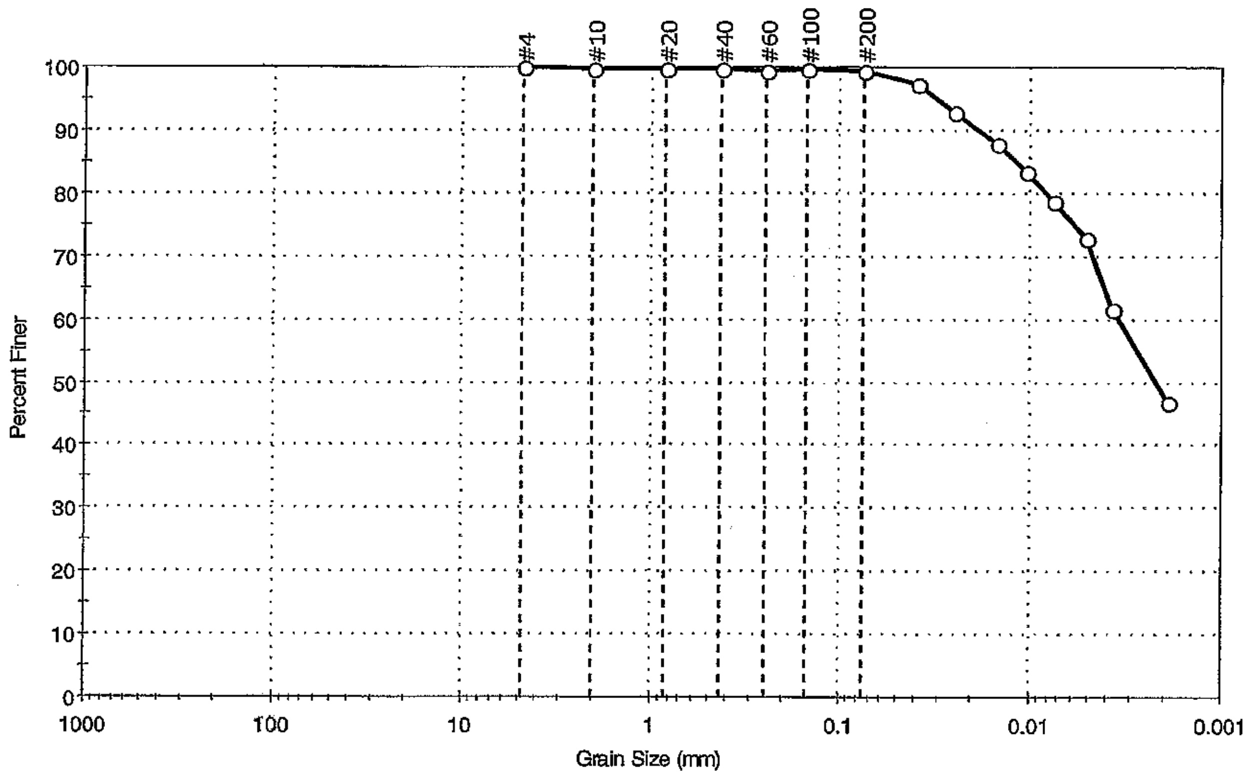
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-0302-06	Sample Type: jar	Tested By:	mll
Sample ID: OL-VC-40016	Test Date: 06/08/07	Checked By:	jdt
Depth : 13.2-16.4 ft	Test Id: 111437		
Test Comment: ---			
Sample Description: Wet, dark gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	0.6	99.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	100		
#200	0.075	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0397	97		
---	0.0253	93		
---	0.0147	88		
---	0.0104	83		
---	0.0074	79		
---	0.0051	73		
---	0.0037	62		
---	0.0019	47		

Coefficients

D_{85} =0.0117 mm D_{30} =N/A

D_{60} =0.0034 mm D_{15} =N/A

D_{50} =0.0022 mm D_{10} =N/A

C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (64))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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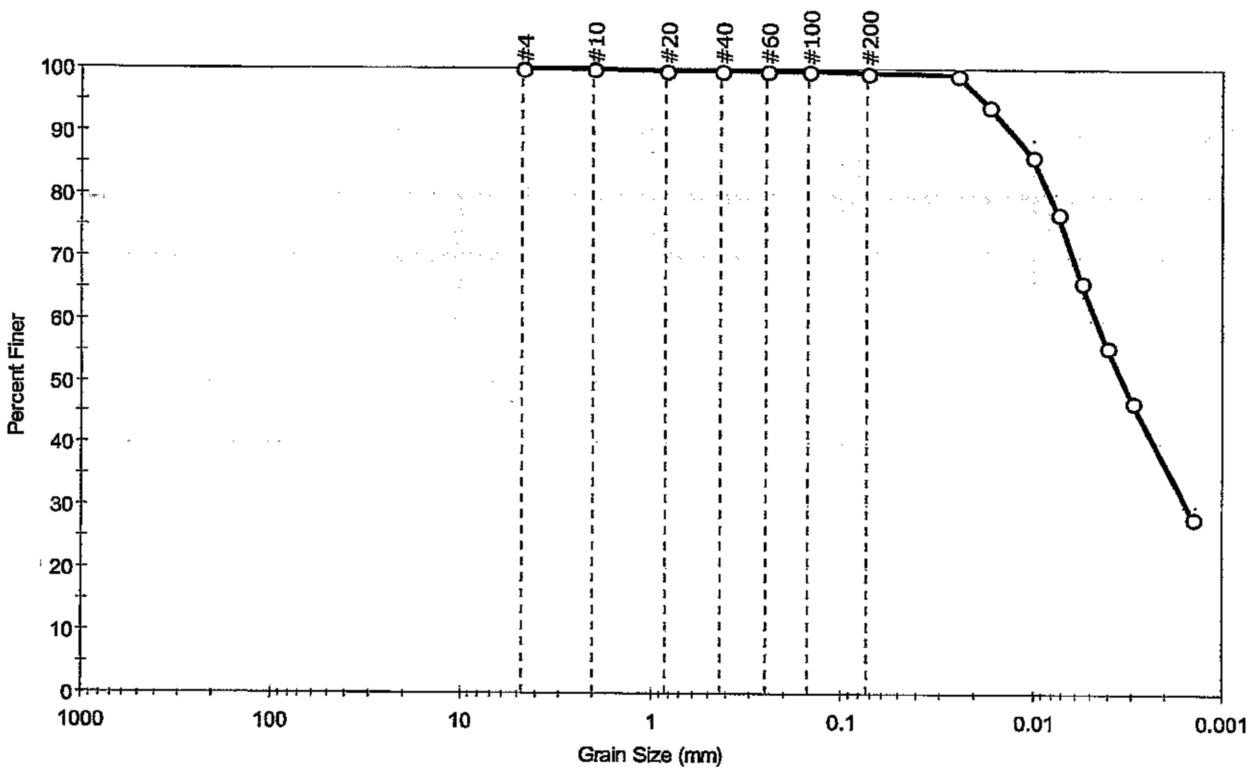
GeoTesting express
a subsidiary of Geocomp Corporation

Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-40016	Sample Type: jar	Tested By:	mll
Sample ID: OL-0287-03	Test Date: 02/08/07	Checked By:	jdt
Depth : 16.5-19.8 ft	Test Id: 105919		
Test Comment: ---			
Sample Description: Moist, gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.5	99.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0253	99		
---	0.0169	94		
---	0.0102	86		
---	0.0075	77		
---	0.0055	66		
---	0.0041	56		
---	0.0030	47		
---	0.0014	28		

Coefficients

D_{85} =0.0098 mm	D_{30} =0.0015 mm
D_{60} =0.0046 mm	D_{15} =N/A
D_{50} =0.0033 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (52))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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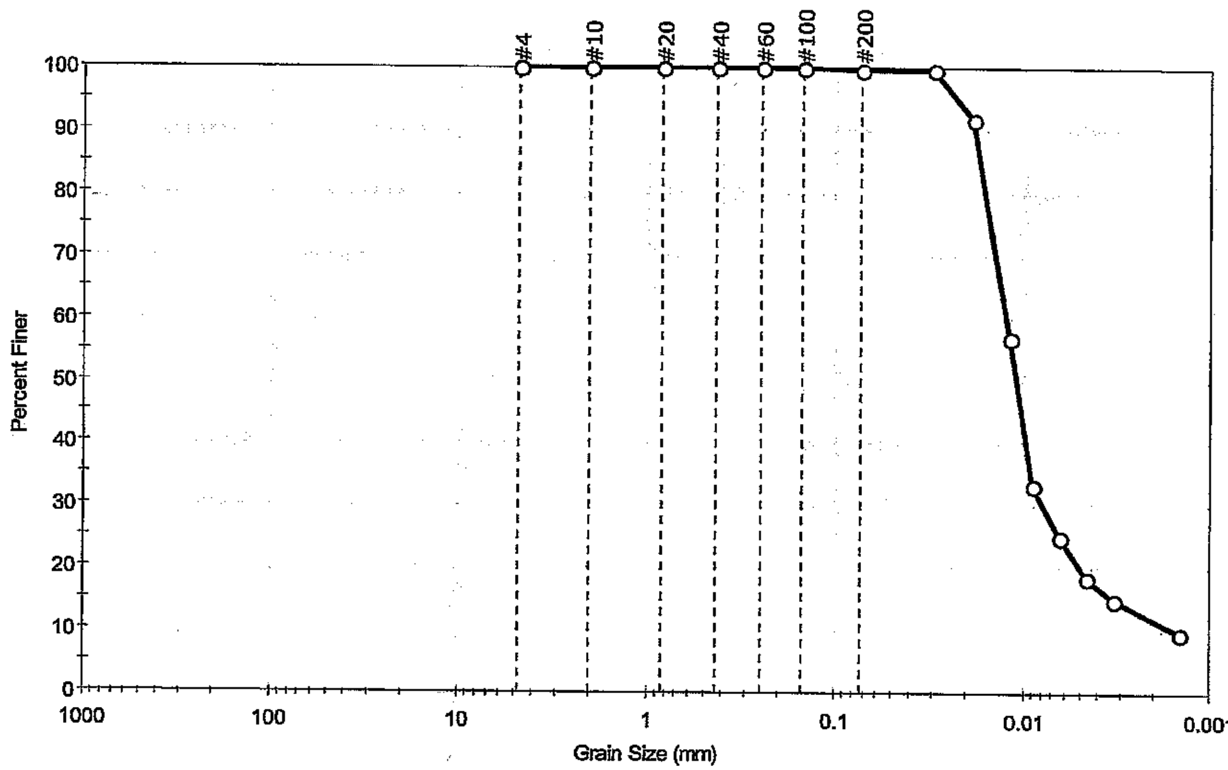
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-40017	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0287-04	Test Date:	02/07/07	Checked By:	jdt
Depth :	0.5-3.3 ft	Test Id:	105920		
Test Comment:	---				
Sample Description:	Wet, black silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	0.2	99.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	100		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0300	100		
---	0.0190	92		
---	0.0121	57		
---	0.0090	33		
---	0.0065	25		
---	0.0047	19		
---	0.0033	15		
---	0.0015	10		

Coefficients

D_{85} =0.0174 mm	D_{30} =0.0079 mm
D_{60} =0.0126 mm	D_{15} =0.0033 mm
D_{50} =0.0111 mm	D_{10} =0.0015 mm
C_u =N/A	C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (24))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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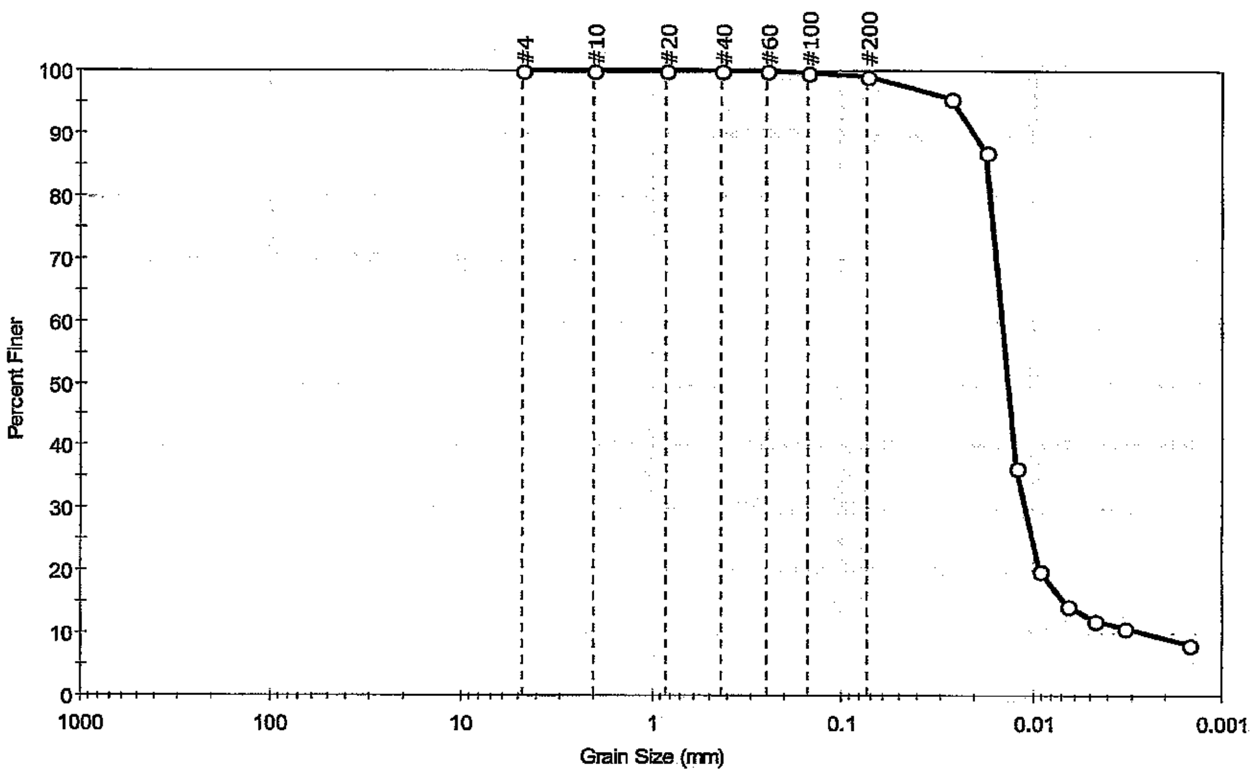
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-40017	Sample Type: jar	Tested By:	mll
Sample ID: OL-0287-05	Test Date: 02/08/07	Checked By:	jdt
Depth : 6.6-9.9 ft	Test Id: 105921		
Test Comment: ---			
Sample Description: Wet, very dark gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.9	99.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	99		
—	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
—	0.0272	96		
—	0.0173	87		
—	0.0123	36		
—	0.0091	20		
—	0.0066	15		
—	0.0047	12		
—	0.0033	11		
—	0.0015	8		

Coefficients

D_{85} = 0.0171 mm	D_{30} = 0.0109 mm
D_{60} = 0.0145 mm	D_{15} = 0.0067 mm
D_{50} = 0.0135 mm	D_{10} = 0.0025 mm
C_u = N/A	C_c = N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (32))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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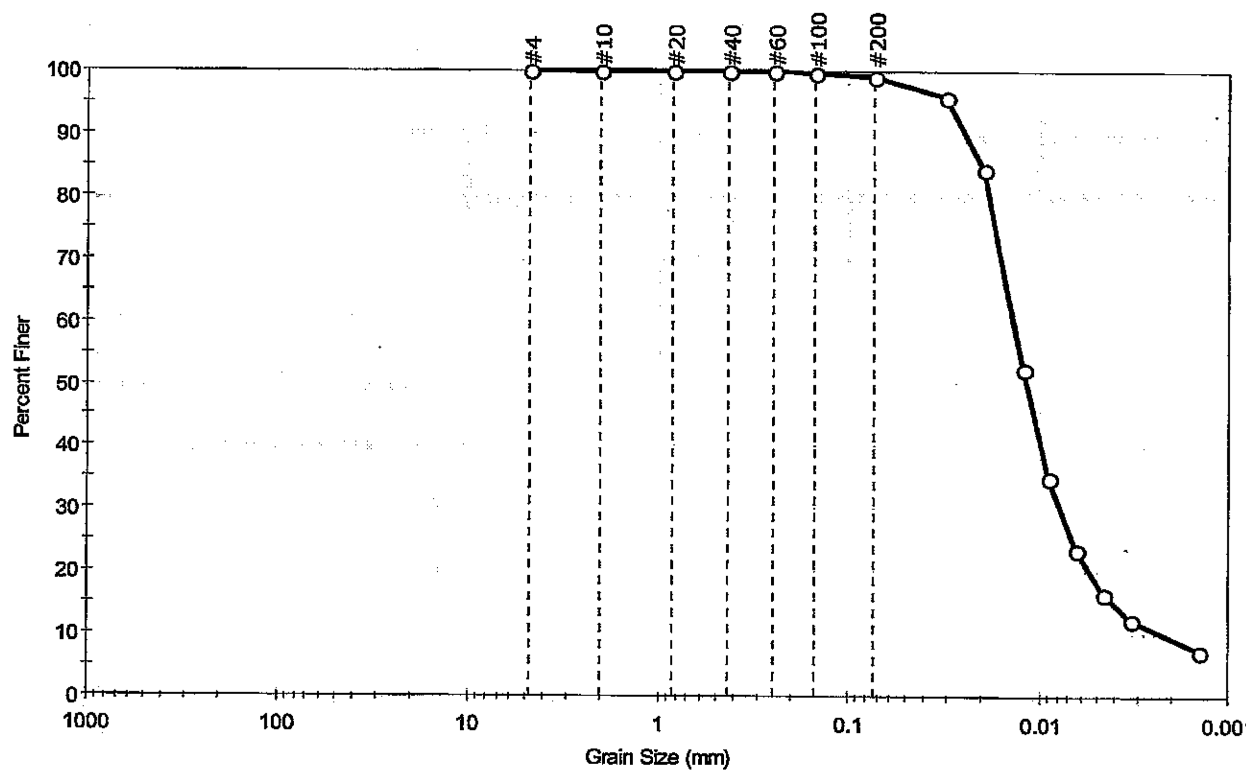
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-40018	Sample Type: jar	Tested By:	mll
Sample ID: OL-0286-04	Test Date: 02/08/07	Checked By:	jdt
Depth : 0-3.3 ft	Test Id: 105899		
Test Comment: ---			
Sample Description: Wet, dark gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.0	99.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	99		
—	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0308	96		
---	0.0197	84		
---	0.0122	53		
---	0.0089	35		
---	0.0065	24		
---	0.0046	16		
---	0.0033	12		
---	0.0014	8		

Coefficients

D_{85} =0.0202 mm D_{30} =0.0077 mm
D_{60} =0.0136 mm D_{15} =0.0041 mm
D_{50} =0.0116 mm D_{10} =0.0022 mm
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (18))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD

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GeoTesting express
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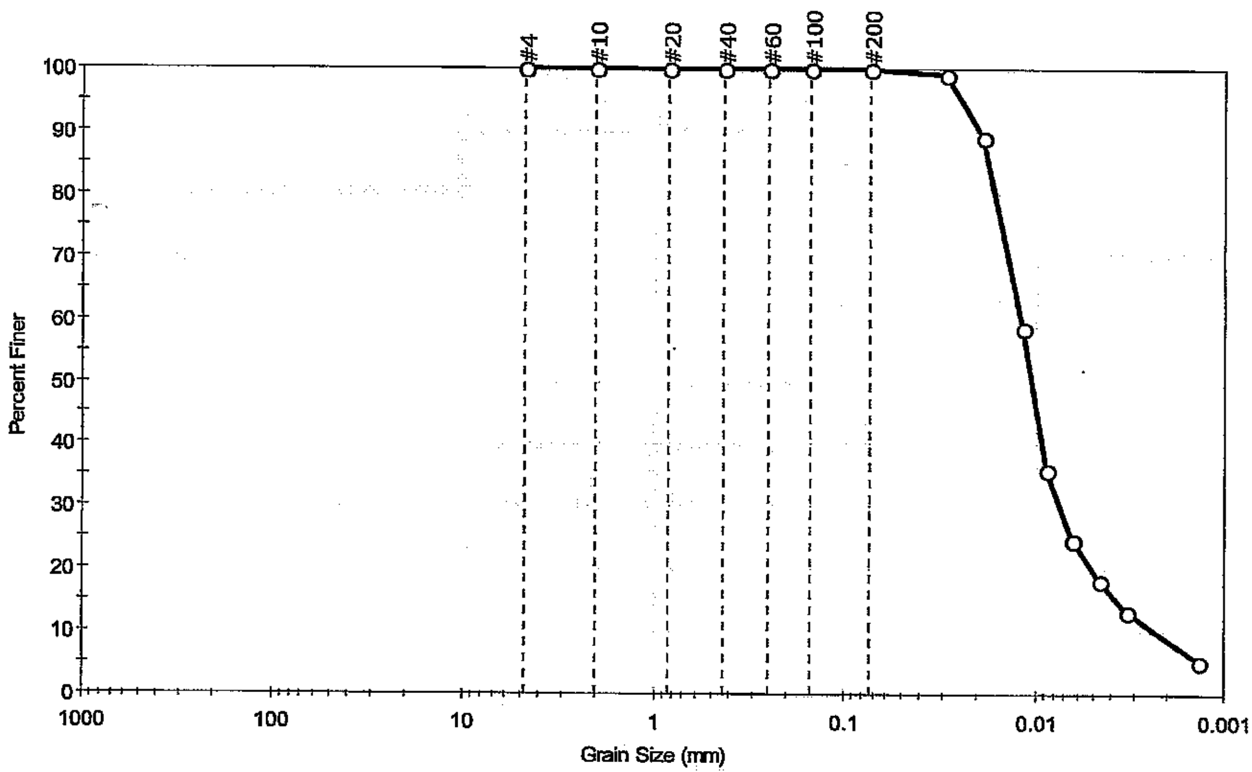
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-40018	Sample Type: jar	Tested By:	mll
Sample ID: OL-0286-05	Test Date: 02/06/07	Checked By:	jdt
Depth : 6.6-9.9 ft	Test Id: 105900		
Test Comment: ---			
Sample Description: Wet, dark gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.1	99.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	100		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0294	99		
---	0.0187	89		
---	0.0117	59		
---	0.0088	36		
---	0.0064	25		
---	0.0046	18		
---	0.0033	13		
---	0.0014	5		

Coefficients

D_{85} =0.0176 mm	D_{30} =0.0074 mm
D_{60} =0.0120 mm	D_{15} =0.0037 mm
D_{50} =0.0105 mm	D_{10} =0.0023 mm
C_u =N/A	C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (26))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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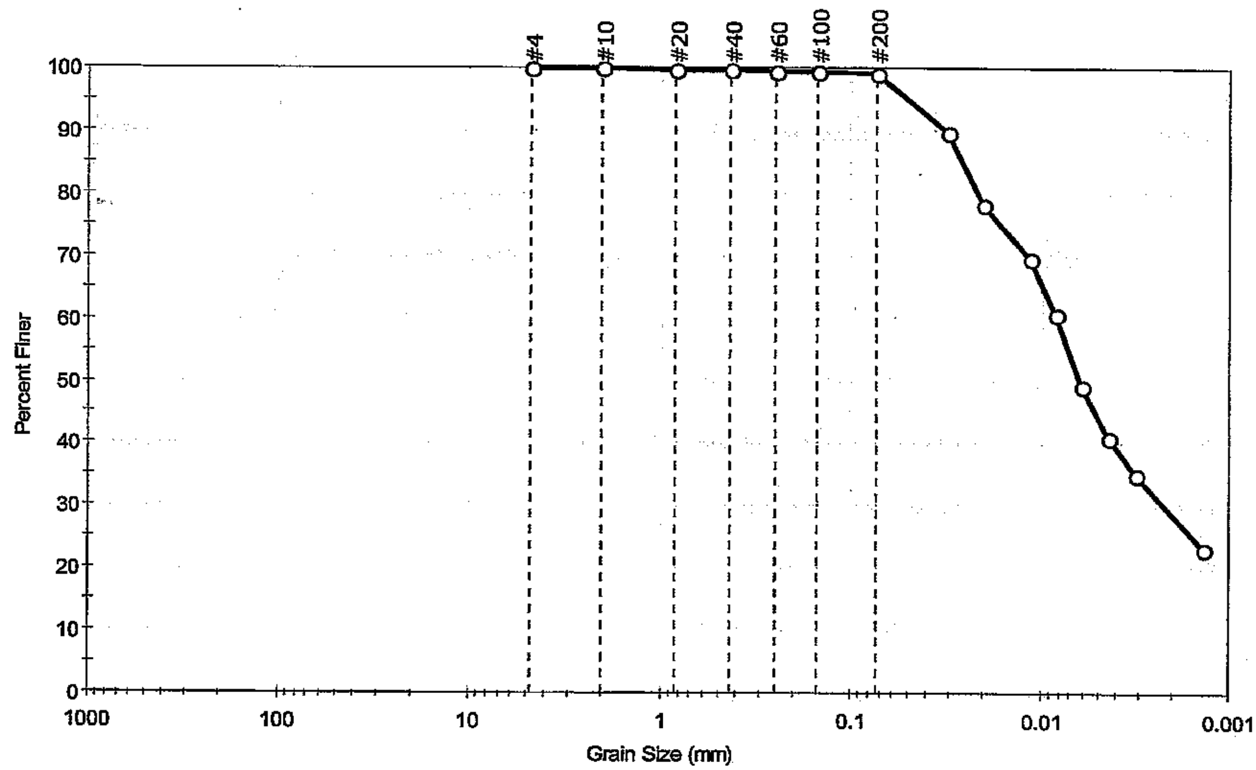
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-40018	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0286-06	Test Date:	02/08/07	Checked By:	jdt
Depth :	16.5-18.6 ft	Test Id:	105901		
Test Comment:	---				
Sample Description:	Moist, olive brown silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.8	99.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	99		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0314	90		
---	0.0200	78		
---	0.0115	69		
---	0.0084	61		
---	0.0061	49		
---	0.0044	41		
---	0.0031	35		
---	0.0014	23		

