Bottom Ash Pond
Initial Safety Factor Assessment
Cardinal Power Plant
Brilliant, Ohio
S&ME Project No. 7217-15-007A

Prepared for:

American Electric Power
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Columbus, Ohio 43215

Prepared by:

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December 30, 2015

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1.0 Introduction

1.1 Background

In April of 2015, the US EPA formally published national regulations for disposal of coal combustion residuals (CCR) from electric facilities. As part of the rule, the owner or operator of the CCR unit must obtain a certification from a qualified professional engineer stating that aspects of the CCR impoundments are in accordance with the rules. Based on our understanding of the Request for Fee Estimate received from AEP on April 29, 2015, AEP specifically requested P.E. certification to fulfill the requirements of 40 CFR § 257.73(e), *Periodic Safety Factor Assessments*. In the employment of BBC&M Engineering, Inc., the undersigned engineers conducted site investigations at the bottom ash pond in 2009 and 2010. Due to our familiarity with the site, S&ME was selected to perform the Safety Factor Assessment for this facility. S&ME understands that certification and/or documentation for other structural integrity criteria will be performed by AEP or other consultants.

1.2 Location and Geologic Conditions

The Cardinal Generating Plant is located along the Ohio River between Brilliant, Ohio and Tiltonsville, Ohio. The Bottom Ash Pond Complex is located along the west bank of the river just to the south of the Unit 3 area. The Bottom Ash Complex consists of two components: the Bottom Ash Pond and the Recirculation Pond. The Bottom Ash Pond is located north of the Recirculation Pond and they are separated by an earthen embankment. The crest elevation for all of the embankments has a minimum Elevation of 670 feet. The total length of the exterior embankment along the Ohio River is approximately 2,000 feet. Based on the current topography around the bottom ash complex, there is no discernable embankment on the north and south ends, thus the areas of the pond embankments are typically identified by referencing the eastern or western embankments. The bottom ash pond is operated at a constant Elevation of 664.5 feet. For comparison, the normal pool for this stretch of the Ohio River is EL. 644, as controlled by the Pike Island Dam Both ponds are isolated from exterior surface water inflow and during normal operation, all water that enters the pond is pumped back to the plant via the pump station located within the Recirculation Pond. The exception is during high rainfall events where the principal spillway may activate releasing water into the Ohio River through an NPDES outfall. The discharge is controlled by a 4-foot wide weir surveyed at Elevation 666.2. A review of the historical plans available for the bottom ash pond facility is included in Appendix V.

The original ground surface at the site is generally located between El. 645 and 655. Near surface soils generally consist of a layer of alluvium silt, clay and fine sand (organic in some locations) over glacial outwash deposits of variable thickness overlying the bedrock surface. The alluvium clays and silts were deposited in the backwater of the Ohio River, while the outwash materials typically consist of sand, gravel and silt deposits deposited during the last ice age. Based on geological literature, the glacial outwash extends to the bedrock surface, estimated to be roughly 50 to 60 feet below the natural ground surface at the pond. The upper most bedrock most likely consists of shale and/or sandstone belonging to the Conemaugh Group of Pennsylvanian Age.

Figure 1-1 – Cardinal Plant

1.3 Previous Investigations

In 2009, the undersigned engineers, when in the employment of BBC&M Engineering, Inc., completed a subsurface investigation and geotechnical assessment of the bottom ash pond embankments. The assessment, dated August 4, 2009, concluded that the embankment exhibited adequate factors of safety against slope failure under steady-state seepage and seismic loading conditions relative to typical US Army Corps of Engineers requirements. In 2010, BBC&M Engineering, Inc. performed additional geotechnical analyses and an hydrology and hydraulic evaluation of the pond. As part of this work, additional slope stability failure modes were examined, including the maximum surcharge pool and rapid drawdown load cases. A report documenting the additional geotechnical analysis, dated December 17, 2010, was submitted as an addendum to the 2009 report. The text from the 2009 report and an excerpt from the 2010 follow-up report is Appendices V and VI.

2.0 Scope of Work

In accordance with AEP's request, the following work items were performed by S&ME:

1. S&ME completed a cursory review of previously conducted assessment work performed by the undersigned engineers, as well as a limited number of construction documents made available by AEP.

2. S&ME visited the site along with personnel from AEP. The site visit was not a formal inspection, but rather served to document any significant modifications or changed conditions that may have taken place since the time of the previous investigations.

3. Upon completing Tasks 1 and 2, S&ME determined that there was insufficient information to certify the structural integrity of the surface impoundment in accordance with the requirements of 40 CFR § 257.73(e). To this end, S&ME was authorized to perform a supplemental investigation to support the safety factor assessment. Details regarding the investigation are described in the following sections of this report.

3.0 Information Review and Site Visit

S&ME conducted a cursory review of previous documents relating to the bottom ash pond and conducted a site visit at the facility. AEP provided S&ME with the following documents:

- Site Development Plan 1973 (Dwg. 3-3017-5 and 3-3027-3)
- Assessment of Dam Safety Final Report, Clough Harbour, & Assoc., December, 2009
- Bottom Ash Pond Subsurface Investigation & Analysis, BBC&M Engineering, Inc., August, 2009
- Addendum to Bottom Ash Pond Investigation, BBC&M Engineering, Inc., December, 2010

On August 18, 2015, the undersigned S&ME personnel met with Dr. Mohammad Ajlouni (AEP Civil Engineering) and Mr. Randy Sims (Landfill Operations) at the Cardinal Plant and conducted a site visit at the bottom ash pond. The participants discussed and observed the operations of the bottom ash and recirculation ponds, including the hydraulic structures within the ponds. During our visit, two localized possible seepage areas were observed on the outboard slope of the eastern embankment of the recirculation pond. Based on discussions with the group, it was believed that the seepage areas were relatively new.

One apparent seepage area was located immediately north of the existing riprap and the other was approximately 300 feet north of the riprap. The limits of the possible seepage areas were delineated with a handheld GPS unit. The apparent seepage areas range from 35 to 50 feet wide by 6 to 8 feet high. The seepage areas were observed to be wetter than the surrounding area and were muddy in some areas, which may be a result of mowing operations. While the ground surface has been softened as a result of seepage, there was no indication of flowing water emanating at either of the areas at the time of our visit. Additionally there was no indication of piping of soil. S&ME understands the riprap on the outboard slope of the recirculation pond to the south of the new seepage area was constructed as an inverted filter; similar seepage conditions were observed in this area resulting in construction of the filter. Based on the historical drawings, the embankments do not contain any internal drains to intercept/control the phreatic surface within the embankment. Despite this, S&ME understands the embankments have otherwise performed well, particularly in regard to shallow sloughs along the outboard slope of the 41 years that they have been in service in the current configuration.

While no other visual observations suggested dam safety concerns, S&ME noted the following modifications to the bottom ash pond complex since the 2009 and 2010 assessments:

- The northern section of the western bottom ash pond embankment was widened on the outboard side to create additional space for construction staging.
- Crest improvements were made to raise low areas and establish a consistent top of dam Elevation of 670 feet.
- The 2009 investigation focused only on the river side embankment. Although the river side embankment is significantly taller than the west embankment, investigation of the west embankment was believed to be warranted.

4.0 Field and Laboratory Work

As part of the 2009 investigation, 7 soil borings were performed along the eastern embankment of the bottom ash pond and recirculation pond. For the 2015 supplemental investigation, S&ME performed 4 soil borings along the western embankments, as well as two additional shallow borings through the eastern embankment crest upstream from the identified seepage areas. The borings are designated as CD-BAP-1501 through B-1505 and MW-BAP-4 through MW-BAP-5. Boring CD-BAP-1503, originally planned to be located at the toe of the west embankment could not be accessed and was not performed. Boring numbers with 'MW' indicate a monitoring well was installed at this location, which were performed as part of a separate hydrogeology study. Additionally, S&ME installed three other monitoring wells, designated MW-BAP-1 through MW-BAP-3, and advanced one soil boring designated CD-BAP-1506 as part of the separate hydrogeology study at the bottom ash pond facility. Although not performed as part of this factor of safety assessment, the results from these explorations were considered in developing our understanding of the embankments and foundation soils. Locations of all explorations are shown on the Plan of Borings included as Drawing No. 1 in Appendix I.

Laboratory testing was performed on selected representative soil samples obtained during the field investigations to determine natural moisture content (ASTM D2216), liquid and plastic limits (S&ME adjustment to ASTM D4318), and grain size analyses (ASTM D422). The results of these and other tests permit an evaluation of the strength, compressibility and permeability characteristics of the soils encountered at this site.

The results of the moisture content testing and of the liquid and plastic limits are graphically displayed on the individual boring logs presented in Appendix I. All laboratory test results, including a summary of laboratory test results and grain size analyses are presented in Appendix II.

5.0 Subsurface Conditions

5.1 Stratigraphy

Borings CD-BAP-1501,CD-BAP-1502, and MW-BAP-5 were performed from the crest of the western embankment, while Boring MW-BAP-4 was performed from the toe of the western embankment. Based on the descriptions of the samples recovered in the borings and laboratory testing, the subsurface stratigraphy for each section can generally be described in descending order from the top of the western embankment as follows:

- Borings CD-BAP-1502 and MW-BAP-5 were performed from the crest of the embankment encountered 15 inches of aggregate at the ground surface overlying 10 to 13 feet of embankment fill consisting of medium-dense to dense fine to coarse sand and gravel and hard clayey silt. SPT N-values (corrected for 60% energy) ranged from 13 to 60 while hand penetrometer measurements on samples exhibiting cohesion ranged from __ to 4.5+ tons per square foot (tsf).
- Boring CD-BAP-1501 was performed from the widened crest area. The boring encountered 15 inches aggregate underlain by 11.5 feet of embankment fill consisting of a thin stratum of medium-stiff clayey silt over of loose to medium dense fine to coarse sand.
- Underlying the embankments, the borings encountered alluvial soils consisting of

Borings CD-BAP-1504 and CD-BAP-1505 were performed from the crest of the eastern embankment adjacent to the observed seepage areas. The main purpose of these boring was to identify potential anomalies within the embankments that would suggest a unique circumstance which could be contributing to the observed seepage. Both borings were advanced to a depth of 16 feet within the embankment fill. For reference, the seepage areas were observed to begin approximately 6 to 8 feet below the crest. These borings, along with results from the sampling from monitoring wells MW-BAP-1, MW-BAP-2 and MW-BAP-3 did not reveal any appreciable differences from the crest borings performed during the 2009 investigation, such as a layer or zone of clean sand, as the embankment fill was already known to contain soils of a varying degree.

The stratigraphy of the eastern embankments is summarized in the text from the 2009 Investigation included as Appendix V.

5.2 Groundwater Conditions

Groundwater observations were made as each boring was being advanced and measurements were made at the completion of drilling. The groundwater observations are graphically displayed on the boring logs and also noted at the bottom of the log, and are referenced from the ground surface. Groundwater was encountered within the crest borings at a depth of approximately 15 feet. Groundwater in Boring MW-BAP-4 was encountered at a depth of 5.5 feet. The groundwater readings correlate to an approximate Elevation of 655 feet.

Temporary open standpipe piezometers were installed in Borings CD-BAP-1504 and CD-BAP-1505 to obtain groundwater information in relation to the observed seepage area. Unfortunately, owing to the presence of overhead electric along the outboard side of the crest, the borings had to be performed near the inboard side of the crest. Several longer term groundwater readings were taken during the course of the field work. The readings are summarized on the individual well logs, and generally range between Elevation 661 and Elevation 663. The readings indicate a small decrease in water level from the recirculation pond operating pool. It should be noted that all of the wells positioned within the crest are located on the inboard side to avoid blocking the road as well as the overhead power lines.

5.3 Shear Strength and Permeability

The laboratory testing results for the 2015 investigation were compared to laboratory testing completed as part of the 2009 investigation. The comparison of the index testing was performed to determine if there was any justification for developing different shear strength and permeability values for the subsurface materials encountered in the western side of the complex than had been previously been estimated for cross-sections on the eastern side in 2009. As the results of the 2009 laboratory index testing are very similar to the new index testing results, S&ME is of the opinion that the strength parameters used to characterize the eastern embankment and foundation soils in 2009 are applicable to the supplemental investigation of the western embankment and foundation soils.

The shear strength parameters used in the slope stability analysis are shown in Table 5-1.

Table 5-1 – Shear Strength Parameters

Material Description	γ_{wet} *(pcf)*	*Effective*		*Reference*
		ϕ'	c′ (psf)	
Newer Embankment Fill	125	31°	0	SPT and Index Testing Correlations
Original Embankment Fill	125	30°	100	Index Testing Correlations
Alluvium Silt and Clay	125	30°	0	Index Testing Correlations
Organic Clayey Silt	125	30°	0	Index Testing Correlations and CU Triaxial Test (BBCM 2009)
Very Loose to Loose Glacial Outwash Sand and Gravel	115	29°	0	SPT and Grain Size Correlations
Medium Dense Glacial Outwash Sand and Gravel	120	34°	0	SPT and Grain Size Correlations
Granular Embankment Fill(1)	115	30°	0	SPT and Grain Size Correlations

(1) Applies only to widened crest area on the northwestern side of bottom ash pond

6.0 Safety Factor Assessment

As part of the safety factor assessment, S&ME completed Parts 1 and 2 of Section 257.73(e) of the Final Rules for the Disposal of Coal Combustion Residuals from Electric Utilities published on April 17, 2015 in the Federal Register. In accordance with the Rule, the analysis was performed for the critical cross-sections(s) that are anticipated to be most susceptible of all cross-sections to structural failure based on appropriate engineering considerations. The Rule specified the following loading conditions for analysis:

i. Static Factor of Safety under the long-term, maximum storage pool loading condition must equal or exceed 1.50.
ii. Calculated static factor of safety under the maximum surcharge pool loading condition must equal or exceed 1.50.
iii. The calculated seismic factor of safety must equal or exceed 1.00.
iv. For dikes constructed of soils susceptible to liquefaction, the calculated liquefaction factor of safety must equal or exceed 1.20.

6.1 Limit Equilibrium Analyses

The 2009 Investigation Report and the 2010 Addendum discuss in detail the subsurface investigation, laboratory testing, parameter justification, seepage analyses and limit equilibrium slope stability analyses that were performed to develop safety factors for the bottom ash pond embankments. As mentioned previously, engineering parameters developed as part of the 2009 and 2010 investigations were utilized for the new analyses associated with the western embankment as the laboratory testing and subsurface investigation did not encounter soil properties that differed greatly from the soils encountered in the previous investigations.

In summary, four sections along the eastern (river-side) embankment and two sections along the western embankment were studied. Both cross-sections through the western embankment are located within the bottom ash pond as the embankment adjacent to the recirculation pond is only 4 to 6 feet high and access to the toe was not readily available. Subsurface information for each section was obtained by performing borings through the crest and toe of the embankment. Based on a review of all six sections explored, three were selected for detailed limit equilibrium stability analysis (two on the eastern embankment and one on the western embankment).

Prior to performing the limit equilibrium stability analyses as part of the 2009 assessment, seepage analyses were performed to develop a better understanding of the likely phreatic surface within the embankment and foundation. The models were calibrated by adding additional total head boundary conditions within the subsurface to best model the groundwater table as observed in the observation wells. Although a classically shaped phreatic surface extending from the ash pond level to the Ohio River was generated by the seepage analyses, much of the seepage emanating from the ponds appears to be moving downward through the newer embankment fill and thin stratum of alluvium soils and into the glacial outwash sand and gravel stratum which essentially serves as a drain.

Results of the slope stability analysis indicate that the critical cross-section occurs through the eastern embankment of the bottom ash pond (referred to as Section D in the 2009 and 2010 assessments). The design cross-section does not vary along the eastern embankment, but Section D yielded the lowest factors of safety due to slight variations in the outboard slope. All load cases performed for the Safety Factor Assessment as well as additional load cases evaluated for typical US Army Corps of Engineer's requirements met the minimum factor of safety for global stability.

One observed seepage area is located just north of Section B and the other is located approximately 200 feet south. Comparison of boring logs for CD-BAP-1504 and CD-BAP-1505 with the log for boring CD-PZ-BAP-0902 located at Section B do not reveal any key differences in the embankment fill. In fact, Boring CD-PZ-BAP-0902 exhibited a larger zone of granular embankment fill located within the observed elevation of seepage on the outboard slope, but no seepage was observed adjacent to this boring. The fill soils are believed to vary laterally through the embankment as much as it was observed to vary vertically at the boring locations, suggesting that the granular layers observed in the borings are unlikely to extend all the way through the embankment. Considering this, it is the opinion of S&ME that at this time, the seepage areas are representative of localized pockets of more permeable soils within the overall embankment matrix. As such, it is not believed that the phreatic surface intercepts the outboard face, but rather that there are narrow zones of seepage with unsaturated soils beneath. Nonetheless, these areas should be addressed, as further discussed below.

As noted, the seepage observed during our August, 2015 site visit appeared to occur in two isolated areas. With time, the outboard slope at these locations may weaken due to the presence of groundwater within close proximity to the ground surface resulting in reduced shear strength and shallow slope failures. Though such a failure would typically be minor in extent, S&ME recommends these areas be addressed in the near future before they lead to more significant issues over time. Construction of an inverted filter may be suitable given the performance of the existing inverted filter on the south end. S&ME also recommends continued monitoring of these areas to ensure soils particles are not being carried from inside the embankment.

6.2 Liquefaction Potential of Embankment Soils

S&ME evaluated the potential of the embankment soils to liquefy during a seismic event. The embankment material is classified as a fined grained material and the recovered samples with gradation testing were evaluated following guidelines presented in the 2003 NEHRP (National Earthquake Hazards Reduction Program) Recommended Provisions for Seismic Regulations for New Buildings and Other Structures. The provisions in Chapter 7 indicate that liquefaction potential in fine grained soils should be assessed provided the following criteria are met (Seed and Idriss 1982; Seed et al., 1983): the weight of the soil particles finer than 0.005 mm is less than 15 percent of the dry unit weight of a specimen of the soil; the liquid limit of soil is less than 35 percent; and the moisture content of the in-place soil is greater than 0.9 times the liquid limit. If all of these criteria are not met, the soils may be considered non-liquefiable.

Laboratory testing results from 16 fine grained samples that were available from the 2009 and 2015 investigations for evaluation of the screening criteria. Of the 16 samples, 8 samples contained data to check all three screening criteria, and 7 samples contained data to check two screening criterion. Based on the results of the screening, no sample met all 3 criteria; therefore, these fine grained embankment fill can be considered non-liquefiable. A table depicting this evaluation is included in Appendix IV.

The potential for the coarse grained embankment soils to resist liquefaction was evaluated. The fine grained (cohesive) and coarse grained (granular) embankment soils appear to be from the same borrow source as there are no well-defined layers and often only minor variations in the percent by weight of the recovered sample change the main description from fine grained to coarse grained. Although construction records were not available, the density of the coarse grained samples and consistency of the fine grained samples within the embankment fill suggest they were well compacted. Based on the controlled manner in which the fill was placed, the coarse grained embankment soils can be considered non-liquefiable.

6.3 Summary of Results

A summary of the computed safety factors for the critical cross-section is provided in Table 5-2. Also included in the table are the minimum values defined in 40 CFR § 257.73(e)(1) subparts (i) through (iv). Graphical output corresponding to the analysis cases are presented in Appendix IV along with additional slope stability load cases evaluated during the course of the bottom ash pond assessments.

Table 6-1 – Safety Factor Summary

Analysis Case	Minimum Safety Factor	Computed Safety Factor
Long-term, maximum storage pool	1.50	1.52
Maximum surcharge pool	1.40	1.52
Pseudo-static seismic loading	1.00	1.09
Embankment Liquefaction	1.20	Non-liquefiable

7.0 Certification

Based on our previous investigations and current assessment of the Bottom Ash Pond facility, S&ME certifies that this assessment meets the requirements of paragraphs (e)(1) and (e)(2) of Part 257.73 for the critical cross-section of the embankment.

We appreciate having been given the opportunity to be of service on this project. If you have any questions, please do not hesitate to contact this office.

Sincerely,

S&ME, Inc.

STATE OF OHIO
MICHAEL T. ROMANELLO
E-74384
REGISTERED PROFESSIONAL ENGINEER

12-30-15

Michael T. Romanello, P.E.
Project Engineer
Registration No. 74384

Michael G. Rowland, P.E.
Senior Engineer
Registration No. 65559

Appendices

Appendix I – 2009 & 2015 Site Investigation Figures

DWG. NO. PLATE 2

BORING	NORTHING	EASTING	ELEVATION
CD-BAP-0901	819021.73	2513493.10	668.68
CD-PZ-BAP-0902	819364.85	2513568.73	668.04
CD-BAP-0903	819345.90	2513647.44	650.07
CD-PZ-BAP-0904	819708.29	2513666.53	668.05
CD-PZ-BAP-0905	819681.02	2513742.24	650.11
CD-BAP-0906	820058.00	2513791.36	668.64
CD-BAP-0907	820022.70	2513886.71	650.34
CD-BAP-1501	820853.00	2513678.00	671
CD-BAP-1502	820838.80	2513713.00	671
CD-BAP-1504	819154.10	2513525.00	670
CD-BAP-1505	819447.60	2513591.00	670
CD-BAP-1506	818752.90	2513205.00	671
MW-BAP-1	820309.50	2513925.00	670
MW-BAP-2	819797.40	2513705.00	670
MW-BAP-3	819116.30	2513518.00	670
MW-BAP-4	820884.30	2513614.00	660
MW-BAP-5	820057.10	2513275.00	670

DATUM: NAD 27/NGVD 29 OHIO SOUTH

SCALE IN FEET

0 100 200

LEGEND

- EXISTING GROUND CONTOUR (1 FT. INTERVAL)
- EXISTING WATER SURFACE (AT TIME OF SURVEY)
- FENCE LINE
- EXISTING VEGETATION
- CV-PZ-BAP-0901 ◐ BORING NUMBER AND LOCATION 2009 INVESTIGATION
- CD-BAP-1501 ⊕ BORING NUMBER AND LOCATION 2015 INVESTIGATION
- MW-BAP-1 ● MONITORING WELL NUMBER AND LOCATION 2015 INVESTIGATION

REFERENCE: AEP CARDINAL DRAWING 94151038

PROJECT NUMBER:	7217-15-007B	DRAWN BY:	MRM
DRAWING DATE:	12-30-2015	ENGINEER:	MTR
LAST UPDATED:	12-30-2015	APPROVED BY:	MGR
		SCALE:	1" = 100'

S&ME
WWW.SMEINC.COM
6190 ENTERPRISE COURT
DUBLIN, OH 43015
(614) 793-2226
ENGINEERING FIRM LICENSE NUMBER: F-0176

DATE	NO.	DESCRIPTION	APPD.
		REVISIONS	

A.E.P.
CARDINAL PLANT
BRILLIANT OHIO

BOTTOM ASH POND
INVESTIGATION
PLAN OF BORINGS

DWG. NO. PLATE 1

SCALE:
CIVIL ENGINEERING
DR:
CH:
ENGR:
PROJ ENGR:
DATE:
APPROVED BY

AMERICAN ELECTRIC POWER
AEP SERVICE CORP.
1 RIVERSIDE PLAZA
COLUMBUS, OH 43215

IGS0694

SYSTEM DATE- DD-MMM-YYYY
SYSTEM TIME- HOUR:MINUTE

EXPLANATION OF SYMBOLS AND TERMS USED ON BORING LOGS FOR SAMPLING AND DESCRIPTION OF SOIL

SAMPLING DATA

▮ - Blocked-in "SAMPLES" column indicates sample was attempted and recovered within this depth interval.

▯ - Sample was attempted within this interval but not recovered.

2/5/9 - The number of blows required for each 6-inch increment of penetration of a "Standard" 2-inch O.D. split-barrel sampler, driven a distance of 18 inches by a 140-pound hammer freely falling 30 inches. Addition of one of the following symbols indicates the use of a split-barrel other than the 2" O.D. sampler:

- $\boxed{\text{2S}}$ - 2½"O.D. split-barrel sampler
- $\boxed{\text{3S}}$ - 3" O.D. split-barrel sampler

P - Shelby tube sampler, 3" O.D., hydraulically pushed.

R - Refusal of sampler in very-hard or dense soil, or on a resistant surface.

50-2" - Number of blows (50) to drive a split-barrel sampler a certain number of inches (2), other than the normal 6-inch increment.

S/D - Split-barrel sampler (S) advanced by weight of drill rods (D),

S/H - Split-barrel sampler (S) advanced by combined weight of rods and drive hammer (H).

SOIL DESCRIPTIONS

All soils have been classified basically in accordance with the Unified Soil Classification System, but this system has been augmented by the use of special adjectives to designate the approximate percentages of minor components as follows:

Adjective	Percent by Weight
trace	1 to 10
little	11 to 20
some	21 to 35
"and"	36 to 50

The following terms are used to describe density and consistency of soils:

Term (Granular Soils)	Blows per foot
Very-loose	Less than 5
Loose	5 to 10
Medium-dense	11 to 30
Dense	31 to 50
Very-dense	Over 50

Term (Cohesive Soils)	Qu (tsf)
Very-soft	Less than 0.25
Soft	0.25 to 0.5
Medium-stiff	0.5 to 1.0
Stiff	1.0 to 2.0
Very-stiff	2.0 to 4.0
Hard	Over 4.0

Page 1 of 1

LOG OF BORING NO. CD-BAP-1501
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

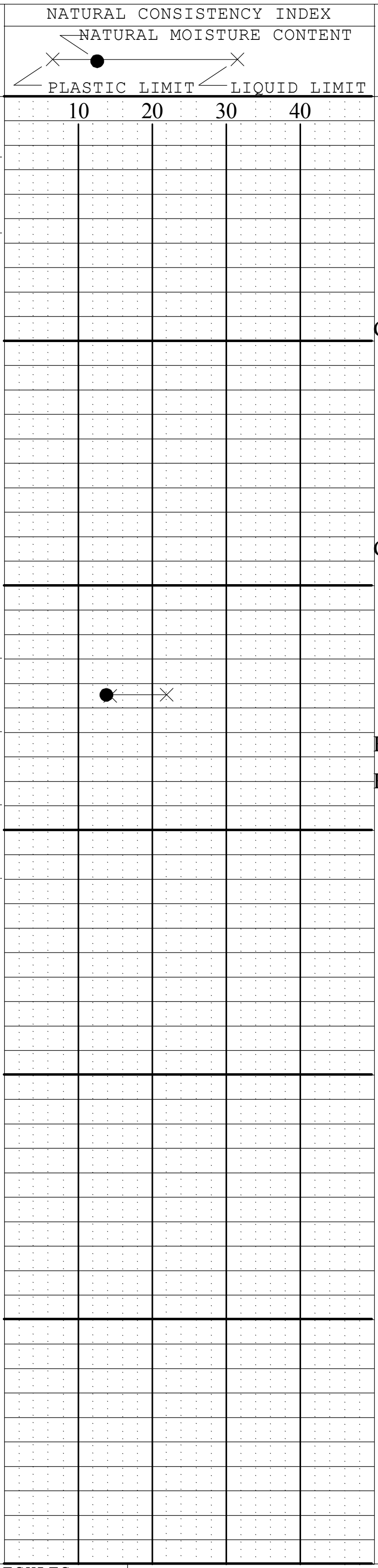
S&ME

LOCATION: **N. 820,853, E. 2,513,678** ELEVATION: **671** DATE: **11/17/15 - 11/18/15**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **16.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	0					AGGREGATE - 15 INCHES	
669.8		1	12/15/21	45	87	FILL: Medium-stiff gray clayey silt, "and" fine to coarse sand, little fine gravel, intermixed with silty clay, damp.	
668.2		2	5/6/4	13	67	FILL: Loose to medium-dense brown and gray fine to coarse sand, little to some silty fine to coarse gravel, little to some silt, damp.	
	5	3	3/3/3	8	53		G
		4	3/2/3	6	53		
		5	1/3/5	10	80		
		6	31/6/8	18	80		G
	10	7	50-1"R		0		
659.5		8	8/19/13	40	73	FILL: Dense brown fine to coarse sand, trace fine gravel, some to "and" clayey silt, damp.	
658.0		9A 9B	10/15/19	43	100	FILL: Stiff to very-stiff gray silty clay, some to "and" fine to coarse sand, little fine to coarse gravel, damp.	H=1.75-2.25 H=3.0-4.0
656.5	15	10	8/8/19	34	67	FILL: Dense brown and gray fine to coarse sand, little fine to coarse gravel, some silt, damp.	
655.0							
						- Boring backfilled with cement bentonite grout. - Boring location recorded with a hand-held GPS unit. Elevation estimated from March, 2015 plant survey. - Datum: Ohio State Plane South NAD 27/ NAVD 29 (Plant Grid).	
	20						
	25						
	30						



WATER LEVEL: ▽ ▼

WATER NOTE:

DATE:

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75

Last Calibration Date : 2/20/2013

Drill Rig Number : S&ME ATV 550-2

JOB: 7217-15-007A

PLATE 3

LOG OF BORING NO. CD-BAP-1502
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

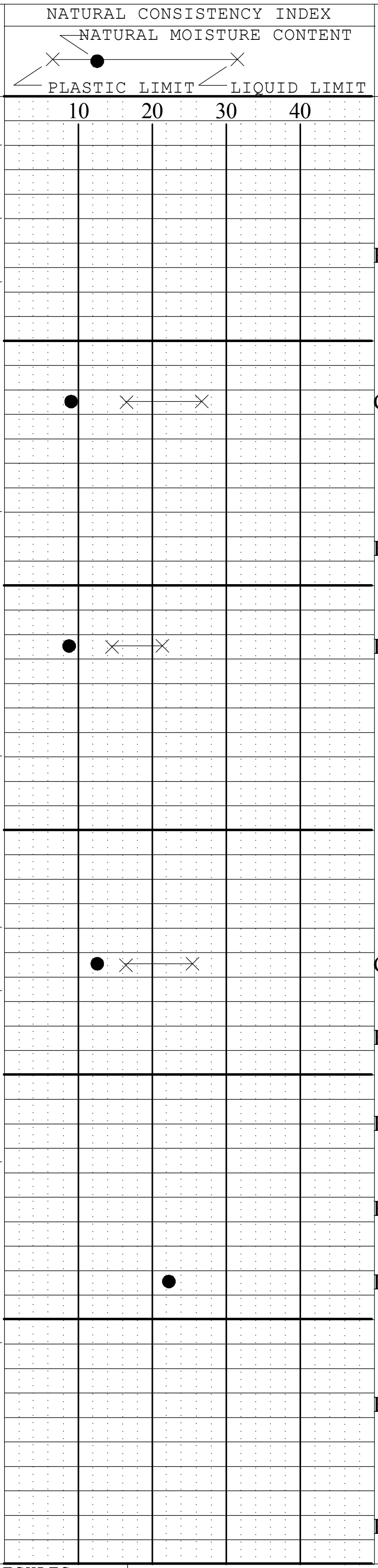
LOCATION: **N. 820,839, E. 2,513,713** ELEVATION: **671** DATE: **11/18/15**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **41.5'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

2010 NEW DEFAULT BORING LOG-W/ N60

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
670.0	0						AGGREGATE - 12 INCHES	
668.5		1		3/12/18	38	53	FILL: Dense brown and gray fine to coarse gravel, some fine to coarse sand, little silt, damp.	
667.2		2		15/18/30	60	80	FILL: Hard brown and gray clayey silt, "and" fine to coarse sand, little fine gravel, damp.	H=4.5
	5	3		32/23/18	51	80	FILL: Medium-dense to very-dense brown and gray fine to coarse sand, little to some fine to coarse gravel, little to some silt, silty clay, or clayey silt (varies), damp.	
		4		10/12/13	31	80		G
662.5		5		8/10/11	26	93		
		6		9/11/15	33	87	FILL: Hard gray and brown clayey silt, some to "and" fine to coarse sand, little fine to coarse gravel, damp.	H=4.5
	10	7		11/15/18	41	53		H=4.5
657.5				P				
	15	8		3/4/7	14	67	FILL: Medium-dense gray and brown fine to coarse sand, some fine to coarse gravel, some silty clay, moist becoming wet.	
654.0				P				
652.7		9		7/7/8	19	87	FILL: Medium-dense gray fine to coarse sand, some fine to coarse gravel, some clayey silt, wet.	G
		10		7/6/3	11	100	Stiff gray clayey silt, some fine to coarse sand, some fine gravel, moist.	H=1.25
649.2	20			P				H=1.25
		11		4/5/5	13	73	Stiff brown silty clay, some fine to coarse sand, little to some fine to coarse gravel, moist.	H=2.5
645.5	25	12		SH/SH/SH	0	33		H=1.25
		13		SH/5/8	16	93	Very-stiff red-brown mottled with gray silty clay, trace to little fine to coarse sand, contains silt seams, damp.	H=3.0-3.75
	30	14		2/4/	13	93		H=3.5



WATER LEVEL: ▽ ▼

WATER NOTE:

DATE:

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75

Last Calibration Date : 2/20/2013

Drill Rig Number : S&ME ATV 550-2

-CONTINUED-

LOG OF BORING NO. CD-BAP-1502
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

LOCATION: **N. 820,839, E. 2,513,713** ELEVATION: **671** DATE: **11/18/15**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **41.5'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

2010 NEW DEFAULT BORING LOG-W/ N60

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
638.5	30	15		3 6 / 5 / 7	15	87	Very-stiff red-brown mottled with gray silty clay, trace to little fine to coarse sand, contains silt seams, damp.	H=3.5
636.5				P			Stiff to very-stiff brown mottled with gray silty clay, some to "and" from to medium sand, trace coarse sand, damp.	H=1.5-2.25
634.0	35	16		1 / 3 / 3	8	100	Loose red-brown from to medium sand, trace coarse sand, "and" silt, damp.	
632.7							Stiff red-brown silty clay, "and" fine to medium sand, trace coarse sand, trace fine gravel, damp.	
		17		3 / 2 / 3	6	100	Very-loose brown fine to medium sand, "and" silt, damp.	H=1.75
629.5	40	18		2 / 2 / 2	5	67		G
	45						- Encountered water at 15.0'. - Boring backfilled with cement bentonite grout. - Boring location surveyed with a hand-held GPS unit. Elevation estimated from March 2015 plant survey. - Datum: Ohio State Plane South NAD 27/NAVD 29 (Plant Grid).	
	50							
	55							
	60							

NATURAL CONSISTENCY INDEX
NATURAL MOISTURE CONTENT
PLASTIC LIMIT LIQUID LIMIT
10 20 30 40

WATER LEVEL: ▽ ▼
WATER NOTE:
DATE:

SYMBOLS USED TO INDICATE TEST RESULTS
G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves
H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75
Last Calibration Date : 2/20/2013
Drill Rig Number : S&ME ATV 550-2

Page 1 of 1

LOG OF BORING NO. CD-BAP-1504
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

S&ME

LOCATION: **N. 819,154, E. 2,513,525** ELEVATION: **670** DATE: **11/16/15**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **18.0'**

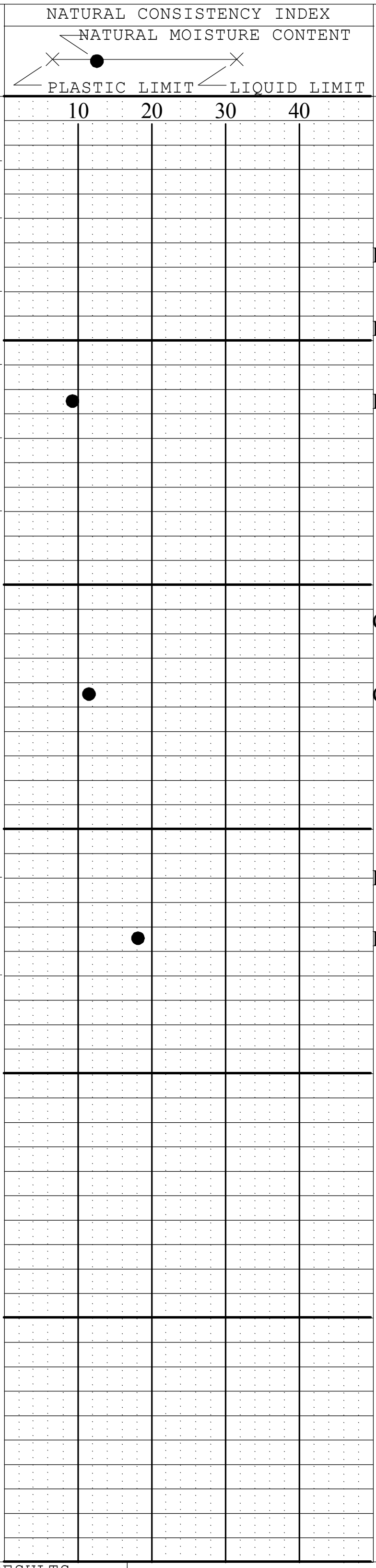
SAMPLER(S): **2" O.D. Split-barrel Sampler**

2010 NEW DEFAULT BORING LOG-W/ N60

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
668.7	0					AGGREGATE - 16 INCHES	
667.5		1	27/18/14	40	87	FILL: Hard gray and brown silty clay, some fine to coarse sand, brown fine gravel, dry.	
666.0		2	18/10/9	24	80	FILL: Medium-dense dark-brown fine to coarse sand, trace fine gravel, trace silt, dry.	H=4.0
664.5	5	3	4/20/19	49	93	FILL: Hard gray and brown silty clay, "and" fine to coarse sand, little fine gravel, dry.	H=4.0
663.0		4	11/18/24	53	100	FILL: Dense dark-gray and brown fine to coarse sand, little to some fine to coarse gravel, some silty clay, dry.	H=4.0
661.5		▽ 5	24/17/14	39	67	FILL: Hard brown silty clay, some fine to coarse sand, little fine gravel, dry.	
		6	11/14/21	44	33	FILL: Medium-dense to dense brown and dark-gray fine to coarse sand, little to some fine to coarse gravel (sandstone fragments), little to "and" silty clay, dry.	
	10	7	7/11/16	34	67		G
		8	11/8/10	23	27		G
		9	8/27/16	54	47		
	15	10	2/4/7	14	0		
654.0		11 2S	11		100	FILL: Medium-stiff to stiff brown and gray silty clay, some fine to coarse sand, little fine to coarse gravel, damp becoming wet.	H=1.5-2.0
652.0		12	1/4/4	10			H=0.75-1.5
	20						
	25						
	30						

DRAFT

- No seepage encountered.
- Encountered water at 16.5'.
- Borehole converted to temporary piezometer upon completion - See Separate Well Log.
- Boring backfilled with cement bentonite grout.
- Boring location surveyed with a hand-held GPS unit. Elevation estimated from March 2015 plant survey.
- Datum: Ohio State Plane South NAD 27/NAVD 29 (Plant Grid).



	▽	▼
WATER LEVEL:	7.9	
WATER NOTE:	In Well	
DATE:	12/10/15	

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75
Last Calibration Date : 2/20/2013
Drill Rig Number : S&ME ATV 550-2

JOB: 7217-15-007A

PLATE 6

Page 1 of 1

LOG OF BORING NO. CD-BAP-1505
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

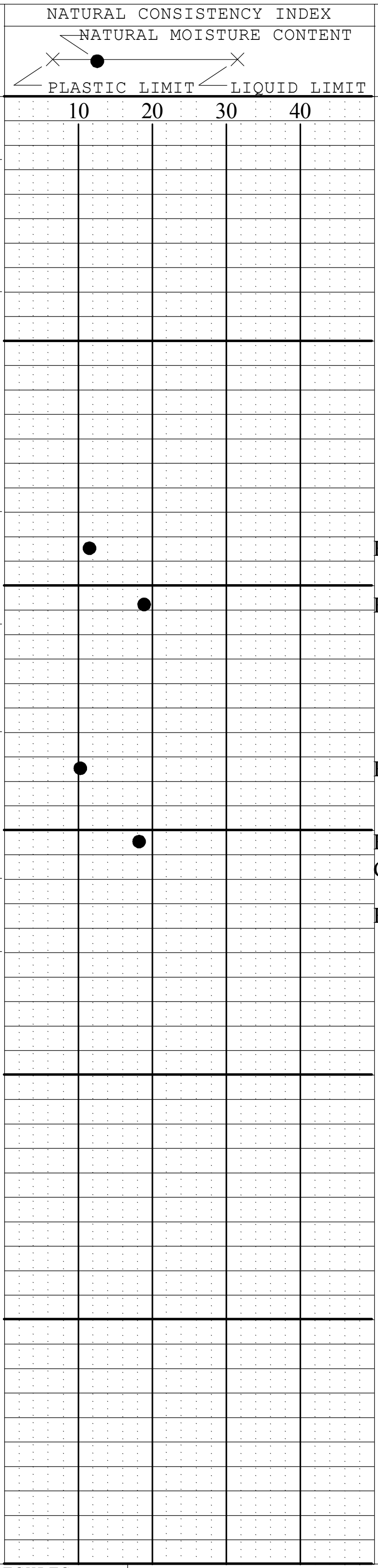
LOCATION: **N. 819,448, E. 2,513,591** ELEVATION: **670** DATE: **11/17/15**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **17.5'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	0					AGGREGATE - 16 INCHES	
668.7		1	9/12/13	31	60	FILL: Medium-dense to dense brown and gray fine to coarse sand, some fine to coarse gravel, little silt, dry.	
		2	9/12/40	65	53		
666.0		3	10/10/9	24	53	FILL: Medium-dense brown fine to coarse gravel, some fine to coarse sand, little to some silt, dry.	
	5	4	6/9/14	29	13		
		5	8/9/13	28	80		
661.5		6	5/7/5	15	53	FILL: Very-stiff to hard brown clayey silt, "and" fine to coarse sand, little to some fine to coarse gravel, damp to moist.	H=3.5
	10	7A	4/7/11	23	100		H=1.5
659.2		7B				FILL: Medium-dense brown and gray fine to coarse sand, some fine to coarse gravel, little silty clay, dry.	
		8	7/5/9	18	73		
657.0		9	4/8/5	16	67	FILL: Hard brown and gray silty clay, some fine to coarse sand, little fine to coarse gravel, moist.	H=4.5
	15	10	3/5/8	16	87		H=4.5 G
654.0		11	4/3/6	11	53	FILL: Medium-stiff brown and gray silty clay, some fine to coarse sand, little fine to coarse gravel, moist.	H=0.5-1.0
652.5							
	20						
	25						
	30						

- No seepage encountered.
- Encountered water at 14.5'.
- Borehole converted to temporary piezometer well upon completion - See Separate Well Log.
- Boring backfilled with cement bentonite grout.
- Boring location surveyed with a hand-held GPS unit. Elevation estimated from March 2015 plant survey.
- Datum: Ohio State Plane South NAD 27/NAVD 29 (Plant Grid).



	▽	▼
WATER LEVEL:	8.8	
WATER NOTE:	In Well	
DATE:	12/10/15	

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75
Last Calibration Date : 2/20/2013
Drill Rig Number : S&ME ATV 550-2

JOB: 7217-15-007A

PLATE 7

LOG OF BORING NO. MW-BAP-4
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

S&ME

LOCATION: **N. 820,884, E. 2,513,614** ELEVATION: **660** DATE: **11/20/15 - 11/23/15**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **40.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	NATURAL CONSISTENCY INDEX NATURAL MOISTURE CONTENT PLASTIC LIMIT — LIQUID LIMIT 10 20 30 40	TEST RESULTS
	0					AGGREGATE - 12 INCHES		
659.0								
		1	4 / 15 / 16	39	87	FILL: Medium-dense to dense gray and brown fine to coarse gravel, some to "and" fine to coarse sand, little to some silt, dry.		H=4.25-4.5
		2	10 / 9 / 5	18	53			
		3	6 / 9 / 7	20	67			
654.7	5							
654.2						FILL: Very-soft brown and gray silty clay, "and" fine to coarse sand, little fine to coarse gravel.		
		4	35 / 13 / 12	31	87	FILL: Dense bown fine to coarse sand, little fine to coarse gravel, "and" clayey silt, cobbles, moist.		
		5	50-3"R		20			
652.5						Stiff to very-stiff dark-brown mottled with dark-gray silty clay, little fine to coarse sand, trace fine gravel, slightly organic, damp.		
		6	2 / 3 / 4	9	87			H=2.0-3.0
	10							
			P					H=1.25-2.5
	15							
643.8						Very-stiff brown mottled with gray silty clay, little fine to medium sand, trace coarse sand, few cobbles, contains silt seams near top of stratum, damp.		
		7	3 / 5 / 6	14	87			H=2.0-3.5
		8	7 / 7 / 7	18				
	20	2S	10		100			H=2.25-3.25
		9	3 / 5 / 6	14	100			H=3.0
		10	3 / 5 / 6	14	100			H=3.25
	25							

WATER LEVEL: ▽ ▼

WATER NOTE:

DATE:

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation Q - Uncon Comp T - Triax Comp C - Consol.	See Separate Curves	H - Penetrometer (tsf) W - Unit Dry Wt (pcf) D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75

Last Calibration Date : 8/2/2013

Drill Rig Number : S&ME ATV 550-2

2010 NEW DEFAULT BORING LOG-W/ N60

-CONTINUED-

LOG OF BORING NO. MW-BAP-4
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

S&ME

LOCATION: **N. 820,884, E. 2,513,614** ELEVATION: **660** DATE: **11/20/15 - 11/23/15**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **40.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

2010 NEW DEFAULT BORING LOG-W/ N60

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	NATURAL CONSISTENCY INDEX (NATURAL MOISTURE CONTENT, PLASTIC LIMIT, LIQUID LIMIT) 10 20 30 40	TEST RESULTS
	25						Very-stiff brown mottled with gray silty clay, little fine to medium sand, trace coarse sand, few cobbles, contains silt seamsnear top of stratum, damp.		
		11A		1/3/4	9	100			H=2.5
633.3		11B					Medium-stiff to stiff brown clayey silt, "and" fine to medium sand, trace coarse sand, includes sand seams, moist.		H=0.5-1.5
		12		1/2/1	4	100			
629.5	30						Very-loose brown and gray fine to medium sand, little to "and" silt (percent varies), contains zones with a trace of coarse sand, wet.		
		13		SH/SH/1	0	100			
		14		SH/SH/1	0	67			
	35	15		SH/1/1	3	67			
		16		SH/SH/1	0	100			
620.0	40								
	45								
	50								

- Encountered water at 5.5'.
- Encountered cobbles at 18.5'.
- Borehole converted to monitoring well upon completion - See separate well log.
- Boring elevation recorded with a hand held GPS unit. Elevation estimated from March 2015 survey.
- Datum: Ohio State Plane South, NAD 27/NAVD 29 (Plant Grid).

WATER LEVEL: ▽ ______ ▼ ______
WATER NOTE: ______ ______
DATE: ______ ______

SYMBOLS USED TO INDICATE TEST RESULTS
G - Gradation, Q - Uncon Comp, T - Triax Comp, C - Consol. — See Separate Curves
H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75
Last Calibration Date : 8/2/2013
Drill Rig Number : S&ME ATV 550-2

LOG OF BORING NO. MW-BAP-5
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

S&ME

LOCATION: **N. 820,057, E. 2,513,275** ELEVATION: **670** DATE: **11/24/15 - 11/25/15**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **62.5'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	NATURAL CONSISTENCY INDEX NATURAL MOISTURE CONTENT PLASTIC LIMIT — LIQUID LIMIT	TEST RESULTS
	0					AGGREGATE - 12 INCHES	10 20 30 40	
669.0								
		1	6/8/11	24	60	FILL: Medium-dense brown fine to coarse sand, some fine to coarse gravel, some to "and" silty clay, dry.		
		2	16/5/5	13	60			
	5	3	4/4/6	13	73			
664.5								
		4	5/9/32	51	87	FILL: Hard gray and brown silty clay, "and" fine to coarse sand, little to some fine to coarse gravel, damp.		H=4.5
		5	16/15/16	39	80			H=4.5
661.5								
		6	10/13/11	30	87	FILL: Medium-dense brown and gray fine to coarse sand, little fine to coarse gravel, some silty clay, damp.		
660.0	10							
			P			FILL: Hard brown silty clay, some fine to coarse sand, some fine to coarse gravel (shale fragments), damp.		H=4.5
		7	3/5/10	19	80			H=4.5
656.5								
		8	10/11/25	45	80	FILL: Medium-dense to dense brown fine to coarse gravel, some fine to coarse sand, some silty clay becoming trace silt at bottom of stratum, damp.		H=3.0
	15	9	11/7/6	16				
653.1		10A	4/6/10	20	100			
		10B				Medium-stiff to stiff gray mottled with dark-gray and brown silty clay, trace fine to coarse sand, trace fine gravel, few roots, few silt seams, slightly organic, moist.		
			P					
	20							
		11	SH/1/3	5	100			H=0.5-1.25
647.0								
		12	2/2/4	8	100	Medium-stiff to very-stiff brown mottled with gray silty clay, trace to little fine to coarse sand, damp.		H=3.5
	25							

WATER LEVEL: ▽ ▼

WATER NOTE:

DATE:

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75
Last Calibration Date : 8/2/2013
Drill Rig Number : S&ME ATV 550-2

-CONTINUED-

LOG OF BORING NO. MW-BAP-5
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

LOCATION: **N. 820,057, E. 2,513,275** ELEVATION: **670** DATE: **11/24/15 - 11/25/15**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **62.5'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	NATURAL CONSISTENCY INDEX NATURAL MOISTURE CONTENT PLASTIC LIMIT LIQUID LIMIT 10 20 30 40	TEST RESULTS
	25						Medium-stiff to very-stiff brown mottled with gray silty clay, trace to little fine to coarse sand, damp.		
			■	P					
			■	P					
	30								
		13	■	2/4/6	13	100			H=2.0-3.5
		14	■	3/4/5	11	100			H=2.5-3.0
	35								
		15	■	2/5/6	14	100			H=2.5
		16	■	2/3/5	10	100			H=2.5
	40								
		17	■	SH/2/3	6	100			H=1.25
		18	■	SH/SH/SH	0	100			H=1.25
624.5	45						Stiff gray mottled with brown and dark-gray silty clay, trace fine to coarse sand, slightly organic, damp.		
		19	■	SH/SH/1	0	100			H=0.75
622.0							Medium-stiff to stiff gray and dark-gray organic clayey silt, trace fine to coarse sand, damp.		
		20	■	SH/SH/SH	0	100			H=0.75-1.25
	50								

WATER LEVEL: ▽ ▼

WATER NOTE:

DATE:

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75

Last Calibration Date : 8/2/2013

Drill Rig Number : S&ME ATV 550-2

LOG OF BORING NO. MW-BAP-5
BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
CARDINAL PLANT, BRILLIANT, OH

LOCATION: **N. 820,057, E. 2,513,275**
ELEVATION: **670**
DATE: **11/24/15 - 11/25/15**
DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger**
COMPLETION DEPTH: **62.5'**
SAMPLER(S): **2" O.D. Split-barrel Sampler**

2010 NEW DEFAULT BORING LOG-W/ N60

NATURAL CONSISTENCY INDEX
NATURAL MOISTURE CONTENT
PLASTIC LIMIT — LIQUID LIMIT
10 20 30 40

TEST RESULTS

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION
619.5	50						Medium-stiff to stiff gray and dark-gray organic clayey silt, trace fine to coarse sand, damp.
							Medium-dense to dense fine to coarse gravel, some to "and" fine to coarse sand, trace to little silt, wet.
		21		6/9/9	23	87	
		22		8/21/34	69	87	
614.6	55						Medium-dense to dense gray and brown fine to coarse sand, "and" fine to coarse gravel, little silt, wet.
		23		14/20/14	43	80	
		24		7/12/16	35	60	
	60						
		25		8/4/5	11	60	
607.5							
	65						- Encountered water at 17.0'. - Borehole converted to monitoring well upon completion. See separate well log. - Boring location recorded with a hand-held GPS unit. Elevation estimated from March 2015 plant survey. - Datum: Ohio State Plane South NAD 27/NAVD 29 (Plant Grid).
	70						
	75						

WATER LEVEL: ▽ ▼
WATER NOTE:
DATE:

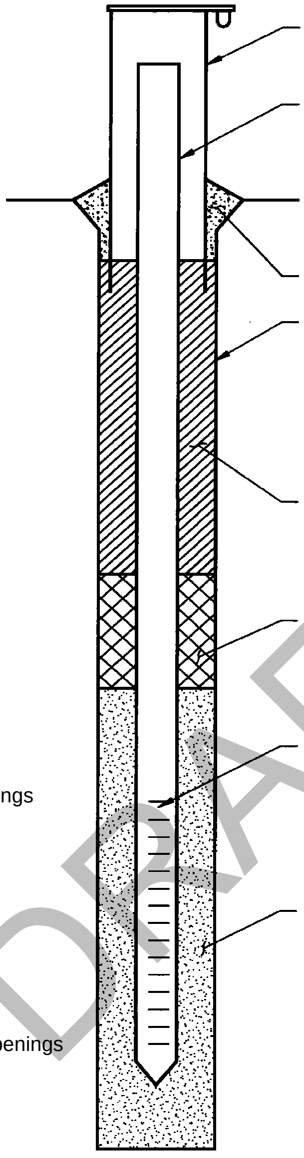
SYMBOLS USED TO INDICATE TEST RESULTS
G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves
H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.75
Last Calibration Date : 8/2/2013
Drill Rig Number : S&ME ATV 550-2

NOTE: This is a DRAFT well log. Ground Elevation is approximate.

S&ME

Elevation (Feet above MSL)	Depth Below Ground Surface (Feet)	
		Top of Cover
664.35	**3.35**	Top of PVC
661.0	**0.0**	Ground Surface
658.3	**2.7**	Top of Grout
639.4	**21.6**	Top of Bentonite
634.1	**26.9**	Top of Filter Pack
		Top of Aquifer
632.1	**28.9**	Top of Screen Openings
622.3	**38.7**	Bottom of Screen Openings
621.7	**39.3**	Bottom of Well
		Bottom of Aquifer
621.0	**40.0**	Bottom of Boring



(NOT TO SCALE)

4 - Inch Diameter Protective Steel Casing

2 - Inch Diameter Flush-Thread PVC Casing

Ground Surface

Concrete

Boring Diameter (in inches)

8 " **0.0** to **39.3**

" to

" to

Grout: **Portland & Quick Gel**

Bentonite Seal: **Bentonite pellets**

10 - Slot Screen

Filter Pack: **#5 quartz sand**

Depth to Static Water:	18.79	18.71			
Static Water Elevation:	645.56	645.64			
Date:	**12/11/15**	**12/15/15**			

Well Development:

12/3 - Bailed 67.5 gallons of water (approx. 18 well volumes) out of well, water level stayed steady.
-Measurement on 12/15 was immediately before slug testing.
-Top cover set in 3'x3' concrete pad. Protective steel bollards placed around concrete pad.

Water Quality Readings (Horiba U-52)

Bucket	NTU	C	ms/cm	PH	ORPmV
15.5	8.8	16.7	1.78	6.36	-7

Well Location: N. 820,884' E. 2,513,614'
Datum: NAD27/NGVD29 OH S

WELL COMPLETION DIAGRAM

Project Name:
AEP CD Bottom Ash Pond Monitoring Wells

Project Location:
Cardinal Plant / Brilliant, Ohio

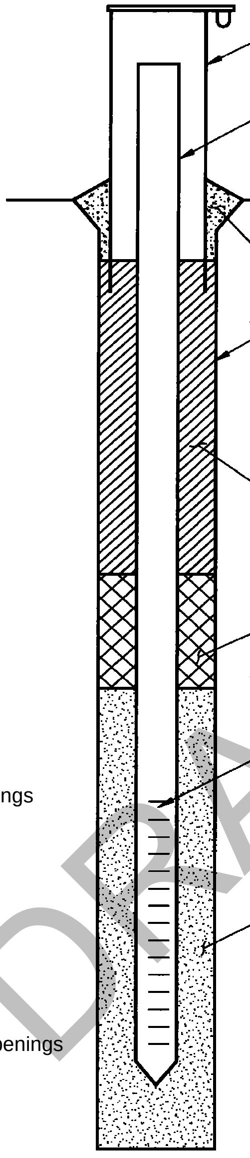
Project Number:
7217-15-007A

Boring Number:
MW-BAP-4

Date Well Installed:
11/23/2015

NOTE: This is a DRAFT well log. Ground Elevation is approximate.