Coefficients

D_{85} =0.0263 mm | D_{30} =0.0022 mm

D_{60} =0.0082 mm | D_{15} =N/A

D_{50} =0.0062 mm | D_{10} =N/A

C_u =N/A | C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (80))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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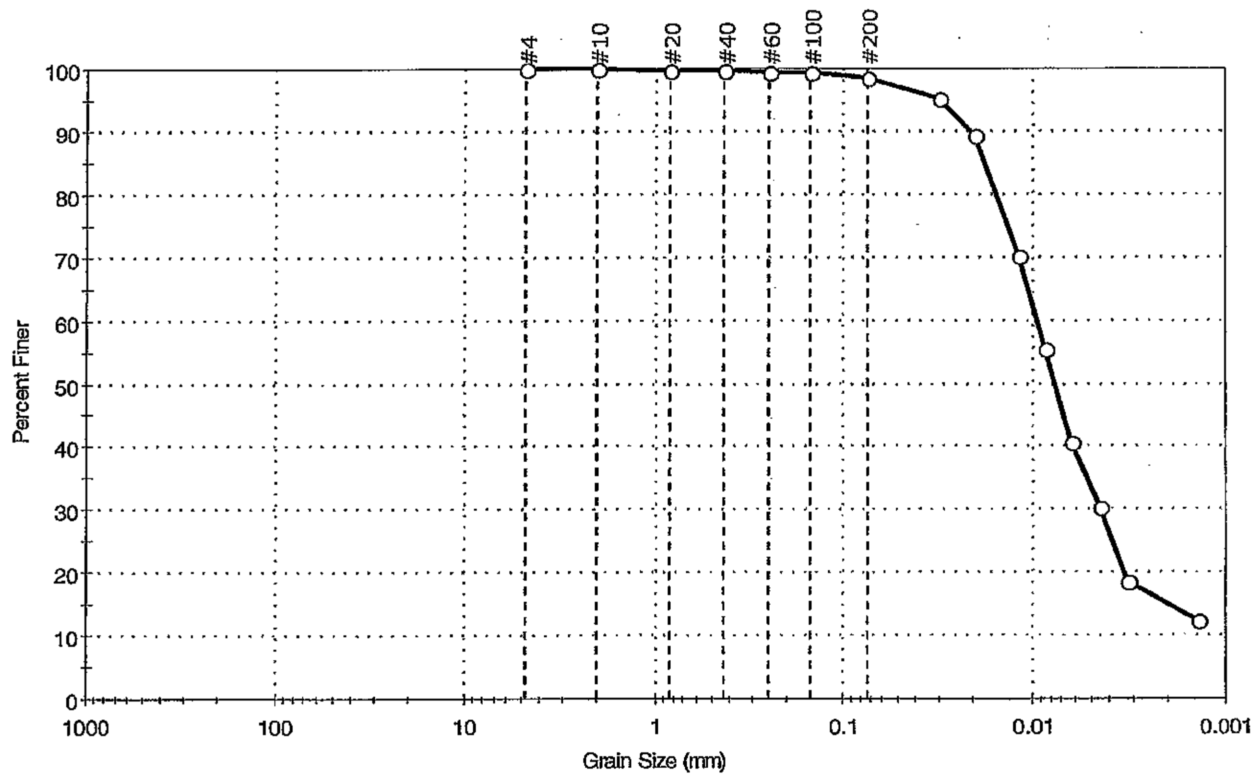
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-40019	Sample Type: jar	Tested By:	mll
Sample ID: OL-0288-07	Test Date: 02/09/07	Checked By:	jdt
Depth : 0.5-3.3 ft	Test Id: 106006		
Test Comment: ---			
Sample Description: Wet, dark gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.5	98.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0306	95		
---	0.0195	89		
---	0.0117	70		
---	0.0085	55		
---	0.0062	41		
---	0.0045	30		
---	0.0033	18		
---	0.0014	12		

Coefficients

D_{85} =0.0174 mm　D_{30} =0.0045 mm
D_{60} =0.0094 mm　D_{15} =0.0020 mm
D_{50} =0.0076 mm　D_{10} =0.0010 mm
C_u =N/A　C_c =N/A

Classification

ASTM　elastic silt (MH)

AASHTO　Clayey Soils (A-7-5 (25))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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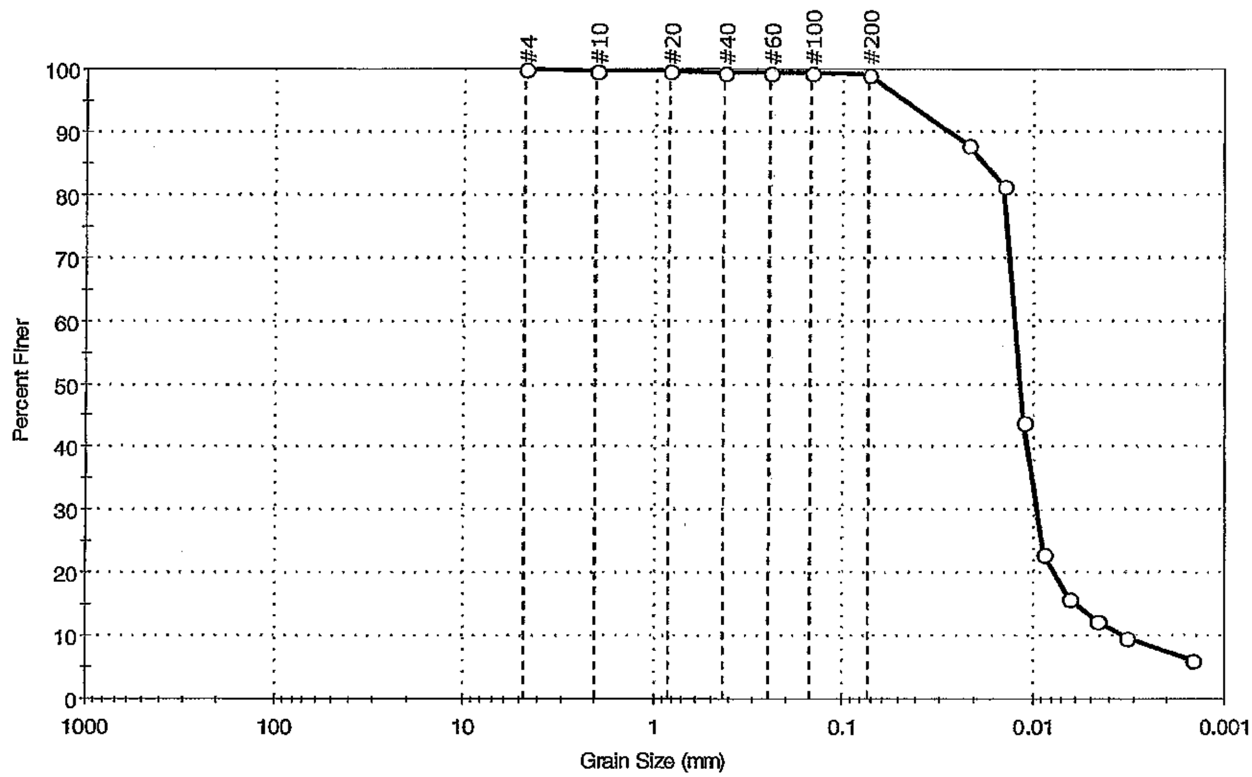
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-40019	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0288-08	Test Date:	02/09/07	Checked By:	jdt
Depth :	9.9-13.2 ft	Test Id:	106007		
Test Comment:	---				
Sample Description:	Wet, dark gray silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.0	99.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	99		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0215	88		
---	0.0142	81		
---	0.0111	44		
---	0.0088	23		
---	0.0064	16		
---	0.0046	12		
---	0.0033	10		
---	0.0015	6		

Coefficients

D_{85} =0.0180 mm D_{30} =0.0095 mm
D_{60} =0.0123 mm D_{15} =0.0059 mm
D_{50} =0.0115 mm D_{10} =0.0034 mm
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (23))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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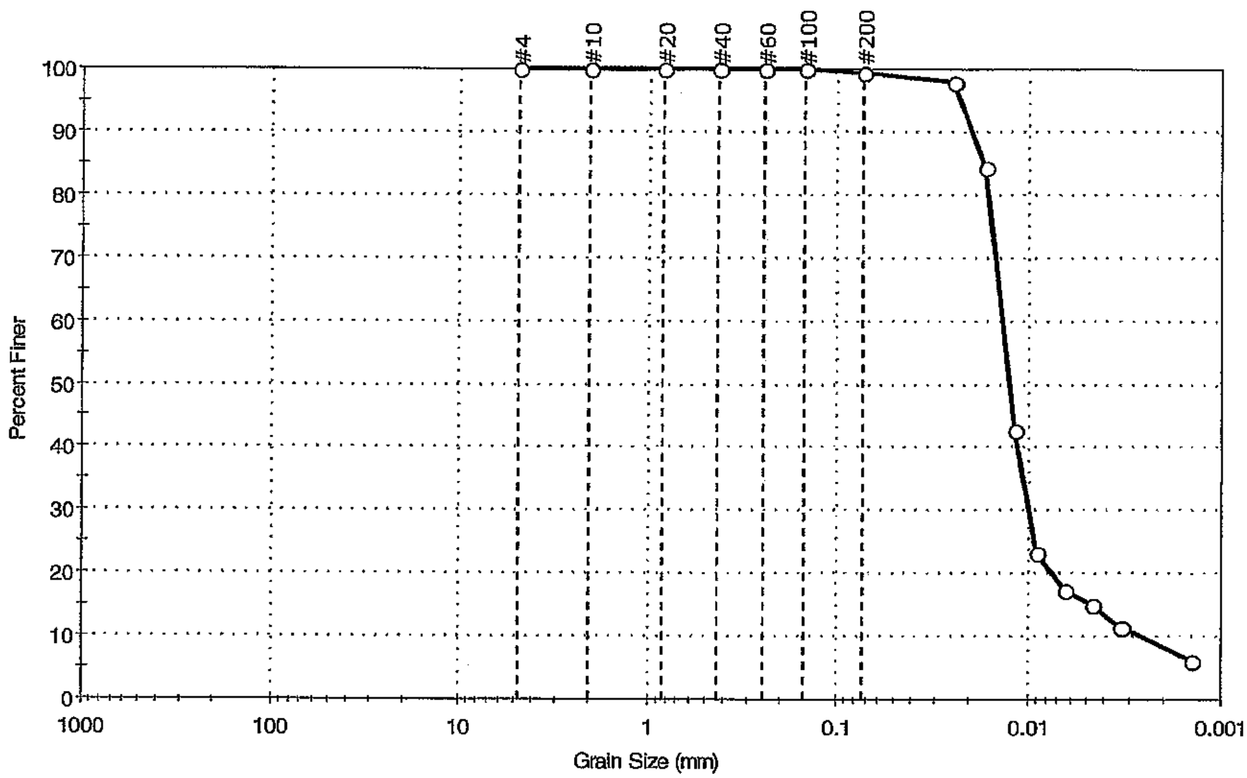
GeoTesting express
a subsidiary of Geocomp Corporation

Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-40019	Sample Type: jar	Tested By:	mll
Sample ID: OL-0288-09	Test Date: 02/09/07	Checked By:	jdt
Depth : 16.5-19.8 ft	Test Id: 106008		
Test Comment: ---			
Sample Description: Moist, gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	0.6	99.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0242	98		
---	0.0166	84		
---	0.0117	43		
---	0.0090	23		
---	0.0065	17		
---	0.0046	15		
---	0.0033	12		
---	0.0014	6		

Coefficients

D_{85} =0.0170 mm	D_{30} =0.0098 mm
D_{60} =0.0136 mm	D_{15} =0.0046 mm
D_{50} =0.0125 mm	D_{10} =0.0026 mm
C_u =N/A	C_c =N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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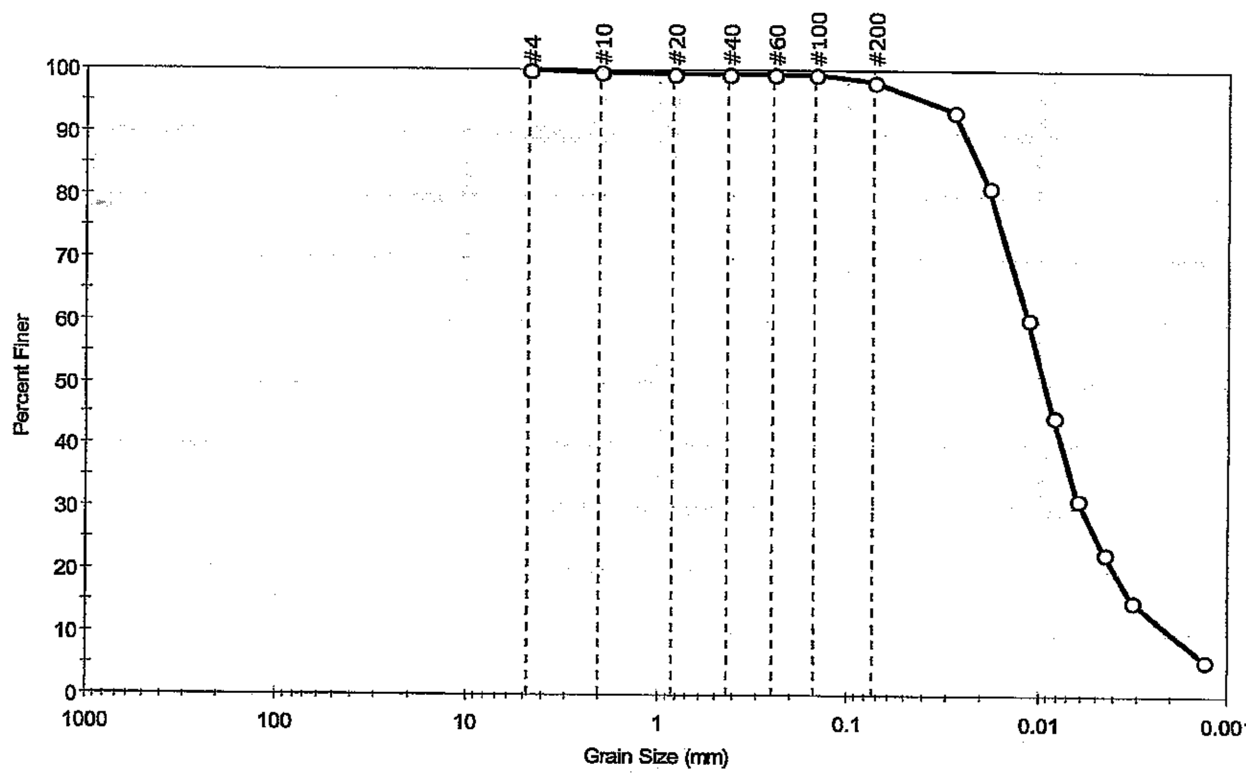
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-40021	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0286-02	Test Date:	02/07/07	Checked By:	jdt
Depth :	0.5-3.3 ft	Test Id:	105897		

Test Comment: ---
Sample Description: Wet, very dark gray silt
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.7	98.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0284	94		
---	0.0185	81		
---	0.0114	60		
---	0.0084	45		
---	0.0062	32		
---	0.0045	23		
---	0.0032	15		
---	0.0013	6		

Coefficients

D_{85} =0.0210 mm	D_{30} =0.0058 mm
D_{60} =0.0114 mm	D_{15} =0.0032 mm
D_{50} =0.0093 mm	D_{10} =0.0020 mm
C_u =N/A	C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (29))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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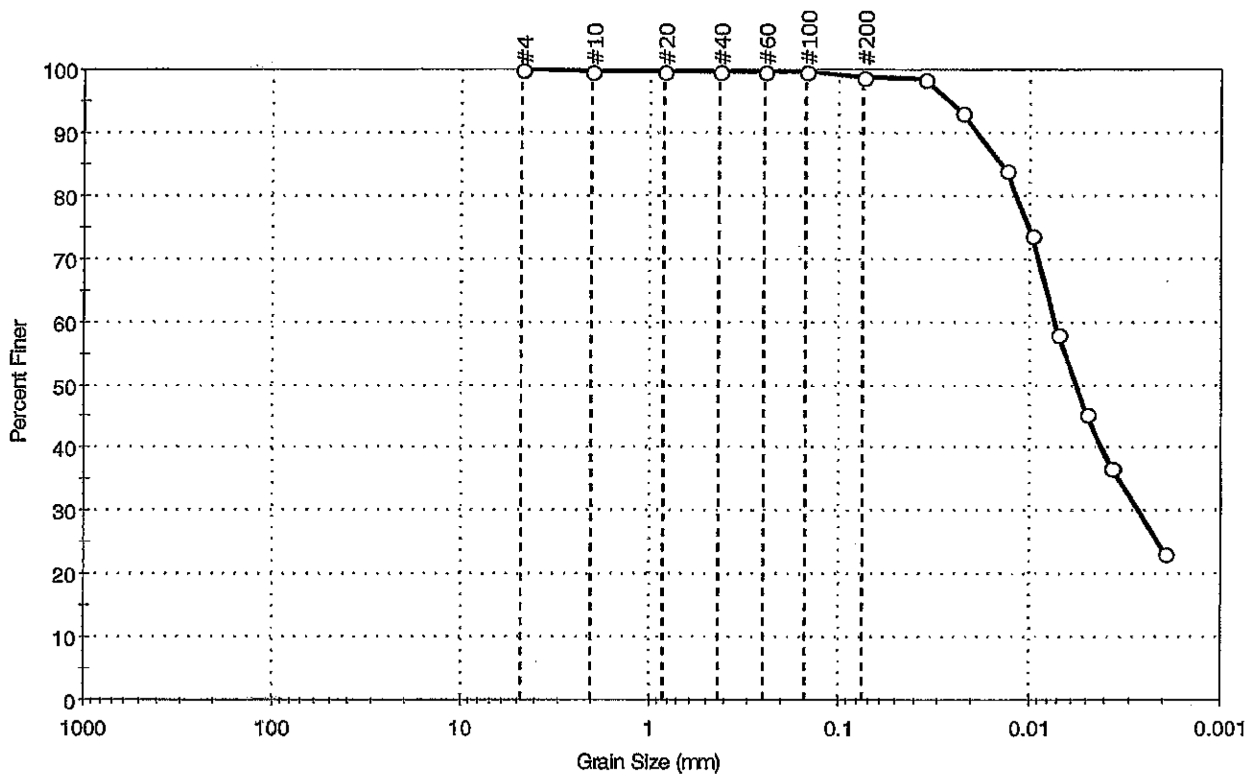
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-0302-07	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-VC-40021	Test Date:	06/08/07	Checked By:	jdt
Depth :	3.3-6.6 ft	Test Id:	111438		
Test Comment:	---				
Sample Description:	Wet, mottled yellowish brown and very dark gray clay				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.2	98.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.075	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0360	98		
---	0.0226	93		
---	0.0130	84		
---	0.0096	74		
---	0.0071	58		
---	0.0050	45		
---	0.0037	37		
---	0.0019	23		

Coefficients

D_{85} =0.0138 mm D_{30} =0.0027 mm
D_{60} =0.0074 mm D_{15} =N/A
D_{50} =0.0056 mm D_{10} =N/A
C_u =N/A C_c =N/A

Classification

ASTM fat clay (CH)

AASHTO Clayey Soils (A-7-6 (31))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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GeoTesting express
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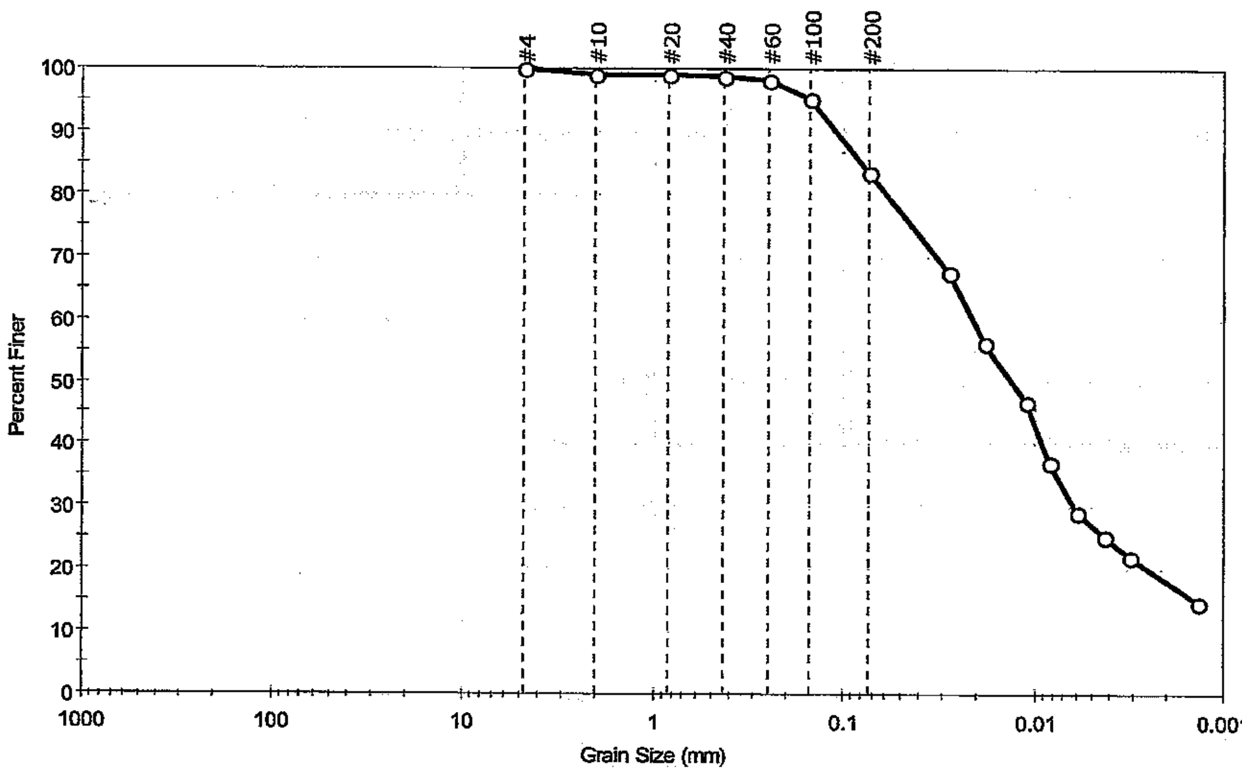
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-40021	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0286-03	Test Date:	02/08/07	Checked By:	jdt
Depth :	13.2-16.5 ft	Test Id:	105898		

Test Comment: ---
Sample Description: Moist, dark olive gray silt with sand
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	16.5	83.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.84	99		
#40	0.42	99		
#60	0.25	98		
#100	0.15	95		
#200	0.074	84		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0285	68		
---	0.0185	56		
---	0.0113	47		
---	0.0083	37		
---	0.0061	29		
---	0.0043	25		
---	0.0031	22		
---	0.0014	15		

Coefficients

D_{85} =0.0808 mm	D_{30} =0.0062 mm
D_{60} =0.0213 mm	D_{15} =0.0014 mm
D_{50} =0.0133 mm	D_{10} =0.0008 mm
C_u =N/A	C_c =N/A

Classification

ASTM elastic silt with sand (MH)

AASHTO Clayey Soils (A-7-5 (29))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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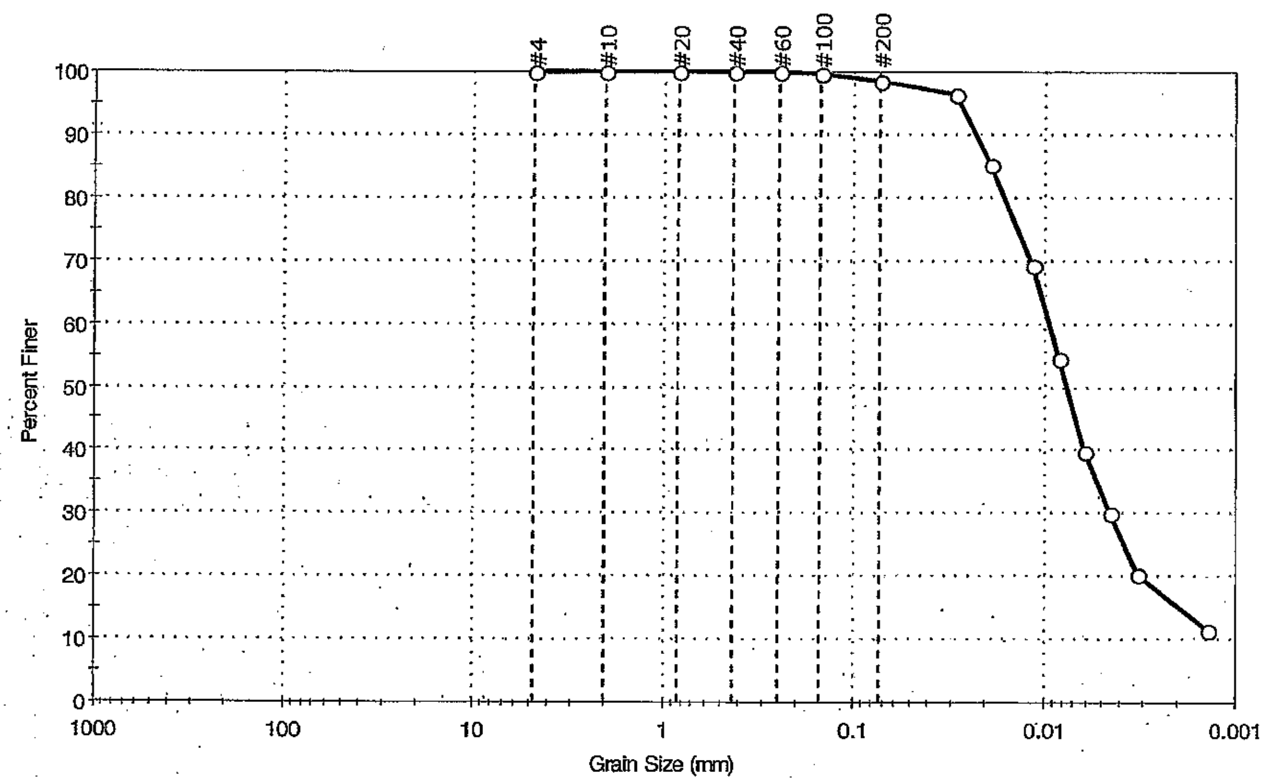
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-40022	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0288-05	Test Date:	02/09/07	Checked By:	jdt
Depth :	0.5-3.3 ft	Test Id:	106004		
Test Comment:	---				
Sample Description:	Moist, dark gray silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.6	98.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0290	96		
---	0.0189	85		
---	0.0114	69		
---	0.0084	55		
---	0.0061	40		
---	0.0044	30		
---	0.0032	20		
---	0.0014	12		

Coefficients

D_{85} =0.0187 mm — D_{30} =0.0044 mm

D_{60} =0.0094 mm — D_{15} =0.0019 mm

D_{50} =0.0076 mm — D_{10} =0.0012 mm

C_u =N/A — C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (28))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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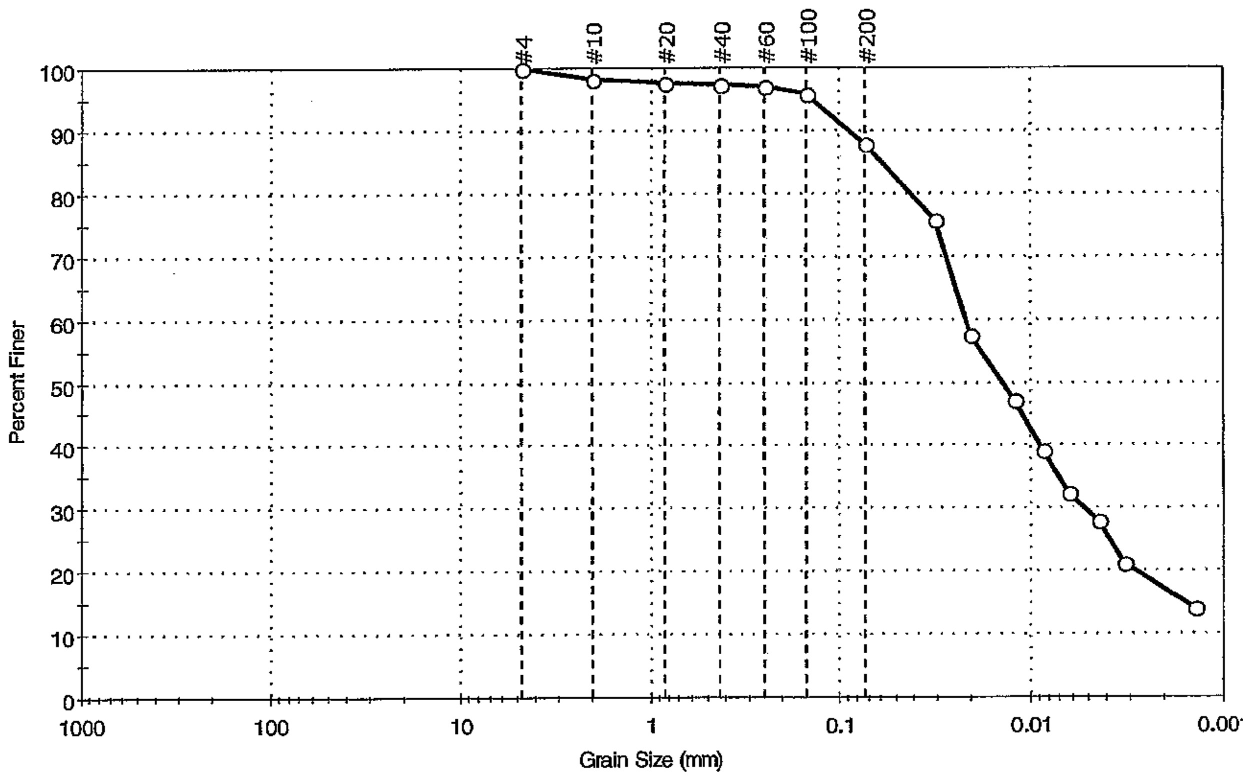
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-40022	Sample Type: jar	Tested By:	mll
Sample ID: OL-0288-06	Test Date: 02/09/07	Checked By:	jdt
Depth : 13.2-16.5 ft	Test Id: 106005		
Test Comment: ---			
Sample Description: Wet, dark brown silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	12.1	87.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	98		
#20	0.84	98		
#40	0.42	97		
#60	0.25	97		
#100	0.15	96		
#200	0.074	88		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0308	76		
---	0.0203	58		
---	0.0119	47		
---	0.0086	39		
---	0.0062	33		
---	0.0044	28		
---	0.0032	21		
---	0.0014	14		

Coefficients

D_{85} =0.0600 mm　D_{30} =0.0051 mm
D_{60} =0.0214 mm　D_{15} =0.0015 mm
D_{50} =0.0137 mm　D_{10} =0.0008 mm
C_u =N/A　C_c =N/A

Classification

ASTM　elastic silt (MH)

AASHTO　Clayey Soils (A-7-5 (46))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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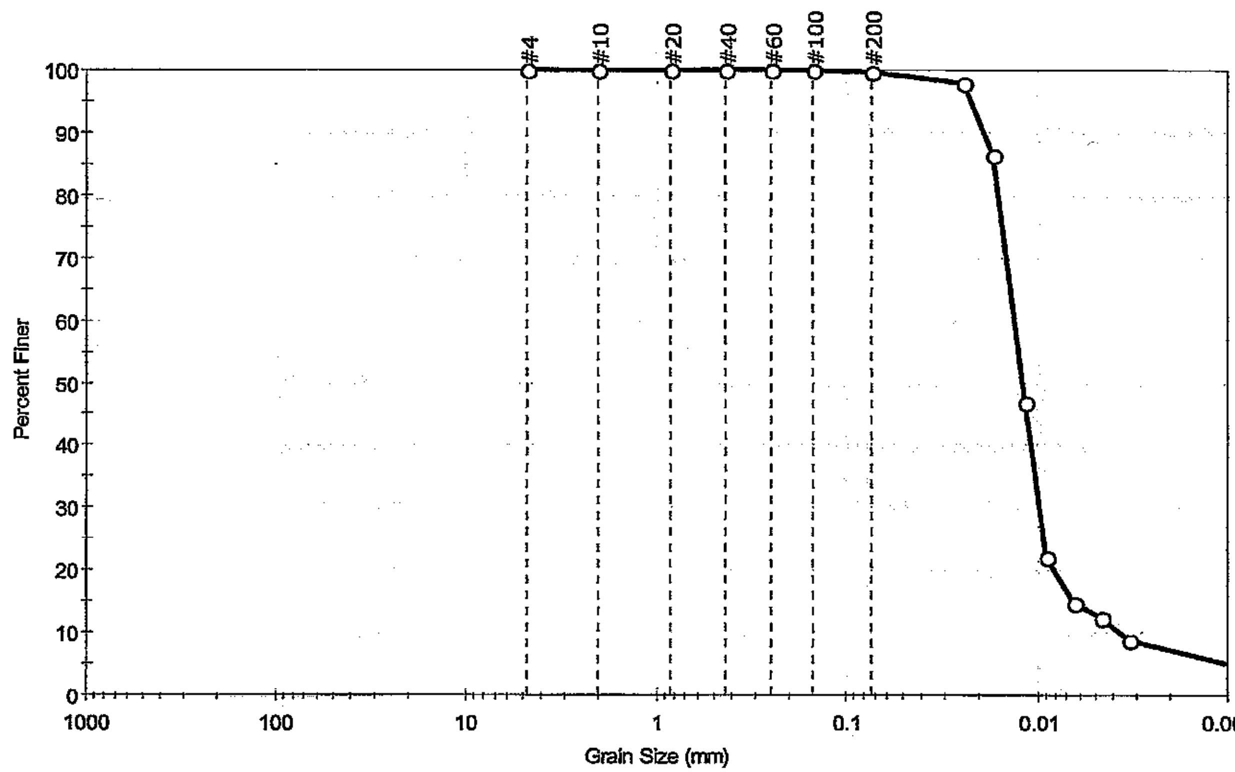
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-40023	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0285-18	Test Date:	02/05/07	Checked By:	jdt
Depth :	3.3-6.6 ft	Test Id:	105848		
Test Comment:	---				
Sample Description:	Wet, very dark gray silt				
Sample Comment:	----				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.4	99.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	100		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0244	98		
---	0.0169	86		
---	0.0116	47		
---	0.0090	22		
---	0.0064	15		
---	0.0046	12		
---	0.0033	9		
---	0.0008	4		

Coefficients

D_{85} =0.0167 mm D_{30} =0.0097 mm

D_{60} =0.0131 mm D_{15} =0.0065 mm

D_{50} =0.0119 mm D_{10} =0.0037 mm

C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (39))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

GeoTesting express
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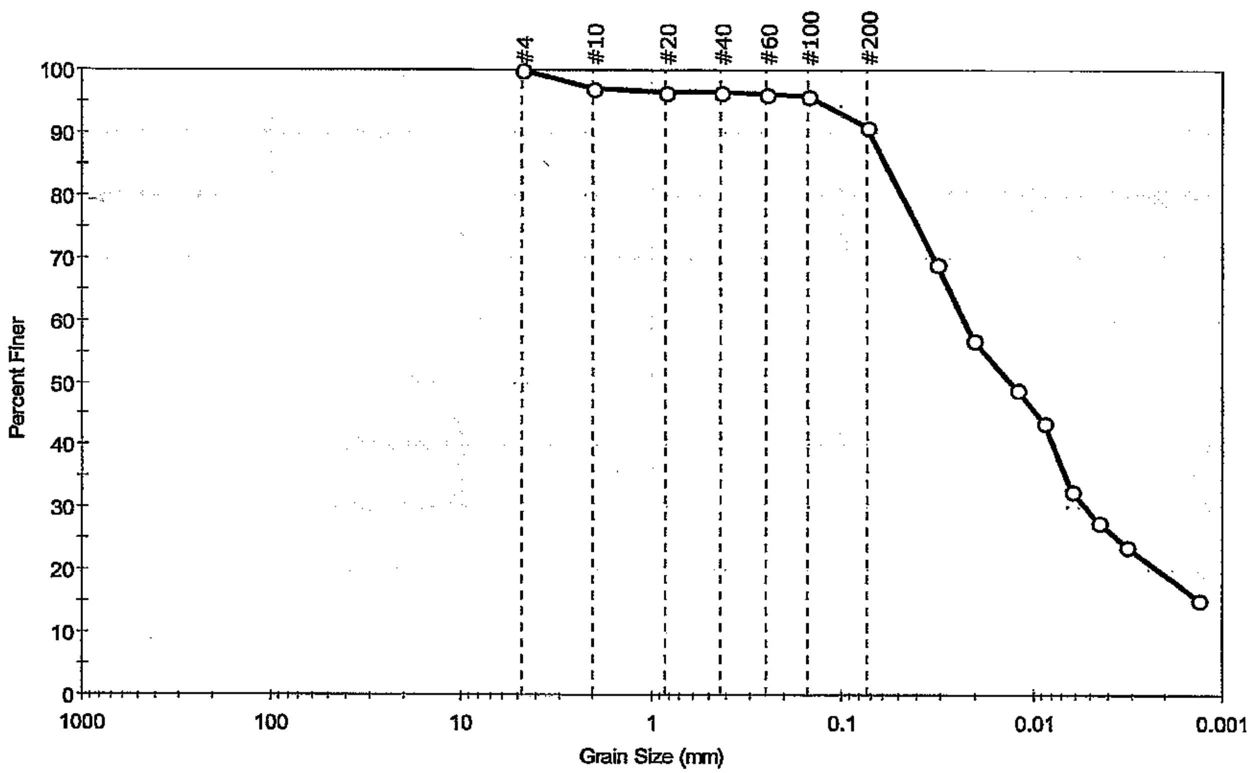
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-40023	Sample Type: jar	Tested By:	mll
Sample ID:OL-0285-19	Test Date: 02/07/07	Checked By:	jdt
Depth : 13.2-16.5 ft	Test Id: 105849		
Test Comment: ---			
Sample Description: Moist, dark brown silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	9.2	90.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	97		
#20	0.84	97		
#40	0.42	96		
#60	0.25	96		
#100	0.15	96		
#200	0.074	91		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0322	69		
---	0.0209	57		
---	0.0122	49		
---	0.0087	44		
---	0.0063	33		
---	0.0045	28		
---	0.0032	24		
---	0.0013	15		

Coefficients

D_{85} =0.0593 mm — D_{30} =0.0052 mm
D_{60} =0.0233 mm — D_{15} =N/A
D_{50} =0.0132 mm — D_{10} =N/A
C_u =N/A — C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (57))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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Sample information for the feasibility study

Sample Number	Station ID	Date	Sample ID	Field Rep	Upper Depth (m)	Lower Depth (m)	Core Length	Data Package ID
SB0019	S344	07/27/00	SB0019	1	0.3	1	2M	K2005759
SB0020	S344	07/27/00	SB0020		1	2	2M	K2005759
SB0029	S338	08/03/00	SB0029		0.3	1.3	2M	K2005951
SB0030	S338	08/03/00	SB0030		1.3	2	2M	K2005951
SB0031	S339	08/03/00	SB0031		0.3	1	2M	K2005951
SB0032	S339	08/03/00	SB0032		1	1.68	2M	K2005951
SB0033	S340	08/03/00	SB0033		0.3	1	2M	K2005951
SB0034	S340	08/03/00	SB0034		1	2	2M	K2005951
SB0037	S342	07/27/00	SB0037		0.3	1	2M	K2005759
SB0038	S342	07/27/00	SB0038		1	2	2M	K2005759
SB0039	S343	08/04/00	SB0039	1	0.3	1	2M	K2005960
SB0040	S343	08/04/00	SB0040		1	2	2M	K2005960
SB0045	S346	08/04/00	SB0045		0.3	1.6	2M	K2005960
SB0046	S346	08/04/00	SB0046		1.6	2	2M	K2005960
SB0047	S347	08/04/00	SB0047		0.3	1	2M	K2005960
SB0048	S347	08/04/00	SB0048		1	2	2M	K2005960
SB0049	S348	08/05/00	SB0049		0.3	1.1	2M	K2006045
SB0050	S348	08/05/00	SB0050		1.1	2	2M	K2006045
SB0053	S350	08/05/00	SB0053		0.3	0.92	2M	K2006045
SB0054	S350	08/05/00	SB0054	1	0.92	2	2M	K2006045
SB0055	S351	08/05/00	SB0055		0.3	1	2M	K2006045
SB0056	S351	08/05/00	SB0056		1	2	2M	K2006045
SB0057	S352	08/10/00	SB0057		0.3	1	2M	K2006154
SB0058	S352	08/10/00	SB0058		1	2	2M	K2006154
SB0063	S341	08/04/00	SB0063		0.3	0.85	2M	K2005960
SB0064	S341	08/04/00	SB0064		0.85	1.6	2M	K2005960
SB0067	S350	08/05/00	SB0054	2	0.92	2	2M	K2006045
SB0070	S344	07/27/00	SB0019	2	0.3	1	2M	K2005759
SF0049	S302	08/14/00	SF0049		0.15	0.3	8M	K2006427
SF0062	S309	08/14/00	SF0062		0	0.15	8M	K2006427
SF0063	S309	08/14/00	SF0063		0.15	0.3	8M	K2006427
SF0064	S310	08/14/00	SF0064		0	0.15	8M	K2006427
SF0065	S310	08/14/00	SF0065		0.15	0.3	8M	K2006427
SF0068	S312	08/14/00	SF0068		0	0.15	8M	K2006427
SF0069	S312	08/14/00	SF0069		0.15	0.3	8M	K2006427
SF0072	S314	08/10/00	SF0072		0	0.15	8M	K2006154
SF0073	S314	08/10/00	SF0073		0.15	0.3	8M	K2006154
SF0075	S315	08/14/00	SF0075		0.15	0.3	8M	K2006427
SF0112	S344	07/27/00	SF0112		0.15	0.3	2M	K2005759
SF0119	S341	08/04/00	SF0119		1.6	2	2M	K2005960
SF0121	S338	08/03/00	SF0121		0	0.15	2M	K2005951
SF0123_E	S339	08/03/00	SF0123_E		1.68	2	2M	K2005951
SF0123	S340	08/15/00	SF0123	1	0	0.02	2M	K2006339
SF0123_R	S340	08/15/00	SF0123	2	0	0.02	2M	K2006412
SF0124	S339	08/03/00	SF0124		0	0.15	2M	K2005951
SF0125	S339	08/03/00	SF0125		0.15	0.3	2M	K2005951
SF0126	S340	08/03/00	SF0126		0	0.15	2M	K2005951
SF0127	S340	08/03/00	SF0127		0.15	0.3	2M	K2005951

Sample information for the feasibility study (cont.)

Sample Number	Station ID	Date	Sample ID	Field Rep	Upper Depth (m)	Lower Depth (m)	Core Length	Data Package ID
SF0128	S341	08/04/00	SF0128		0	0.15	2M	K2005960
SF0129	S341	08/04/00	SF0129		0.15	0.3	2M	K2005960
SF0130_T	S342	08/10/00	SF0130_T		0	0.15	2M	K2006154
SF0131	S342	07/27/00	SF0131		0.15	0.3	2M	K2005759
SF0132	S343	08/04/00	SF0132		0	0.15	2M	K2005960
SF0133	S343	08/04/00	SF0133		0.15	0.3	2M	K2005960
SF0138	S346	08/04/00	SF0138		0	0.15	2M	K2005960
SF0139	S346	08/04/00	SF0139		0.15	0.3	2M	K2005960
SF0140	S347	08/04/00	SF0140		0	0.15	2M	K2005960
SF0141	S347	08/04/00	SF0141		0.15	0.3	2M	K2005960
SF0142	S348	08/05/00	SF0142		0	0.15	2M	K2006045
SF0143	S348	08/05/00	SF0143		0.15	0.3	2M	K2006045
SF0146	S350	08/05/00	SF0146		0	0.15	2M	K2006045
SF0147	S350	08/05/00	SF0147		0.15	0.3	2M	K2006045
SF0149	S351	08/05/00	SF0149		0	0.15	2M	K2006045
SF0151	S352	08/10/00	SF0151		0	0.15	2M	K2006154
SF0152	S352	08/10/00	SF0152		0.15	0.3	2M	K2006154
SF0167	S343	08/04/00	SB0039	2	0.3	1	2M	K2005960
SF0173	S351	08/15/00	SF0173		0	0.02	2M	K2006339
VC0009	S302	07/22/00	VC0009		0.3	0.59	8M	K2005515
VC0010	S302	07/22/00	VC0010		0.59	1.59	8M	K2005515
VC0011	S302	07/22/00	VC0011		1.59	2.59	8M	K2005515
VC0012	S302	07/22/00	VC0012		2.59	3.59	8M	K2005515
VC0013	S302	07/22/00	VC0013		3.59	4.59	8M	K2005515
VC0014	S302	07/22/00	VC0014		4.59	5.59	8M	K2005515
VC0015	S302	07/22/00	VC0015		5.59	6.59	8M	K2005515
VC0016	S302	07/22/00	VC0016		6.59	7.61	8M	K2005515
VC0065	S309	07/20/00	VC0065		0.74	1.74	8M	K2005510
VC0066	S309	07/20/00	VC0066	1	1.74	2.74	8M	K2005510
VC0067	S309	07/20/00	VC0067		2.74	3.74	8M	K2005510
VC0068	S309	07/20/00	VC0068		3.74	4.74	8M	K2005510
VC0069	S309	07/20/00	VC0069		4.74	5.78	8M	K2005510
VC0070	S309	07/20/00	VC0070		5.78	6.27	8M	K2005510
VC0071	S309	07/20/00	VC0071		6.27	6.74	8M	K2005510
VC0072	S309	07/20/00	VC0072		6.74	6.96	8M	K2005510
VC0073	S310	07/20/00	VC0073		0.3	1	8M	K2005510
VC0074	S310	07/20/00	VC0074		1	2	8M	K2005510
VC0075	S310	07/20/00	VC0075		2	3	8M	K2005510
VC0076	S310	07/20/00	VC0076	1	3	4	8M	K2005510
VC0077	S310	07/20/00	VC0077		4	5	8M	K2005510
VC0078	S310	07/20/00	VC0078		5	6	8M	K2005510
VC0079	S310	07/20/00	VC0079		6	6.53	8M	K2005510
VC0080	S310	07/20/00	VC0080		6.53	7.24	8M	K2005510
VC0081	S311	07/20/00	VC0081		0.3	1	8M	K2005510
VC0082	S311	07/20/00	VC0082		1	2	8M	K2005510
VC0083	S311	07/20/00	VC0083		2	3	8M	K2005510
VC0084	S311	07/20/00	VC0084		3	4	8M	K2005510
VC0085	S311	07/20/00	VC0085		4	5	8M	K2005510

S302

COLUMBIA ANALYTICAL SERVICES, INC.

Analytical Report

Client: Exponent Environmental Group, Inc.
Project: OL RI/FS Phase 2A / 8600BCP.003.0801
Sample Matrix: Sediment

Service Request: K2006427
Date Collected: 8/14/00
Date Received: 8/15/00
Date Analyzed: 8/28/00

Particle Size Determination
ASTM Method D 422

Sample Name: SF0049
Lab Code: K2006427-001

Gravel and Sand
(Sieve Analysis)

Description	Sieve Size	Weight (g)	Percent Passing
Gravel	No.3/4"(19.0 mm)	0.0000	100
Gravel	No.3/8"(9.50 mm)	0.0000	100
Medium Gravel	No.4 (4.75 mm)	0.0000	100
Fine Gravel	No.10 (2.00 mm)	0.0000	100
Very Coarse Sand	No.20 (0.850 mm)	0.0134	100
Coarse Sand	No.40 (0.425 mm)	0.0375	99.9
Medium Sand	No.60 (0.250 mm)	0.0421	99.8
Fine Sand	No.140 (0.106 mm)	0.3127	99.2
Very Fine Sand	No.200 (0.0750 mm)	0.7894	97.6

Silt and Clay
(Hydrometer Analysis)

Particle Diameter	Percent Passing
0.074 mm	97.5
0.005 mm	27.2
0.001 mm	7.5

Approved By: ______________________ Date: ____________
1A/102094

		Sample Name:	SF0049		
		Lab Code:	K2006427-001		
		X	Y		
		arithmetic	logarithmic	Convert Y	Value of Y
		Percent Passing	Particle Diameter	mm to nm	Log form
Sieve		(%)	(mm)	(nm)	(log)
3/4"		100.0	19.0	19000000	7.279
3/8"		100.0	9.5	9500000	6.978
4		100.0	4.75	4750000	6.677
10		100.0	2.00	2000000	6.301
20		100.0	0.850	850000	5.929
40		99.9	0.425	425000	5.628
60		99.8	0.250	250000	5.398
140		99.2	0.106	106000	5.025
200		97.6	0.0750	75000	4.875
2		84.7	0.0298	29817.64788	4.474
5		74.7	0.0197	19668.92627	4.294
15		56.8	0.0122	12152.91898	4.085
30		46.8	0.0089	8891.101637	3.949
60		32.9	0.0066	6570.336525	3.818
250		18.9	0.0034	3351.87589	3.525
1440		11.0	0.0014	1445.048639	3.160
	determined hydrometer				
		mm	mm to nm	log hyd x	% Passing
		0.074	74000	4.87	97.5
		0.005	5000	3.70	27.2
		0.001	1000	3.00	7.5

COLUMBIA ANALYTICAL SERVICES, INC.