Elevation (Feet above MSL)	Depth Below Ground Surface (Feet)	
		Top of Cover
672.88	**2.88**	Top of PVC
670.0	**0.0**	Ground Surface
663.4	**6.6**	Top of Grout
625.8	**44.2**	Top of Bentonite
620.3	**49.7**	Top of Filter Pack
		Top of Aquifer
618.3	**51.7**	Top of Screen Openings
608.5	**61.5**	Bottom of Screen Openings
607.9	**62.1**	Bottom of Well
		Bottom of Aquifer
607.5	**62.5**	Bottom of Boring



(NOT TO SCALE)

4 - Inch Diameter Protective Steel Casing

2 - Inch Diameter Flush-Thread PVC Casing

Ground Surface

Concrete

Boring Diameter (in inches)

8 " **0.0** to **62.1**

" to

" to

Grout: **Portland & Quick Gel**

Bentonite Seal: **Bentonite pellets**

10 - Slot Screen

Filter Pack: **#5 quartz sand**

Depth to Static Water:	27.3	27.55	27.15	27.13	
Static Water Elevation:	645.58	645.33	645.73	645.75	
Date:	**11/29/15**	**12/7/15**	**12/11/15**	**12/15/15**	

Well Development:

12/10 - Bailed 61.5 gallons of water (approx. 13 well volumes) out of well, water level stayed steady.
-Measurement on 12/15 was immediately before slug testing.
-Top cover set in 3'x3' concrete pad. Protective steel bollards placed around concrete pad.

Water Quality Readings (Horiba U-52)

Bucket	NTU	C	ms/cm	PH	ORPmV
16	24.3	15.08	1.46	6.86	-56

Note: For several buckets the NTU was leveled out in the 20's.

Well Location: N. 820,057' E. 2,513,274'
Datum: NAD27/NGVD29 OH S

WELL COMPLETION DIAGRAM

Project Name:
AEP CD Bottom Ash Pond Monitoring Wells

Project Location:
Cardinal Plant / Brilliant, Ohio

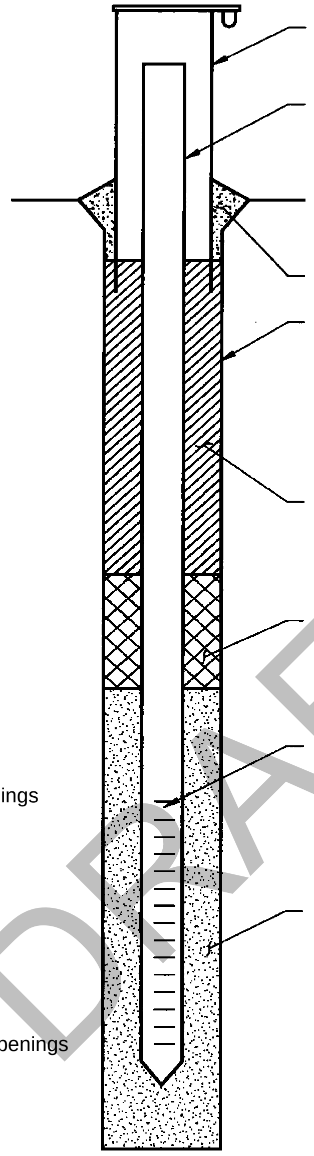
Project Number:
7217-15-007A

Boring Number:
MW-BAP-5

Date Well Installed:
11/25/2015

S&ME

Elevation (Feet above MSL)	Depth Below Ground Surface (Feet)	
		Top of Cover
672.45	2.45	Top of PVC
670.0	0.0	Top of Bentonite
657.7	12.3	Top of Filter Pack
		Top of Aquifer
655.7	14.3	Top of Screen Openings
653.5	16.5	Bottom of Screen Openings
653.2	16.8	Bottom of Well
		Bottom of Aquifer
652.0	18.0	Bottom of Boring


(NOT TO SCALE)

No cover installed, well abandoned on 12/15/15

2 - Inch Diameter Flush-Thread PVC Casing

Ground Surface

Hole Plug

Boring Diameter (in inches)

8 " **0.0** to **18.0**

" to

" to

Grout: **no grout**

Bentonite Seal: **Bentonite Chips (hole plug)**

10 - Slot Screen

Filter Pack: **#5 quartz sand**

Depth to Static Water:	9.2	9.75	9.69		
Static Water Elevation:	663.25	662.70	662.76		
Date:	**11/29/15**	**12/11/15**	**12/15/15**		

Well Location: N. 819,154' E. 2,513,525'
Datum: NAD27/NGVD29 OH S

WELL COMPLETION DIAGRAM

Project Name:
AEP CD Bottom Ash Pond Monitoring Wells

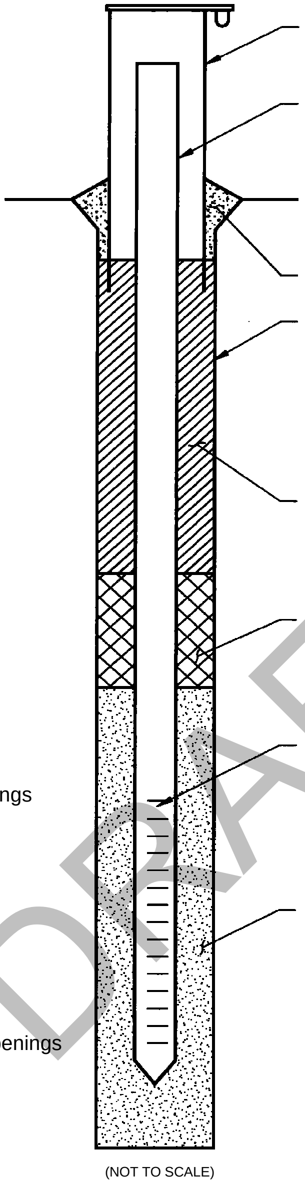
Project Location:
Cardinal Plant / Brilliant, Ohio

Project Number:
7217-15-007A

Boring Number:
CD-BAP-1504

Date Well Installed:
11/25/2015

Elevation (Feet above MSL)	Depth Below Ground Surface (Feet)	
		Top of Cover
673.33	**3.33**	Top of PVC
670.0	**0.0**	Ground Surface
669.5	**0.5**	Top of Grout
659.6	**10.4**	Top of Bentonite
657.2	**12.8**	Top of Filter Pack
		Top of Aquifer
658.0	**12.0**	Top of Screen Openings
653.2	**16.8**	Bottom of Screen Openings
652.5	**17.5**	Bottom of Well
		Bottom of Aquifer
652.5	**17.5**	Bottom of Boring


(NOT TO SCALE)

No cover installed, well abandoned on 12/15/15

2 - Inch Diameter Flush-Thread PVC Casing

Ground Surface

Hole Plug

Boring Diameter (in inches)

8 " **0.0** to **17.5**

" to

" to

Grout: **Portland & Quick Gel**

Bentonite Seal: **Bentonite Chips (hole plug)**

10 - Slot Screen

Filter Pack: **#5 quartz sand**

Depth to Static Water:	11.4	12.15	11.54		
Static Water Elevation:	661.93	661.18	661.79		
Date:	**11/29/15**	**12/11/15**	**12/15/15**		

Well Location: N. 819,448' E. 2,513,591'
Datum: NAD27/NGVD29 OH S

WELL COMPLETION DIAGRAM

Project Name:
AEP CD Bottom Ash Pond Monitoring Wells

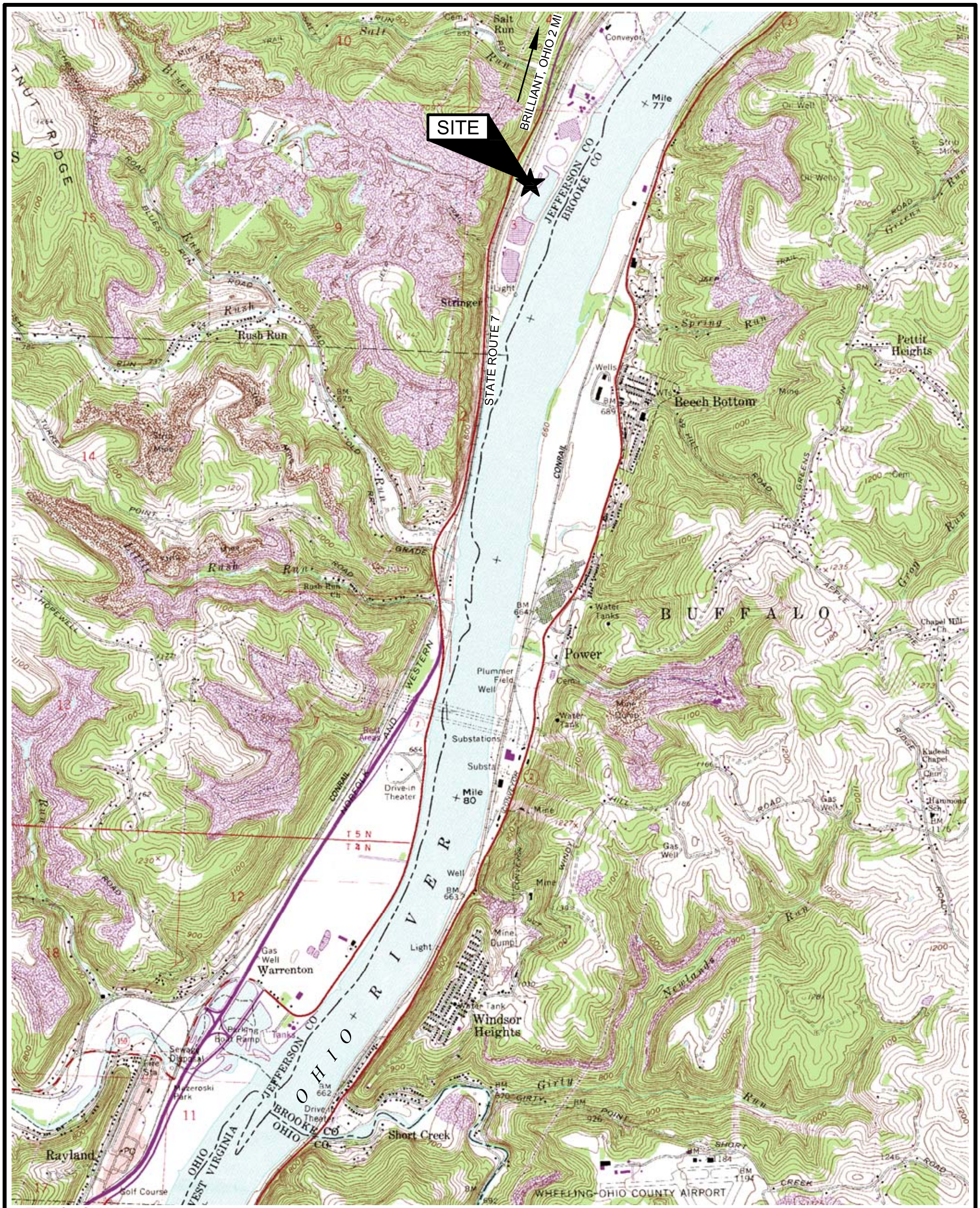
Project Location:
Cardinal Plant / Brilliant, Ohio

Project Number:
7217-15-007A

Boring Number:
CD-BAP-1505

Date Well Installed:
11/25/2015

2009 SITE INVESTIGATION



TILTONSVILLE

Tiltonsville Quadrangle

VICINITY MAP

Cardinal Generating Plant
Ash Pond Investigation
Brilliant, Ohio

Project: 011-11497-013	Drawn By: MTR
Drawing Date: 7-2-09	Approved By: MGR
Last Updated: 7-6-2009	Scale: 1" = 3000' 1:1

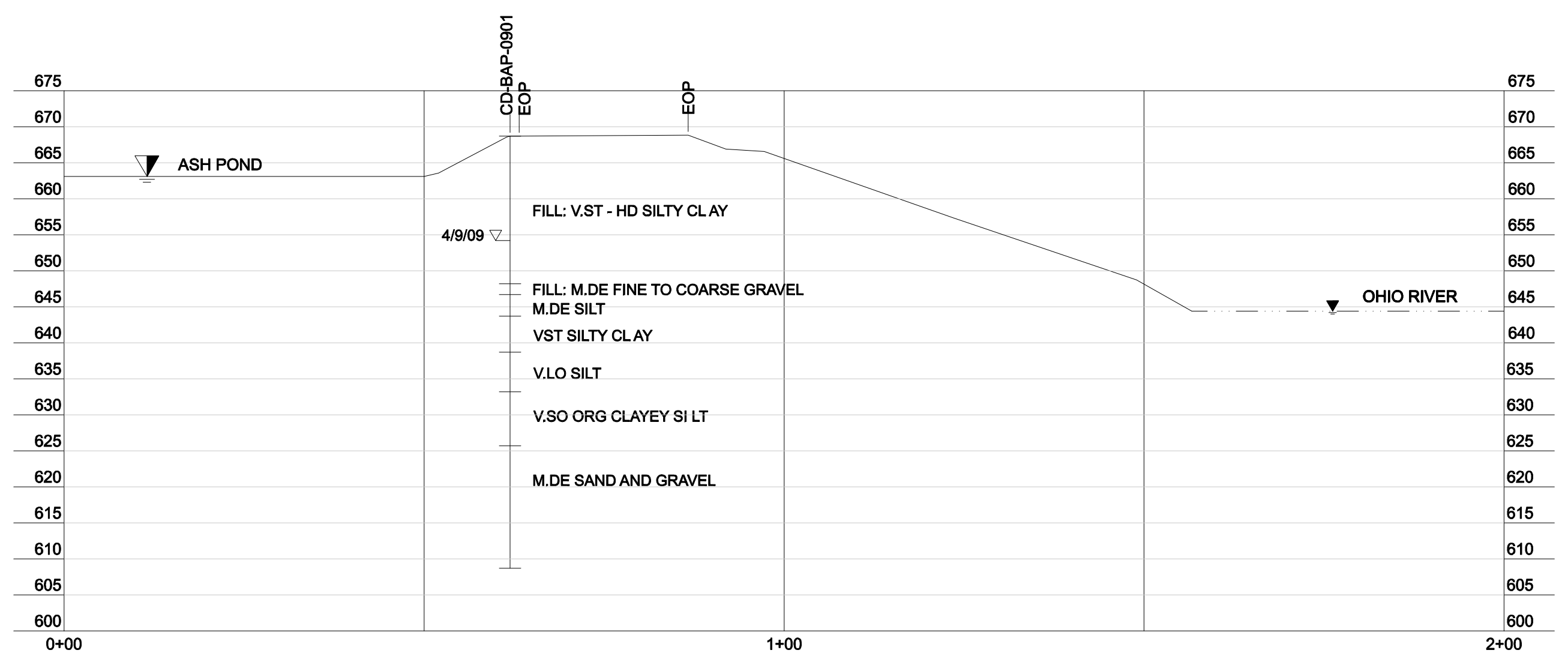
BBCM
SOLUTIONS TO BUILD ON

Columbus (614) 793-2226
Cleveland (216) 901-1000
Cincinnati (513) 771-8471
Dayton (937) 424-1011

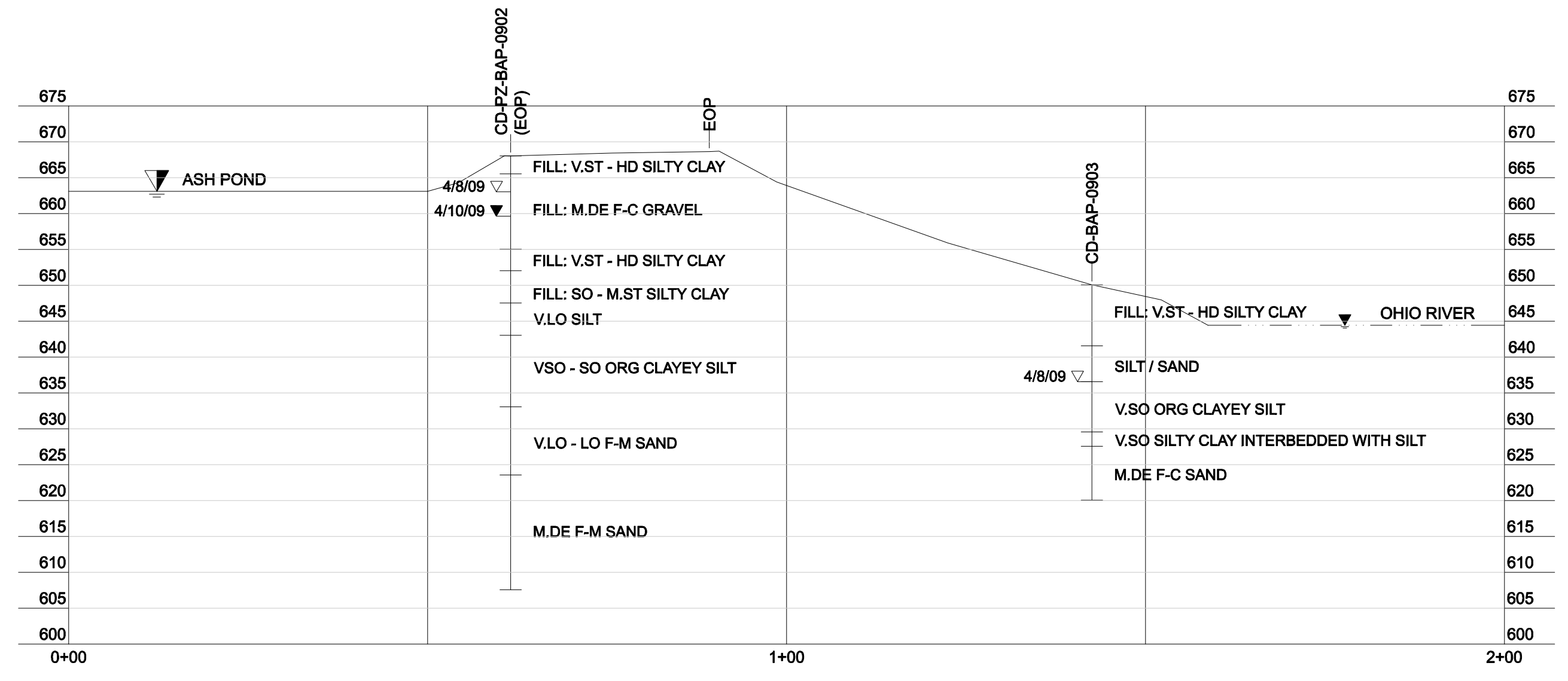
PLATE 1

Images: ~Tiltonsville Ohio Quad Map.tif
Xrefs:
File Last Updated: Jul 06, 2009
Plot Info: 7-22-2009 @ 3:23pm By: MRomanello
BBC&M Filename: I:\DEPTS\CADD\Drawings\Projects\011-11497-013\VMap.dwg Layout: 8.5x11P

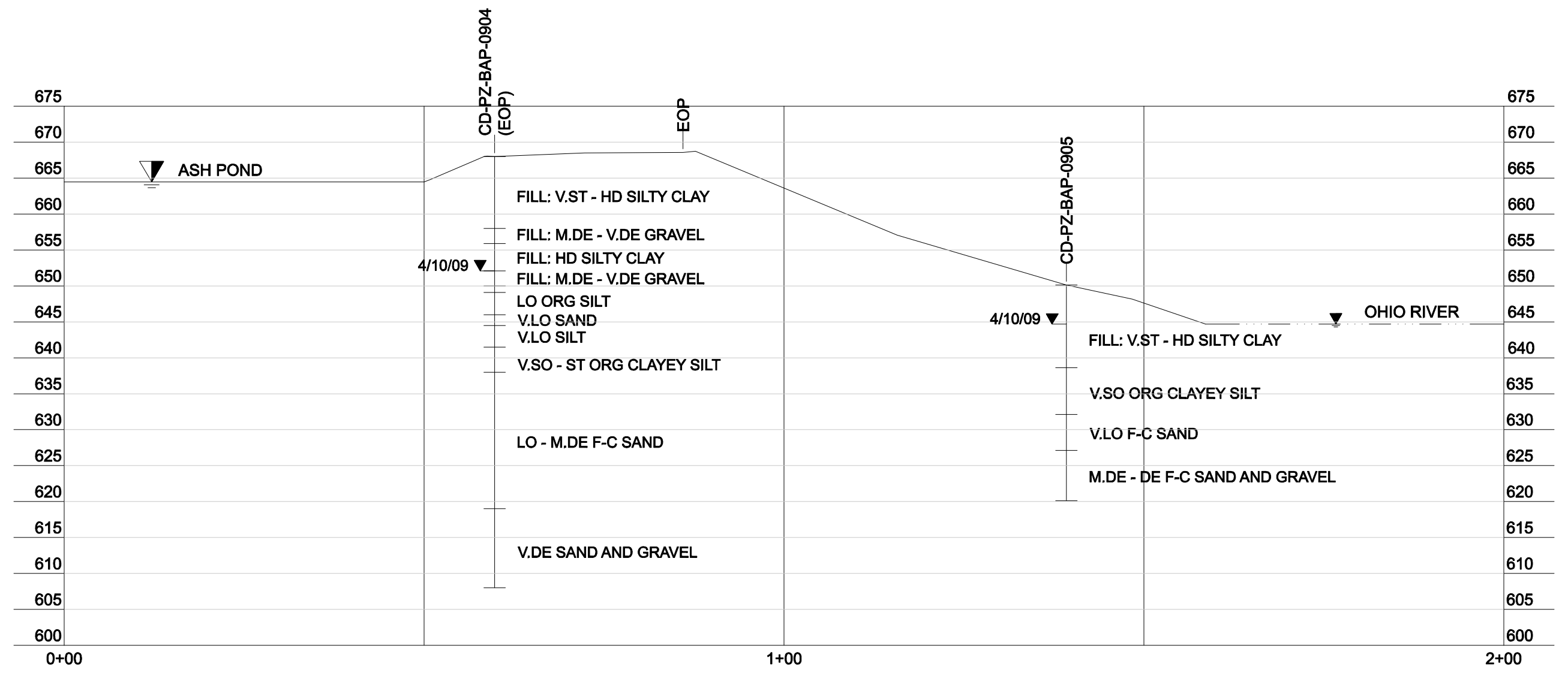
DWG. NO. PLATE 3



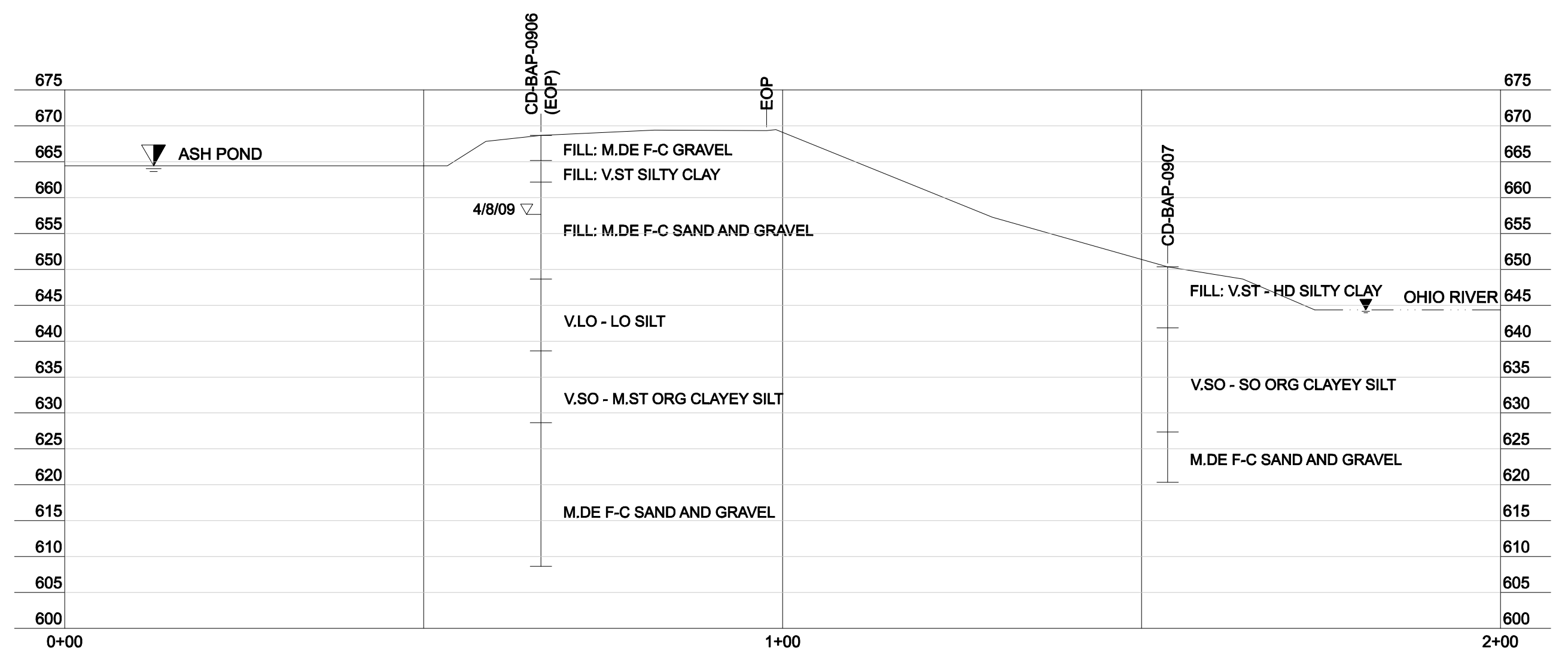
SECTION 'A'
Boring BAP-0901



SECTION 'B'
Borings BAP-0902 & BAP-0903



SECTION 'C'
Borings BAP-0904 & BAP-0905

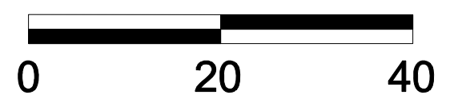


SECTION 'D'
Borings BAP-0906 & BAP-0907

LEGEND

4/20/09 ▼	OBSERVATION WELL READING: ELEVATION AND DATE
4/3/09 ▽	SEEPAGE ENCOUNTERED DURING DRILLING
V.SO / SO	SOFT / VERY SOFT
M.ST	M. STIFF
ST / V.ST	STIFF / VERY STIFF
HD	HARD
V.LO / LO	VERY LOOSE / LOOSE
M.DE	MEDIUM DENSE
DE / V.DE	DENSE / VERY DENSE
ORG	ORGANIC
— — —	EXISTING WATER SURFACE (AT TIME OF INVESTIGATION)

SCALE IN FEET



REFERENCE: AEP CARDINAL DRAWING 94151038
DATUM: NAD 27/NGVD 29 OHIO SOUTH

PROJECT NUMBER:	011-11497-013	DRAWN BY:	RSH
DRAWING DATE:	7-1-09	ENGINEER:	MTR
LAST UPDATED:	7-23-09	APPROVED BY:	MGR
		SCALE:	1" = 20'

BBCM
SOLUTIONS TO BUILD ON
Columbus (614) 793-2226
Cleveland (216) 901-1000
Cincinnati (513) 771-8471
Dayton (937) 424-1011

DATE	NO.	DESCRIPTION	APPD.
		REVISIONS	

A.E.P.
CARDINAL PLANT
BRILLIANT OHIO

BOTTOM ASH POND
INVESTIGATION
SECTIONS

DWG. NO. PLATE 3

SCALE:
CIVIL ENGINEERING
DR:
CH:
ENGR:
PROJ ENGR:
DATE:
APPROVED BY

AEP AMERICAN ELECTRIC POWER

AEP SERVICE CORP.
1 RIVERSIDE PLAZA
COLUMBUS, OH 43215

SYSTEM DATE- DD-MMM-YYYY
SYSTEM TIME- HOUR:MINUTE

EXPLANATION OF SYMBOLS AND TERMS USED ON BORING LOGS FOR SAMPLING AND DESCRIPTION OF SOIL

SAMPLING DATA

▮ - Blocked-in "SAMPLES" column indicates sample was attempted and recovered within this depth interval.

▯ - Sample was attempted within this interval but not recovered.

2/5/9 - The number of blows required for each 6-inch increment of penetration of a "Standard" 2-inch O.D. split-barrel sampler, driven a distance of 18 inches by a 140-pound hammer freely falling 30 inches. Addition of one of the following symbols indicates the use of a split-barrel other than the 2" O.D. sampler:

- 2S - 2½"O.D. split-barrel sampler
- 3S - 3" O.D. split-barrel sampler

P - Shelby tube sampler, 3" O.D., hydraulically pushed.

R - Refusal of sampler in very-hard or dense soil, or on a resistant surface.

50-2" - Number of blows (50) to drive a split-barrel sampler a certain number of inches (2), other than the normal 6-inch increment.

S/D - Split-barrel sampler (S) advanced by weight of drill rods (D),

S/H - Split-barrel sampler (S) advanced by combined weight of rods and drive hammer (H).

SOIL DESCRIPTIONS

All soils have been classified basically in accordance with the Unified Soil Classification System, but this system has been augmented by the use of special adjectives to designate the approximate percentages of minor components as follows:

Adjective	Percent by Weight
trace	1 to 10
little	11 to 20
some	21 to 35
"and"	36 to 50

The following terms are used to describe density and consistency of soils:

Term (Granular Soils)	Blows per foot
Very-loose	Less than 5
Loose	5 to 10
Medium-dense	11 to 30
Dense	31 to 50
Very-dense	Over 50

Term (Cohesive Soils)	Qu (tsf)
Very-soft	Less than 0.25
Soft	0.25 to 0.5
Medium-stiff	0.5 to 1.0
Stiff	1.0 to 2.0
Very-stiff	2.0 to 4.0
Hard	Over 4.0

Page 1 of 3

LOG OF BORING NO. CD-BAP-0901
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

BBCM

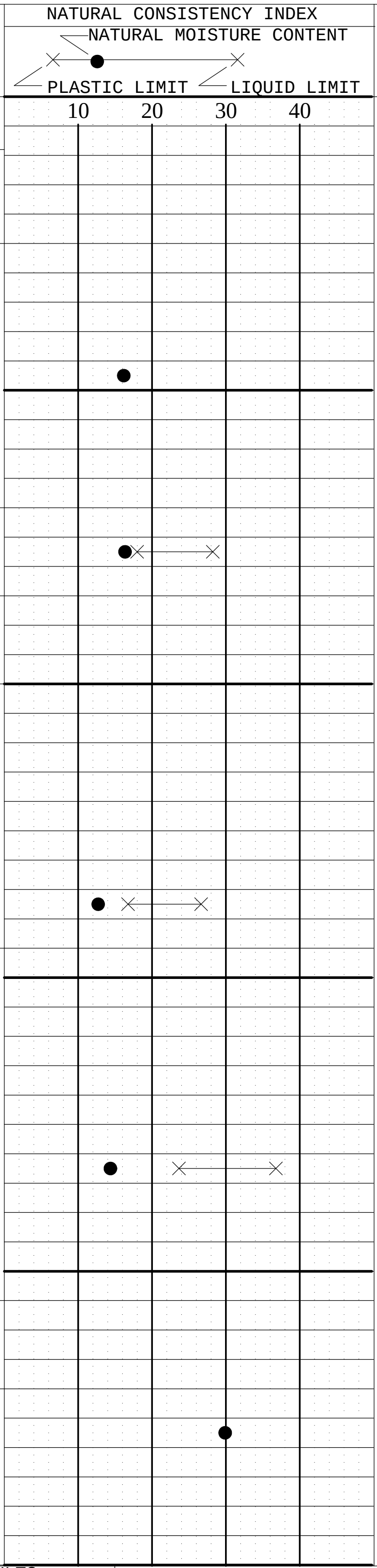
LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.7** DATE: **4/8/09 - 4/9/09**

DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
667.8	0					GRAVEL FILL - 0.9 FEET	
666.2		1	8/13/8	30	80	FILL: Hard gray and brown silty clay, some fine to coarse sand, some fine to coarse gravel (sandstone, siltstone, and shale fragments), dry.	H=4.5+
		2	6/4/7	16	67	FILL: Medium-dense to dense brown and gray fine to coarse gravel (sandstone, siltstone, and shale fragments), some fine to coarse sand, "and" silty clay, dry.	H=2.5-3.5
	5	3	12/12/30	60	100		H=2.5
661.7		4	13/22/20	60	80		H=4.5+
660.2		5	5/10/16	37	93	FILL: Hard gray clayey silt, some fine to coarse sand, some fine to coarse gravel (sandstone, siltstone and shale fragments), dry.	H=4.5+
658.7	10	6	6/8/16	34	87	FILL: Very-stiff brown and gray silty clay, some fine to coarse sand, some fine to coarse gravel (sandstone, siltstone, and shale fragments), dry.	H=3.0-4.0
		7	24/25/24	70	100	FILL: Medium-dense to dense gray and brown fine to coarse gravel (sandstone, siltstone, and shale fragments), some fine to coarse sand, some silty clay becoming "and" clayey silt with depth, dry.	H=4.5+
		8	10/7/7	20	67		
654.2	∇	9	8/6/14	29	73		H=4.5+
	15	10	5/8/14	32	80	FILL: Very-stiff to hard brown and gray silty clay, some fine to coarse sand, some fine to coarse gravel (sandstone, siltstone, and shale fragments), medium-dense gray and brown fine to coarse gravel (shale fragments) seam from 17.5' to 18.3', moist to wet.	H=4.0-4.5+
		11	3/5/9	20	67		H=3.8-4.5+
		12	3/5/10	22	53		G
648.2	20	13	3/9/9	26	53		H=4.5
646.7		14	7/9/13	32	67	FILL: Medium-dense gray fine to coarse gravel (shale fragments), little fine to coarse sand, little silty clay, moist to wet.	H=4.5
		15	6/9/10	27	80	Medium-dense gray silt, trace clay, trace fine to medium sand, moist to wet.	G
643.7	25	16A	P				



WATER LEVEL:	∇ 13.8	▼
WATER NOTE:	Inside HSA	
DATE:	4/9/09	

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

JOB: 011-11497-013 -CONTINUED- **PLATE 5**

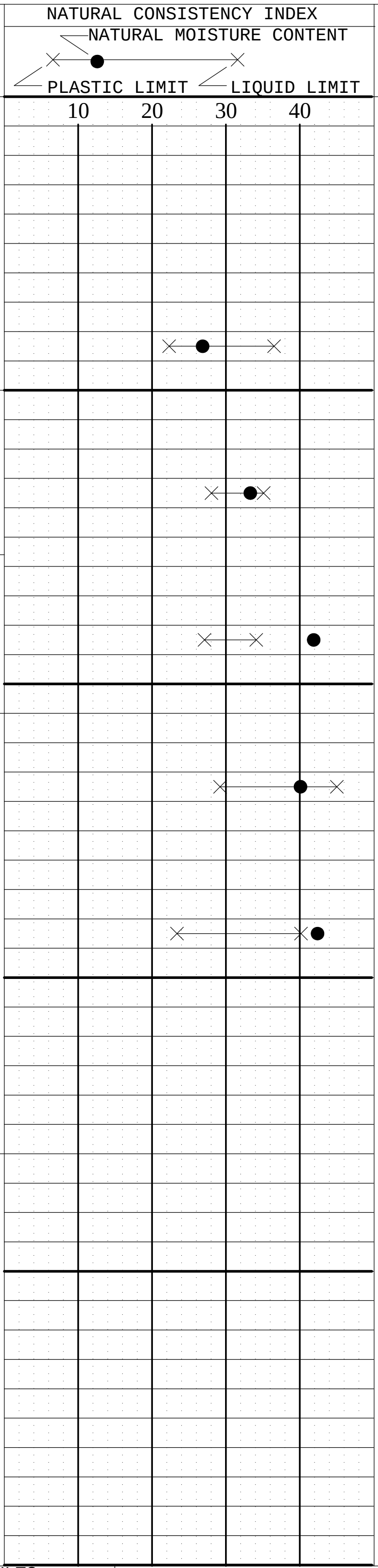
LOG OF BORING NO. CD-BAP-0901
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.7** DATE: **4/8/09 - 4/9/09**

DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	25	16B				Very-stiff brown mottled with gray silty clay, trace fine sand, damp.	
		17	3/6/9	22	67		H=2.5-3.5
		18	3/3/4	10	100		H=1.6-2.5 G
638.7	30					Gray mottled with dark-gray and brown clayey silt, some fine sand, trace medium to coarse sand, few seams and lenses of silty clay and fine sand, damp.	
		19	P				H=1.0-1.5 G
635.9						Very-loose dark-brown and gray organic silt, some fine sand, moist to wet.	
		20	1/2/2	6	100		H=0.7 G
633.2	35					Soft to medium-stiff gray mottled with dark-gray organic clayey silt, little to some fine sand, trace medium to coarse sand, few lenses of fine sand interbedded with organic silt near top of stratum, moist to wet.	
		21	2/2/2	6	100		H=0.4 G
		22	2/3/3	9	100		H=0.5-0.8 G
	40						
		23	2/2/3	7	67		H=0.3-0.7
625.7						Medium-dense to dense brown and gray fine to coarse gravel, some fine to coarse sand, trace silt, wet.	
		24	9/11/13	34	53		
	45						
		25	9/12/16	40	53		
		26	11/19/20	56	53		
	50						



WATER LEVEL: ▽ 13.8 ▼
WATER NOTE: Inside HSA
DATE: 4/9/09

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

LOG OF BORING NO. CD-BAP-0901
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

BBCM

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.7** DATE: **4/8/09 - 4/9/09**
DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.0'**
SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	NATURAL CONSISTENCY INDEX NATURAL MOISTURE CONTENT PLASTIC LIMIT — LIQUID LIMIT 10 20 30 40	TEST RESULTS
	50						Medium-dense to dense brown and gray fine to coarse gravel, some fine to coarse sand, trace silt, wet.		
		27	■	10/16/21	53	33			
		28	■	6/10/10	29	33			
	55								
		29	■	6/11/10	30	40			
610.7							Medium-dense brown fine to medium sand, trace coarse sand, trace fine gravel, trace silt, wet.		
		30	■	7/10/10	29	40			
608.7	60								
							- Seepage encountered at 14.5'. - Borehole grouted upon completion. - Boring location and elevation surveyed by AEP.		
	65								
	70								
	75								

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

WATER LEVEL: ▽ **13.8** ▼
WATER NOTE: **Inside HSA**
DATE: **4/9/09**

SYMBOLS USED TO INDICATE TEST RESULTS
G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves
H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : **0.86**
Last Calibration Date : **02/17/09**
Drill Rig Number : **TRUCK 55**

LOG OF BORING NO. CD-PZ-BAP-0902
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

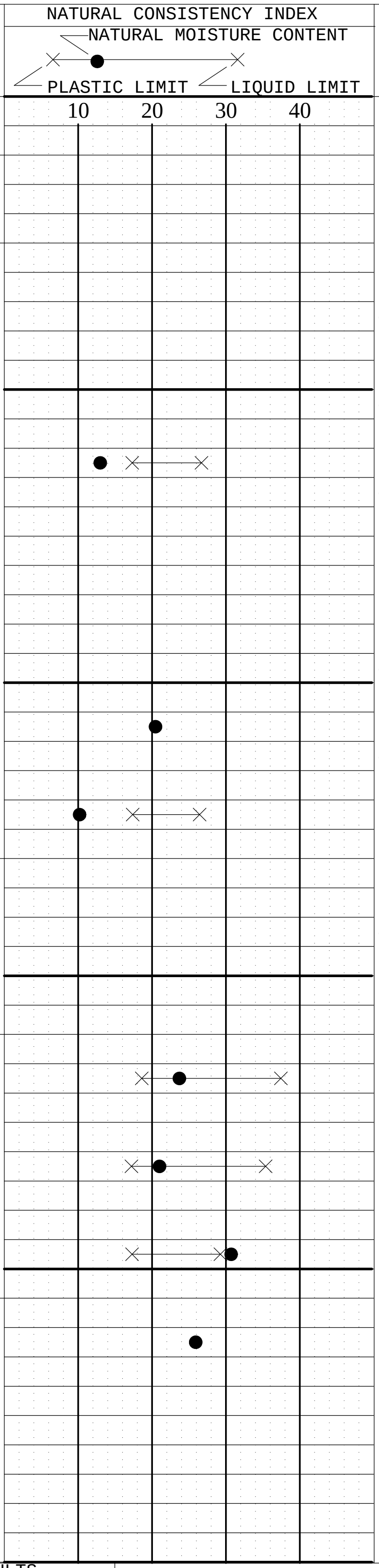
BBCM

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.0** DATE: **4/8/09**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.5'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	0					GRAVEL FILL - 1.0 FEET	
667.0		1	5/5/7	17	87	FILL: Very-stiff to hard brown silty clay, some fine to coarse sand, some fine to coarse gravel (sandstone, siltstone, and shale fragments), dry.	H=3.5-4.0
665.5		2	6/6/8	20	80	FILL: Medium-dense brown and gray fine to coarse gravel (sandstone, siltstone, and shale fragments), some fine to coarse sand, some silty clay, cobbles near top of stratum, dry.	H=3.75-4.25
	5	3	6/9/10	27	73		H=4.0-4.5+
		4	8/5/7	17	73		H=3.0-4.25 G
	▼	5	9/9/7	23	53		H=3.5-4.0
		6	12/6/5	16	27		H=3.75-4.0
	10 ▽	7	10/9/11	29	60		H=4.0-4.5+
		8	3/5/7	17	73		H=3.0-3.75 G
655.0		9	3/3/4	10	33	FILL: Very-stiff to hard brown and gray silty clay, some fine to coarse sand, trace to some fine gravel (siltstone and shale fragments), damp to wet.	H=3.75-4.5+
	15	10	2/2/3	7	40		H=2.5-2.75
652.0		11	3/4/5	13	67	FILL: Soft to medium-stiff brown and gray silty clay, some fine to coarse sand, trace to some fine gravel (siltstone and shale fragments), brown and gray fine to coarse gravel, some near middle of stratum, wet.	H=1.0-2.0
		12	1/2/2	6	40		H=1.5-2.25 G
	20	13	1/SH/1	1	20		H=0.0-0.25 G
647.5		14	2/2/1	4	100	Very-loose gray and dark-gray silt, little to some clay, trace becoming some with depth fine sand, wet.	G
		15	2/1/1	3	53		G
643.0	25	16	SH/SH/1	1	53		



	▽	▼
WATER LEVEL:	10.7	8.4
WATER NOTE:	Inside HSA	Inside Well
DATE:	4/8/09	4/10/09

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
} See Separate Curves

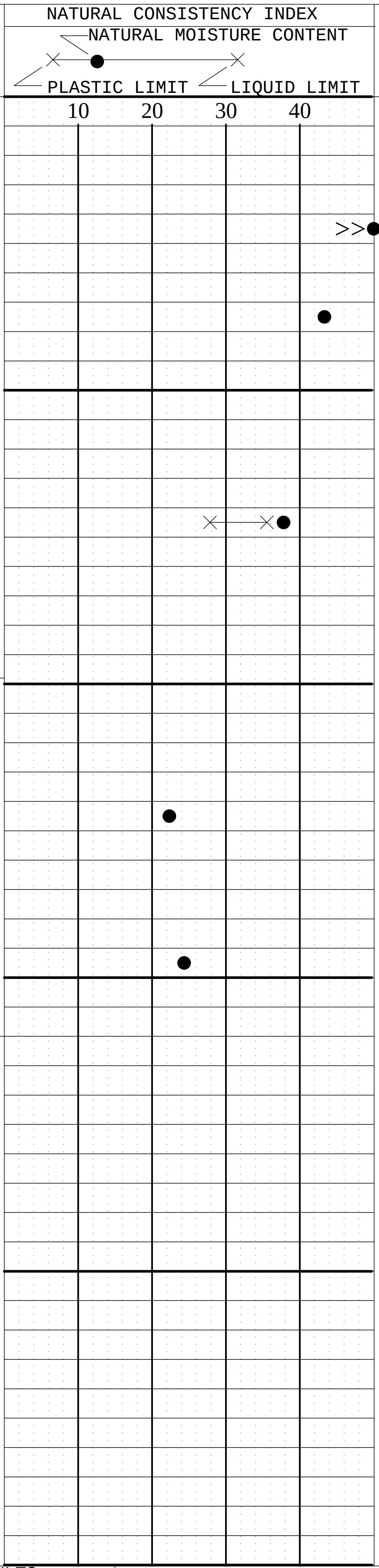
H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

LOG OF BORING NO. CD-PZ-BAP-0902
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.0** DATE: **4/8/09**
DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.5'**
SAMPLER(S): **2" O.D. Split-barrel Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	25	17	1/1/2	4	80	Very-soft to soft gray mottled with dark-gray organic clayey silt, trace fine sand, few lenses of organic silt near bottom of stratum, wet.	H=0.3
		18	SH/1/2	4	80		LOI=10.4% H=0.0-0.1 G
		19	SH/1/2	4	100		MC=54 H=0.0 G
	30						
		20	SH/1/1	3	73		G
		21A	2/3/3	9			
633.1	35	21B				Very-loose to loose brown and gray fine to medium sand, trace coarse sand, trace to little silt interbedded with organic clayey silt, wet.	
		22	2/2/3	7	73		G
	40	23	SH/1/2	4	80		G
627.0						Medium-dense brown fine to medium sand, trace coarse sand, trace silt, trace to some fine gravel, trace coarse gravel, trace silt, wet.	
		24	2/3/10	19	100		G
		25A	5/7/11	26			
	45	25B					
		26	6/10/13	33	67		
		27	10/15/13	40	33		
	50						



	▽	▼
WATER LEVEL:	10.7	8.4
WATER NOTE:	Inside HSA	Inside Well
DATE:	4/8/09	4/10/09

SYMBOLS USED TO INDICATE TEST RESULTS
G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves
H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

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LOG OF BORING NO. CD-PZ-BAP-0902
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.0** DATE: **4/8/09**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.5'**

SAMPLER(S): **2" O.D. Split-barrel Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION
	50					Medium-dense brown fine to medium sand, trace coarse sand, trace silt, trace to some fine gravel, trace coarse gravel, trace silt, wet.
		28	1/8/10	26	80	
	55	29	1/2/9	16	67	
		30	3/3/7	14	67	
		31	4/3/7	14		
607.9	60					
	65					
	70					
	75					

NATURAL CONSISTENCY INDEX
NATURAL MOISTURE CONTENT
PLASTIC LIMIT LIQUID LIMIT
10 20 30 40

TEST RESULTS

- Cobbles encountered from 4.0' to 7.0'.
- Seepage encountered at 5.5'.
- Groundwater encountered at 13.0'.
- Borehole converted to observation well upon completion. See separate well log.
- Boring location and elevation surveyed by AEP.

	▽	▼
WATER LEVEL:	**10.7**	**8.4**
WATER NOTE:	**Inside HSA**	**Inside Well**
DATE:	**4/8/09**	**4/10/09**

SYMBOLS USED TO INDICATE TEST RESULTS
G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves
H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

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LOG OF BORING NO. CD-BAP-0903
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

BBCM

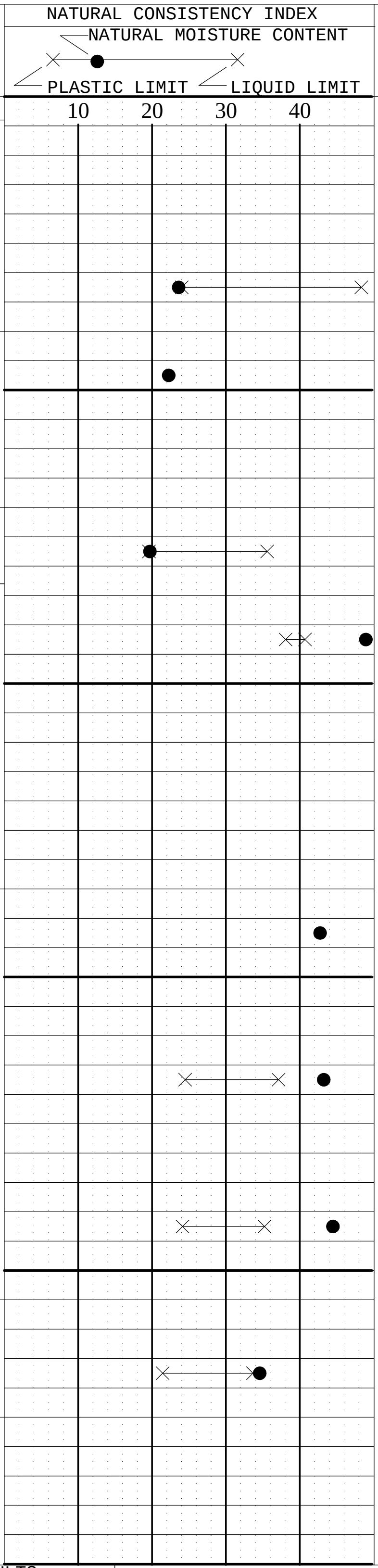
LOCATION: **See Plate 2 of Appendix A** ELEVATION: **650.1** DATE: **4/8/09**

DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **30.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
649.7	0						TOPSOIL - 0.4 FEET	
		1		2/5/6	15	67	FILL: Very-stiff to hard brown mottled with gray and dark-brown silty clay, trace fine to medium sand, few roots, damp.	H=3.6-3.8
646.1		2		4/6/6	16	53		H=3.3-4.5 G
	5	3		2/5/6	15	80	FILL: Very-stiff to hard brown mottled with gray silty clay, trace fine sand, damp.	H=2.6-4.1
643.1		4		8/11/13	33	80		H=4.5
641.8		5		6/6/6	16	67	FILL: Very-stiff to hard brown mottled with dark-gray and gray silty clay, little fine to coarse sand, trace fine gravel, few lenses of dark-gray silt, damp.	H=3.5-4.5 G
	10	6		5/6/6	16	67	Medium-stiff dark-gray organic clayey silt, trace fine sand, many lenses of fine sand, few decayed roots, damp to moist.	H=0.6 G
			P					
636.6	15	7		SH/1/1	3	67	Very-soft gray mottled with dark-gray organic clayey silt interbedded with organic silt, little fine sand, few seams and lenses of silt and fine sand, moist to wet.	H=0.0 G
	▽	8		SH/1/1	3	67		H=0.0 G
629.6	20	9		SH/1/1	3	73		H=0.0 G
627.6		10		1/2/4	8	60	Very-soft gray silty clay interbedded with silt, trace fine sand, few seams of fine sand, few roots, moist to wet.	H=0.2 G
	25	11		2/4/7	15	47	Medium-dense brown and gray fine to coarse sand, trace medium to coarse sand, trace fine to coarse gravel, little silt, few seams of silty clay, wet.	G



WATER LEVEL: ▽ 16.5 ▼

WATER NOTE: Inside HSA

DATE: 4/8/09

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.82
Last Calibration Date : 11/19/07
Drill Rig Number : D50

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LOG OF BORING NO. CD-BAP-0903
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **650.1** DATE: **4/8/09**

DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **30.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION	NATURAL CONSISTENCY INDEX / NATURAL MOISTURE CONTENT / PLASTIC LIMIT / LIQUID LIMIT (10 20 30 40)	TEST RESULTS
624.6	25						Medium-dense brown and gray fine to coarse gravel, some fine to coarse sand, trace silt, wet.		
		12	■	6/10/12	30	33			
		13	■	7/7/7	19	47			
620.1	30								
	35						- Seepage encountered at 13.5'. - Groundwater encountered at 22.5'. - At 26.0', 1.8' heave, shook augers to sample. - Borehole grouted upon completion. - Boring location and elevation surveyed by AEP.		
	40								
	45								
	50								

WATER LEVEL: ▽ 16.5 ▼

WATER NOTE: Inside HSA

DATE: 4/8/09

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.82

Last Calibration Date : 11/19/07

Drill Rig Number : D50

LOG OF BORING NO. CD-PZ-BAP-0904
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

BBCM

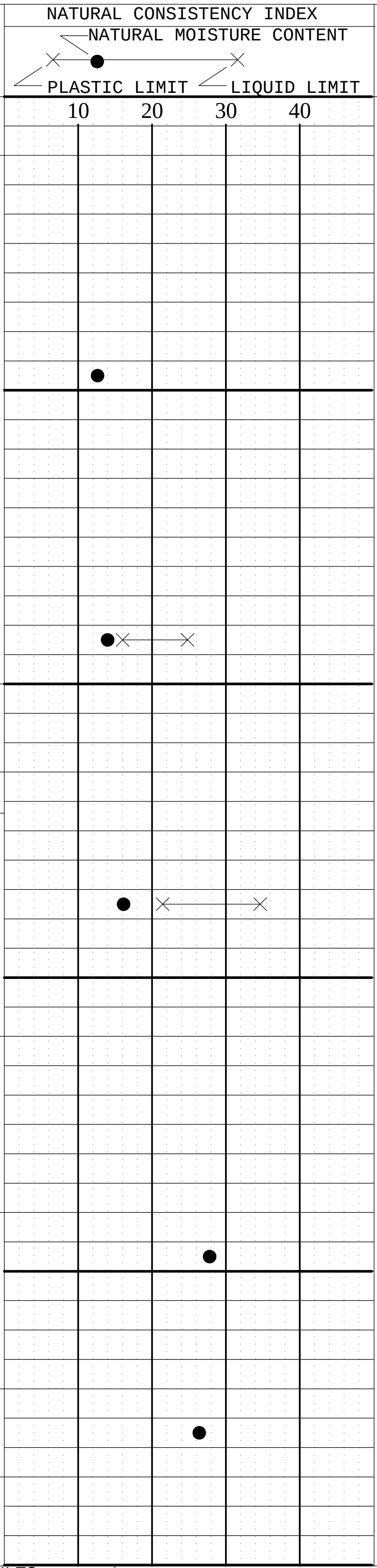
2008 NEW DEFAULT BORING LOG-W/ N60 11497013.GPJ BBCM.GDT 8/4/09

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.1** DATE: **4/7/09**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	0					GRAVEL FILL - 1.0 FEET	
667.1		1	6/6/8	20	100	FILL: Very-stiff to hard brown and gray silty clay, some fine to coarse sand, some fine to coarse gravel (sandstone, siltstone, and shale fragments), fine to coarse gravel seams near middle of stratum, dry.	H=4.25-4.5+
		2	6/8/11	27	53		H=4.5+
	5	3	9/11/12	33	93		H=3.5-4.0
		4	12/15/17	46	7		
		5	12/8/8	23	13		
		6	2/8/17	36	80		H=2.75-3.5 G
658.1	10	7	20/50-3"R		33	FILL: Very-dense brown and gray fine to coarse gravel (sandstone, siltstone, and shale fragments), little fine sand, trace silt, dry.	
656.6		8A	13/14/17	44		FILL: Dense brown and gray fine to coarse gravel (sandstone fragments), cobbles, "and" fine to medium sand, trace coarse sand, trace silt, dry.	
655.9		8B					H=4.5+
		9	3/5/9	20	73	FILL: Hard brown with gray silty clay, little to some fine to coarse sand, trace fine gravel, dry.	H=2.5-40
	15	10	5/6/7	19	80		H=3.0-4.25
652.1	▼ ▽	11	4/6/12	26	60	FILL: Medium-dense brown and gray fine to coarse gravel (very-soft shale fragments), some fine to coarse sand, some silty clay, cobbles, damp.	G
		12A	4/6/8	20			
649.1		12B					
	20	13	2/2/2	6	87	Loose gray and dark-gray organic silt, little clay, little to some fine to medium sand, wet.	G
		14	2/3/4	10	47		
646.1		15	SH/1/2	4	47	Very-loose gray and dark-gray fine to medium sand, trace coarse sand, little fine gravel, some organic silt, wet.	G
644.6		16	SH/SH/SH	0	53	Very-loose gray silt, little clay, little fine sand, wet.	
	25						



WATER LEVEL: ▽ 16.0 ▼ 15.9
WATER NOTE: Inside HSA Inside Well
DATE: 4/7/09 4/10/09

SYMBOLS USED TO INDICATE TEST RESULTS
G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves
H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