Analytical Report

Client: Exponent Environmental Group, Inc.
Project: OL RI/FS Phase 2A / 8600BCP.003.0801
Sample Matrix: Soil

Service Request: K2005515
Date Collected: 7/22/00
Date Received: 7/23/00
Date Analyzed: 8/1/00

Particle Size Determination
ASTM Method D 422

Sample Name: VC0009
Lab Code: K2005515-001

Gravel and Sand
(Sieve Analysis)

Description	Sieve Size	Weight (g)	Percent Passing
Gravel	No.3/4"(19.0 mm)	0.0000	100
Gravel	No.3/8"(9.50 mm)	0.0000	100
Medium Gravel	No.4 (4.75 mm)	0.0000	100
Fine Gravel	No.10 (2.00 mm)	0.0000	100
Very Coarse Sand	No.20 (0.850 mm)	0.0216	100
Coarse Sand	No.40 (0.425 mm)	0.0311	99.9
Medium Sand	No.60 (0.250 mm)	0.1538	99.6
Fine Sand	No.140 (0.106 mm)	2.0186	95.4
Very Fine Sand	No.200 (0.0750 mm)	0.4355	94.5

Silt and Clay
(Hydrometer Analysis)

Particle Diameter	Percent Passing
0.074 mm	94.4
0.005 mm	31.5
0.001 mm	0.9

Approved By: ______________________________ Date: ______________
1A/102094

		Sample Name:	**VC0009**		
		Lab Code:	**K2005515-001**		
		X	**Y**		
		arithmetic	**logarithmic**	**Convert Y**	**Value of Y**
		Percent Passing	**Particle Diameter**	**mm to nm**	**Log form**
Sieve		**(%)**	**(mm)**	**(nm)**	**(log)**
3/4"		100.0	19.0	19000000	7.279
3/8"		100.0	9.5	9500000	6.978
4		100.0	4.75	4750000	6.677
10		100.0	2.00	2000000	6.301
20		100.0	0.850	850000	5.929
40		99.9	0.425	425000	5.628
60		99.6	0.250	250000	5.398
140		95.4	0.106	106000	5.025
200		94.5	0.0750	75000	4.875
2		84.1	0.0299	29879.29106	4.475
5		79.9	0.0192	19215.27494	4.284
15		69.5	0.0115	11540.10016	4.062
30		57.1	0.0085	8523.259038	3.931
60		40.5	0.0064	6353.132941	3.803
250		15.6	0.0033	3260.324769	3.513
1440		5.2	0.0014	1411.435279	3.150
	determined hydrometer				
		mm	**mm to nm**	**log hyd x**	**% Passing**
		0.074	74000	4.87	94.4
		0.005	5000	3.70	31.5
		0.001	1000	3.00	0.9

COLUMBIA ANALYTICAL SERVICES, INC.

Analytical Report

Client:	Exponent Environmental Group, Inc.	**Service Request:**	K2005515
Project:	OL RI/FS Phase 2A / 8600BCP.003.0801	**Date Collected:**	7/22/00
Sample Matrix:	Soil	**Date Received:**	7/23/00
		Date Analyzed:	8/1/00

Particle Size Determination
ASTM Method D 422

Sample Name: VC0010
Lab Code: K2005515-002

Gravel and Sand
(Sieve Analysis)

Description	Sieve Size	Weight (g)	Percent Passing
Gravel	No.3/4"(19.0 mm)	0.0000	100
Gravel	No.3/8"(9.50 mm)	0.0000	100
Medium Gravel	No.4 (4.75 mm)	0.0000	100
Fine Gravel	No.10 (2.00 mm)	0.0000	100
Very Coarse Sand	No.20 (0.850 mm)	0.0790	99.8
Coarse Sand	No.40 (0.425 mm)	0.0175	99.8
Medium Sand	No.60 (0.250 mm)	0.0143	99.8
Fine Sand	No.140 (0.106 mm)	0.1276	99.5
Very Fine Sand	No.200 (0.0750 mm)	0.0924	99.3

Silt and Clay
(Hydrometer Analysis)

Particle Diameter	Percent Passing
0.074 mm	99.3
0.005 mm	42.3
0.001 mm	5.7

Approved By: ______________________________ Date: ______________
1A/102094

		Sample Name:	VC0010		
		Lab Code:	K2005515-002		
		X	Y		
		arithmetic	logarithmic	Convert Y	Value of Y
		Percent Passing	Particle Diameter	mm to nm	Log form
Sieve		(%)	(mm)	(nm)	(log)
3/4"		100.0	19.0	19000000	7.279
3/8"		100.0	9.5	9500000	6.978
4		100.0	4.75	4750000	6.677
10		100.0	2.00	2000000	6.301
20		99.8	0.850	850000	5.929
40		99.8	0.425	425000	5.628
60		99.8	0.250	250000	5.398
140		99.5	0.106	106000	5.025
200		99.3	0.0750	75000	4.875
2		95.7	0.0277	27714.38682	4.443
5		93.7	0.0177	17696.05135	4.248
15		79.6	0.0109	10871.33239	4.036
30		65.5	0.0081	8123.679121	3.910
60		49.4	0.0061	6077.881238	3.784
250		25.2	0.0031	3132.614125	3.496
1440		11.1	0.0014	1372.851548	3.138
	determined hydrometer				
		mm	mm to nm	log hyd x	% Passing
		0.074	74000	4.87	99.3
		0.005	5000	3.70	42.3
		0.001	1000	3.00	5.7

COLUMBIA ANALYTICAL SERVICES, INC.

Analytical Report

Client: Exponent Environmental Group, Inc.
Project: OL RI/FS Phase 2A / 8600BCP.003.0801
Sample Matrix: Soil

Service Request: K2005515
Date Collected: 7/22/00
Date Received: 7/23/00
Date Analyzed: 8/1/00

Particle Size Determination
ASTM Method D 422

Sample Name: VC0011
Lab Code: K2005515-003

Gravel and Sand
(Sieve Analysis)

Description	Sieve Size	Weight (g)	Percent Passing
Gravel	No.3/4"(19.0 mm)	0.0000	100
Gravel	No.3/8"(9.50 mm)	0.0000	100
Medium Gravel	No.4 (4.75 mm)	0.0000	100
Fine Gravel	No.10 (2.00 mm)	0.0000	100
Very Coarse Sand	No.20 (0.850 mm)	0.1104	99.8
Coarse Sand	No.40 (0.425 mm)	0.0261	99.7
Medium Sand	No.60 (0.250 mm)	0.0240	99.7
Fine Sand	No.140 (0.106 mm)	0.3896	98.9
Very Fine Sand	No.200 (0.0750 mm)	0.1652	98.6

Silt and Clay
(Hydrometer Analysis)

Particle Diameter	Percent Passing
0.074 mm	98.5
0.005 mm	34.4
0.001 mm	9.6

Approved By: ______________________ Date: ____________
1A/102094

		Sample Name:	**VC0011**		
		Lab Code:	**K2005515-003**		
		X	**Y**		
		arithmetic	**logarithmic**	**Convert Y**	**Value of Y**
		Percent Passing	**Particle Diameter**	**mm to nm**	**Log form**
Sieve		**(%)**	**(mm)**	**(nm)**	**(log)**
3/4"		100.0	19.0	19000000	7.279
3/8"		100.0	9.5	9500000	6.978
4		100.0	4.75	4750000	6.677
10		100.0	2.00	2000000	6.301
20		99.8	0.850	850000	5.929
40		99.7	0.425	425000	5.628
60		99.7	0.250	250000	5.398
140		98.9	0.106	106000	5.025
200		98.6	0.0750	75000	4.875
2		96.0	0.0275	27547.13969	4.440
5		87.9	0.0181	18080.77989	4.257
15		71.8	0.0112	11160.46415	4.048
30		57.6	0.0083	8312.410396	3.920
60		43.5	0.0062	6160.939584	3.790
250		15.2	0.0032	3201.991671	3.505
1440		11.1	0.0014	1364.565565	3.135
	determined hydrometer				
		mm	**mm to nm**	**log hyd x**	**% Passing**
		0.074	74000	4.87	98.5
		0.005	5000	3.70	34.4
		0.001	1000	3.00	9.6

COLUMBIA ANALYTICAL SERVICES, INC.

Analytical Report

Client:	Exponent Environmental Group, Inc.	**Service Request:**	K2005515
Project:	OL RI/FS Phase 2A / 8600BCP.003.0801	**Date Collected:**	7/22/00
Sample Matrix:	Soil	**Date Received:**	7/23/00
		Date Analyzed:	8/1/00

Particle Size Determination
ASTM Method D 422

Sample Name: VC0012
Lab Code: K2005515-004

Gravel and Sand
(Sieve Analysis)

Description	Sieve Size	Weight (g)	Percent Passing
Gravel	No.3/4"(19.0 mm)	0.0000	100
Gravel	No.3/8"(9.50 mm)	0.0000	100
Medium Gravel	No.4 (4.75 mm)	0.0000	100
Fine Gravel	No.10 (2.00 mm)	0.0000	100
Very Coarse Sand	No.20 (0.850 mm)	0.0771	99.8
Coarse Sand	No.40 (0.425 mm)	0.0331	99.8
Medium Sand	No.60 (0.250 mm)	0.0220	99.7
Fine Sand	No.140 (0.106 mm)	0.1143	99.5
Very Fine Sand	No.200 (0.0750 mm)	0.2011	99.1

Silt and Clay
(Hydrometer Analysis)

Particle Diameter	Percent Passing
0.074 mm	99.0
0.005 mm	20.5
0.001 mm	5.2

Approved By: ______________________ Date: __________
1A/102094

	Sample Name:	VC0012		
	Lab Code:	K2005515-004		
	X	Y		
	arithmetic	logarithmic	Convert Y	Value of Y
	Percent Passing	Particle Diameter	mm to nm	Log form
Sieve	(%)	(mm)	(nm)	(log)
3/4"	100.0	19.0	19000000	7.279
3/8"	100.0	9.5	9500000	6.978
4	100.0	4.75	4750000	6.677
10	100.0	2.00	2000000	6.301
20	99.8	0.850	850000	5.929
40	99.8	0.425	425000	5.628
60	99.7	0.250	250000	5.398
140	99.5	0.106	106000	5.025
200	99.1	0.0750	75000	4.875
2	92.1	0.0282	28242.94479	4.451
5	88.0	0.0182	18190.55385	4.260
15	69.8	0.0113	11315.68671	4.054
30	55.7	0.0084	8421.615721	3.925
60	21.2	0.0066	6621.319264	3.821
250	19.2	0.0032	3186.204417	3.503
1440	9.1	0.0014	1380.139373	3.140
	determined hydrometer			
	mm	mm to nm	log hyd x	% Passing
	0.074	74000	4.87	99.0
	0.005	5000	3.70	20.5
	0.001	1000	3.00	5.2

COLUMBIA ANALYTICAL SERVICES, INC.

Analytical Report

Client:	Exponent Environmental Group, Inc.	**Service Request:**	K2005515
Project:	OL RI/FS Phase 2A / 8600BCP.003.0801	**Date Collected:**	7/22/00
Sample Matrix:	Soil	**Date Received:**	7/23/00
		Date Analyzed:	8/1/00

Particle Size Determination
ASTM Method D 422

Sample Name: VC0013
Lab Code: K2005515-005

Gravel and Sand
(Sieve Analysis)

Description	Sieve Size	Weight (g)	Percent Passing
Gravel	No.3/4"(19.0 mm)	0.0000	100
Gravel	No.3/8"(9.50 mm)	0.0000	100
Medium Gravel	No.4 (4.75 mm)	0.0000	100
Fine Gravel	No.10 (2.00 mm)	0.0000	100
Very Coarse Sand	No.20 (0.850 mm)	0.0162	100
Coarse Sand	No.40 (0.425 mm)	0.0129	99.9
Medium Sand	No.60 (0.250 mm)	0.0152	99.9
Fine Sand	No.140 (0.106 mm)	0.3340	99.2
Very Fine Sand	No.200 (0.0750 mm)	0.3723	98.5

Silt and Clay
(Hydrometer Analysis)

Particle Diameter	Percent Passing
0.074 mm	98.4
0.005 mm	40.8
0.001 mm	4.3

Approved By: ______________________________ Date: ______________
1A/102094

		Sample Name:	**VC0013**		
		Lab Code:	**K2005515-005**		
		X	**Y**		
		arithmetic	**logarithmic**	**Convert Y**	**Value of Y**
		Percent Passing	**Particle Diameter**	**mm to nm**	**Log form**
Sieve		**(%)**	**(mm)**	**(nm)**	**(log)**
3/4"		100.0	19.0	19000000	7.279
3/8"		100.0	9.5	9500000	6.978
4		100.0	4.75	4750000	6.677
10		100.0	2.00	2000000	6.301
20		100.0	0.850	850000	5.929
40		99.9	0.425	425000	5.628
60		99.9	0.250	250000	5.398
140		99.2	0.106	106000	5.025
200		98.5	0.0750	75000	4.875
2		92.7	0.0286	28583.8184	4.456
5		86.6	0.0186	18573.92893	4.269
15		74.3	0.0113	11274.5254	4.052
30		62.1	0.0083	8343.647298	3.921
60		49.9	0.0062	6151.237234	3.789
250		21.4	0.0032	3206.690693	3.506
1440		9.2	0.0014	1396.799311	3.145
	determined hydrometer				
		mm	**mm to nm**	**log hyd x**	**% Passing**
		0.074	74000	4.87	98.4
		0.005	5000	3.70	40.8
		0.001	1000	3.00	4.3

COLUMBIA ANALYTICAL SERVICES, INC.

Analytical Report

Client: Exponent Environmental Group, Inc.
Project: OL RI/FS Phase 2A / 8600BCP.003.0801
Sample Matrix: Soil

Service Request: K2005515
Date Collected: 7/22/00
Date Received: 7/23/00
Date Analyzed: 8/1/00

Particle Size Determination
ASTM Method D 422

Sample Name: VC0014
Lab Code: K2005515-006

Gravel and Sand
(Sieve Analysis)

Description	Sieve Size	Weight (g)	Percent Passing
Gravel	No.3/4"(19.0 mm)	0.0000	100
Gravel	No.3/8"(9.50 mm)	0.0000	100
Medium Gravel	No.4 (4.75 mm)	0.0000	100
Fine Gravel	No.10 (2.00 mm)	0.0000	100
Very Coarse Sand	No.20 (0.850 mm)	0.0918	99.8
Coarse Sand	No.40 (0.425 mm)	0.0290	99.8
Medium Sand	No.60 (0.250 mm)	0.0272	99.7
Fine Sand	No.140 (0.106 mm)	0.2194	99.3
Very Fine Sand	No.200 (0.0750 mm)	0.3263	98.6

Silt and Clay
(Hydrometer Analysis)

Particle Diameter	Percent Passing
0.074 mm	98.4
0.005 mm	45.5
0.001 mm	12.9

Approved By: ______________________________ Date: ____________
1A/102094

		Sample Name:	**VC0014**		
		Lab Code:	**K2005515-006**		
		X	**Y**		
		arithmetic	**logarithmic**	**Convert Y**	**Value of Y**
		Percent Passing	**Particle Diameter**	**mm to nm**	**Log form**
Sieve		**(%)**	**(mm)**	**(nm)**	**(log)**
3/4"		100.0	19.0	19000000	7.279
3/8"		100.0	9.5	9500000	6.978
4		100.0	4.75	4750000	6.677
10		100.0	2.00	2000000	6.301
20		99.8	0.850	850000	5.929
40		99.8	0.425	425000	5.628
60		99.7	0.250	250000	5.398
140		99.3	0.106	106000	5.025
200		98.6	0.0750	75000	4.875
2		88.4	0.0288	28761.79104	4.459
5		84.3	0.0185	18512.88543	4.267
15		72.2	0.0112	11228.22276	4.050
30		66.1	0.0081	8123.679121	3.910
60		51.8	0.0060	6037.19268	3.781
250		29.5	0.0031	3096.372023	3.491
1440		17.3	0.0014	1350.752171	3.131
	determined hydrometer				
		mm	**mm to nm**	**log hyd x**	**% Passing**
		0.074	74000	4.87	98.4
		0.005	5000	3.70	45.5
		0.001	1000	3.00	12.9

COLUMBIA ANALYTICAL SERVICES, INC.

Analytical Report

Client:	Exponent Environmental Group, Inc.	**Service Request:**	K2005515
Project:	OL RI/FS Phase 2A / 8600BCP.003.0801	**Date Collected:**	7/22/00
Sample Matrix:	Soil	**Date Received:**	7/23/00
		Date Analyzed:	8/1/00

Particle Size Determination
ASTM Method D 422

Sample Name: VC0015
Lab Code: K2005515-007

Gravel and Sand
(Sieve Analysis)

Description	Sieve Size	Weight (g)	Percent Passing
Gravel	No.3/4"(19.0 mm)	0.0000	100
Gravel	No.3/8"(9.50 mm)	0.0000	100
Medium Gravel	No.4 (4.75 mm)	0.0000	100
Fine Gravel	No.10 (2.00 mm)	0.0000	100
Very Coarse Sand	No.20 (0.850 mm)	0.1298	99.7
Coarse Sand	No.40 (0.425 mm)	0.0901	99.6
Medium Sand	No.60 (0.250 mm)	0.0509	99.5
Fine Sand	No.140 (0.106 mm)	0.1416	99.2
Very Fine Sand	No.200 (0.0750 mm)	0.1273	98.9

Silt and Clay
(Hydrometer Analysis)

Particle Diameter	Percent Passing
0.074 mm	98.7
0.005 mm	48.3
0.001 mm	0.0

Approved By: ______________________________ Date: ______________
1A/102094

		Sample Name:	VC0015		
		Lab Code:	K2005515-007		
		X	Y		
		arithmetic	logarithmic	Convert Y	Value of Y
		Percent Passing	Particle Diameter	mm to nm	Log form
Sieve		(%)	(mm)	(nm)	(log)
3/4"		100.0	19.0	19000000	7.279
3/8"		100.0	9.5	9500000	6.978
4		100.0	4.75	4750000	6.677
10		100.0	2.00	2000000	6.301
20		99.7	0.850	850000	5.929
40		99.6	0.425	425000	5.628
60		99.5	0.250	250000	5.398
140		99.2	0.106	106000	5.025
200		98.9	0.0750	75000	4.875
2		93.7	0.0508	50848.05736	4.706
5		91.7	0.0325	32461.45364	4.511
15		81.6	0.0196	19591.03504	4.292
30		75.5	0.0142	14201.13819	4.152
60		69.5	0.0103	10282.03104	4.012
250		51.4	0.0052	5243.167685	3.720
1440		25.2	0.0024	2396.711347	3.380
	determined hydrometer				
		mm	mm to nm	log hyd x	% Passing
		0.074	74000	4.87	98.7
		0.005	5000	3.70	48.3
		0.001	1000	3.00	-4.1

COLUMBIA ANALYTICAL SERVICES, INC.

Analytical Report

Client:	Exponent Environmental Group, Inc.	**Service Request:**	K2005515
Project:	OL RI/FS Phase 2A / 8600BCP.003.0801	**Date Collected:**	7/22/00
Sample Matrix:	Soil	**Date Received:**	7/23/00
		Date Analyzed:	8/1/00

Particle Size Determination
ASTM Method D 422

Sample Name: VC0016
Lab Code: K2005515-008

Gravel and Sand
(Sieve Analysis)

Description	Sieve Size	Weight (g)	Percent Passing
Gravel	No.3/4"(19.0 mm)	0.0000	100
Gravel	No.3/8"(9.50 mm)	0.0000	100
Medium Gravel	No.4 (4.75 mm)	0.0000	100
Fine Gravel	No.10 (2.00 mm)	0.0000	100
Very Coarse Sand	No.20 (0.850 mm)	0.3423	99.3
Coarse Sand	No.40 (0.425 mm)	0.0571	99.2
Medium Sand	No.60 (0.250 mm)	0.0419	99.1
Fine Sand	No.140 (0.106 mm)	0.1223	98.9
Very Fine Sand	No.200 (0.0750 mm)	0.2449	98.4

Silt and Clay
(Hydrometer Analysis)

Particle Diameter	Percent Passing
0.074 mm	98.2
0.005 mm	51.2
0.001 mm	19.0

Approved By: ______________________________ Date: ______________
1A/102094

		Sample Name:	VC0016		
		Lab Code:	K2005515-008		
		X	Y		
		arithmetic	logarithmic	Convert Y	Value of Y
		Percent Passing	Particle Diameter	mm to nm	Log form
Sieve		(%)	(mm)	(nm)	(log)
3/4"		100.0	19.0	19000000	7.279
3/8"		100.0	9.5	9500000	6.978
4		100.0	4.75	4750000	6.677
10		100.0	2.00	2000000	6.301
20		99.3	0.850	850000	5.929
40		99.2	0.425	425000	5.628
60		99.1	0.250	250000	5.398
140		98.9	0.106	106000	5.025
200		98.4	0.0750	75000	4.875
2		93.8	0.0508	50848.05736	4.706
5		87.7	0.0331	33057.79739	4.519
15		79.7	0.0198	19756.53444	4.296
30		73.6	0.0143	14315.31786	4.156
60		67.6	0.0104	10360.89582	4.015
250		51.4	0.0054	5374.878469	3.730
1440		35.3	0.0023	2326.771272	3.367
	determined hydrometer				
		mm	mm to nm	log hyd x	% Passing
		0.074	74000	4.87	98.2
		0.005	5000	3.70	51.2
		0.001	1000	3.00	19.0

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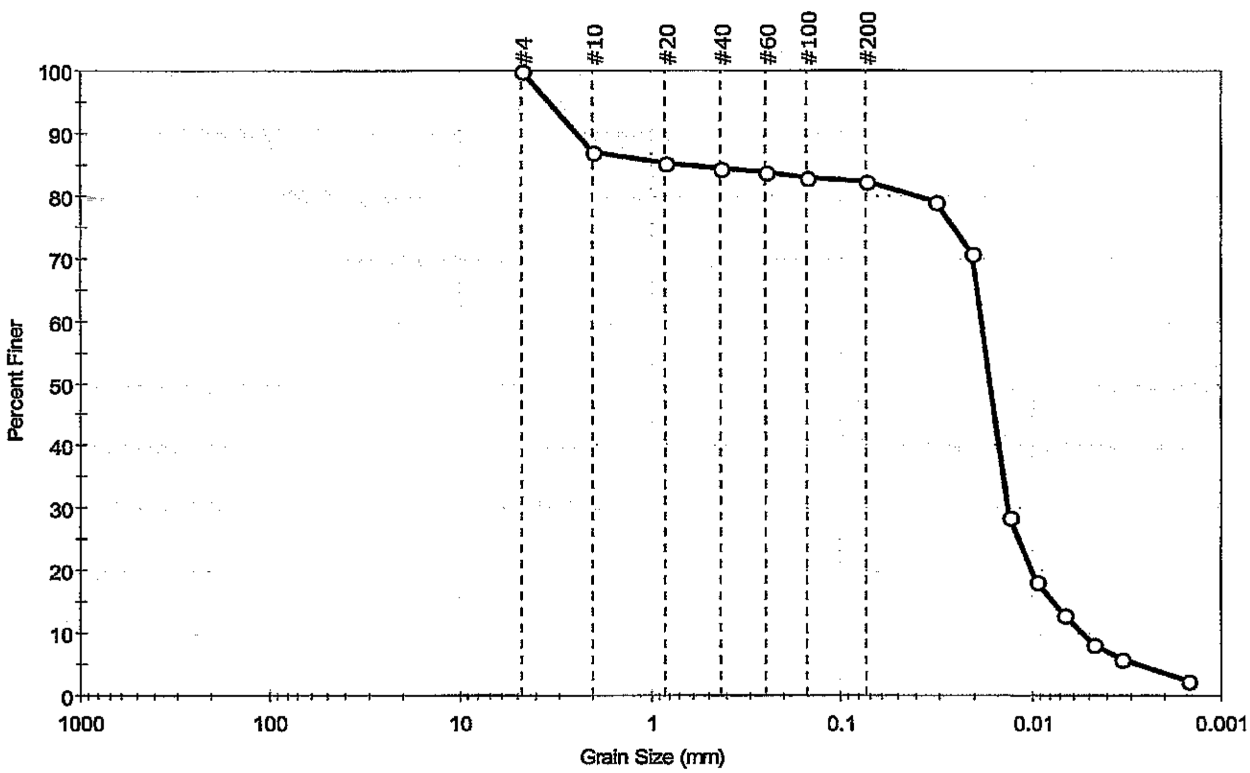
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-30034	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0285-13	Test Date:	02/06/07	Checked By:	jdt
Depth :	0.5-3.3 ft	Test Id:	105843		
Test Comment:	---				
Sample Description:	Moist, light gray silt with sand				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	17.8	82.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	87		
#20	0.84	85		
#40	0.42	84		
#60	0.25	84		
#100	0.15	83		
#200	0.074	82		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0321	79		
---	0.0209	71		
---	0.0131	29		
---	0.0094	18		
---	0.0067	13		
---	0.0048	8		
---	0.0034	6		
---	0.0015	2		

Coefficients

D_{85} =0.7678 mm	D_{30} =0.0133 mm
D_{60} =0.0185 mm	D_{15} =0.0077 mm
D_{50} =0.0166 mm	D_{10} =0.0054 mm
C_u =N/A	C_c =N/A

Classification

ASTM elastic silt with sand (MH)

AASHTO Clayey Soils (A-7-5 (59))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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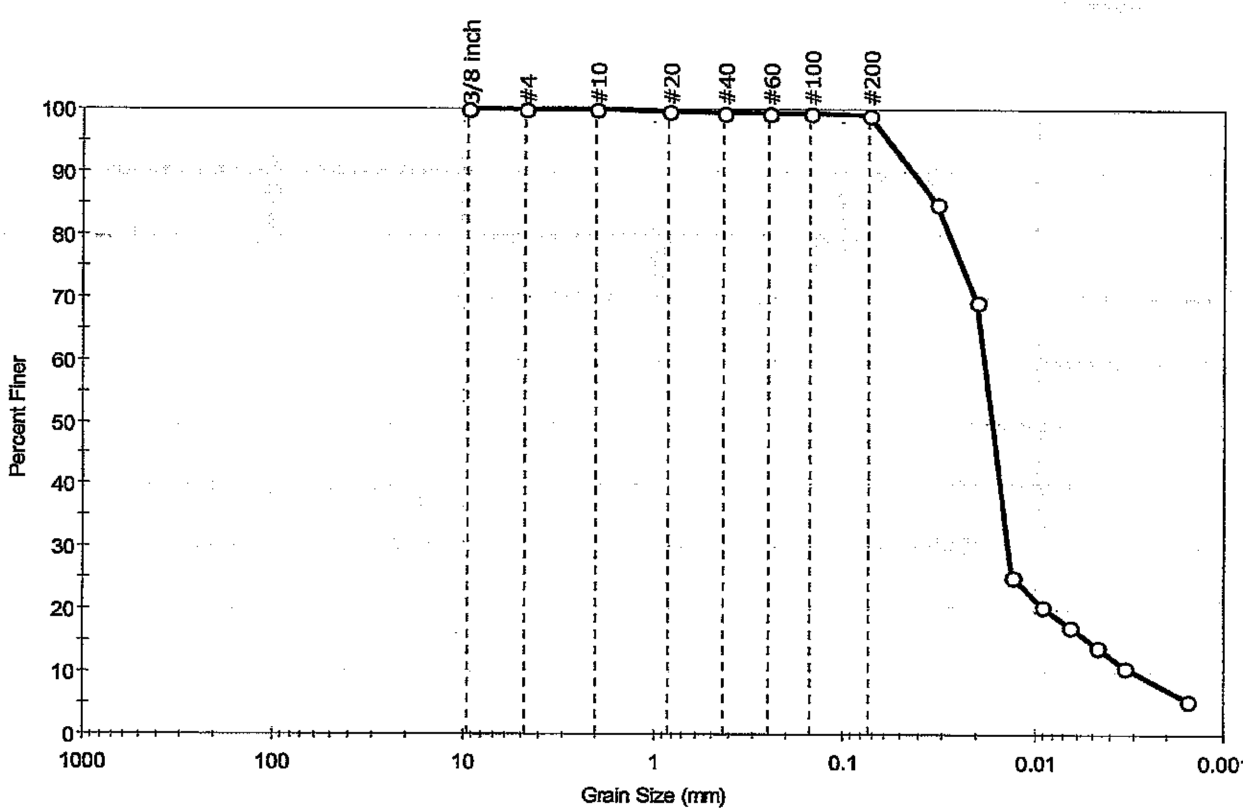
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-30034	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0285-14	Test Date:	02/06/07	Checked By:	jdt
Depth :	9.9-13.2 ft	Test Id:	105844		
Test Comment:	---				
Sample Description:	Moist, white silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.9	99.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
3/8 inch	9.51	100		
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	99		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0326	85		
---	0.0204	69		
---	0.0131	25		
---	0.0093	21		
---	0.0066	17		
---	0.0047	14		
---	0.0033	11		
---	0.0016	6		

Coefficients

D_{85} =0.0327 mm | D_{30} =0.0137 mm
D_{60} =0.0186 mm | D_{15} =0.0051 mm
D_{50} =0.0168 mm | D_{10} =0.0029 mm
C_u =N/A | C_c =N/A

Classification

ASTM N/A

AASHTO Silty Soils (A-4 (0))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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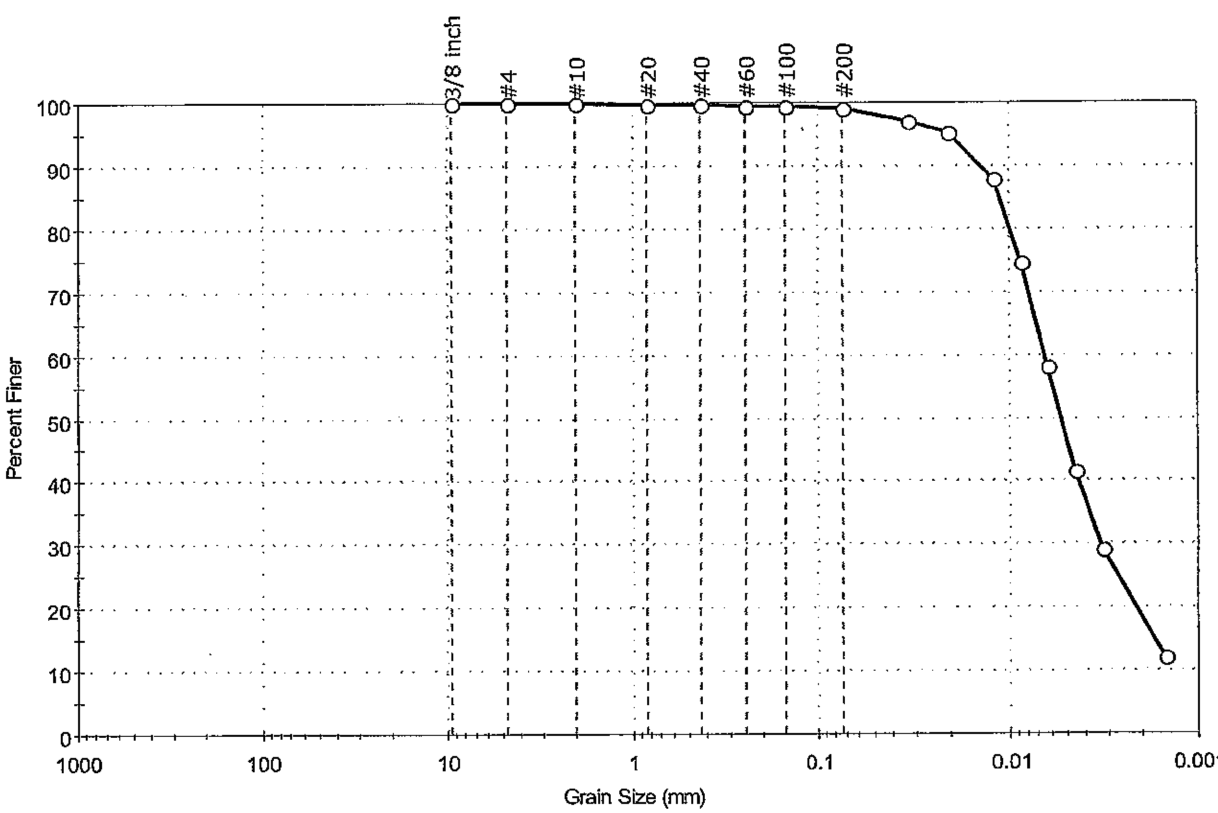
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-30035	Sample Type: jar	Tested By:	mll
Sample ID:OL-0282-18	Test Date: 01/30/07	Checked By:	jdt
Depth : 6.6-9.9 ft	Test Id: 105659		
Test Comment: ---			
Sample Description: Moist, white silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



%Cobble	%Gravel	%Sand	%Silt & Clay Size
—	0.0	0.9	99.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
3/8 inch	9.50	100		
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	99		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0334	97		
---	0.0207	95		
---	0.0120	88		
---	0.0086	75		
---	0.0063	58		
---	0.0045	42		
---	0.0032	29		
---	0.0015	12		

Coefficients

D_{85} =0.0111 mm D_{30} =0.0033 mm
D_{60} =0.0065 mm D_{15} =0.0017 mm
D_{50} =0.0053 mm D_{10} =0.0014 mm
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (63))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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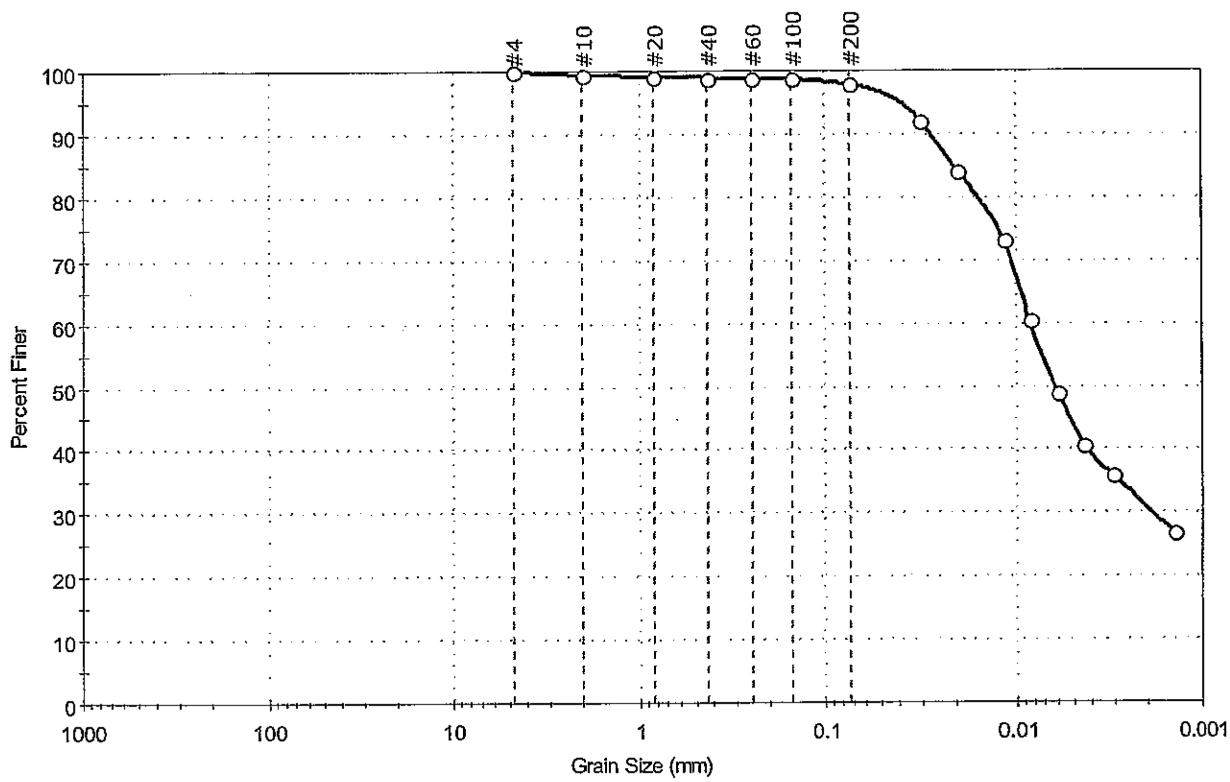
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-30035	Sample Type: jar	Tested By:	mll
Sample ID: OL-0282-19	Test Date: 01/30/07	Checked By:	jdt
Depth : 16.5-19.6 ft	Test Id: 105660		
Test Comment: ---			
Sample Description: Moist, grayish brown silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



%Cobble	%Gravel	%Sand	%Silt & Clay Size
—	0.0	2.1	97.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.84	99		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0307	92		
---	0.0195	84		
---	0.0115	73		
---	0.0084	60		
---	0.0059	49		
---	0.0044	41		
---	0.0031	36		
---	0.0014	27		

Coefficients

D_{85} =0.0207 mm — D_{30} =0.0019 mm

D_{60} =0.0083 mm — D_{15} =N/A

D_{50} =0.0061 mm — D_{10} =N/A

C_u =N/A — C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (84))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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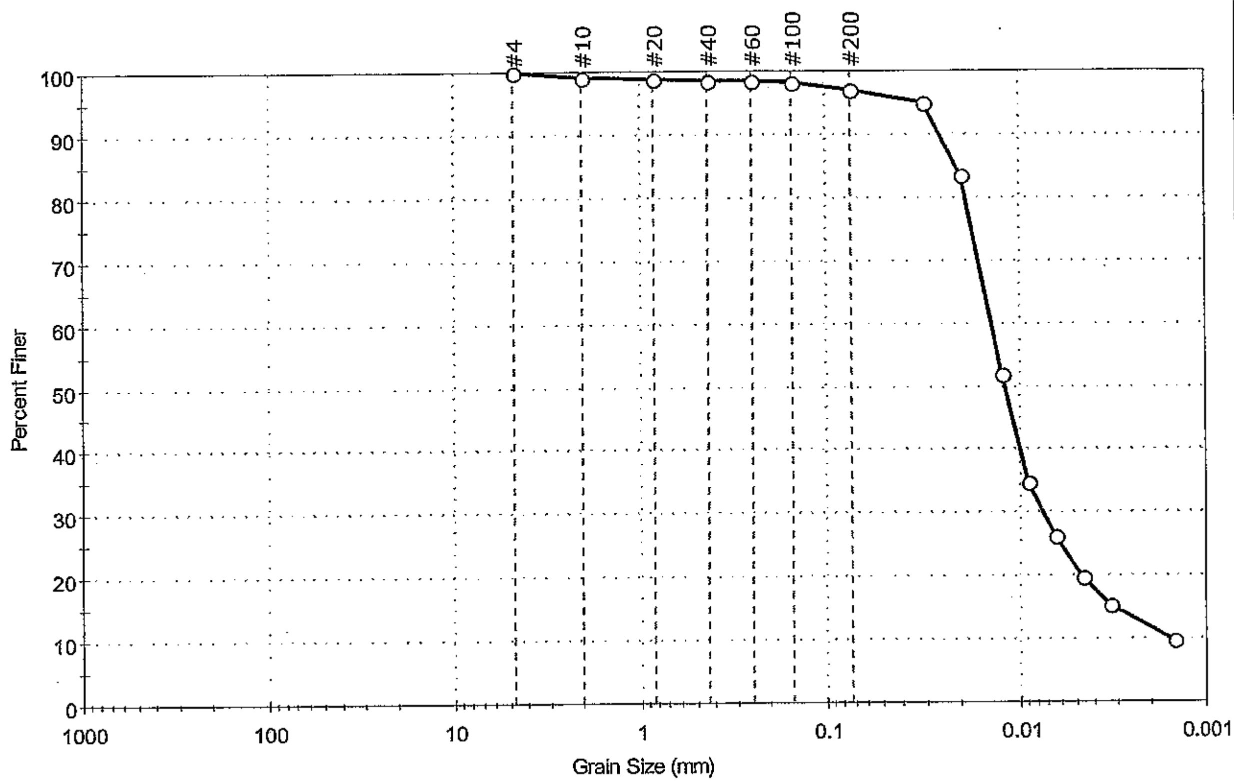
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-30036	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0282-20	Test Date:	01/29/07	Checked By:	jdt
Depth :	0.5-3.3 ft	Test Id:	105661		
Test Comment:	---				
Sample Description:	Wet, very dark gray silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



%Cobble	%Gravel	%Sand	%Silt & Clay Size
—	0.0	2.9	97.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	99		
#20	0.84	99		
#40	0.42	99		
#60	0.25	99		
#100	0.15	98		
#200	0.074	97		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0310	95		
---	0.0198	84		
---	0.0122	52		
---	0.0090	35		
---	0.0064	26		
---	0.0046	20		
---	0.0033	15		
---	0.0015	10		

Coefficients

D_{85} =0.0209 mm D_{30} =0.0075 mm
D_{60} =0.0138 mm D_{15} =0.0031 mm
D_{50} =0.0118 mm D_{10} =0.0015 mm
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (39))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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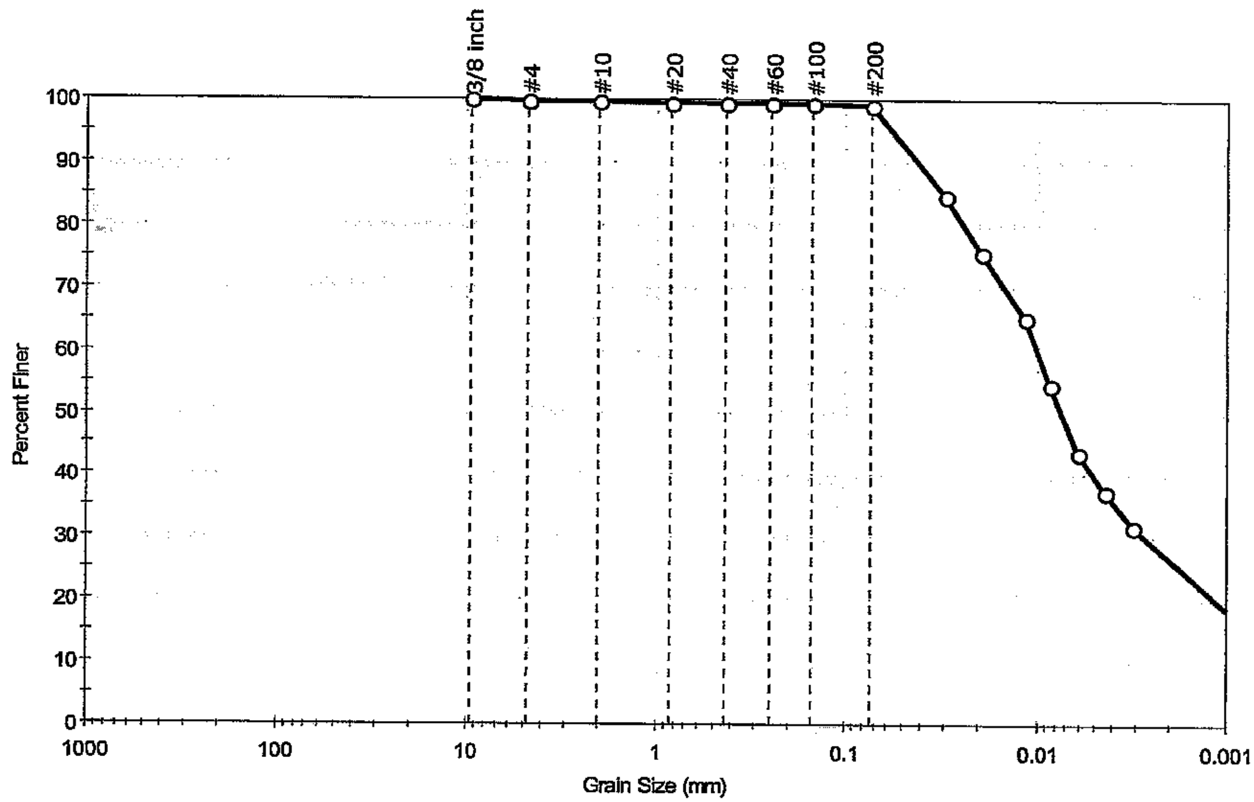
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-30036	Sample Type:	jar	Tested By:	mil
Sample ID:	OL-0285-01	Test Date:	02/05/07	Checked By:	jdt
Depth :	9.9-13.2 ft	Test Id:	105831		

Test Comment: ---
Sample Description: Moist, dark olive brown silt
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.3	0.6	99.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
3/8 Inch	9.51	100		
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0300	85		
---	0.0199	75		
---	0.0117	65		
---	0.0085	55		
---	0.0061	44		
---	0.0044	38		
---	0.0031	32		
---	0.0008	16		

Coefficients

D_{85} =0.0309 mm — D_{30} =0.0027 mm
D_{60} =0.0100 mm — D_{15} =N/A
D_{50} =0.0074 mm — D_{10} =N/A
C_u =N/A — C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (80))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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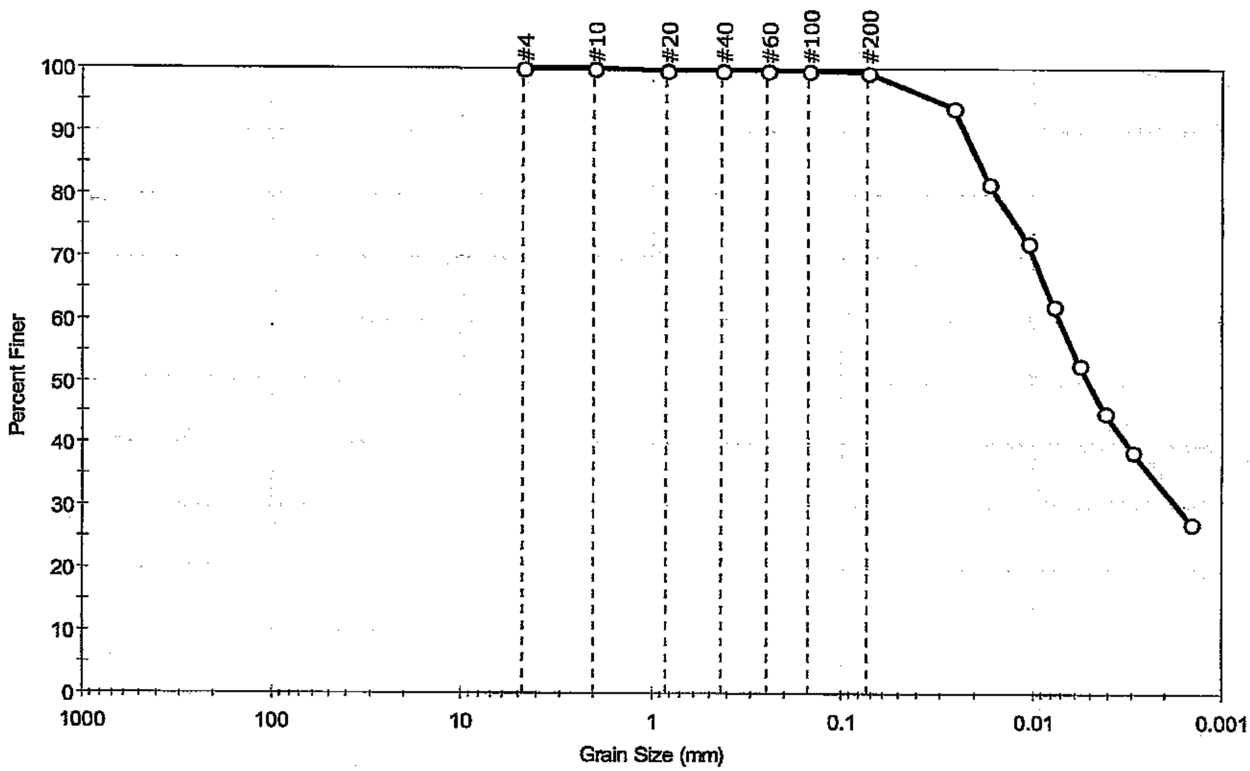
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-30036	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0285-02	Test Date:	02/06/07	Checked By:	jdt
Depth :	16.5-17.3 ft	Test Id:	105832		

Test Comment: ---
Sample Description: Moist, gray silt
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.5	99.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	100		
—	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0265	94		
---	0.0173	82		
---	0.0105	72		
---	0.0077	62		
---	0.0057	53		
---	0.0042	45		
---	0.0030	39		
---	0.0015	28		