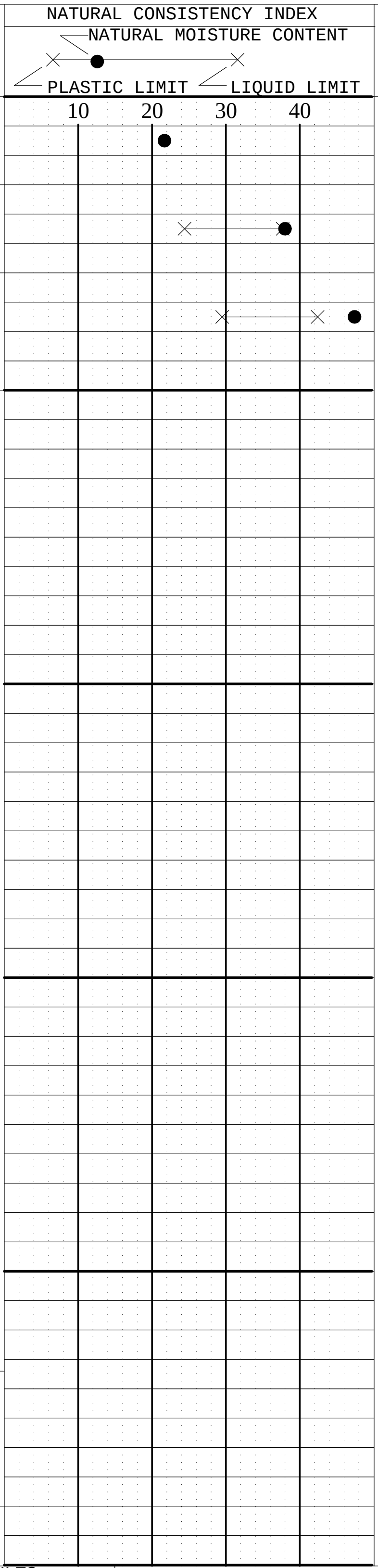
LOG OF BORING NO. CD-PZ-BAP-0904
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.1** DATE: **4/7/09**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	25	17	■	SR / SH / 3	4	53	Very-loose gray silt, little clay, little fine sand, wet.	G
641.6		18	■	SH / 1 / 3	6	100	Medium-stiff to stiff gray mottled with dark-gray organic clayey silt, interbedded with organic silt, little fine to coarse sand, trace fine gravel, wet.	H=0.75-1.25 G
640.1		19	■	1 / 1 / 3	6	87	Very-soft to soft gray mottled with dark-gray organic clayey silt, trace fine sand, wet.	H=0.0-0.5 G
638.1	30						Loose to medium-dense brown and gray fine to medium sand, trace coarse sand, trace to some silt, few seams of gray mottled with dark-gray silty clay near bottom of stratum, contains zones interbedded with silt, wet.	
				P				
		20A 20B	■	5 / 5 / 7	17			
	35							
		21	■	2 / 3 / 5	11	93		G
		22	■	2 / 2 / 5	10	100		
	40							
		23	■	2 / 2 / 5	10	100		
		24	■	2 / 8 / 12	29	100		
	45							
621.4		25A 25B	■	4 / 11 / 17	40		Medium-dense brown and gray fine to coarse gravel, "and" fine to coarse sand, trace silt, wet.	
619.1		26	■	12 / 29 / 50-5"R		93	See description on the following page.	
	50							



WATER LEVEL:	▽ 16.0	▼ 15.9
WATER NOTE:	Inside HSA	Inside Well
DATE:	4/7/09	4/10/09

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

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LOG OF BORING NO. CD-PZ-BAP-0904
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

BBCM

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.1** DATE: **4/7/09**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	NATURAL CONSISTENCY INDEX (NATURAL MOISTURE CONTENT; PLASTIC LIMIT; LIQUID LIMIT) 10 20 30 40	TEST RESULTS
	50						Very-dense brown and gray fine to coarse sand, some fine to coarse sand, trace silt, zones of fine to coarse gravel, wet.		
		27	■	8/40/50-4"R		87			
		28	■	10/50-5"R		33			
	55								
		29	■	9/28/50-3"R		67			
		30	■	16/50-5"R		67			
608.1	60								
							- Cobbles encountered at 10.0', 11.5' and 13.0'. - Groundwater encountered at 16.0'. - Borehole converted to observation well upon completion. See separate well log. - Boring location and elevation surveyed by AEP.		
	65								
	70								
	75								

	▽	▼
WATER LEVEL:	16.0	15.9
WATER NOTE:	Inside HSA	Inside Well
DATE:	4/7/09	4/10/09

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

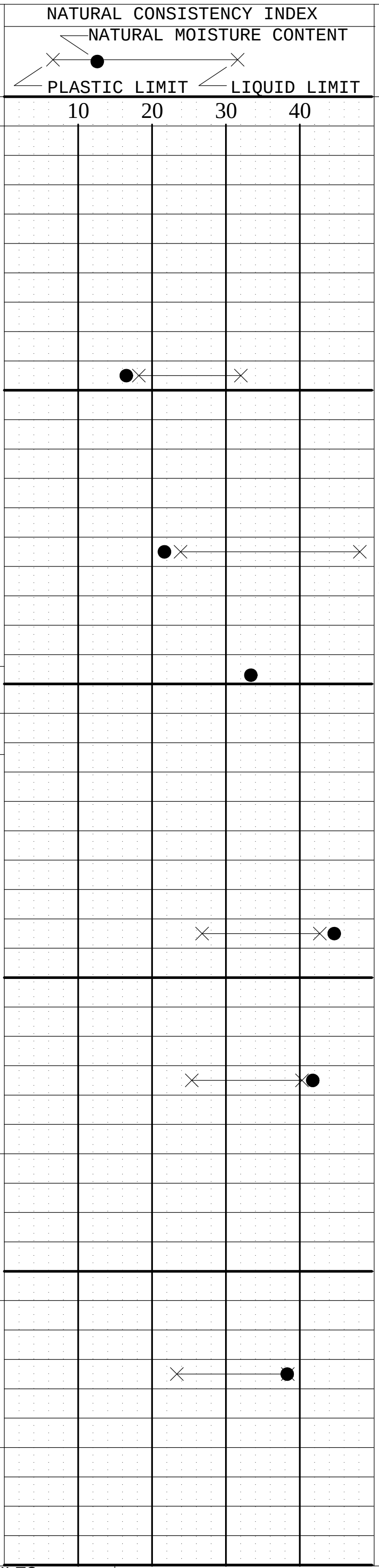
LOG OF BORING NO. CD-PZ-BAP-0905
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **650.1** DATE: **4/6/09**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **30.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
649.6	0						ROOTMAT - 0.5 FEET	
		1		3/3/5	11	67	FILL: Very-stiff to hard brown mottled with gray silty clay, trace fine sand, few lenses of dark-gray silt and fine sand near bottom of stratum, moist.	H=4.0-4.5
		2		3/6/8	19	100		H=4.0-4.5
	5 ▼	3		6/7/10	23	100		H=3.0-4.5 G
		4		12/13/22	48	100		H=4.5+
	▽	5		9/11/14	34	100		H=4.0-4.5+
640.4		6A		6/5/10	21			H=3.5-4.5
639.6	10	6B					FILL: Stiff to very-stiff brown mottled with gray silty clay interbedded with dark-gray organic silt, little fine to coarse sand, trace fine gravel, moist.	H=1.5-3.0 G
638.9		7A		2/2/2	5		FILL: Very-stiff brown mottled with gray silty clay, trace fine to coarse sand, trace fine gravel, moist.	H=3.5-3.75
		7B					Very-soft gray mottled with dark-gray organic clayey silt, trace fine to coarse sand, trace fine gravel, moist becoming wet.	H=0.0
	15	8		SH/SH/SH	0	100		H=0.0 G LOI=8.4%
		9		SH/SH/SH	0	100		H=0.0 G
632.1		10		SH/SH/2	3	33	Very-loose brown and gray fine to coarse gravel, some fine to coarse sand, little silt, contains decayed wood, wet.	H=0.5
629.6	20	11		6/7/5	16	27	Very-soft gray mottled with brown silty clay, little fine to medium sand, few seams of fine to medium sand, wet.	G
627.1		12		6/10/12	30	53	Medium-dense to dense brown and gray fine to coarse sand, trace to little fine to coarse gravel, trace silt, contains roots near top of stratum, contains zones of fine to coarse gravel, wet.	
	25							



	▽	▼
WATER LEVEL:	8.0	5.4
WATER NOTE:	Inside Well	Inside Well
DATE:	4/7/09	4/10/09

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.82
Last Calibration Date : 11/19/07
Drill Rig Number : D50

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

LOG OF BORING NO. CD-PZ-BAP-0905
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **650.1** DATE: **4/6/09**

DRILLING METHOD: **4-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **30.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION	NATURAL CONSISTENCY INDEX NATURAL MOISTURE CONTENT PLASTIC LIMIT LIQUID LIMIT 10 20 30 40	TEST RESULTS
	25						Medium-dense to dense brown and gray fine to coarse sand, trace to little fine to coarse gravel, trace silt, contains roots near top of stratum, contains zones of fine to coarse gravel, wet.		
		13	■	7/12/23	48	67			G
		14	■	9/12/25	51	73			
620.1	30								
							- Groundwater encountered at 18.0'. - Encountered decayed wood at 18.5'. - Borehole converted to observation well upon completion. See separate well log. - Boring location and elevation surveyed by AEP.		
	35								
	40								
	45								
	50								

	▽	▼
WATER LEVEL:	8.0	5.4
WATER NOTE:	Inside Well	Inside Well
DATE:	4/7/09	4/10/09

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
(G, Q, T, C:) See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.82
Last Calibration Date : 11/19/07
Drill Rig Number : D50

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

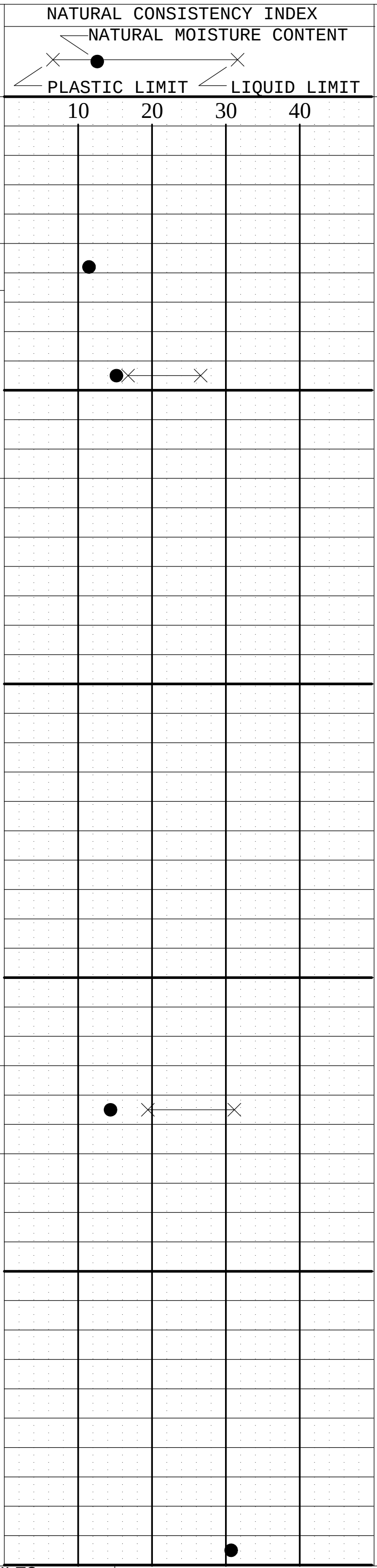
LOG OF BORING NO. CD-BAP-0906
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.6** DATE: **4/9/09 - 4/10/09**

DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	0	1	8/12/17	42	20	FILL: Medium-dense brown and gray fine to coarse gravel (shale and siltstone fragments), some fine to coarse sand, some silty clay, dry.	
666.1		2A	16/8/8	23		FILL: Medium-dense dark-gray fine to medium sand, trace coarse sand, little fine gravel, some clayey silt, dry to damp.	
665.3		2B				FILL: Very-stiff brown and gray silty clay and clayey silt, some fine to coarse sand, little fine gravel (sandstone, siltstone, and shale fragments), damp.	H=2.5-3.5
	5	3	6/4/5	13	33		H=2.3
		4	6/8/9	24	40		H=2.3-3.3
662.1		5	6/7/7	20	67	FILL: Medium-dense brown and gray fine to coarse gravel "and" fine to coarse sand, some silty clay (sandstone and siltstone fragments), stiff brown silty clay seam at 13.5', damp.	
		6A	P				
	10 ▽	6B					
		7	11/11/12	33	60		
		8	9/13/10	33	67		G
		9	9/16/19	50	60		H=2.2
	15	10	10/11/11	32	40		
652.1		11	7/7/6	19	53	FILL: Very-stiff brown silty clay, some fine to coarse sand, some fine to coarse gravel, damp to moist.	H=2.2 G
650.6		12A	P			Very-loose to loose gray silt, trace to some fine sand, trace to little fine to medium sand, trace fine gravel, few seams of gray fine to medium sand, damp becoming wet at 20'.	
		12B					
	20	13	1/1/3	6			80
			SR/SR/SR	0	0		
		14	SH/SH/1	1	67		
		15	1/1/1	3	100		
	25						



WATER LEVEL:	▽ 10.3	▼
WATER NOTE:	Inside HSA	
DATE:	4/10/09	

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

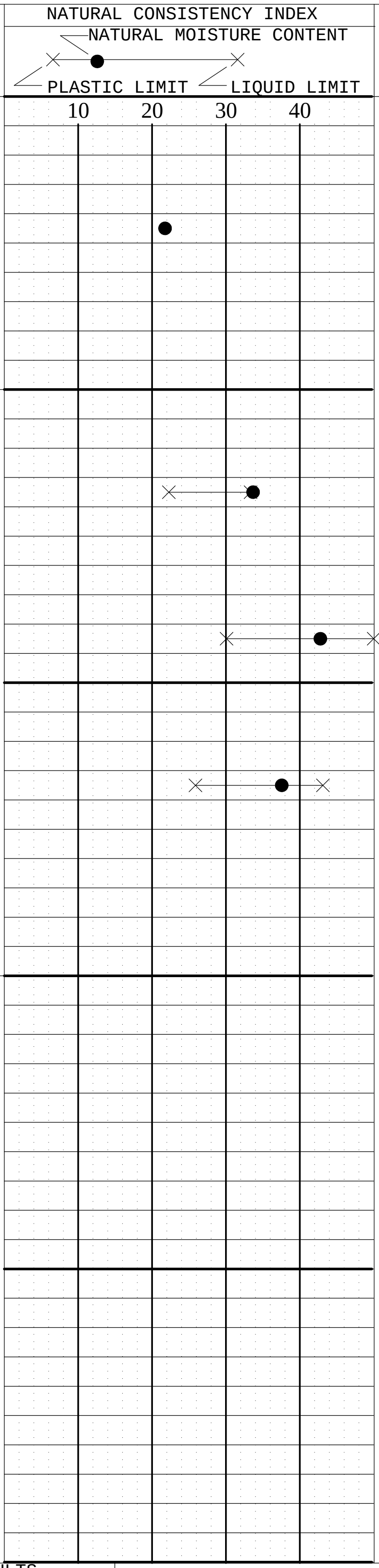
-CONTINUED-

LOG OF BORING NO. CD-BAP-0906
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.6** DATE: **4/9/09 - 4/10/09**

DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**



ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	25							G
		16		3/4/5	13	67	Very-loose to loose gray silt, trace to some fine sand, trace to little fine to medium sand, trace fine gravel, few seams of gray fine to medium sand, damp becoming wet at 20'.	G
		17		3/1/2	4	80		G
		18		2/2/2	6	67		
638.6	30						Very-soft to medium-stiff gray organic clayey silt, trace fine to coarse sand, trace fine gravel, contains seams of silty clay, silt and fine to medium sand, wet.	
		19		1/1/3	6	67		H=0.9 G
		20		2/2/3	7	60		H=0.0-0.25 G
	35							LOI=7.9%
		21		2/2/3	7	47		H=0.0 G
		22		3/5/9	20	53		H=0.9
628.6	40						Medium-dense brown and gray fine to coarse gravel, some fine to coarse sand, trace to little silt, contains zones of fine to coarse sand, wet.	
		23		5/6/7	19	40		
		24		6/7/9	23	47		G
	45							
		25		10/13/15	40	70		
		26		6/10/14	34	67		
	50							

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

WATER LEVEL: ▽ **10.3** ▼
WATER NOTE: **Inside HSA**
DATE: **4/10/09**

SYMBOLS USED TO INDICATE TEST RESULTS
G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves
H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86
Last Calibration Date : 02/17/09
Drill Rig Number : TRUCK 55

LOG OF BORING NO. CD-BAP-0906
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **668.6** DATE: **4/9/09 - 4/10/09**

DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **60.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N_{60}	SAMPLE REC-%	DESCRIPTION	NATURAL CONSISTENCY INDEX — NATURAL MOISTURE CONTENT, PLASTIC LIMIT, LIQUID LIMIT (10 20 30 40)	TEST RESULTS
	50					Medium-dense brown and gray fine to coarse gravel, some fine to coarse sand, trace to little silt, contains zones of fine to coarse sand, wet.		
		27	10/10/16	37	47			
		28	9/10/12	32	60			
	55							
		29	10/15/33	69	33			
			3/5/11	23				
608.6	60							
						- Groundwater encountered at 20.0'. - Cobbles encountered throughout the borehole. - Borehole grouted upon completion. - Boring location and elevation surveyed by AEP.		
	65							
	70							
	75							

WATER LEVEL: ▽ **10.3** ▼

WATER NOTE: **Inside HSA**

DATE: **4/10/09**

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.86

Last Calibration Date : 02/17/09

Drill Rig Number : TRUCK 55

JOB: 011-11497-013

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

LOG OF BORING NO. CD-BAP-0907
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

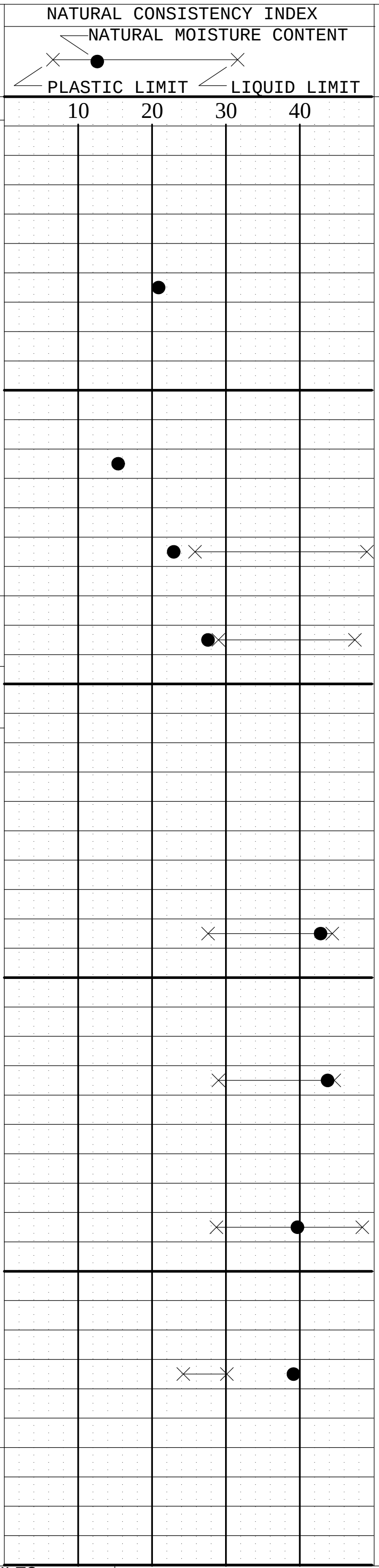
BBCM

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **650.3** DATE: **4/8/09**

DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **30.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
649.9	0					TOPSOIL - 0.4 FEET	
		1	4/5/5	14	47	FILL: Very-stiff to hard brown mottled with gray silty clay, trace to little fine to coarse sand, trace fine gravel, few roots near top of stratum, contains fine to medium sand lenses and seams near middle of stratum, damp.	H=2.2-2.4
		2	4/5/10	21	73		H=3.9-4.2
	5	3	4/6/7	18	80		H=4.5
		4	9/11/15	36	100		H=4.5
		5	5/7/8	21	67		H=4.1-4.5
641.8		6A	P			FILL: Hard brown, gray and dark-gray silty clay intermixed with organic silt, little fine to coarse sand, trace fine gravel, damp.	H=4.5 G
640.6	10	6B				Stiff gray organic silt, little fine to medium sand, few lenses of fine sand, damp to moist.	H=2.2
639.6		7	SH/SH/SH	0	67	Very-soft to soft gray organic clayey silt, little fine to medium sand, trace fine gravel, damp to moist.	H=0.0 G
	15	8	SH/SH/SH	0	73		H=0.0 G
	∇	9	SH/SH/SH	0	67		H=0.0-0.25 G
	20	10	SH/SH/SH	0	73		H=0.0-0.25 G
		11	SH/SH/3	4	67		H=0.0-0.50 G
627.3		12	2/6/8	19	33	Medium-dense gray-brown and gray fine to coarse gravel, "and" fine to coarse sand, trace to little silt, wet.	
	25						



WATER LEVEL: ∇ 16.3 ▼
WATER NOTE: Inside HSA
DATE: 4/8/09

SYMBOLS USED TO INDICATE TEST RESULTS

G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.82
Last Calibration Date : 11/19/07
Drill Rig Number : D50

Page 2 of 2

LOG OF BORING NO. CD-BAP-0907
CARDINAL PLANT ASH POND INVESTIGATION
BRILLIANT, OHIO

LOCATION: **See Plate 2 of Appendix A** ELEVATION: **650.3** DATE: **4/8/09**

DRILLING METHOD: **3-1/4" I.D. Hollow-stem Auger** COMPLETION DEPTH: **30.0'**

SAMPLER(S): **2" O.D. Split-barrel Sampler 3" O.D. Shelby Tube Sampler**

NATURAL CONSISTENCY INDEX — NATURAL MOISTURE CONTENT — PLASTIC LIMIT — LIQUID LIMIT: 10 20 30 40

ELEV.	DEPTH, FEET	SAMPLE NUMBER	SAMPLE	SAMPLE EFFORT	N60	SAMPLE REC-%	DESCRIPTION	TEST RESULTS
	25						Medium-dense gray-brown and gray fine to coarse gravel, "and" fine to coarse sand, trace to little silt, wet.	
		13	■	8/12/13	34	40		G
		14	■	6/7/9	22	47		
620.3	30							
	35							
	40							
	45							
	50							

- Seepage encountered at 11.0'.
- Groundwater encountered at 23.0'.
- Borehole grouted upon completion.
- Boring location and elevation surveyed by AEP.

2008 NEW DEFAULT BORING LOG-W/ N60 111497013.GPJ BBCM.GDT 8/4/09

	▽	▼
WATER LEVEL:	16.3	
WATER NOTE:	Inside HSA	
DATE:	4/8/09	

SYMBOLS USED TO INDICATE TEST RESULTS

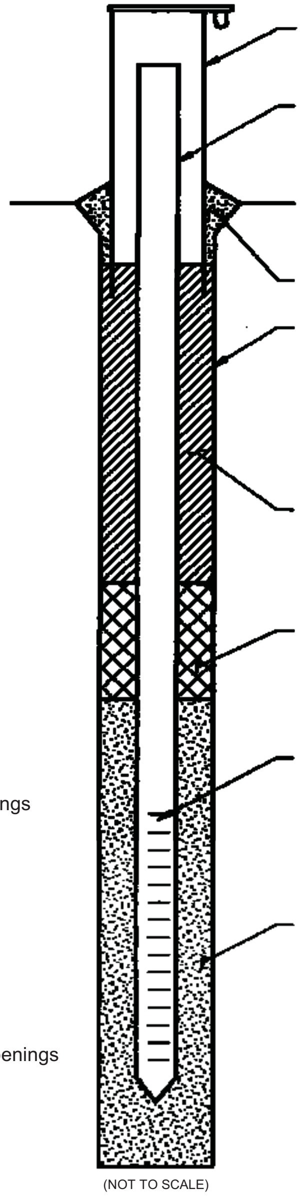
G - Gradation
Q - Uncon Comp
T - Triax Comp
C - Consol.
See Separate Curves

H - Penetrometer (tsf)
W - Unit Dry Wt (pcf)
D - Relative Dens (%)

Drill Rod Energy Ratio : 0.82
Last Calibration Date : 11/19/07
Drill Rig Number : D50

BBCM
SOLUTIONS TO BUILD ON

Elevation (Feet above MSL)	Depth Below Ground Surface (Feet)	
		Top of Cover
		Top of PVC
668.0	0.0	Ground Surface
N/A	N/A	Top of Grout
666.5	1.5	Top of Bentonite
659.8	8.2	Top of Filter Pack
N/A	N/A	Top of Aquifer
658.0	10.0	Top of Screen Openings
608.0	60.0	Bottom of Screen Openings
608.0	60.0	Bottom of Well
N/A	N/A	Bottom of Aquifer
607.5	60.5	Bottom of Boring


(NOT TO SCALE)

4 - Inch Diameter Protective Steel Casing

2 - Inch Diameter Flush-Thread PVC Casing

Ground Surface

Ground Surface

Concrete

Boring Diameter (in inches)
7 " **0.0** to **60.5**
" to
" to

Grout: **N/A**

Bentonite Seal: **Hole Plug**

10 - Slot Screen

Filter Pack: **No. 4 Quartz Sand8.2' - 24.9'**
Natural Sand 24.9' - 60.5'

Static Water Level:	**657.30**	**659.60**			
Date:	**4/8/09**	**4/10/09**			

Well Development:
Removed approximately 10 well volumes during development and well remained silty. Additional well development performed and well remained slightly silty at completion of bailing. Set steel casing in 3'x3' concrete pad. Placed steel bollards around concrete pad.

WELL COMPLETION DIAGRAM

Project Name:
Cardinal Plant Ash Pond Investigation

Project Location:
Brilliant, Ohio

Project Number:
011-11497-013

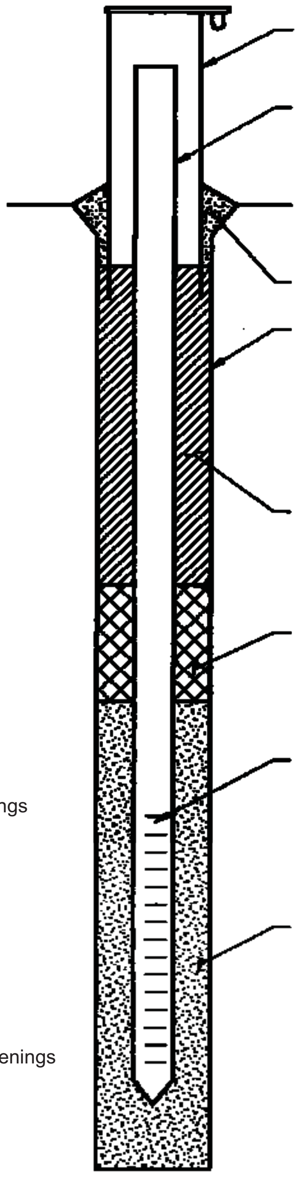
Boring Number:
CD-PZ-BAP-0902

Date Well Installed:
4/8/2009

PLATE 23

BBCM
SOLUTIONS TO BUILD ON

Elevation (Feet above MSL)	Depth Below Ground Surface (Feet)	
		Top of Cover
		Top of PVC
668.1	**0.0**	Ground Surface
N/A	**N/A**	Top of Grout
665.1	**3.0**	Top of Bentonite
660.1	**8.0**	Top of Filter Pack
N/A	**N/A**	Top of Aquifer
658.6	**9.5**	Top of Screen Openings
608.6	**59.5**	Bottom of Screen Openings
608.6	**59.5**	Bottom of Well
N/A	**N/A**	Bottom of Aquifer
608.1	**60.0**	Bottom of Boring


(NOT TO SCALE)

4 - Inch Diameter Protective Steel Casing

2 - Inch Diameter Flush-Thread PVC Casing

Ground Surface

Concrete

Boring Diameter (in inches)
7 " **0.0** to **60.0**
" to
" to

Grout: **N/A**

Bentonite Seal: **Hole Plug**

10 - Slot Screen

Filter Pack: **No. 4 Quartz Sand 8.0' - 32.5'**
Natural Sand 32.5' - 60.0'

Static Water Level:	**652.20**				
Date:	**4/10/09**				

Well Development:
Removed approximately 10 well volumes during development and well remained silty. Additional well development performed and well remained slightly silty at completion of bailing. Set steel casing in 3'x3' concrete pad. Placed steel bollards around concrete pad.