Coefficients

D_{85} =0.0194 mm	D_{30} =0.0017 mm
D_{60} =0.0072 mm	D_{15} =N/A
D_{50} =0.0051 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (36))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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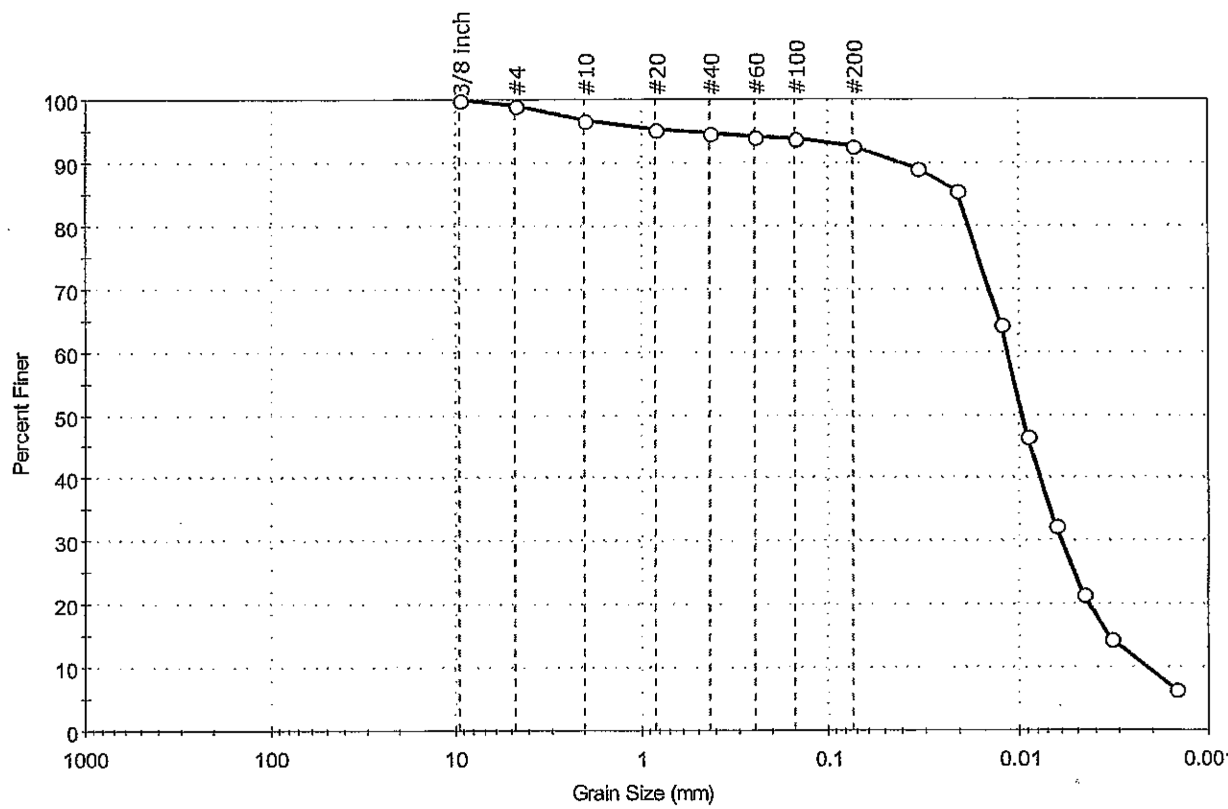
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-30037	Sample Type: jar	Tested By:	mll
Sample ID: OL-0282-17	Test Date: 01/29/07	Checked By:	jdt
Depth : 0.5-3.3 ft	Test Id: 105658		
Test Comment: ---			
Sample Description: Wet, dark gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



%Cobble	%Gravel	%Sand	%Silt & Clay Size
—	1.0	6.4	92.6

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
3/8 inch	9.50	100		
#4	4.75	99		
#10	2.00	97		
#20	0.84	95		
#40	0.42	95		
#60	0.25	94		
#100	0.15	94		
#200	0.074	93		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0332	89		
---	0.0205	86		
---	0.0122	64		
---	0.0089	47		
---	0.0064	32		
---	0.0046	22		
---	0.0033	15		
---	0.0015	7		

Coefficients

D_{85} =0.0202 mm D_{30} =0.0060 mm
D_{60} =0.0113 mm D_{15} =0.0033 mm
D_{50} =0.0095 mm D_{10} =0.0021 mm
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (36))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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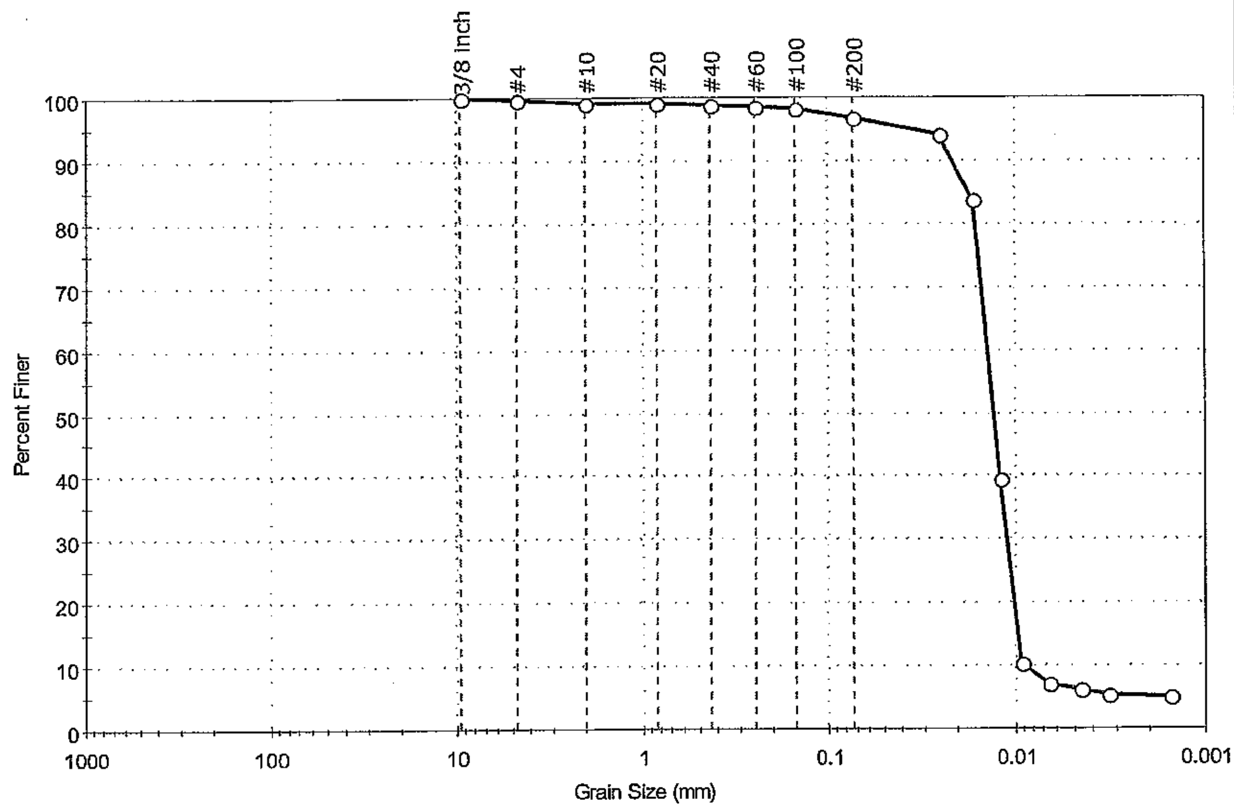
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-30037	Sample Type: jar	Tested By:	mll
Sample ID:OL-0282-15	Test Date: 01/30/07	Checked By:	jdt
Depth : 9.9-13.2 ft	Test Id: 105656		
Test Comment: ---			
Sample Description: Wet, dark gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.4	2.7	96.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
3/8 inch	9.50	100		
#4	4.75	100		
#10	2.00	99		
#20	0.84	99		
#40	0.42	99		
#60	0.25	99		
#100	0.15	98		
#200	0.074	97		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0251	94		
---	0.0166	84		
---	0.0118	39		
---	0.0093	10		
---	0.0066	7		
---	0.0046	6		
---	0.0033	5		
---	0.0015	5		

Coefficients

D_{85} =0.0174 mm D_{30} =0.0109 mm
D_{60} =0.0138 mm D_{15} =0.0096 mm
D_{50} =0.0128 mm D_{10} =0.0089 mm
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (42))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

GeoTesting express
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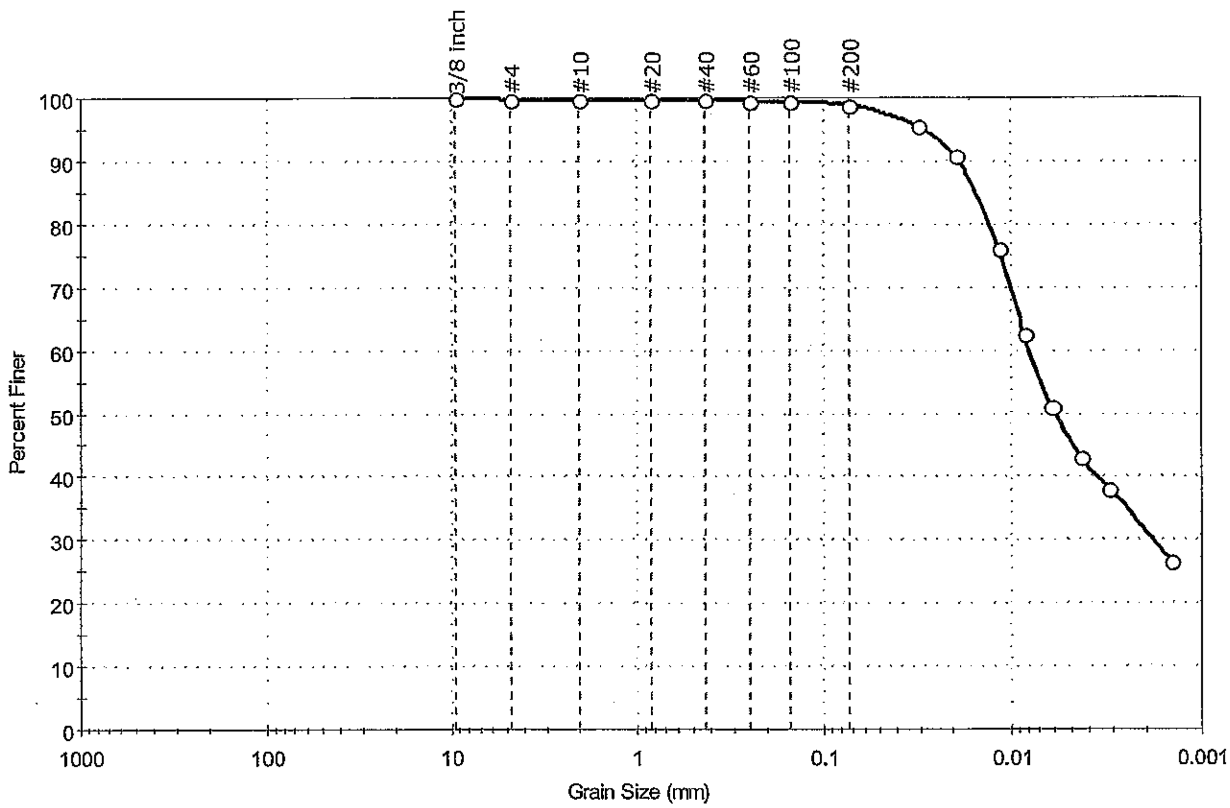
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-30037	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0282-16	Test Date:	01/30/07	Checked By:	jdt
Depth :	13.2-16.5 ft	Test Id:	105657		
Test Comment:	---				
Sample Description:	Moist, olive brown silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.2	0.9	98.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
3/8 inch	9.50	100		
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	99		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0310	95		
---	0.0194	91		
---	0.0115	76		
---	0.0084	63		
---	0.0061	51		
---	0.0044	43		
---	0.0031	38		
---	0.0015	27		

Coefficients

D_{85} =0.0158 mm　　D_{30} =0.0018 mm

D_{60} =0.0078 mm　　D_{15} =N/A

D_{50} =0.0059 mm　　D_{10} =N/A

C_u =N/A　　C_c =N/A

Classification

ASTM　elastic silt (MH)

AASHTO　Clayey Soils (A-7-5 (66))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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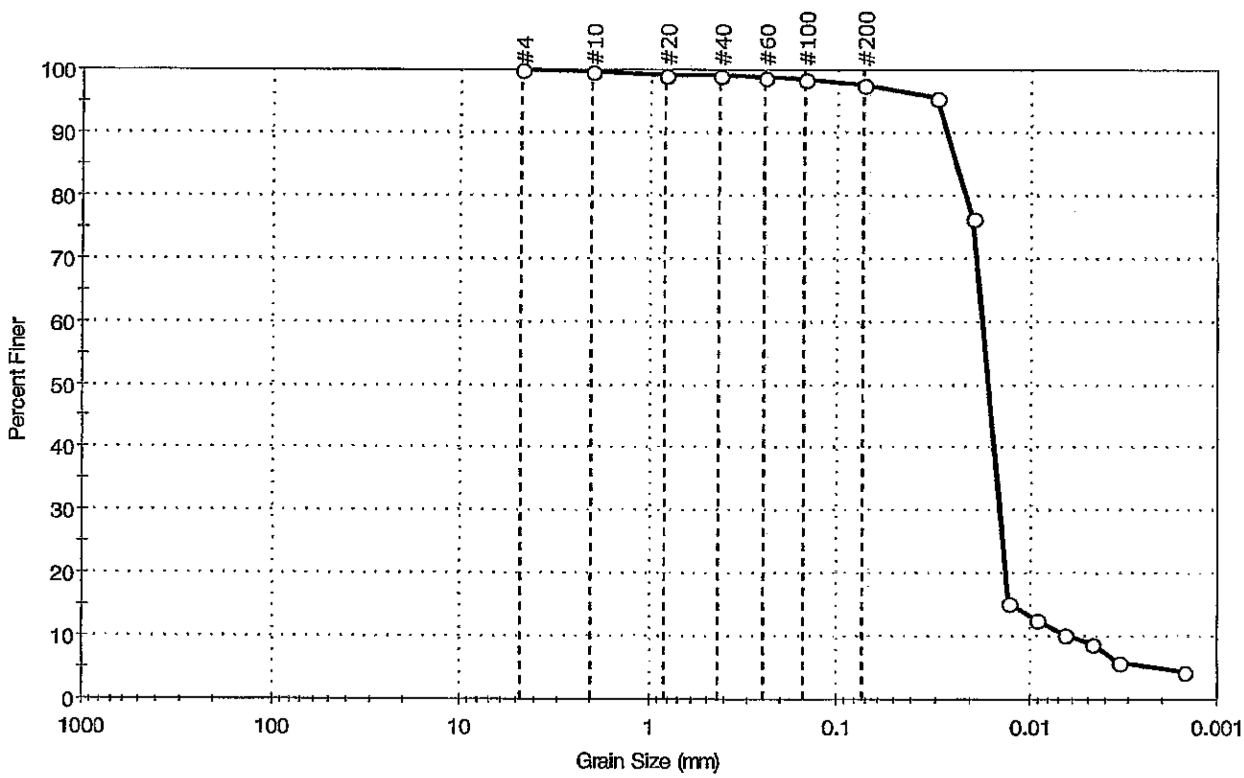
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-20067	Sample Type: jar	Tested By:	mll
Sample ID: OL-0289-09	Test Date: 01/25/07	Checked By:	jdt
Depth : 0-3.3 ft	Test Id: 106061		
Test Comment: ---			
Sample Description: Wet, black silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	2.2	97.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	99		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0303	96		
---	0.0198	76		
---	0.0129	15		
---	0.0092	13		
---	0.0066	10		
---	0.0047	9		
---	0.0034	6		
---	0.0015	4		

Coefficients

D_{85} =0.0240 mm D_{30} =0.0143 mm
D_{60} =0.0177 mm D_{15} =0.0124 mm
D_{50} =0.0165 mm D_{10} =0.0063 mm
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (62))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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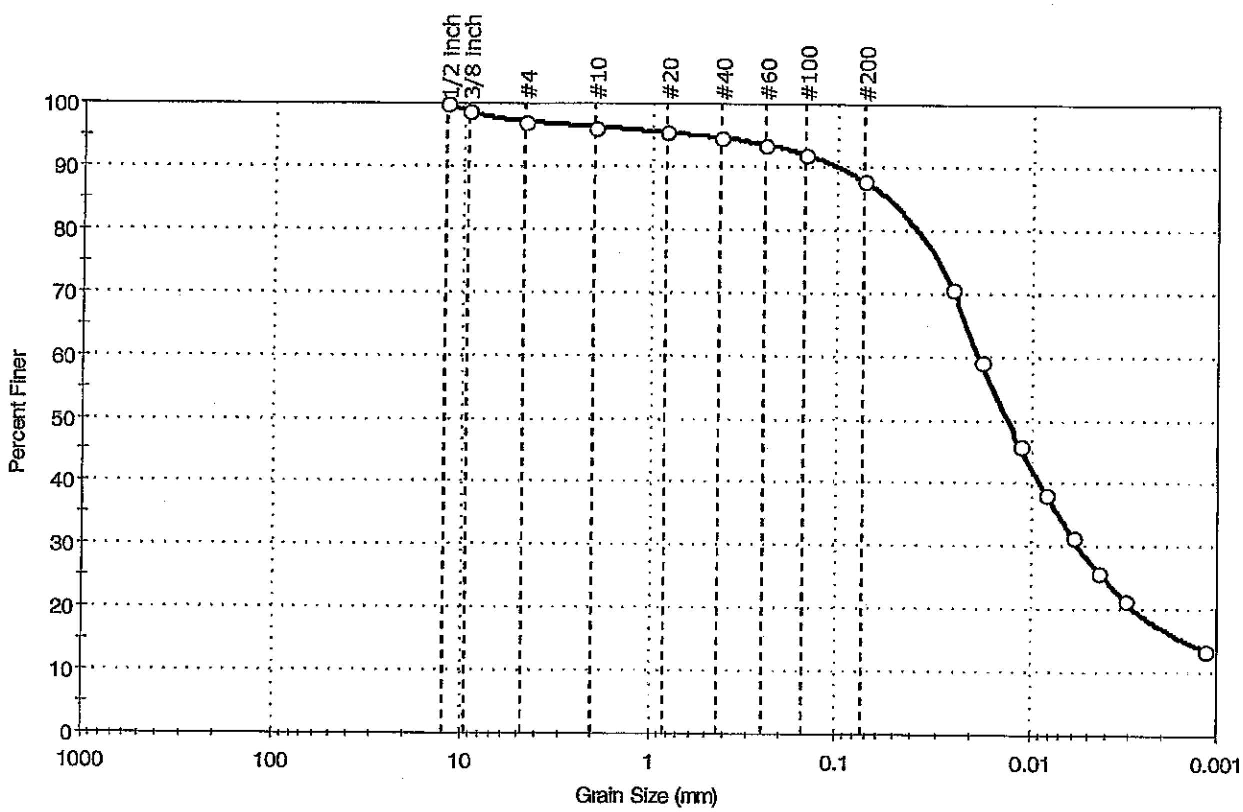
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-20067	Sample Type: jar	Tested By:	mll
Sample ID: OL-0289-10	Test Date: 02/13/07	Checked By:	jdt
Depth : 6.6-9.9 ft	Test Id: 106062		
Test Comment: ---			
Sample Description: Moist, very dark gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	2.8	9.3	87.9

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
1/2 inch	12.50	100		
3/8 inch	9.50	99		
#4	4.75	97		
#10	2.00	96		
#20	0.84	95		
#40	0.42	95		
#60	0.25	94		
#100	0.15	92		
#200	0.074	88		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0257	71		
---	0.0180	59		
---	0.0114	46		
---	0.0083	38		
---	0.0061	31		
---	0.0044	26		
---	0.0032	21		
---	0.0012	14		

Coefficients

D_{85} =0.0618 mm D_{30} =0.0056 mm
D_{60} =0.0184 mm D_{15} =0.0014 mm
D_{50} =0.0131 mm D_{10} =0.0007 mm
C_u =N/A C_c =N/A

Classification

ASTM   elastic silt (MH)

AASHTO   Clayey Soils (A-7-5 (19))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD

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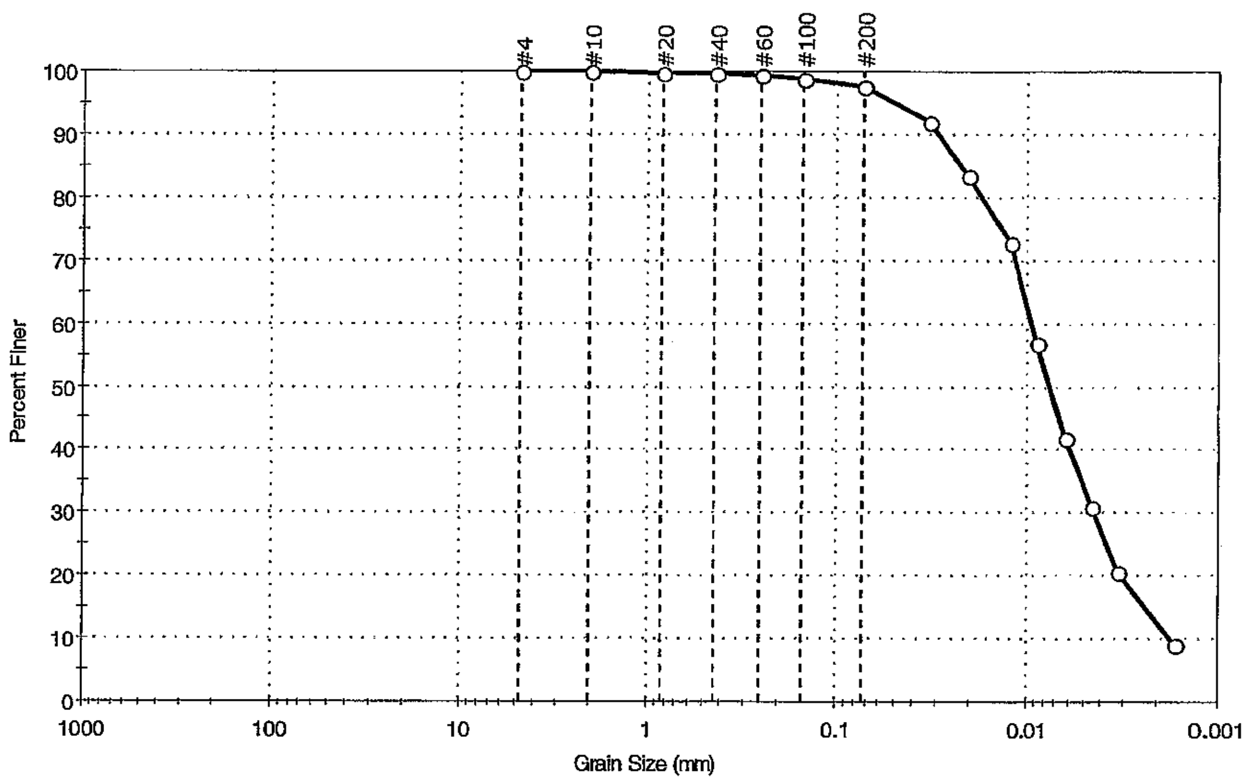
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-20073	Sample Type:	jar	Tested By:	sam
Sample ID:	OL-0232-12	Test Date:	01/04/07	Checked By:	jdt
Depth :	3.3-6.6 ft	Test Id:	103374		
Test Comment:	---				
Sample Description:	Wet, dark gray silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	2.3	97.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0333	92		
---	0.0208	83		
---	0.0122	73		
---	0.0088	57		
---	0.0063	42		
---	0.0045	31		
---	0.0033	21		
---	0.0016	9		

Coefficients

D_{85} =0.0227 mm D_{30} =0.0044 mm

D_{60} =0.0093 mm D_{15} =0.0023 mm

D_{50} =0.0075 mm D_{10} =0.0017 mm

C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (30))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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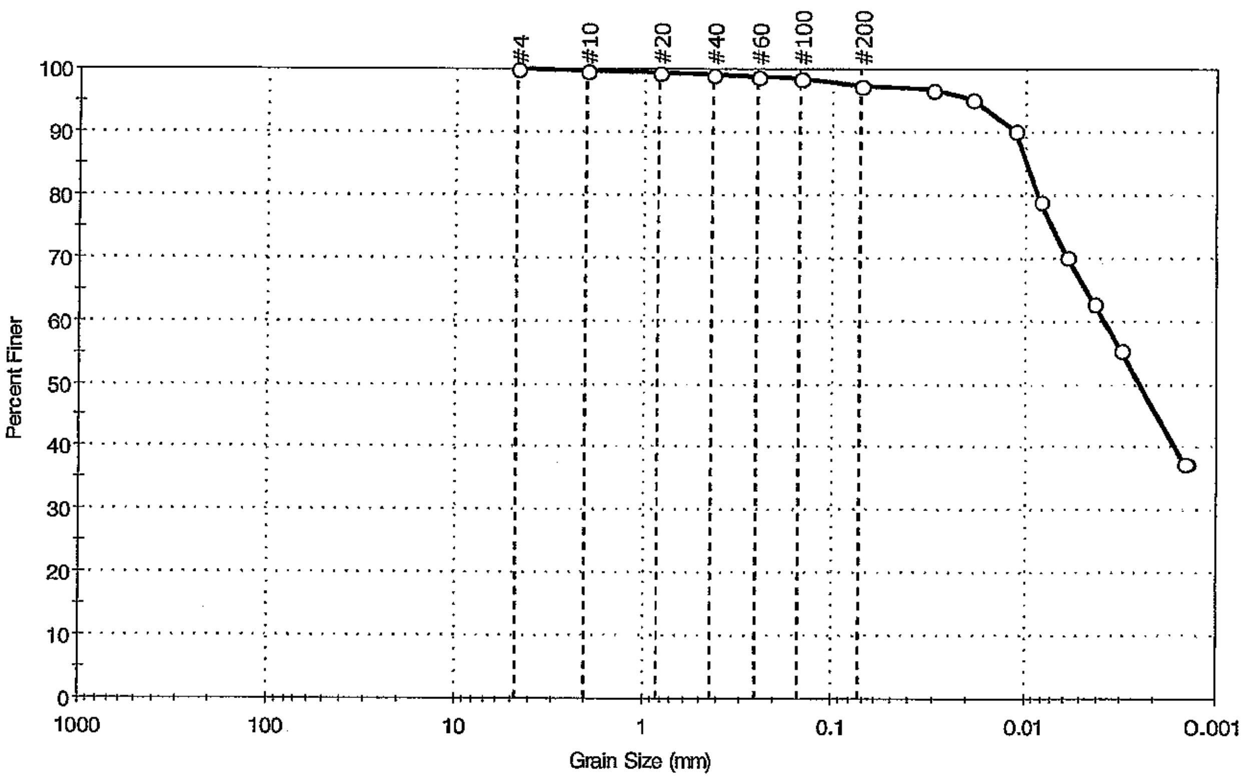
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-20073	Sample Type:	jar	Tested By:	sam
Sample ID:	OL-0232-13	Test Date:	01/04/07	Checked By:	jdt
Depth :	13.2-16.5 ft	Test Id:	103375		
Test Comment:	---				
Sample Description:	Moist, dark gray silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	2.6	97.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	99		
#40	0.42	99		
#60	0.25	99		
#100	0.15	98		
#200	0.074	97		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0312	97		
---	0.0195	95		
---	0.0113	90		
---	0.0082	79		
---	0.0059	70		
---	0.0042	63		
---	0.0030	55		
---	0.0014	38		

Coefficients

D_{85} =0.0097 mm D_{30} =N/A
D_{60} =0.0037 mm D_{15} =N/A
D_{50} =0.0024 mm D_{10} =N/A
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (50))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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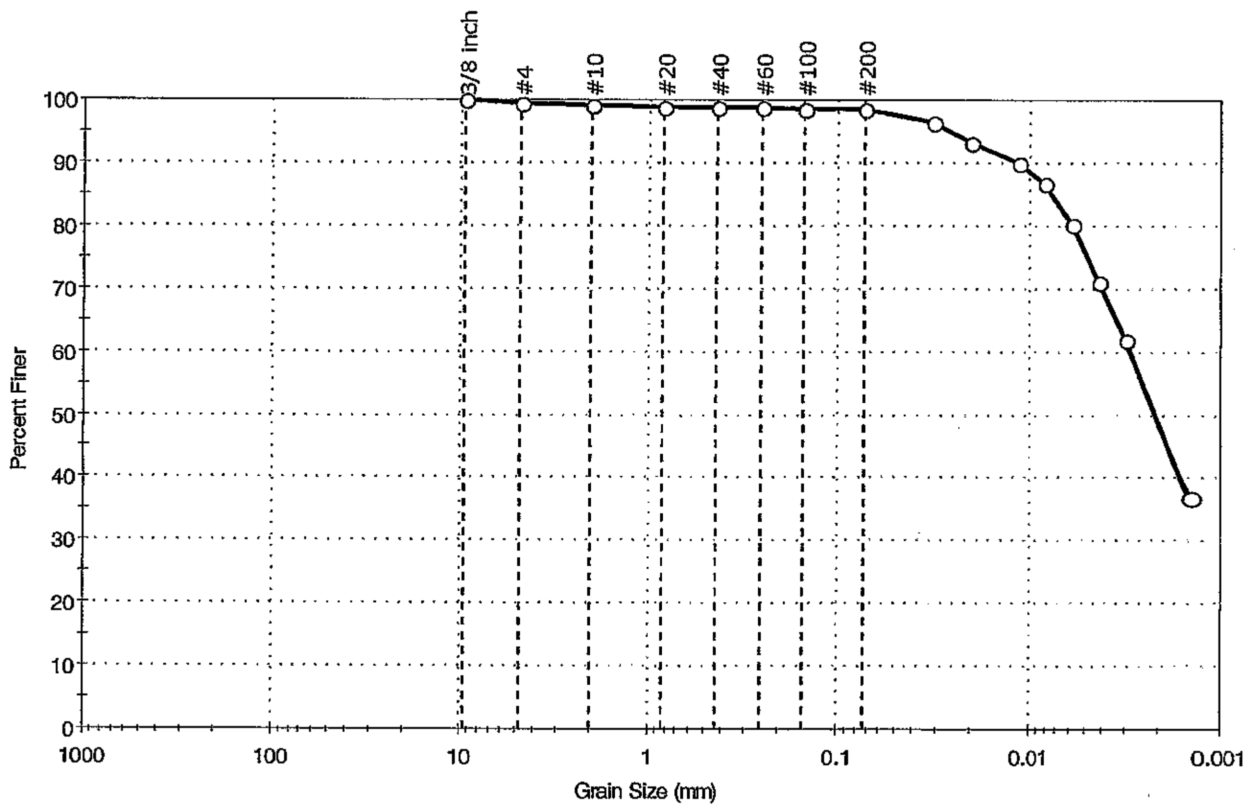
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-20073	Sample Type: jar	Tested By:	sam
Sample ID: OL-0232-14	Test Date: 01/05/07	Checked By:	jdt
Depth : 16.5-19.3 ft	Test Id: 103376		
Test Comment: ---			
Sample Description: Moist, gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.7	0.8	98.5

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
3/8 inch	9.51	100		
#4	4.75	99		
#10	2.00	99		
#20	0.84	99		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0318	97		
---	0.0201	93		
---	0.0115	90		
---	0.0082	87		
---	0.0059	80		
---	0.0042	71		
---	0.0030	62		
---	0.0014	37		

Coefficients

D_{85} =0.0075 mm D_{30} =N/A
D_{60} =0.0028 mm D_{15} =N/A
D_{50} =0.0021 mm D_{10} =N/A
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (36))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : SOFT

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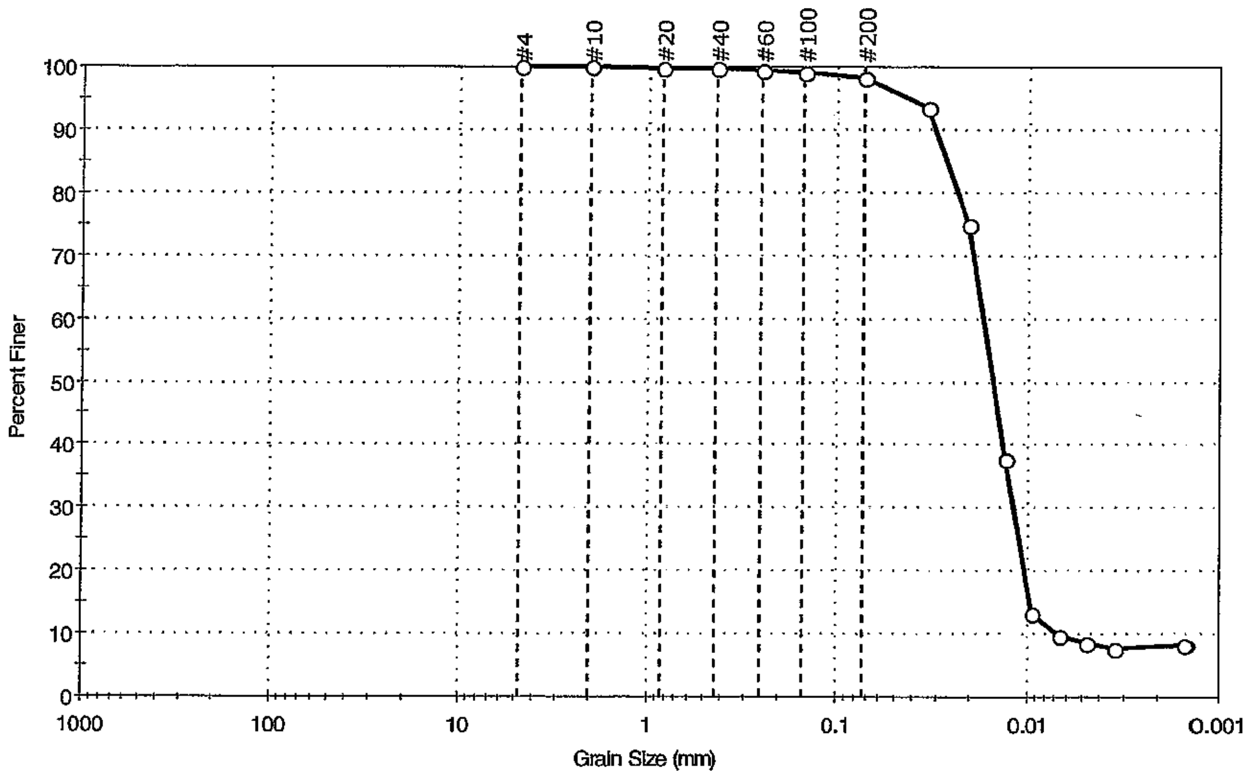
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-20074	Sample Type:	jar	Tested By:	sam
Sample ID:	OL-0232-15	Test Date:	01/12/07	Checked By:	jdt
Depth :	0-3.3 ft	Test Id:	103377		
Test Comment:	---				
Sample Description:	Wet, black silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.6	98.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0342	93		
---	0.0208	75		
---	0.0130	38		
---	0.0095	13		
---	0.0066	10		
---	0.0048	9		
---	0.0034	8		
---	0.0015	8		

Coefficients

D_{85} =0.0273 mm — D_{30} =0.0118 mm

D_{60} =0.0173 mm — D_{15} =0.0097 mm

D_{50} =0.0152 mm — D_{10} =0.0068 mm

C_u =N/A — C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (78))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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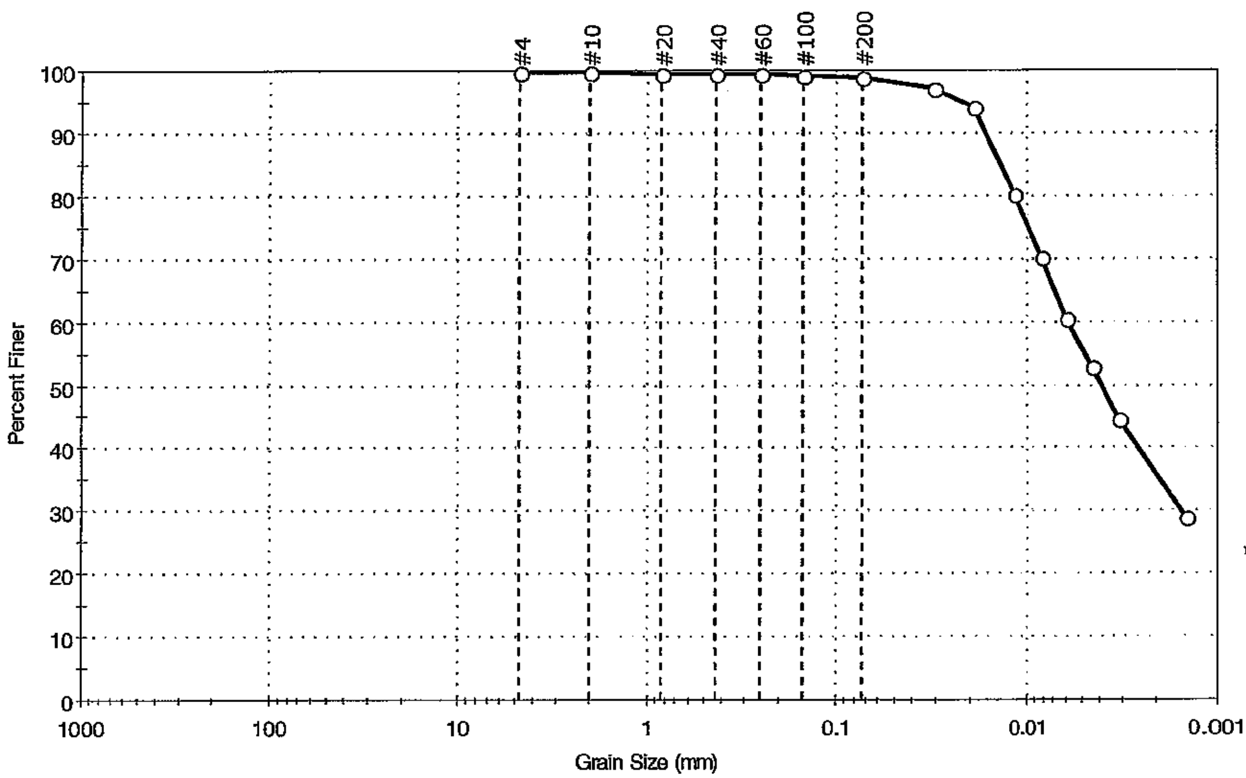
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-20074	Sample Type: jar	Tested By:	sam
Sample ID: OL-0232-16	Test Date: 01/10/07	Checked By:	jdt
Depth : 9.9-13.2 ft	Test Id: 103378		
Test Comment: ---			
Sample Description: Moist, dark grayish brown clay			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.3	1.0	98.7

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0312	97		
---	0.0193	94		
---	0.0115	80		
---	0.0082	70		
---	0.0060	61		
---	0.0044	53		
---	0.0031	44		
---	0.0014	29		

Coefficients

D_{85} =0.0138 mm | D_{30} =0.0015 mm
D_{60} =0.0059 mm | D_{15} =N/A
D_{50} =0.0039 mm | D_{10} =N/A
C_u =N/A | C_c =N/A

Classification

ASTM fat clay (CH)

AASHTO Clayey Soils (A-7-5 (66))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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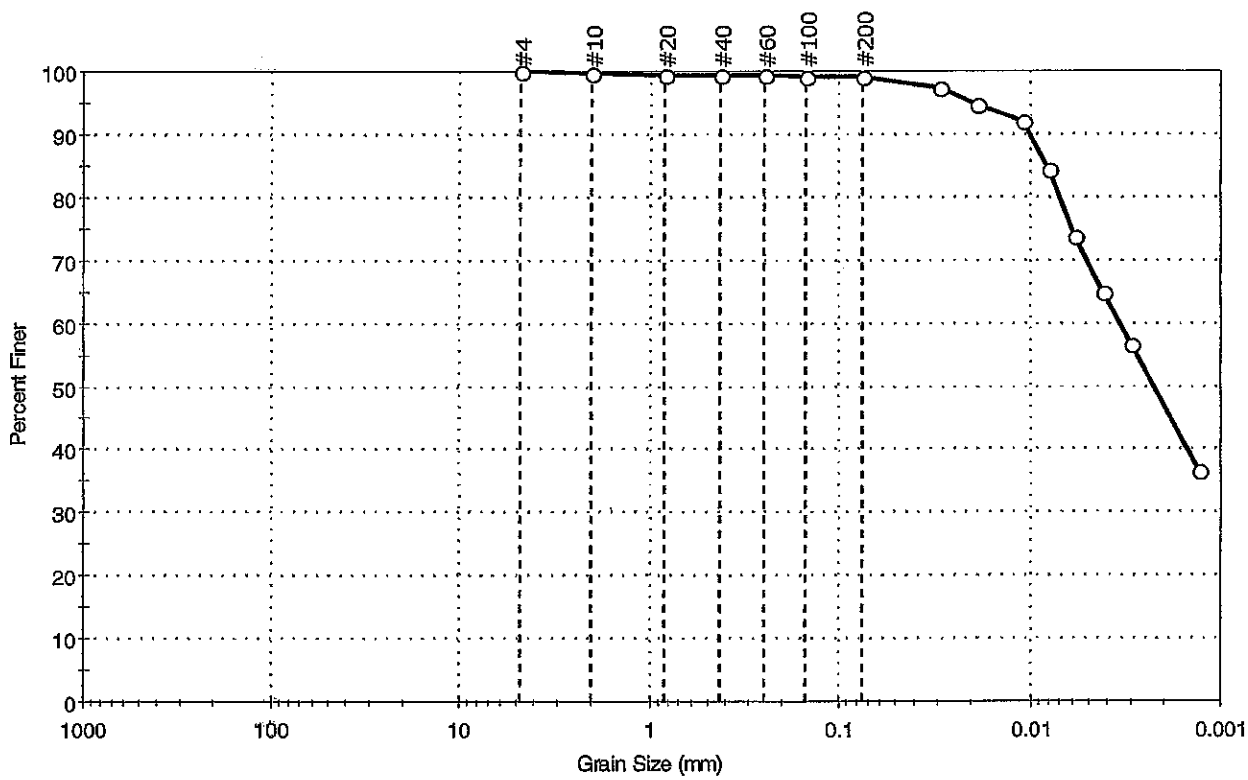
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-0297-01	Sample Type: jar	Tested By:	mll
Sample ID: OL-VC-20074	Test Date: 06/20/07	Checked By:	jdt
Depth : 13.2-16.5 ft	Test Id: 111431		

Test Comment: ---
Sample Description: Moist, dark olive gray silt
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	1.0	99.0

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#200	0.075	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0295	97		
---	0.0188	95		
---	0.0109	92		
---	0.0079	84		
---	0.0058	74		
---	0.0042	65		
---	0.0030	57		
---	0.0013	37		

Coefficients

D_{85} = 0.0082 mm D_{30} = N/A
D_{60} = 0.0034 mm D_{15} = N/A
D_{50} = 0.0023 mm D_{10} = N/A
C_u = N/A C_c = N/A

Classification

ASTM   elastic silt (MH)

AASHTO   Clayey Soils (A-7-5 (56))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED
Sand/Gravel Hardness : HARD

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GeoTesting express
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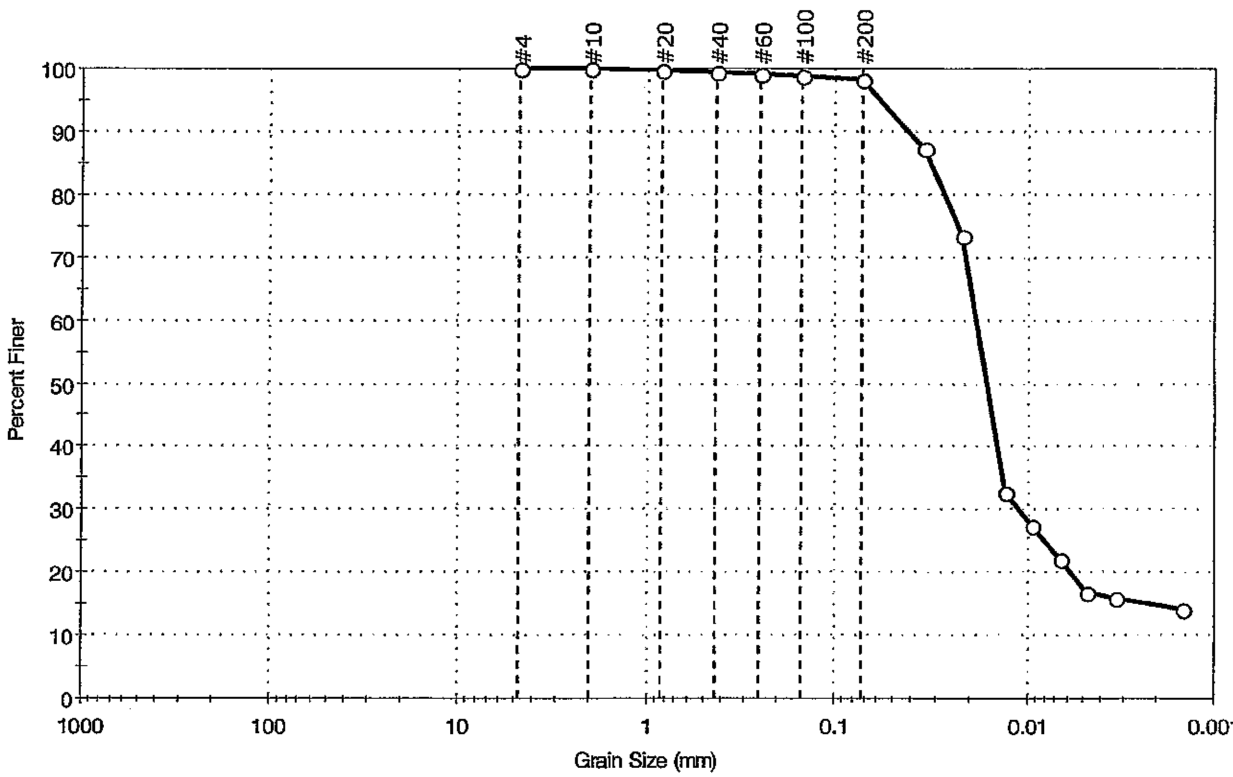
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-20076	Sample Type:	jar	Tested By:	sam
Sample ID:	OL-0232-20	Test Date:	01/04/07	Checked By:	jdt
Depth :	0-3.3 ft	Test Id:	103382		
Test Comment:	---				
Sample Description:	Wet, black silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.7	98.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0348	87		
---	0.0220	74		
---	0.0132	33		
---	0.0093	27		
---	0.0066	22		
---	0.0047	17		
---	0.0033	16		
---	0.0015	14		

Coefficients

D_{85} = 0.0322 mm | D_{30} = 0.0110 mm
D_{60} = 0.0185 mm | D_{15} = 0.0021 mm
D_{50} = 0.0163 mm | D_{10} = 0.0002 mm
C_u = N/A | C_c = N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (112))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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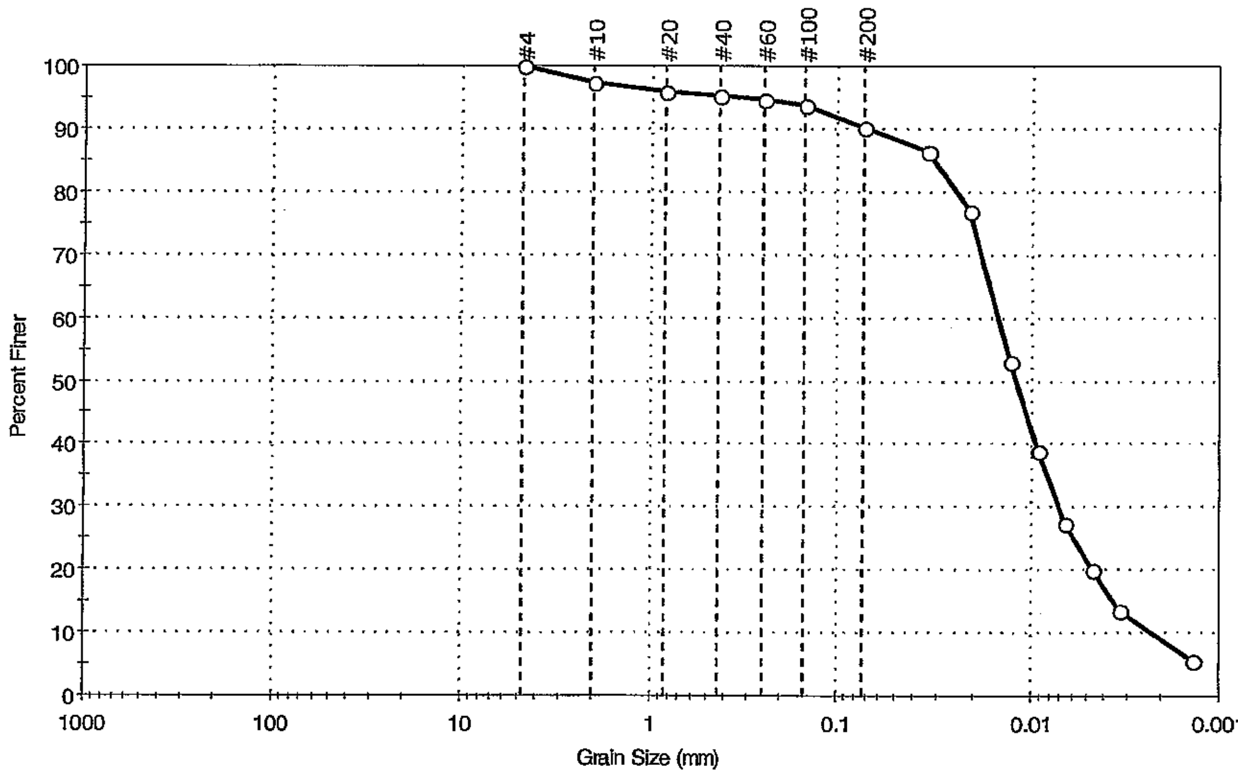
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-20076	Sample Type: jar	Tested By:	mll
Sample ID: OL-0233-01	Test Date: 12/12/06	Checked By:	jdt
Depth : 9.9-13.2 ft	Test Id: 103425		
Test Comment: ---			
Sample Description: Moist, mottled pale yellow and light reddish gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	9.8	90.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	97		
#20	0.84	96		
#40	0.42	95		
#60	0.25	95		
#100	0.15	94		
#200	0.074	90		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0343	86		
---	0.0214	77		
---	0.0127	53		
---	0.0091	39		
---	0.0065	27		
---	0.0047	20		
---	0.0033	14		
---	0.0014	5		