WELL COMPLETION DIAGRAM

Project Name:
Cardinal Plant Ash Pond Investigation

Project Location:
Brilliant, Ohio

Project Number:
011-11497-013

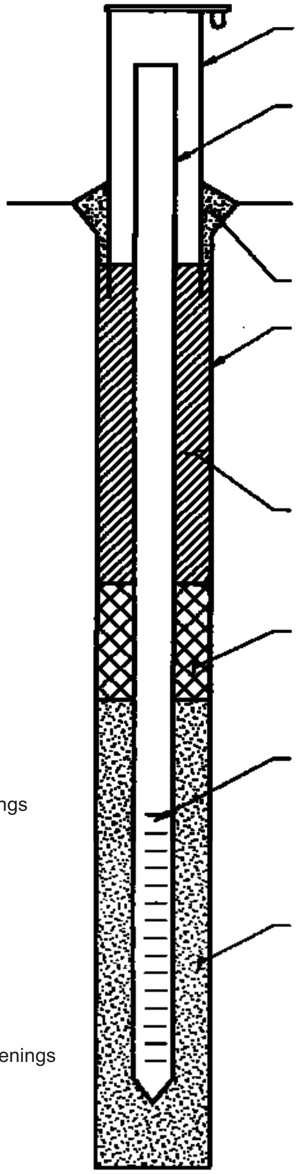
Boring Number:
CD-PZ-BAP-0904

Date Well Installed:
4/7/2009

PLATE 24

BBCM
SOLUTIONS TO BUILD ON

Elevation (Feet above MSL)	Depth Below Ground Surface (Feet)	
		Top of Cover
		Top of PVC
650.1	**0.0**	Ground Surface
N/A	**N/A**	Top of Grout
647.6	**2.5**	Top of Bentonite
642.1	**8.0**	Top of Filter Pack
N/A	**N/A**	Top of Aquifer
641.6	**8.5**	Top of Screen Openings
621.6	**28.5**	Bottom of Screen Openings
621.6	**28.5**	Bottom of Well
N/A	**N/A**	Bottom of Aquifer
620.1	**30.0**	Bottom of Boring



(NOT TO SCALE)

4 - Inch Diameter Protective Steel Casing

2 - Inch Diameter Flush-Thread PVC Casing

Ground Surface

Concrete

Boring Diameter (in inches)

7 "	**0.0**	to	**30.0**
"		to	
"		to	

Grout: **N/A**

Bentonite Seal: **Hole Plug**

10 - Slot Screen

Filter Pack: **No. 4 Quartz Sand 8.0' - 32.5'**
Natural Sand 18.0' - 30.0'

Static Water Level:	**642.10**	**644.70**			
Date:	**4/7/09**	**4/10/09**			

Well Development:
Removed approximately 10 well volumes during development. Well remained silty at completion of bailing. Set steel casing in 3'x3' concrete pad. Placed steel bollards around concrete pad.

WELL COMPLETION DIAGRAM

Project Name:
Cardinal Plant Ash Pond Investigation

Project Location:
Brilliant, Ohio

Project Number:
011-11497-013

Boring Number:
CD-PZ-BAP-0905

Date Well Installed:
4/6/2009

PLATE 25

Appendix II – 2009 & 2015 Laboratory Testing Results

SUMMARY OF LABORATORY TEST RESULTS

BORING	G'int Id.	MC	LL	PL	PI	GRADATION			COMPACTION		TRIAXIAL			DIRECT SHEAR			UNCONFIN COMPRESS	CONSOLID.	SPECIFIC GRAVITY	UNIT DRY WEIGHT	REMOLDED	PERMEABILITY				RELATIVE DENSITY	LOI	ROCK CORE	SHELBY TUBE	Slake Index
						sieve	Hydrometer short	Hydrometer long	standard	modified	uncons. undrain	consolid undrain w/pores	drained	drained	undrain	residual						cohesive	non/cohes	rigid wall	flexible wall					
		%	%	%	%	* SEE INDIVIDUAL TEST CURVES														PCF						%	%			
CD-BAP-1501	4.75					*																								
CD-BAP-1501	9.25					*																								
CD-BAP-1501	12.25	13.9	22	14	8																									
CD-BAP-1502	6.25	9.1	27	16	11	*		*																						
CD-BAP-1502	11.25	8.9	21	14	7																									
CD-BAP-1502	17.75	12.7	26	16	10	*		*																						
CD-BAP-1502	20.00																												*	
CD-BAP-1502	24.25	22.4																												
CD-BAP-1502	32.50																												*	
CD-BAP-1502	40.75					*																								
CD-BAP-1504	6.25	9.4																												
CD-BAP-1504	10.75					*																								
CD-BAP-1504	12.25	11.6				*																								
CD-BAP-1504	17.25	18.2																												
CD-BAP-1505	9.25	11.6																												
CD-BAP-1505	10.40	19.0																												
CD-BAP-1505	13.75	10.4																												
CD-BAP-1505	15.25	18.3				*																								

SUM REG

TESTING SUMMARY - STANDARD

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15

SUMMARY OF LABORATORY TEST RESULTS

BORING	G'int Id.	MC	LL	PL	PI	GRADATION			COMPACTION		TRIAXIAL			DIRECT SHEAR			UNCONFIN COMPRESS	CONSOLID.	SPECIFIC GRAVITY	UNIT DRY WEIGHT	REMOLDED	PERMEABILITY				RELATIVE DENSITY	LOI	ROCK CORE	SHELBY TUBE	Slake Index
							Hydrometer																							
						sieve	short	long	standard	modified	uncons. undrain	consolid. undrain w/pores	drained	drained	undrain	residual						cohesive	non/cohes	rigid wall	flexible wall					
		%	%	%	%	* SEE INDIVIDUAL TEST CURVES														PCF						%	%			
MW-BAP-4	6.25	15.0	25	16	9	*		*																						
MW-BAP-4	9.25	24.3	43	21	22																									
MW-BAP-4	14.50																												*	
MW-BAP-4	32.25					*																								
MW-BAP-4	39.25					*																								
MW-BAP-5	4.75	12.8	30	17	13	*		*																						
MW-BAP-5	9.25	10.3	30	18	12																									
MW-BAP-5	11.00																												*	
MW-BAP-5	21.75	39.9	48	26	22	*		*																			5.9			
MW-BAP-5	27.00																												*	
MW-BAP-5	29.00																												*	
MW-BAP-5	41.75	29.7																												
MW-BAP-5	51.75					*																								
MW-BAP-5	59.25					*																								

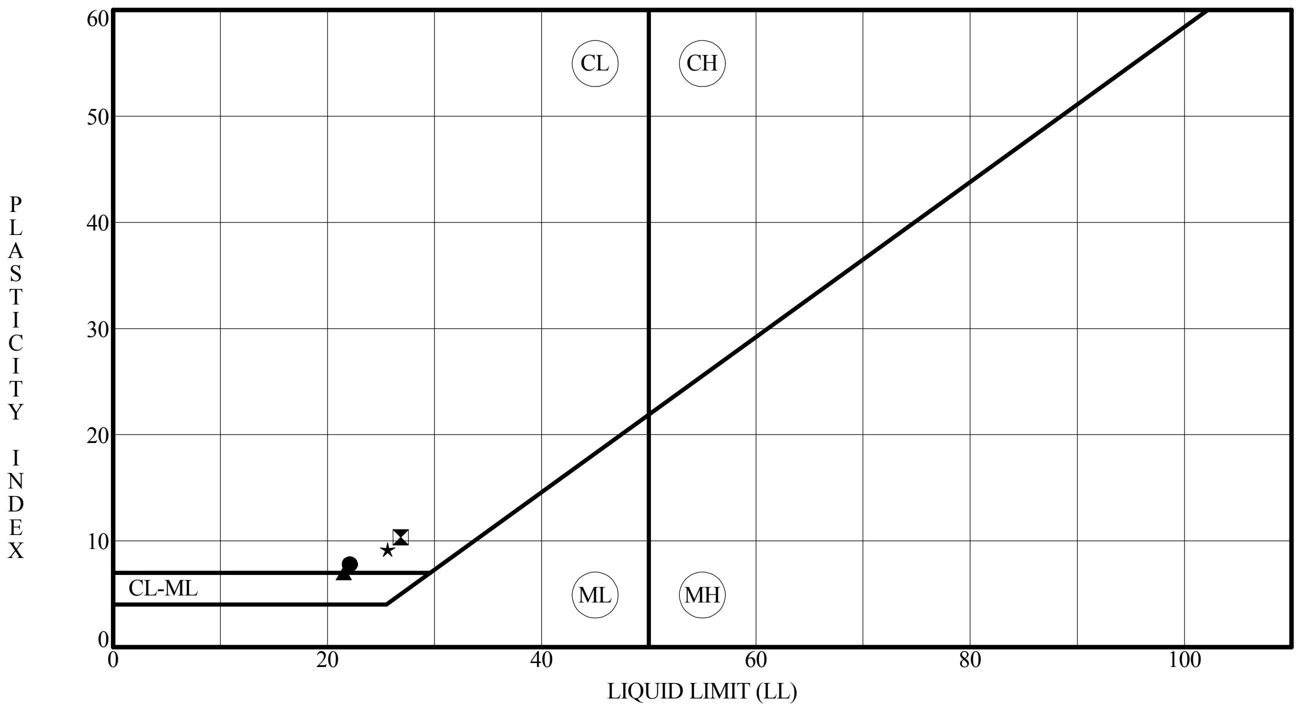
S&ME

TESTING SUMMARY - STANDARD

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15

SUM REG

ATTERBERG LIMITS' RESULTS - ASTM D4318



Specimen Id.	Depth	MC	LL	PL	PI	Fines	ASTM Classification
● **CD-BAP-1501**	**12.25**	**14**	**22**	**14**	**8**		
⧗ **CD-BAP-1502**	**6.25**	**9**	**27**	**16**	**11**	**28.6**	**CLAYEY SAND with GRAVEL SC**
▲ **CD-BAP-1502**	**11.25**	**9**	**21**	**14**	**7**		
★ **CD-BAP-1502**	**17.75**	**13**	**26**	**16**	**10**	**27.9**	**CLAYEY SAND with GRAVEL SC**

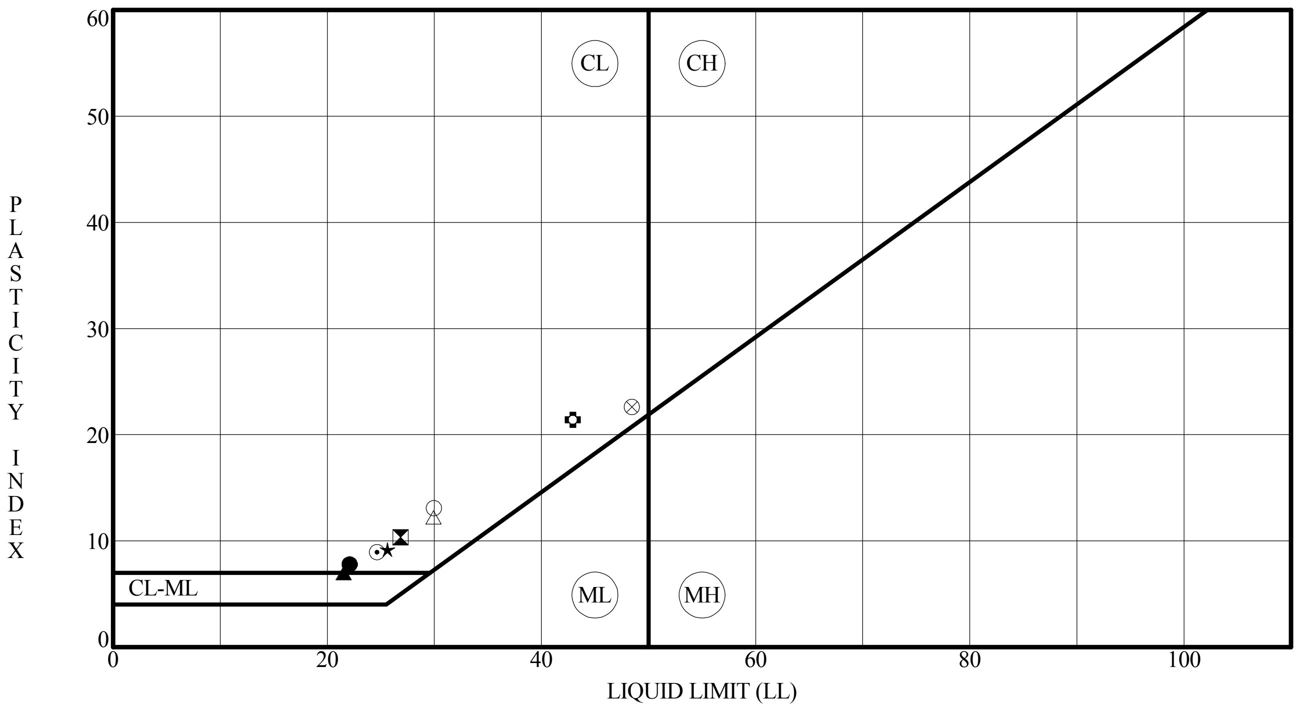
PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION

LOCATION CARDINAL PLANT, BRILLIANT, OH

JOB NO. 7217-15-007A **DATE** 12/30/15

ALPI-REG

ATTERBERG LIMITS' RESULTS - ASTM D4318

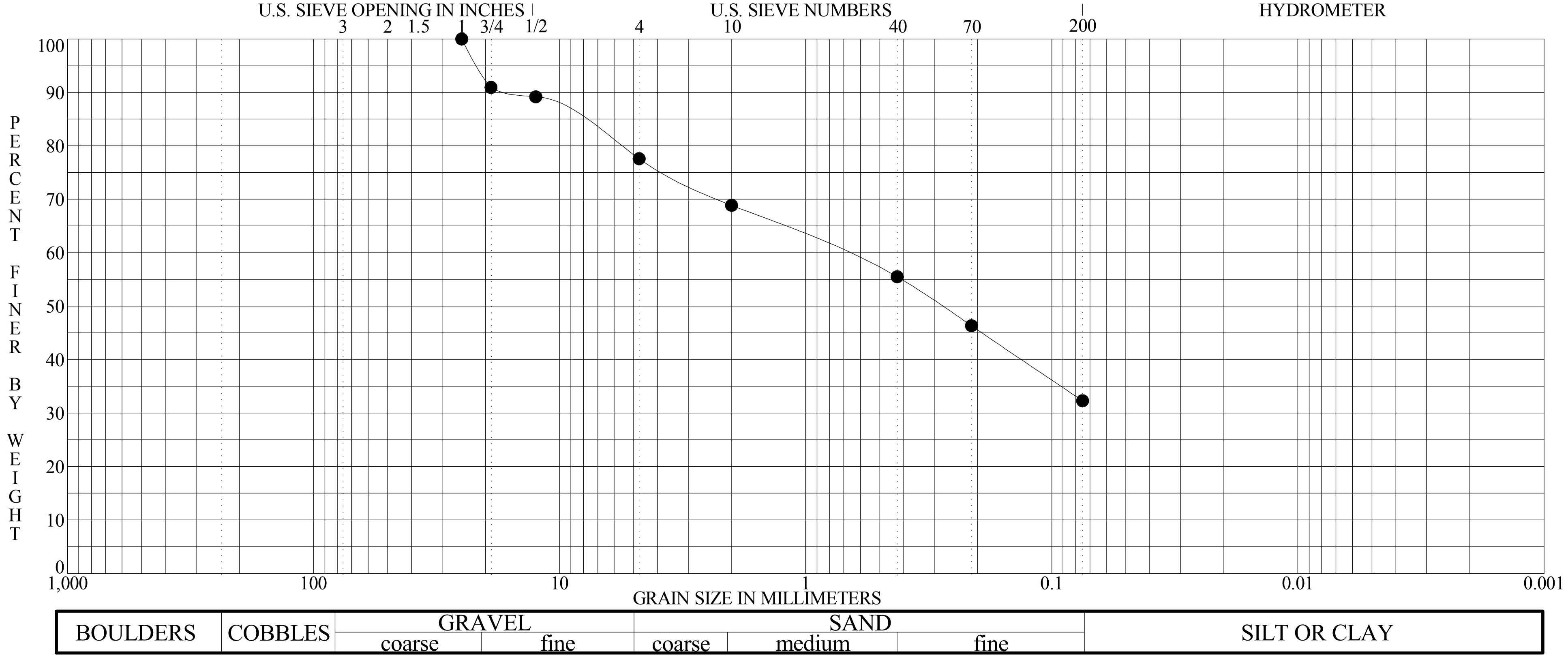


ALPI-REG

	Specimen Id.	Depth	MC	LL	PL	PI	Fines	ASTM Classification
●	CD-BAP-1501	12.25	14	22	14	8		
⧗	CD-BAP-1502	6.25	9	27	16	11	28.6	CLAYEY SAND with GRAVEL SC
▲	CD-BAP-1502	11.25	9	21	14	7		
★	CD-BAP-1502	17.75	13	26	16	10	27.9	CLAYEY SAND with GRAVEL SC
⊙	MW-BAP-4	6.25	15	25	16	9	41.2	CLAYEY SAND SC
✚	MW-BAP-4	9.25	24	43	21	22		
○	MW-BAP-5	4.75	13	30	17	13	38.8	CLAYEY SAND with GRAVEL SC
△	MW-BAP-5	9.25	10	30	18	12		
⊗	MW-BAP-5	21.75	40	48	26	22	94.9	LEAN CLAY CL

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

GRN-REG W/ASTM DESC.



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-BAP-1501 S-3 4.0' to 4.8'	Gray and brown fine to coarse sand, some fine to coarse gravel, some silt.						

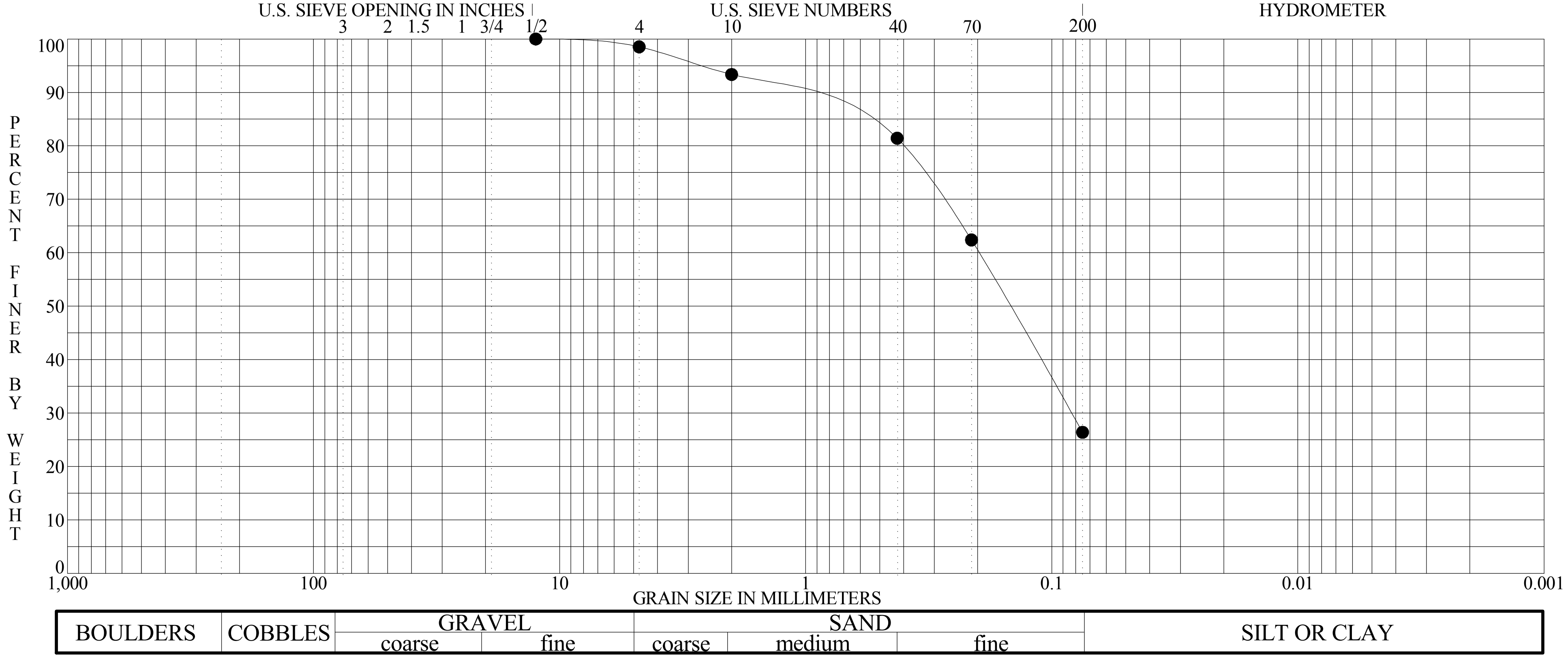
Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-BAP-1501 S-3 4.0' to 4.8'	25.0000	21.4832	0.7155	0.2797		22.4	45.3	32.3	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15

GRN-REG W/ASTM DESC.



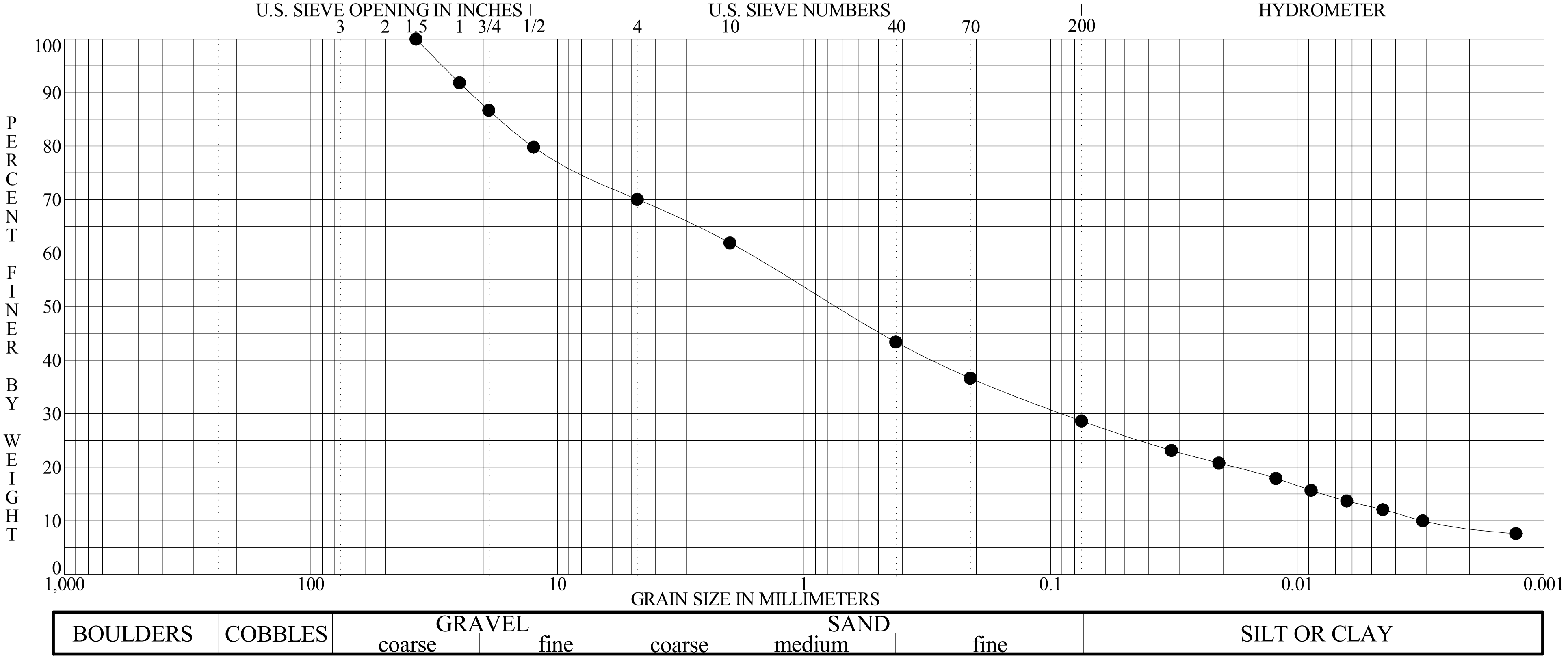
Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-BAP-1501 S-6 8.5' to 9.7'	Red-brown and gray fine to coarse sand, trace fine gravel, some silt.						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-BAP-1501 S-6 8.5' to 9.7'	12.5000	2.6291	0.1978	0.1482		1.5	72.1	26.4	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-1502 S-4 5.5' to 6.7'**	**Gray and brown fine to coarse sand, some fine to coarse gravel, some silty clay.** **CLAYEY SAND with GRAVEL SC**	**9**	**27**	**16**	**11**	**1.508**	**547.388**

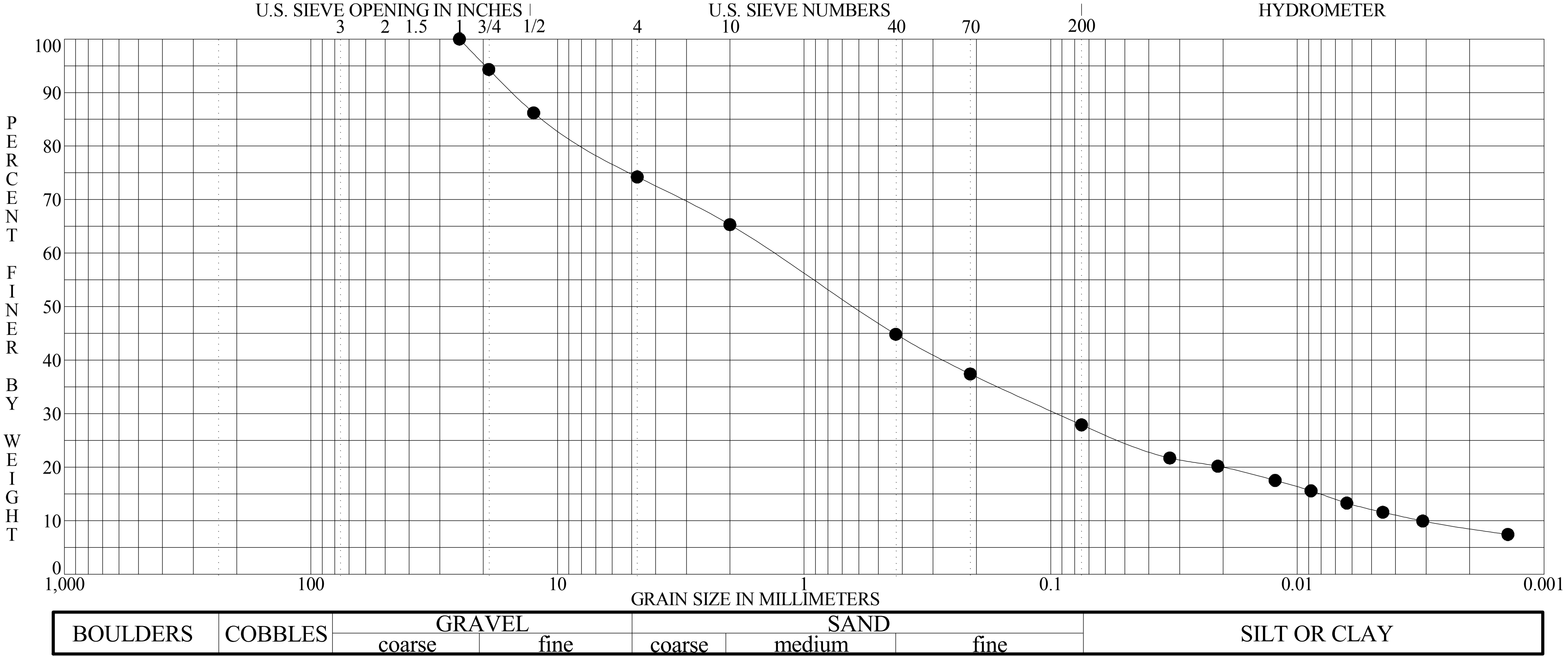
Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-1502 S-4 5.5' to 6.7'**	**37.5000**	**29.2411**	**1.7048**	**0.7385**	**0.0031**	**29.9**	**41.4**	**16.1**	**12.6**

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

GRN-REG W/ASTM DESC.