Coefficients

D_{85} =0.0320 mm	D_{30} =0.0071 mm
D_{60} =0.0148 mm	D_{15} =0.0036 mm
D_{50} =0.0118 mm	D_{10} =0.0022 mm
C_u =N/A	C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (57))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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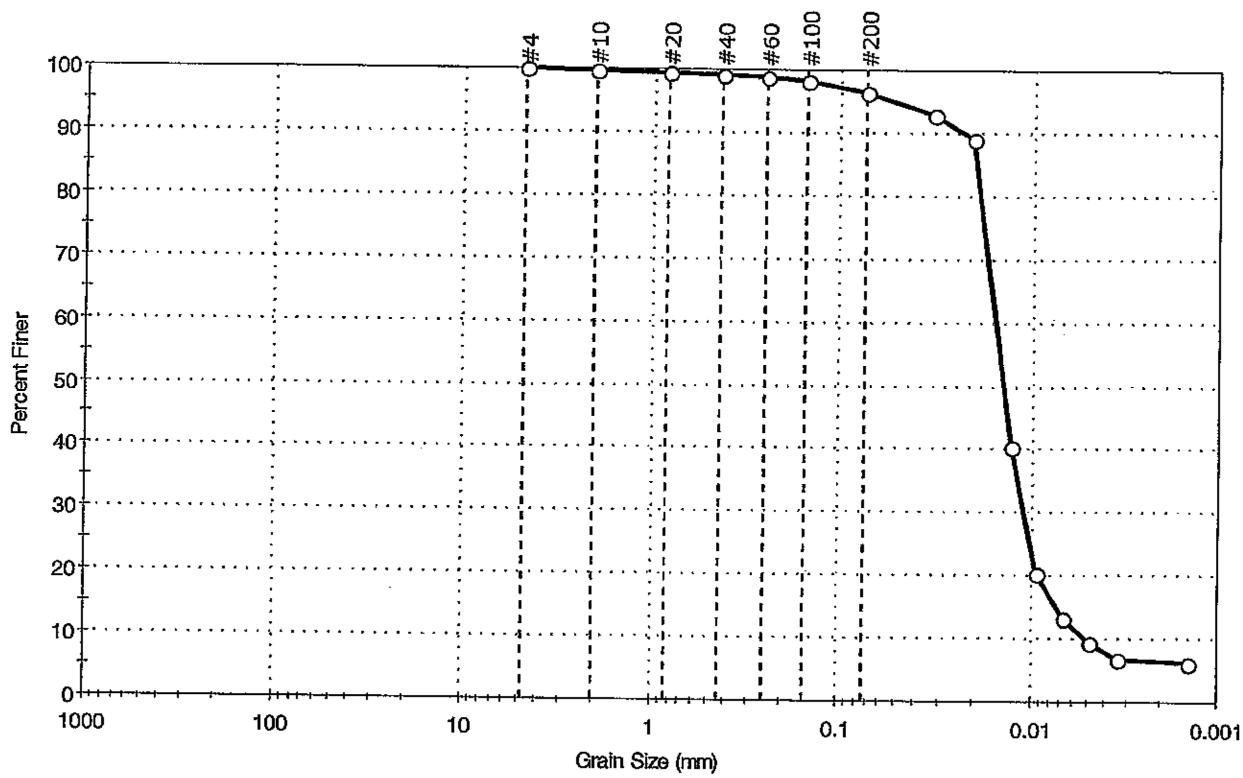
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-20077	Sample Type: jar	Tested By:	mll
Sample ID: OL-0233-02	Test Date: 01/17/07	Checked By:	jdt
Depth : 0-3.3 ft	Test Id: 103426		
Test Comment: ---			
Sample Description: Moist, black silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	3.6	96.4

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	99		
#40	0.42	99		
#60	0.25	99		
#100	0.15	98		
#200	0.074	96		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0334	93		
---	0.0208	89		
---	0.0130	40		
---	0.0094	20		
---	0.0067	13		
---	0.0048	10		
---	0.0034	7		
---	0.0014	6		

Coefficients

D_{85} =0.0200 mm　　D_{30} =0.0110 mm
D_{60} =0.0157 mm　　D_{15} =0.0073 mm
D_{50} =0.0142 mm　　D_{10} =0.0050 mm
C_u =N/A　　C_c =N/A

Classification

ASTM　elastic silt (MH)

AASHTO　Clayey Soils (A-7-5 (116))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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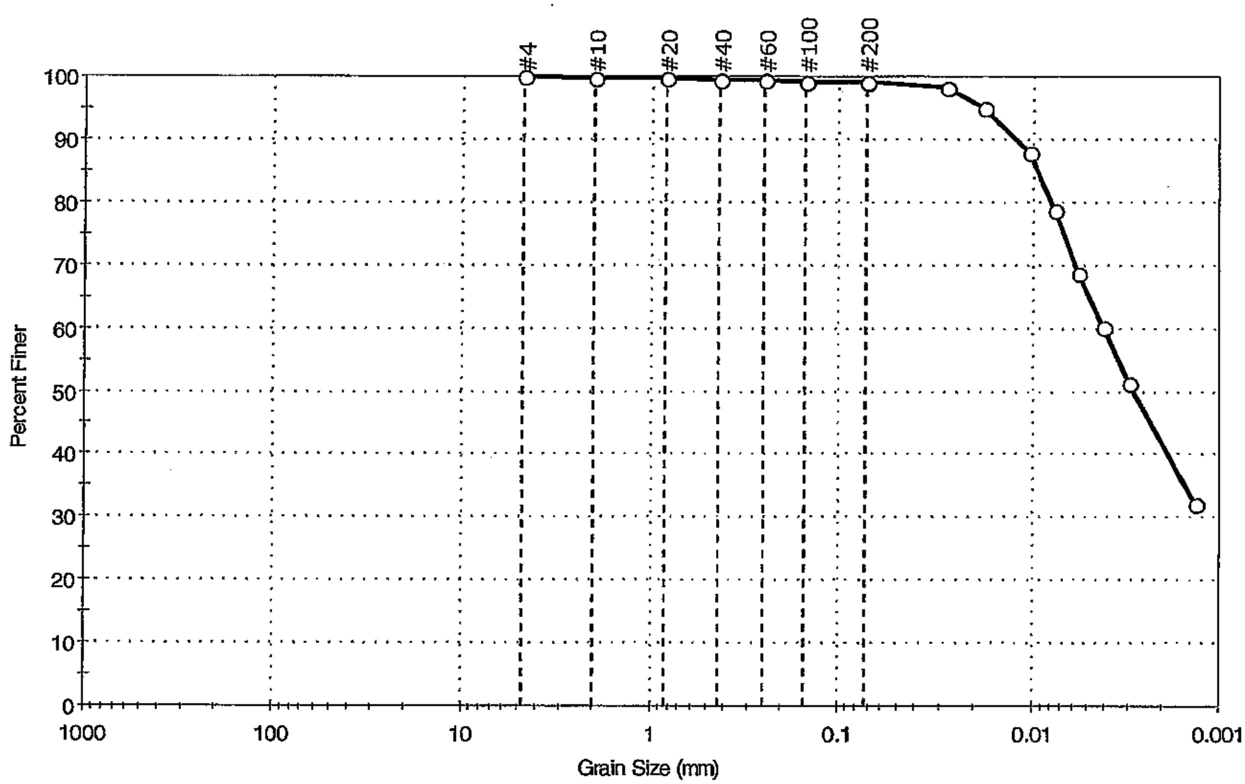
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-20077	Sample Type: jar	Tested By:	mll
Sample ID:OL-0233-03	Test Date: 01/15/07	Checked By:	jdt
Depth : 13.2-16.5 ft	Test Id: 103427		
Test Comment: ---			
Sample Description: Moist, olive brown silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
---	0.0	0.9	99.1

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	99		
#100	0.15	99		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0284	98		
---	0.0178	95		
---	0.0105	88		
---	0.0077	79		
---	0.0056	69		
---	0.0041	60		
---	0.0030	51		
---	0.0013	32		

Coefficients

D_{85} =0.0095 mm	D_{30} =N/A
D_{60} =0.0041 mm	D_{15} =N/A
D_{50} =0.0028 mm	D_{10} =N/A
C_u =N/A	C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (50))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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GeoTesting express
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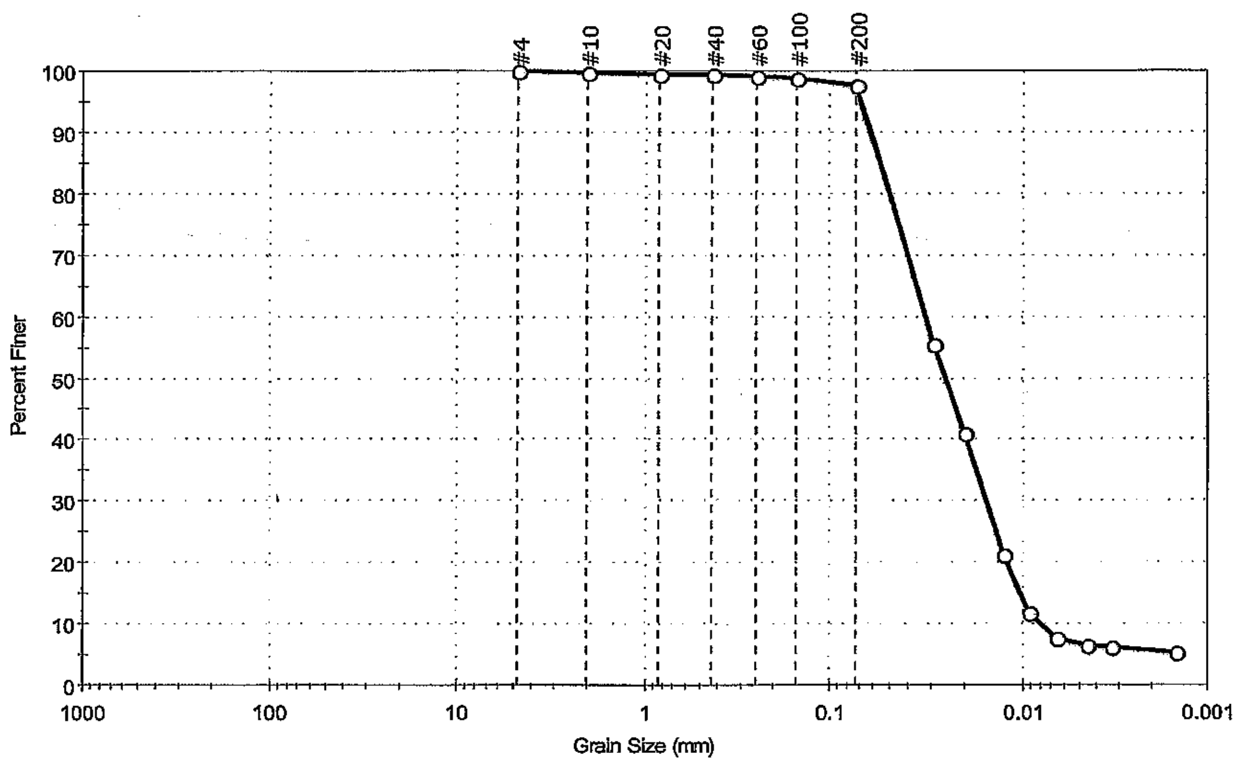
Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-VC-60054	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-0284-20	Test Date:	01/25/07	Checked By:	jdt
Depth :	0.5-3.3 ft	Test Id:	105773		

Test Comment: ---
Sample Description: Moist, black silt
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	2.2	97.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	99		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0299	56		
---	0.0200	41		
---	0.0126	21		
---	0.0092	12		
---	0.0066	8		
---	0.0045	7		
---	0.0033	6		
---	0.0015	5		

Coefficients

D_{85} =0.0563 mm D_{30} =0.0155 mm
D_{60} =0.0329 mm D_{15} =0.0103 mm
D_{50} =0.0257 mm D_{10} =0.0080 mm
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (100))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR
Sand/Gravel Hardness : HARD

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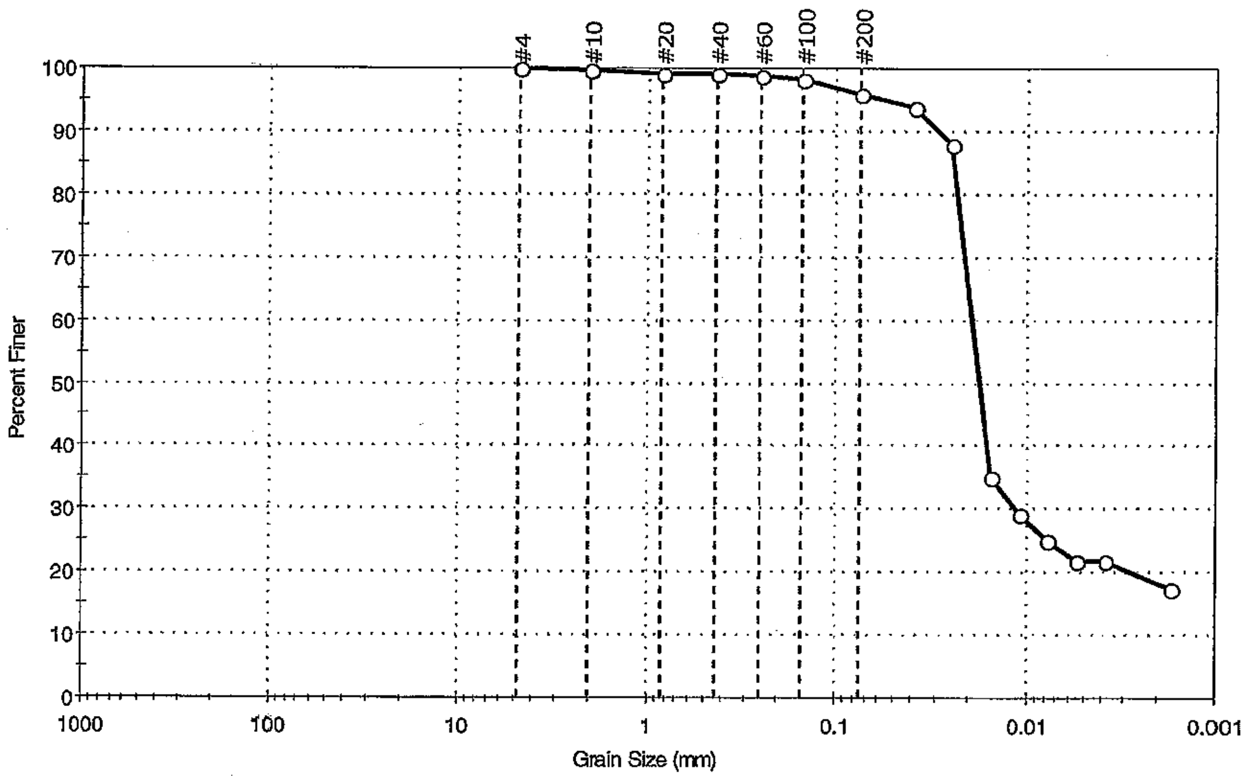
GeoTesting express
a subsidiary of Geocomp Corporation

Client:	Parsons Engineering Science				
Project:	Onondaga				
Location:	Syracuse			Project No:	GTX-7143
Boring ID:	OL-0298-04	Sample Type:	jar	Tested By:	mll
Sample ID:	OL-VC-60054	Test Date:	06/12/07	Checked By:	jdt
Depth :	3.3-6.6 ft	Test Id:	111442		
Test Comment:	---				
Sample Description:	Wet, black silt				
Sample Comment:	---				

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	4.2	95.8

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	99		
#40	0.42	99		
#60	0.25	99		
#100	0.15	98		
#200	0.075	96		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0396	94		
---	0.0248	88		
---	0.0154	35		
---	0.0109	29		
---	0.0078	25		
---	0.0054	22		
---	0.0038	22		
---	0.0017	17		

Coefficients

D_{85} =0.0241 mm | D_{30} =0.0115 mm
D_{60} =0.0193 mm | D_{15} =N/A
D_{50} =0.0176 mm | D_{10} =N/A
C_u =N/A | C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (65))

Sample/Test Description

Sand/Gravel Particle Shape : ROUNDED

Sand/Gravel Hardness : HARD

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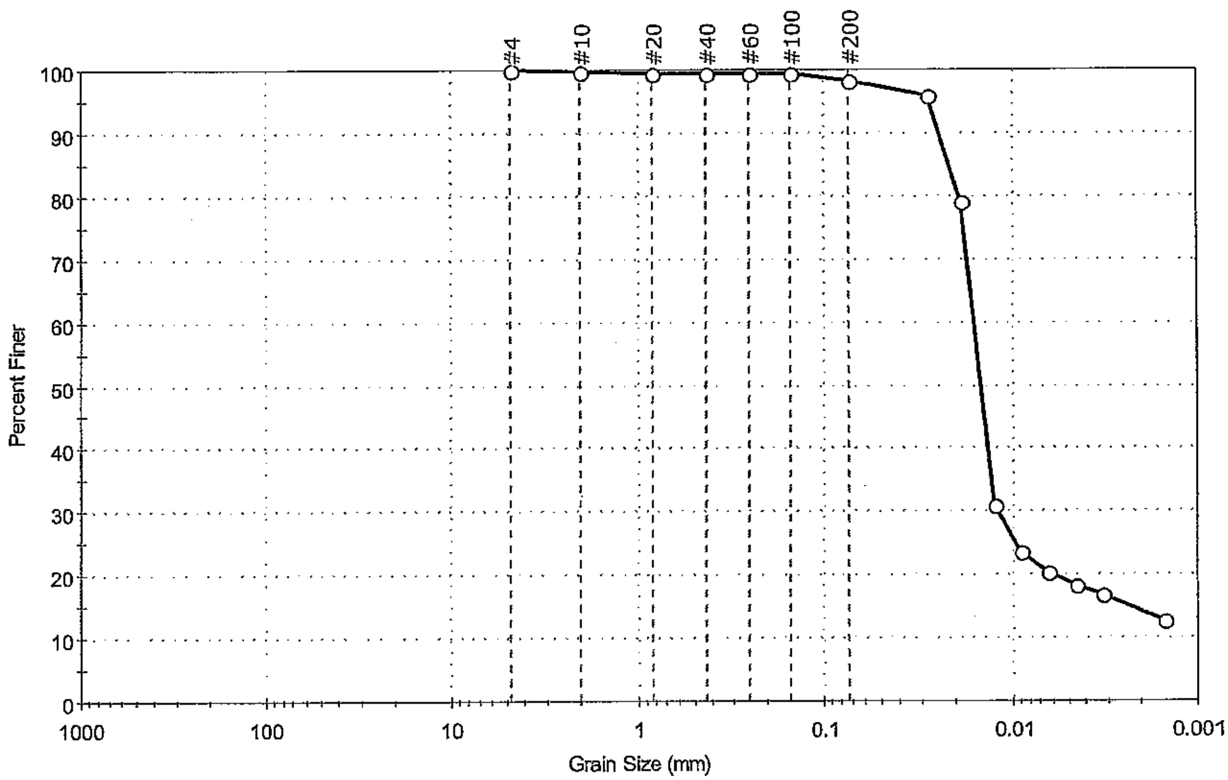
Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-60054	Sample Type: jar	Tested By:	mll
Sample ID: OL-0282-11	Test Date: 01/30/07	Checked By:	jdt
Depth : 6.6-9.9 ft	Test Id: 105652		
Test Comment: ---			
Sample Description: Moist, very dark gray silt			
Sample Comment: ---			

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	1.7	98.3

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	99		
#60	0.25	99		
#100	0.15	99		
#200	0.074	98		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0281	96		
---	0.0186	79		
---	0.0125	31		
---	0.0090	24		
---	0.0064	20		
---	0.0045	18		
---	0.0032	17		
---	0.0015	13		

Coefficients

D_{85} =0.0216 mm D_{30} =0.0120 mm
D_{60} =0.0159 mm D_{15} =0.0023 mm
D_{50} =0.0147 mm D_{10} =0.0009 mm
C_u =N/A C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (53))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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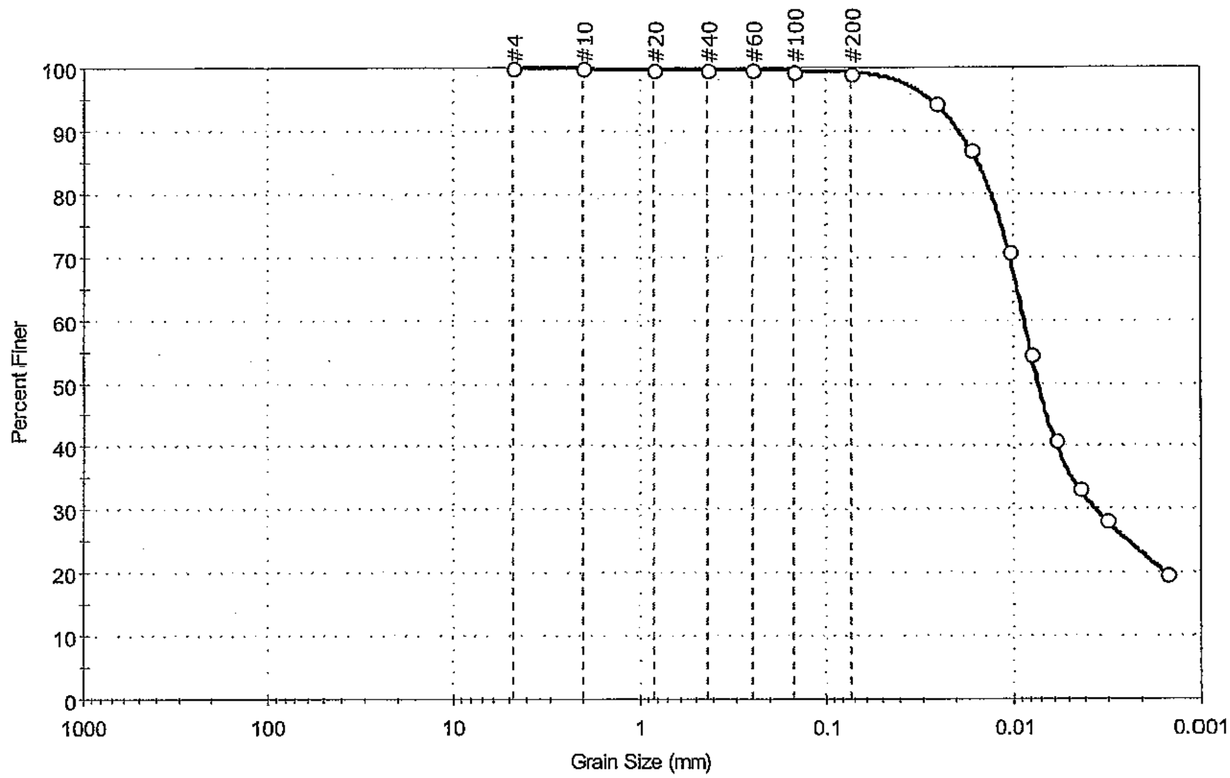
GeoTesting express
a subsidiary of Geocomp Corporation

Client: Parsons Engineering Science			
Project: Onondaga			
Location: Syracuse		Project No:	GTX-7143
Boring ID: OL-VC-60054	Sample Type: jar	Tested By:	mll
Sample ID: OL-0282-12	Test Date: 01/30/07	Checked By:	jdt
Depth : 16.5-18.5 ft	Test Id: 105653		

Test Comment: ---
Sample Description: Moist, very dark grayish brown silt
Sample Comment: ---

Particle Size Analysis - ASTM D 422-63 (reapproved 2002)



% Cobble	% Gravel	% Sand	% Silt & Clay Size
—	0.0	0.8	99.2

Sieve Name	Sieve Size, mm	Percent Finer	Spec. Percent	Complies
#4	4.75	100		
#10	2.00	100		
#20	0.84	100		
#40	0.42	100		
#60	0.25	100		
#100	0.15	100		
#200	0.074	99		
---	Particle Size (mm)	Percent Finer	Spec. Percent	Complies
---	0.0260	94		
---	0.0168	87		
---	0.0105	71		
---	0.0079	55		
---	0.0059	41		
---	0.0043	33		
---	0.0031	28		
---	0.0015	20		

Coefficients

D_{85} =0.0158 mm
D_{30} =0.0035 mm
D_{60} =0.0087 mm
D_{15} =N/A
D_{50} =0.0072 mm
D_{10} =N/A
C_u =N/A
C_c =N/A

Classification

ASTM elastic silt (MH)

AASHTO Clayey Soils (A-7-5 (65))

Sample/Test Description

Sand/Gravel Particle Shape : ANGULAR

Sand/Gravel Hardness : HARD

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