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	CD-BAP-1502 S-9 17.0' to 18.3	**Gray fine to coarse sand, some fine to coarse gravel, some clayey silt.** **CLAYEY SAND with GRAVEL SC**	13	26	16	10	2.113	425.827

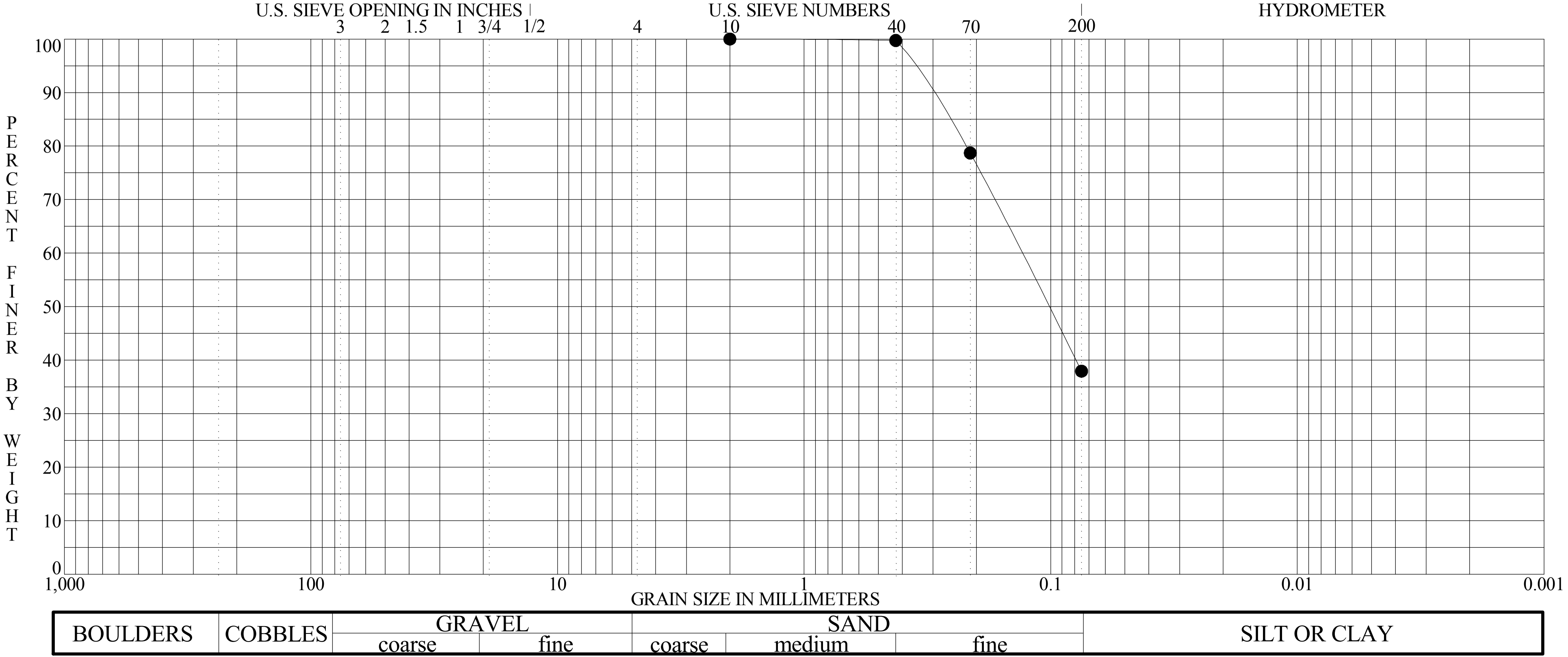
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	CD-BAP-1502 S-9 17.0' to 18.3	25.0000	19.6384	1.3380	0.6282	0.0031	25.8	46.3	15.8	12.1

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15

GRN-REG W/ASTM DESC.



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	CD-BAP-1502 S-18 40.0' to 41.0'	Brown fine to medium sand, "and" silt.						

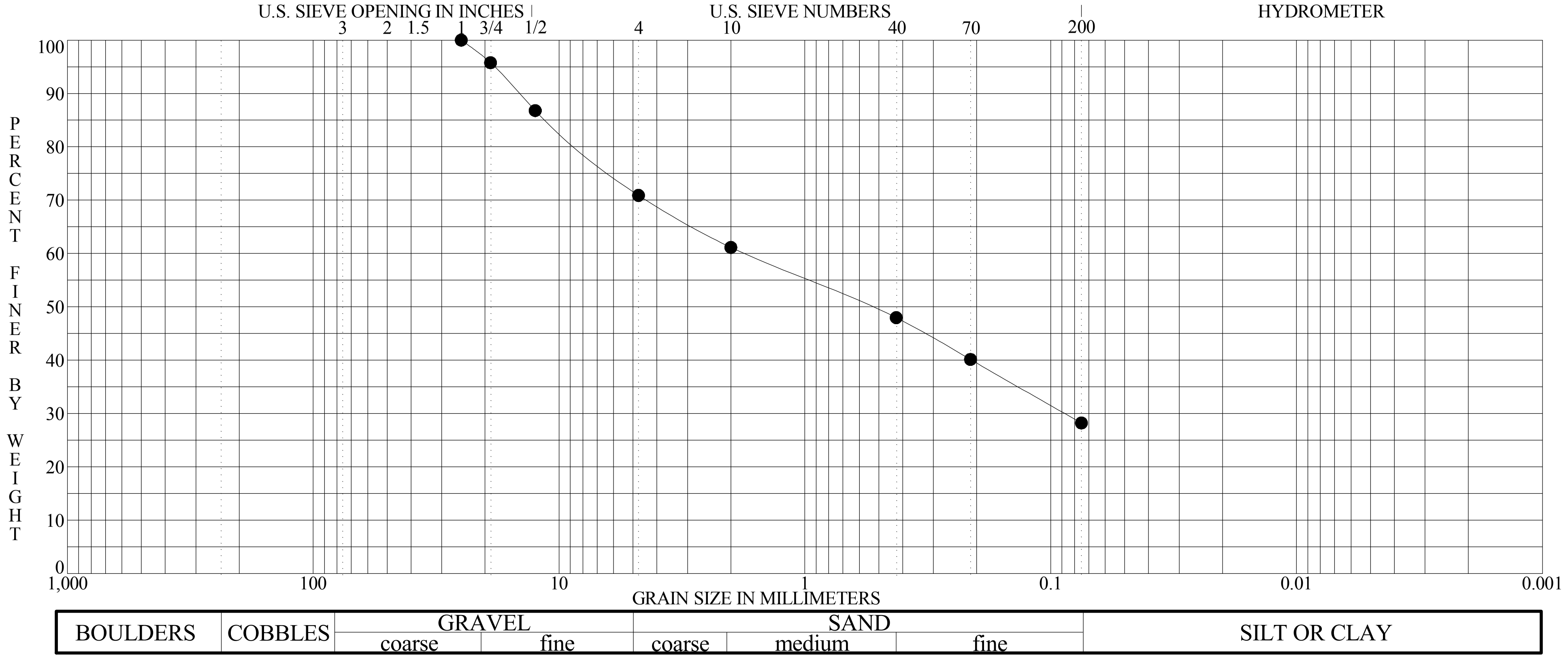
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	CD-BAP-1502 S-18 40.0' to 41.0'	2.0000	0.3633	0.1316	0.1020		0.0	62.1	37.9	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15

PLATE 9



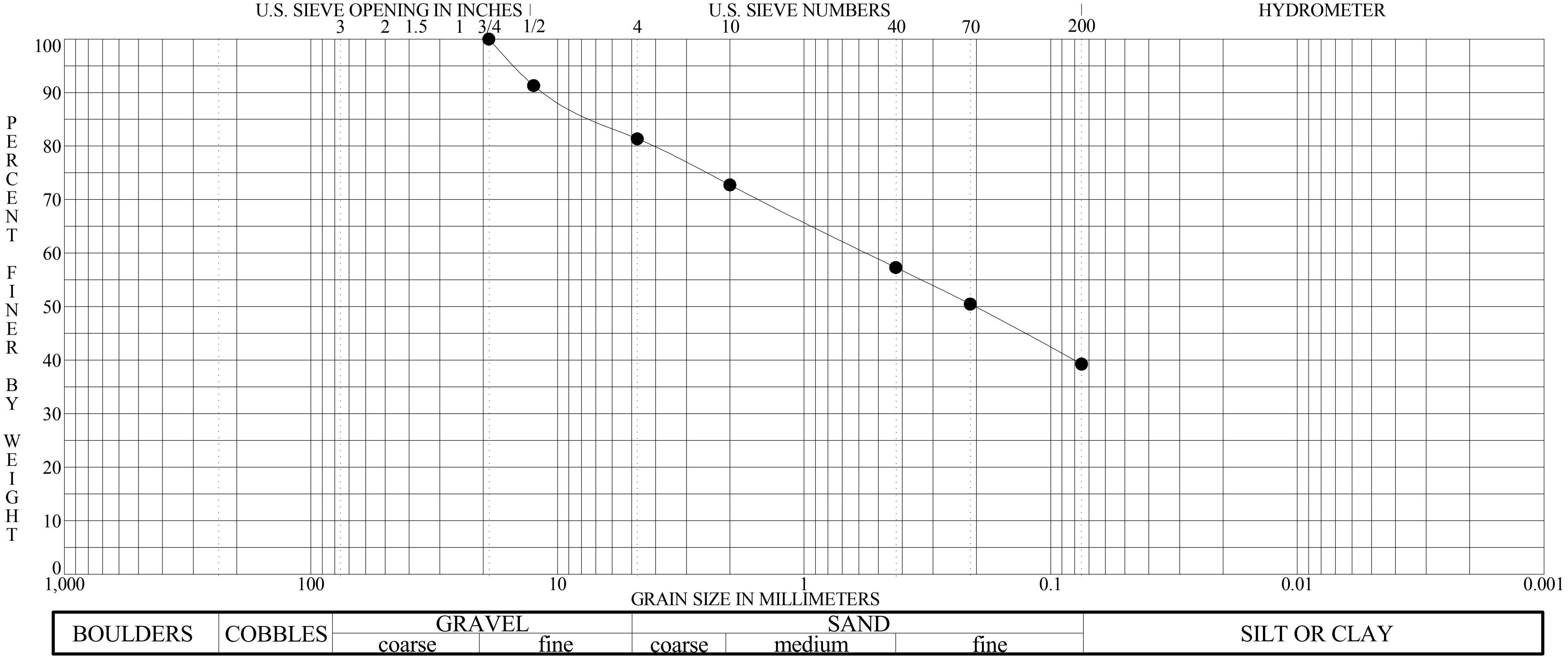
	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	CD-BAP-1504 S-7 10.0' to 11.0'	Dark-gray fine to coarse sand, some fine to coarse gravel (sandstone fragments), some silty clay.						

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	CD-BAP-1504 S-7 10.0' to 11.0'	25.0000	18.3349	1.7501	0.5398		29.1	42.7	28.2	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-1504 S-8 11.5' to 11.9'**	**Dark-gray and brown fine to coarse sand, little fine gravel, "and" silt.**	**12**					

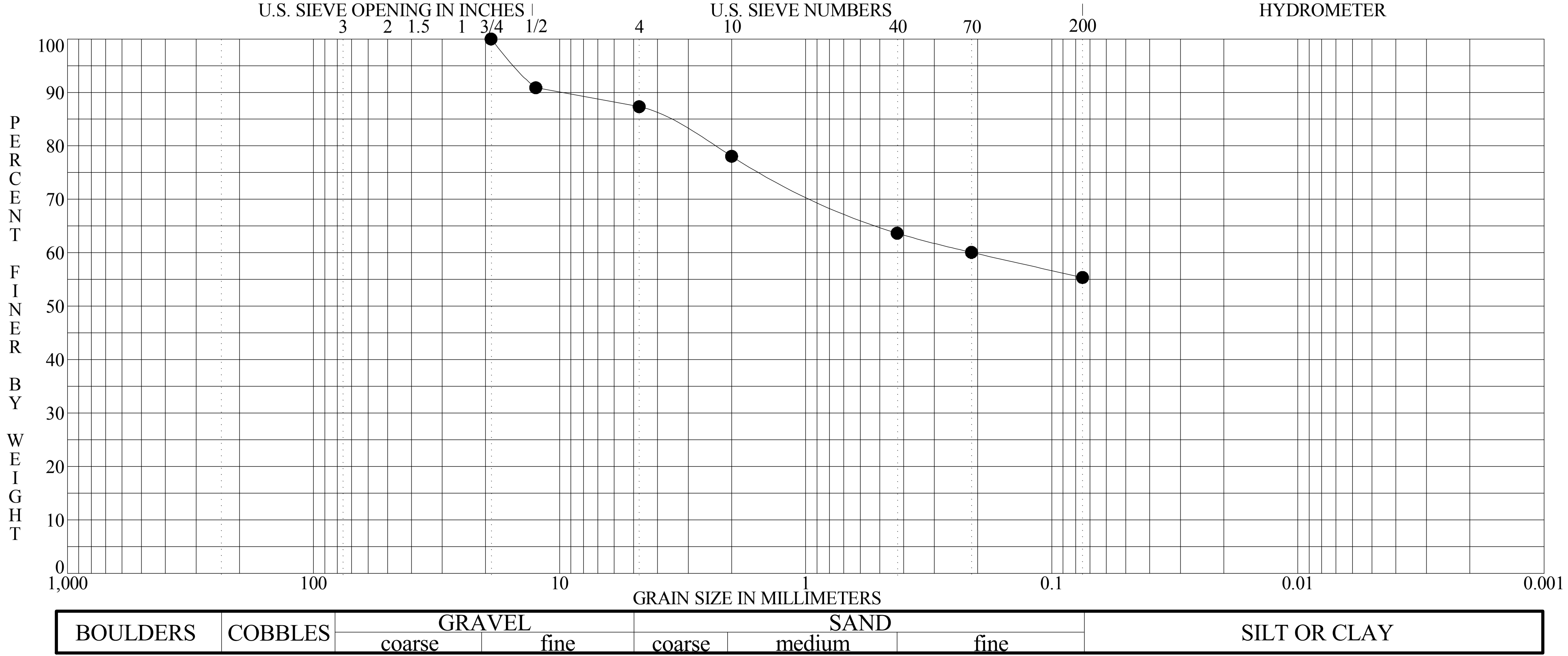
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-1504 S-8 11.5' to 11.9'**	**19.0000**	**14.9354**	**0.5566**	**0.2026**		**18.6**	**42.1**	**39.3**	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

GRN-REG W/ASTM DESC.



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	CD-BAP-1505 S-10 14.5' to 15.8'	Yellow-brown and brown silty clay, some fine to coarse sand, little fine gravel.	18					

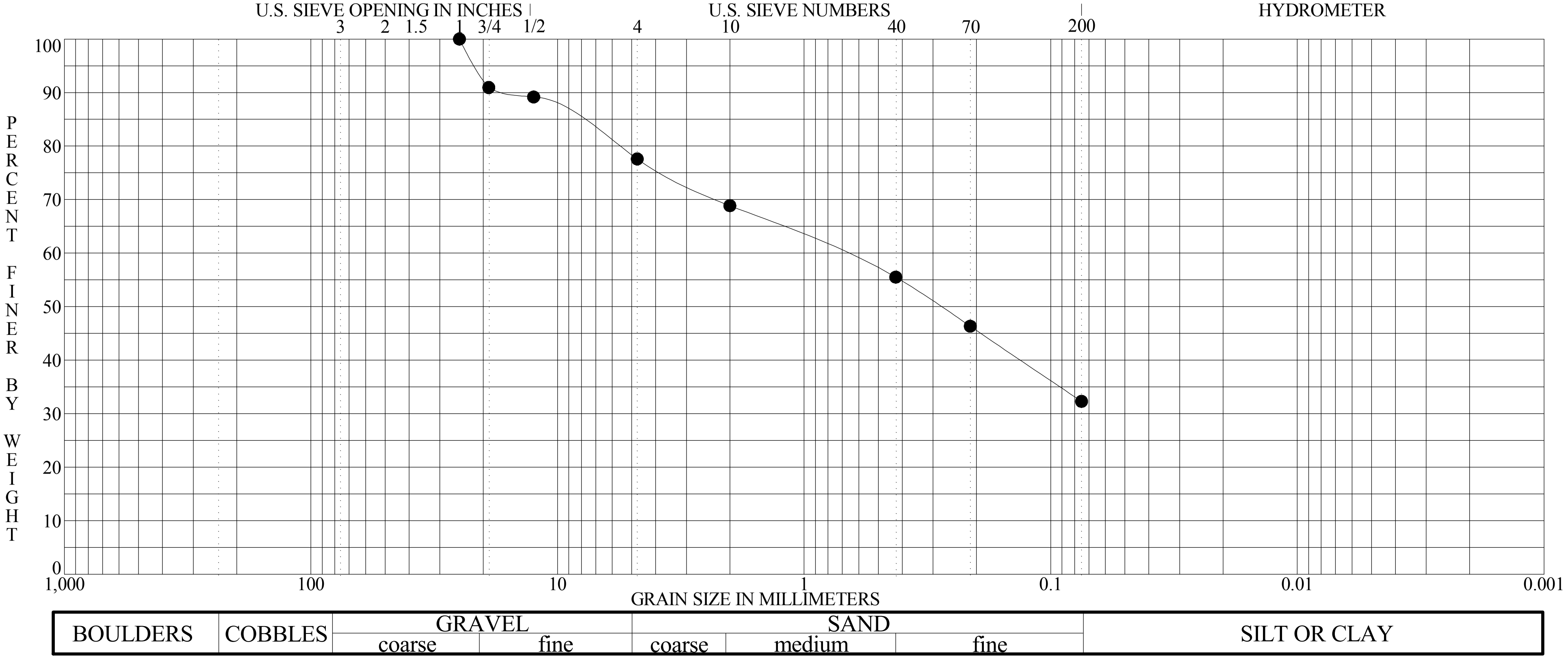
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	CD-BAP-1505 S-10 14.5' to 15.8'	19.0000	15.1011	0.2089			12.7	32.0	55.4	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15

PLATE 12



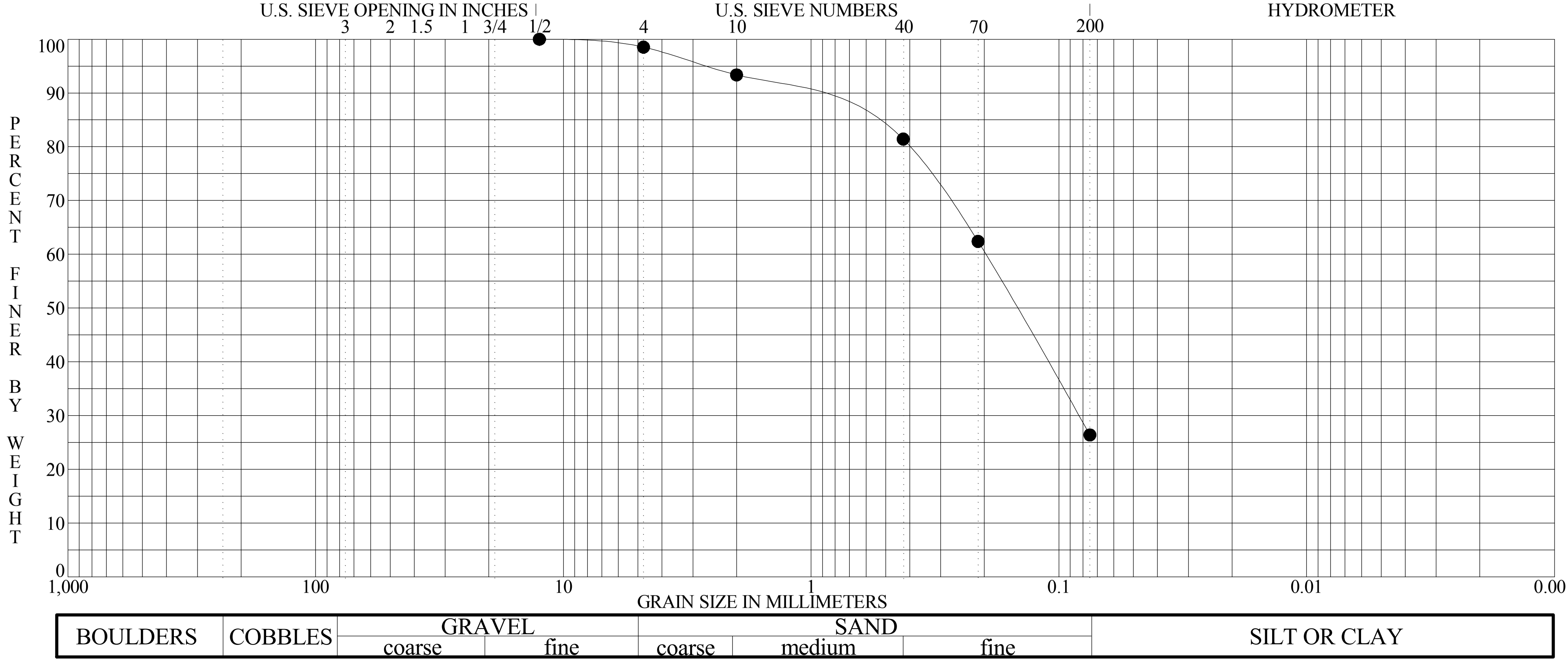
Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-1501 S-3 4.0' to 4.8'**	**Gray and brown fine to coarse sand, some fine to coarse gravel, some silt.**						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-1501 S-3 4.0' to 4.8'**	**25.0000**	**21.4832**	**0.7155**	**0.2797**		**22.4**	**45.3**	**32.3**	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-BAP-1501 S-6 8.5' to 9.7'	**Red-brown and gray fine to coarse sand, trace fine gravel, some silt.**						

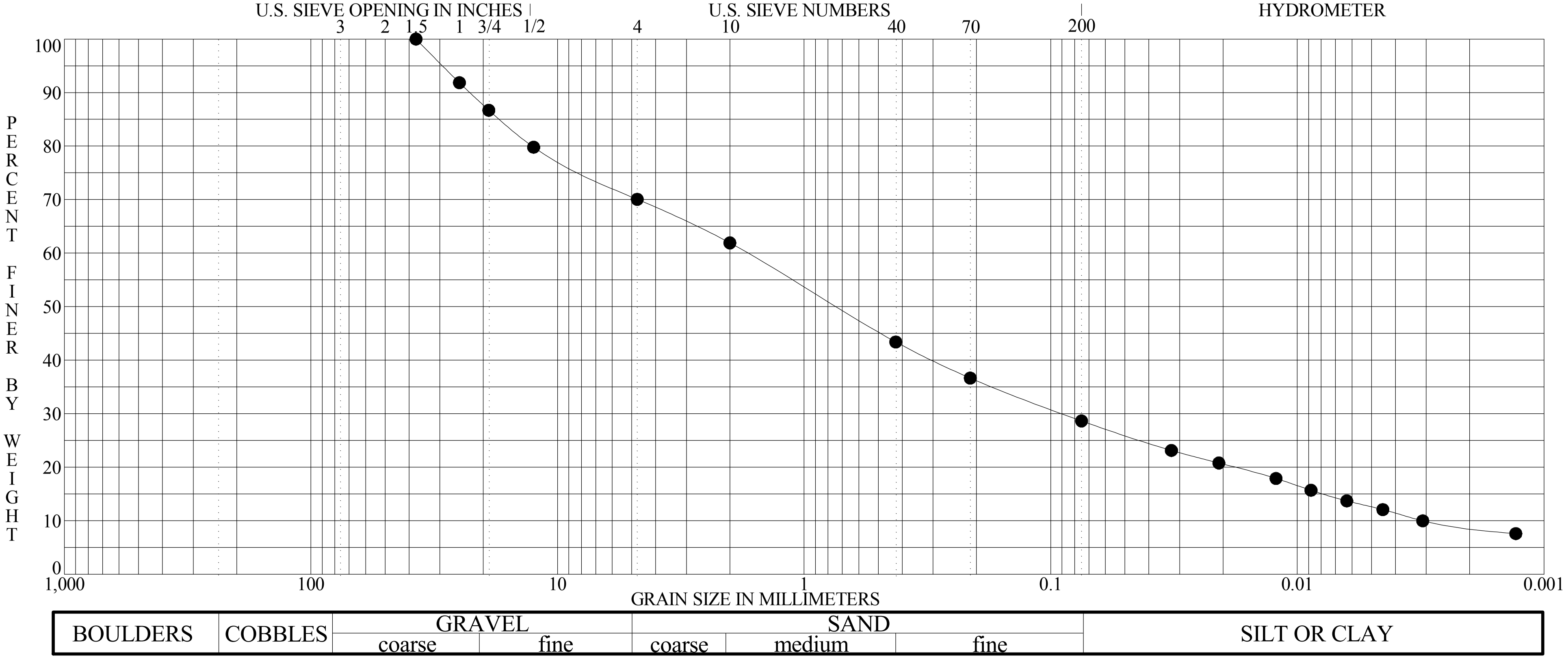
Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-BAP-1501 S-6 8.5' to 9.7'	12.5000	2.6291	0.1978	0.1482		1.5	72.1	26.4	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

GRN-REG W/ASTM DESC.



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-1502 S-4 5.5' to 6.7'**	**Gray and brown fine to coarse sand, some fine to coarse gravel, some silty clay.** **CLAYEY SAND with GRAVEL SC**	**9**	**27**	**16**	**11**	**1.508**	**547.388**

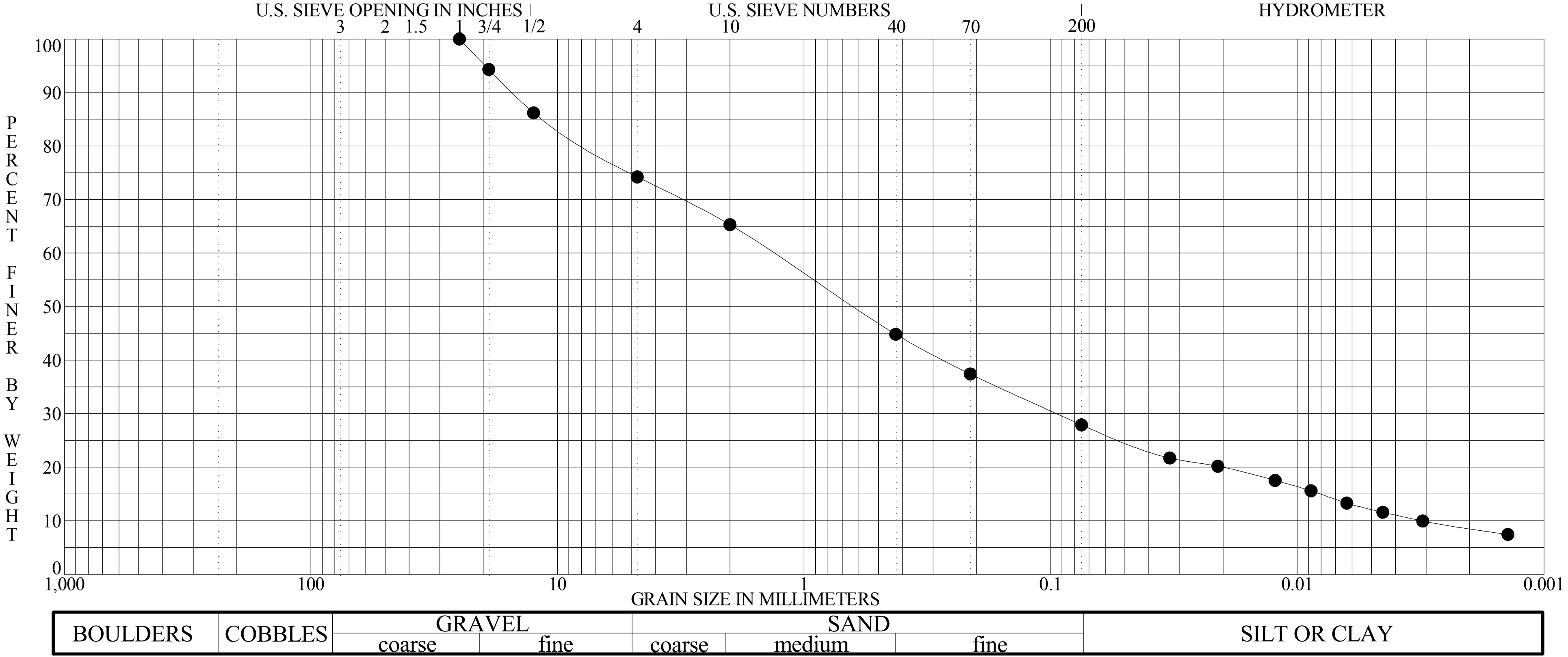
Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-1502 S-4 5.5' to 6.7'**	**37.5000**	**29.2411**	**1.7048**	**0.7385**	**0.0031**	**29.9**	**41.4**	**16.1**	**12.6**

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

GRN-REG W/ASTM DESC.



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-1502 S-9 17.0' to 18.3**	**Gray fine to coarse sand, some fine to coarse gravel, some clayey silt.** **CLAYEY SAND with GRAVEL SC**	**13**	**26**	**16**	**10**	**2.113**	**425.827**

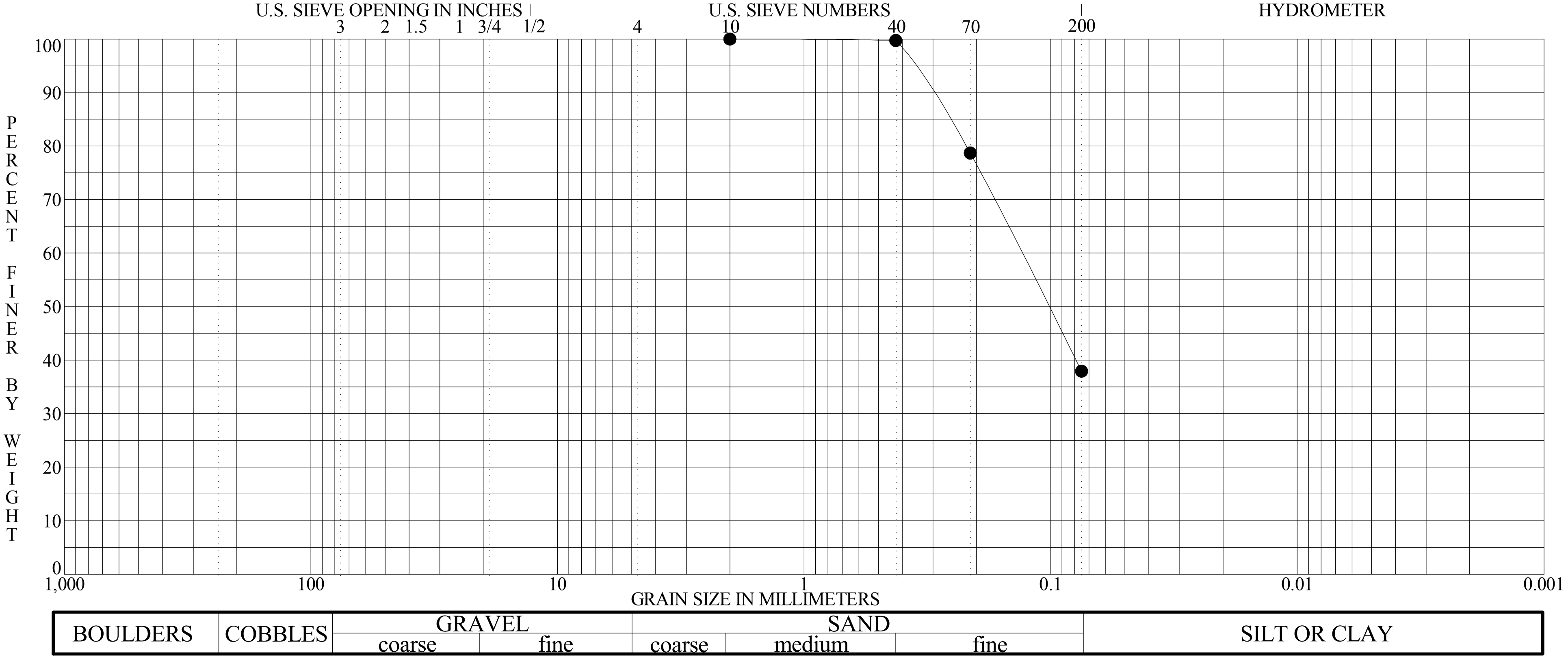
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-1502 S-9 17.0' to 18.3**	**25.0000**	**19.6384**	**1.3380**	**0.6282**	**0.0031**	**25.8**	**46.3**	**15.8**	**12.1**

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

GRN-REG W/ASTM DESC.



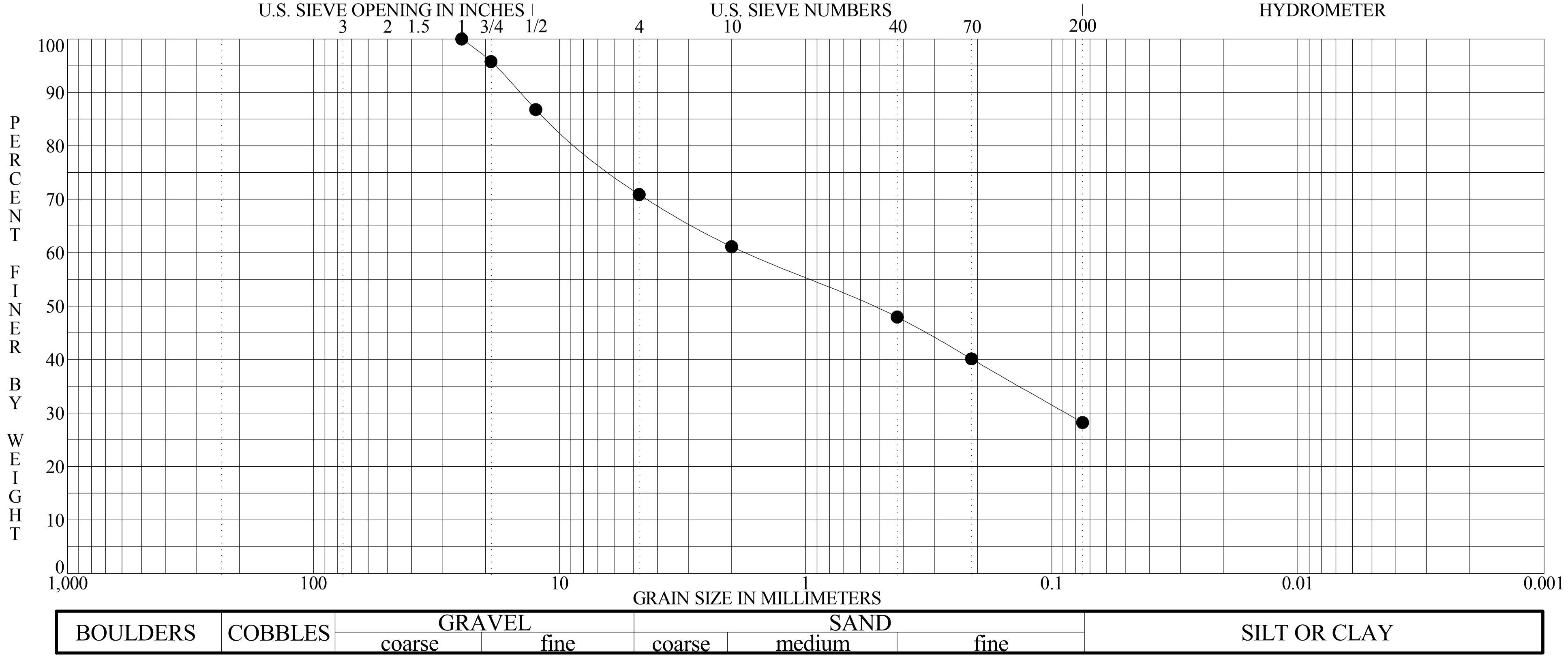
	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	CD-BAP-1502 S-18 40.0' to 41.0'	Brown fine to medium sand, "and" silt.						

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	CD-BAP-1502 S-18 40.0' to 41.0'	2.0000	0.3633	0.1316	0.1020		0.0	62.1	37.9	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-1504 S-7 10.0' to 11.0'**	**Dark-gray fine to coarse sand, some fine to coarse gravel (sandstone fragments), some silty clay.**						

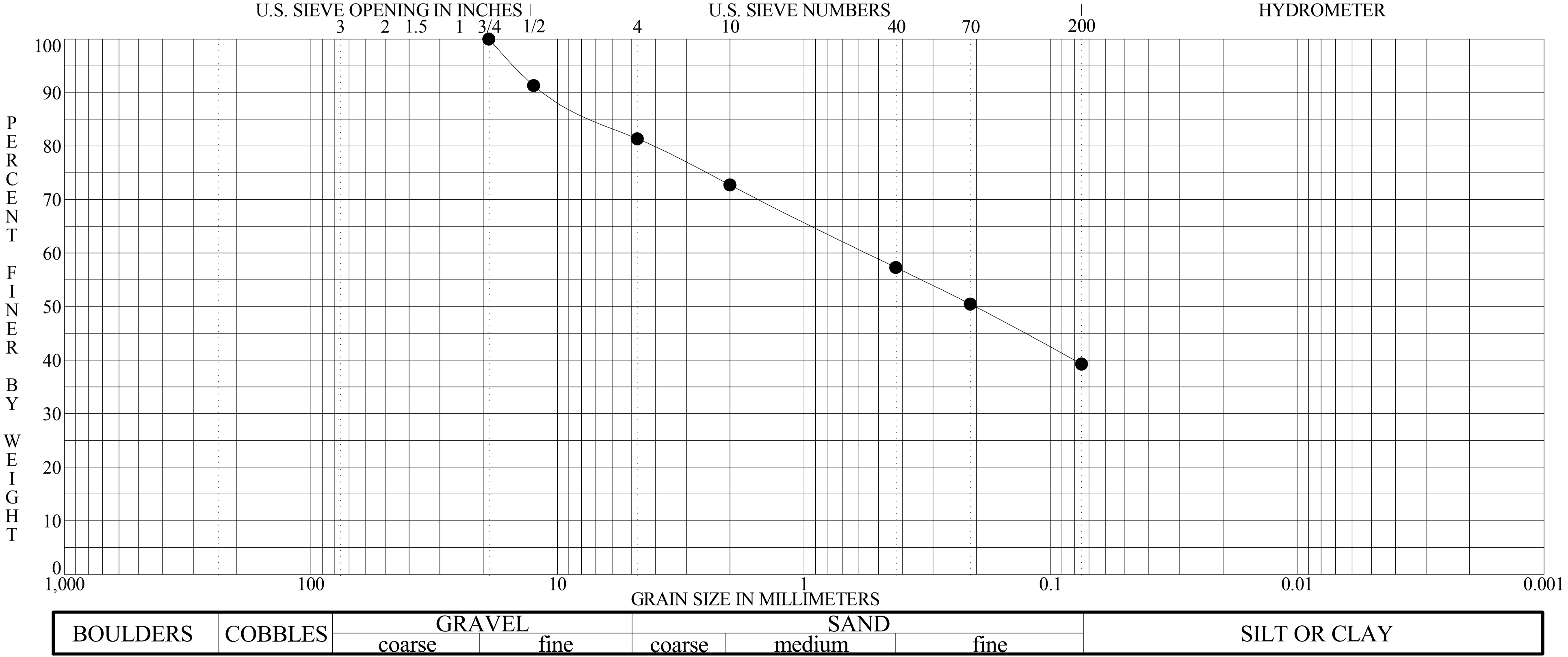
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-1504 S-7 10.0' to 11.0'**	**25.0000**	**18.3349**	**1.7501**	**0.5398**		**29.1**	**42.7**	**28.2**	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

GRN-REG W/ASTM DESC.



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	CD-BAP-1504 S-8 11.5' to 11.9'	Dark-gray and brown fine to coarse sand, little fine gravel, "and" silt.	12					

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	CD-BAP-1504 S-8 11.5' to 11.9'	19.0000	14.9354	0.5566	0.2026		18.6	42.1	39.3	

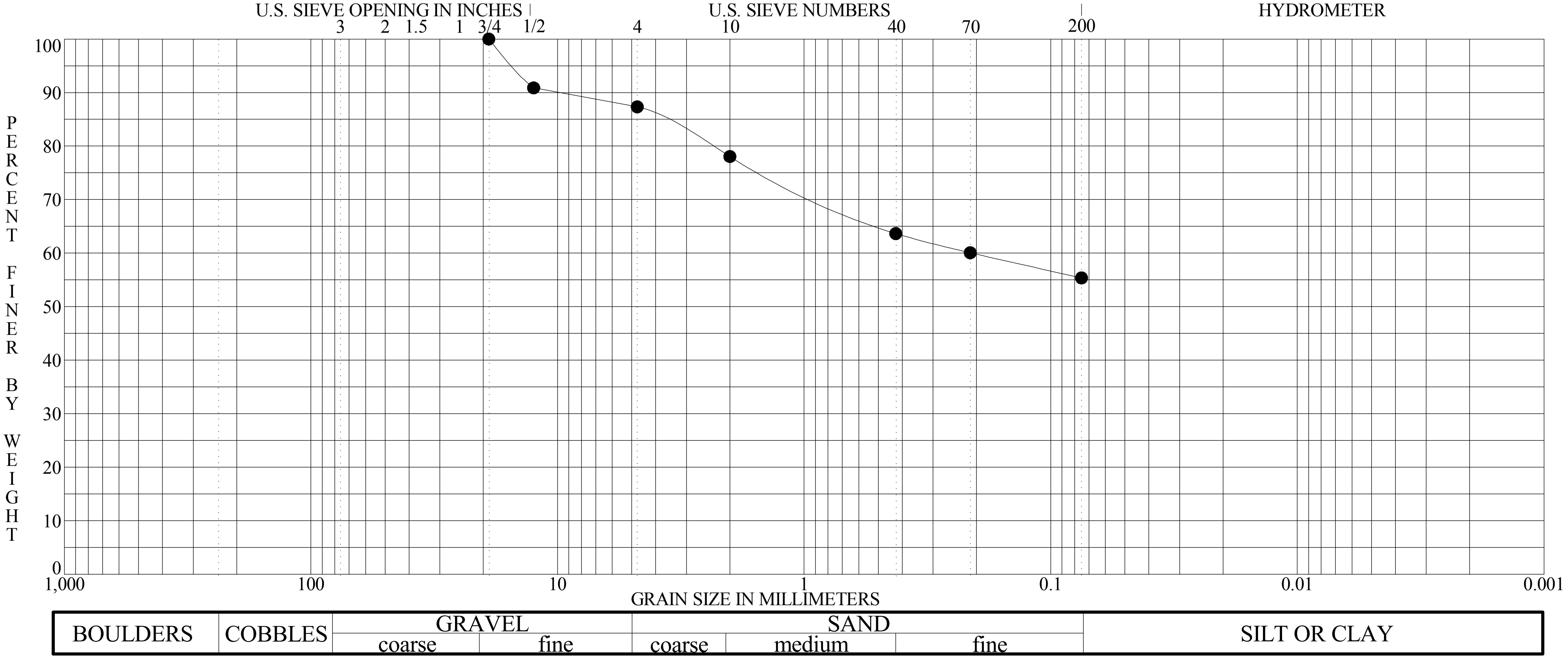
ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

PLATE 19

GRN-REG W/ASTM DESC.



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	CD-BAP-1505 S-10 14.5' to 15.8'	Yellow-brown and brown silty clay, some fine to coarse sand, little fine gravel.	18					

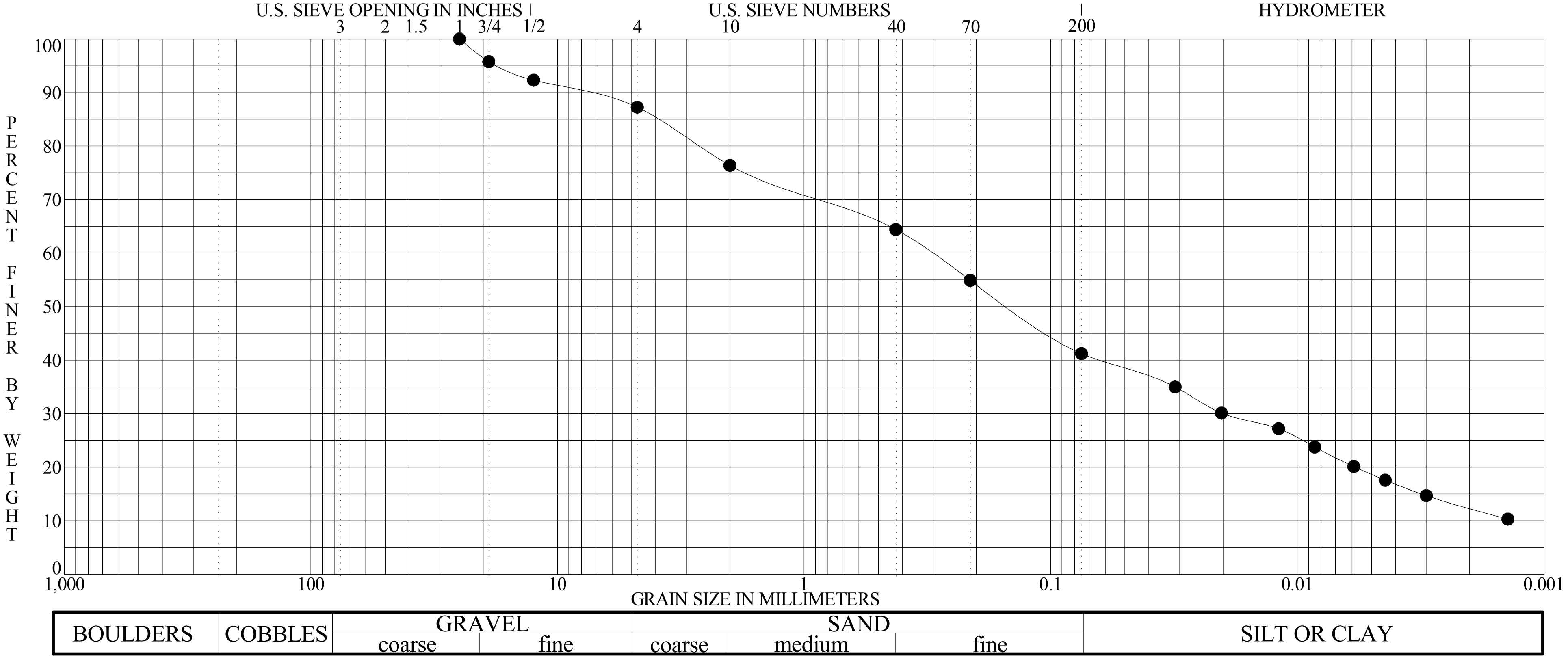
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	CD-BAP-1505 S-10 14.5' to 15.8'	19.0000	15.1011	0.2089			12.7	32.0	55.4	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A DATE 12/30/15

GRN-REG W/ASTM DESC.



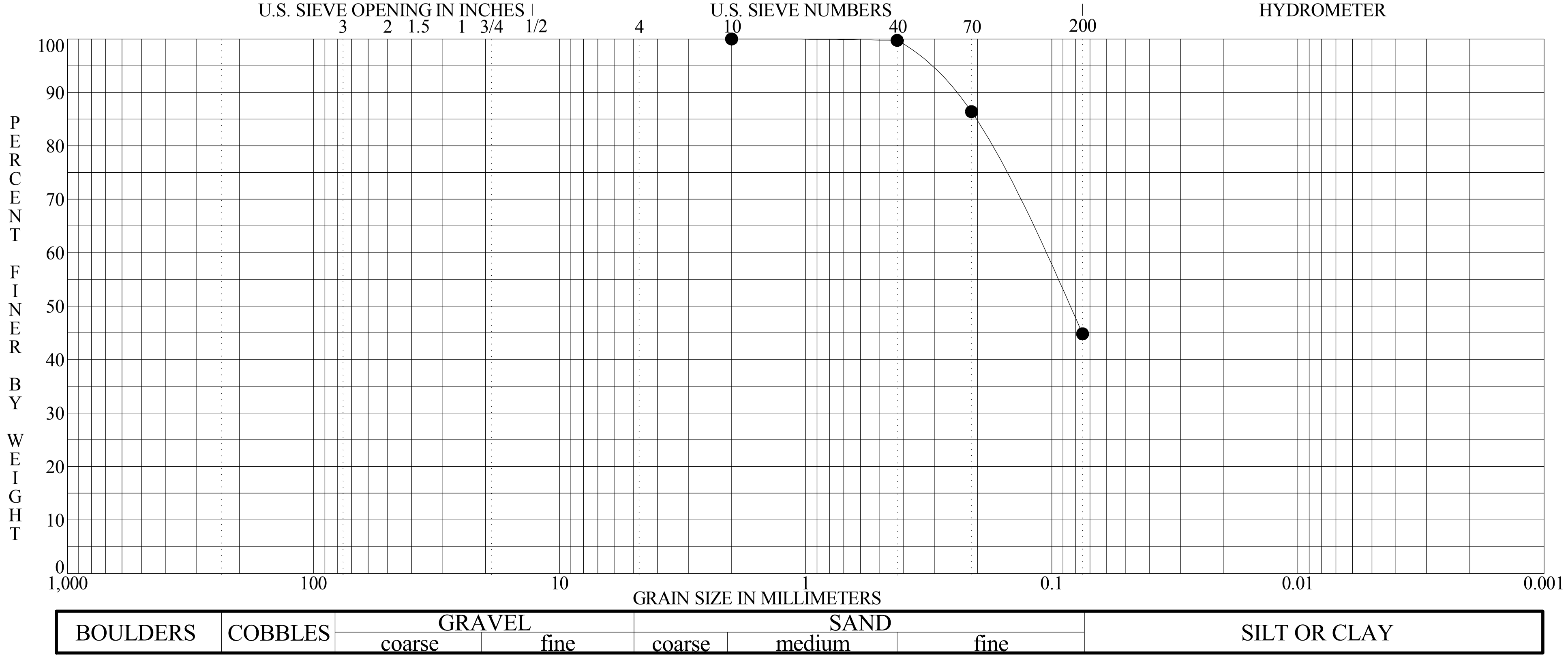
	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**MW-BAP-4 S-4 5.5' to 6.8'**	**Brown fine to coarse sand, little fine to coarse gravel, "and" clayey silt.** **CLAYEY SAND SC**	**15**	**25**	**16**	**9**		

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**MW-BAP-4 S-4 5.5' to 6.8'**	**25.0000**	**17.2870**	**0.3075**	**0.1460**		**12.7**	**46.0**	**22.5**	**18.7**

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A
DATE 12/30/15



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	MW-BAP-4 S-13 31.5' to 32.5'	Gray fine to medium sand, "and" silt.						

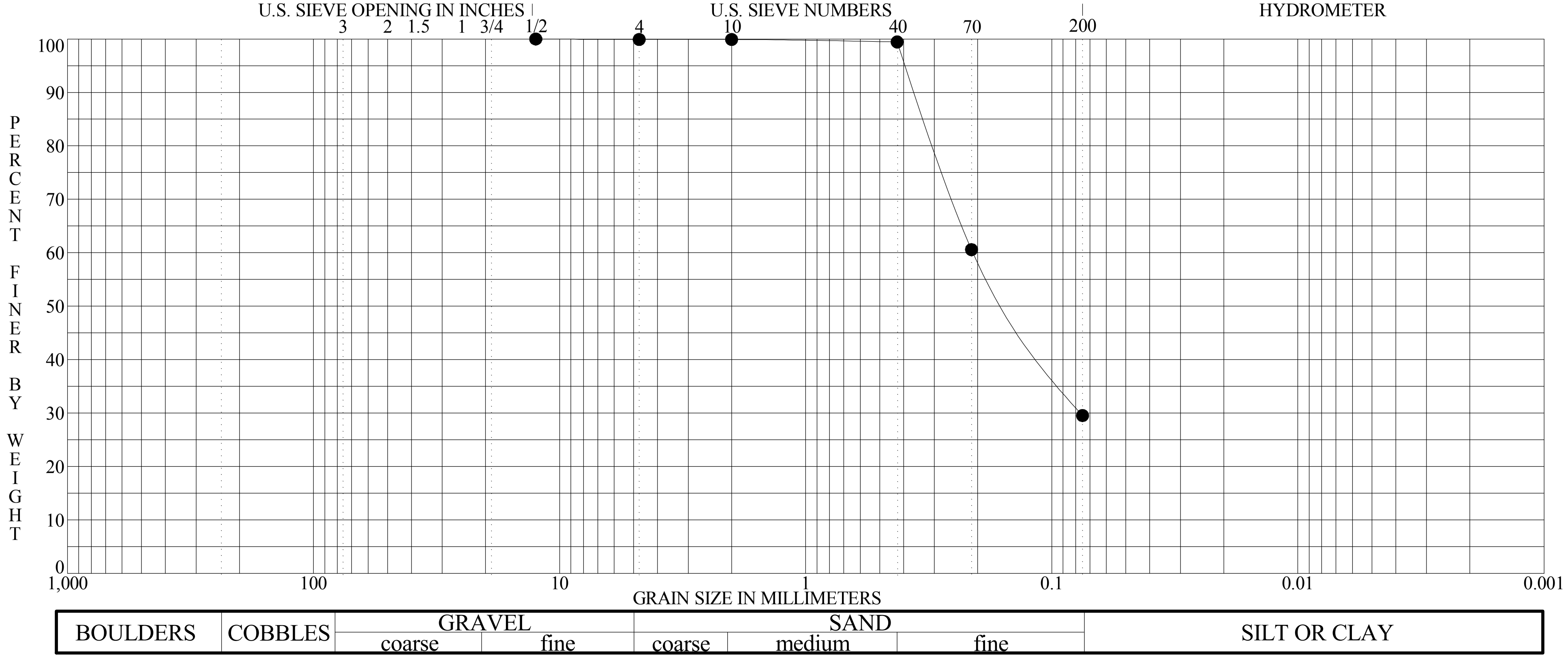
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	MW-BAP-4 S-13 31.5' to 32.5'	2.0000	0.3319	0.1096	0.0854		0.0	55.2	44.8	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

GRN-REG W/ASTM DESC.



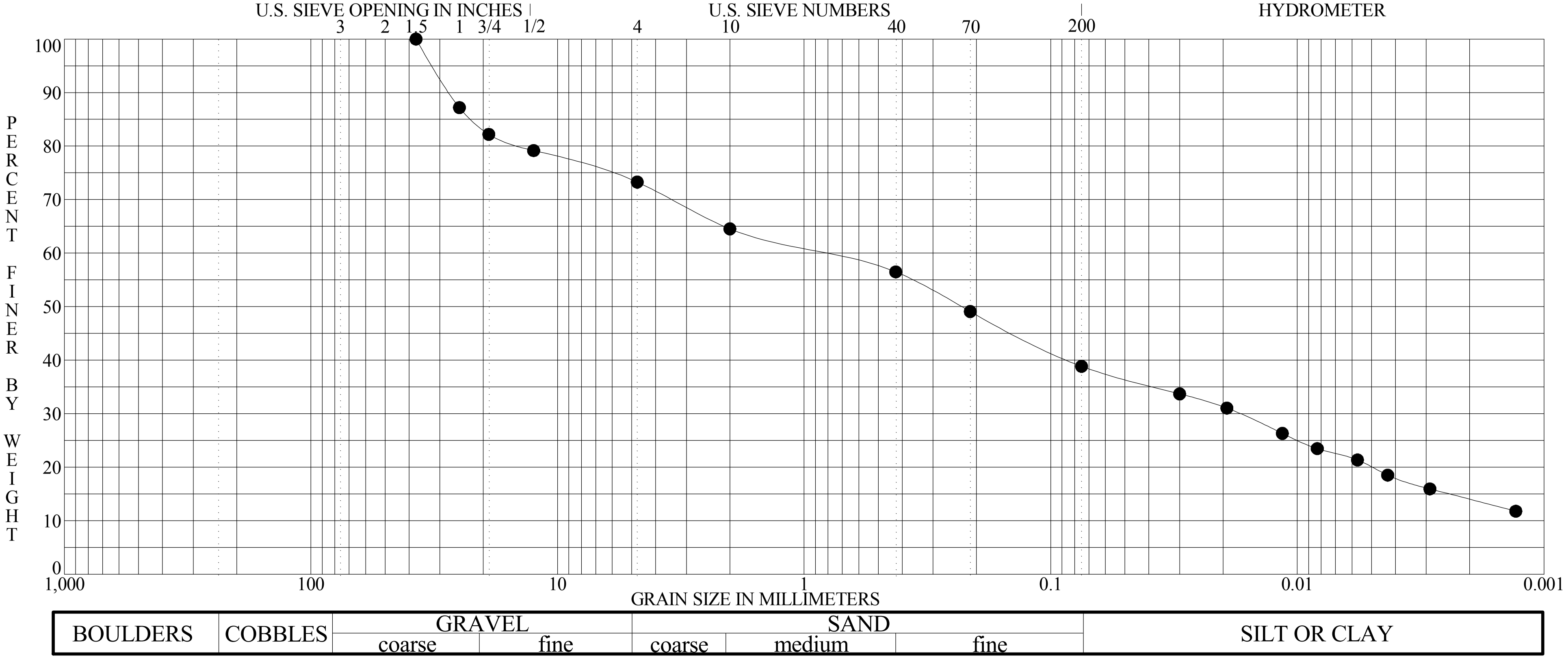
Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **MW-BAP-4 S-16 38.5' to 40.0'**	**Gray fine to coarse sand, trace fine gravel, some silt.**						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **MW-BAP-4 S-16 38.5' to 40.0'**	**12.5000**	**0.3925**	**0.2079**	**0.1488**		**0.1**	**70.4**	**29.5**	

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**MW-BAP-5 S-3 4.0' to 5.1'**	**Brown fine to coarse sand, some fine to coarse gravel, "and" silty clay.** **CLAYEY SAND with GRAVEL SC**	**13**	**30**	**17**	**13**		

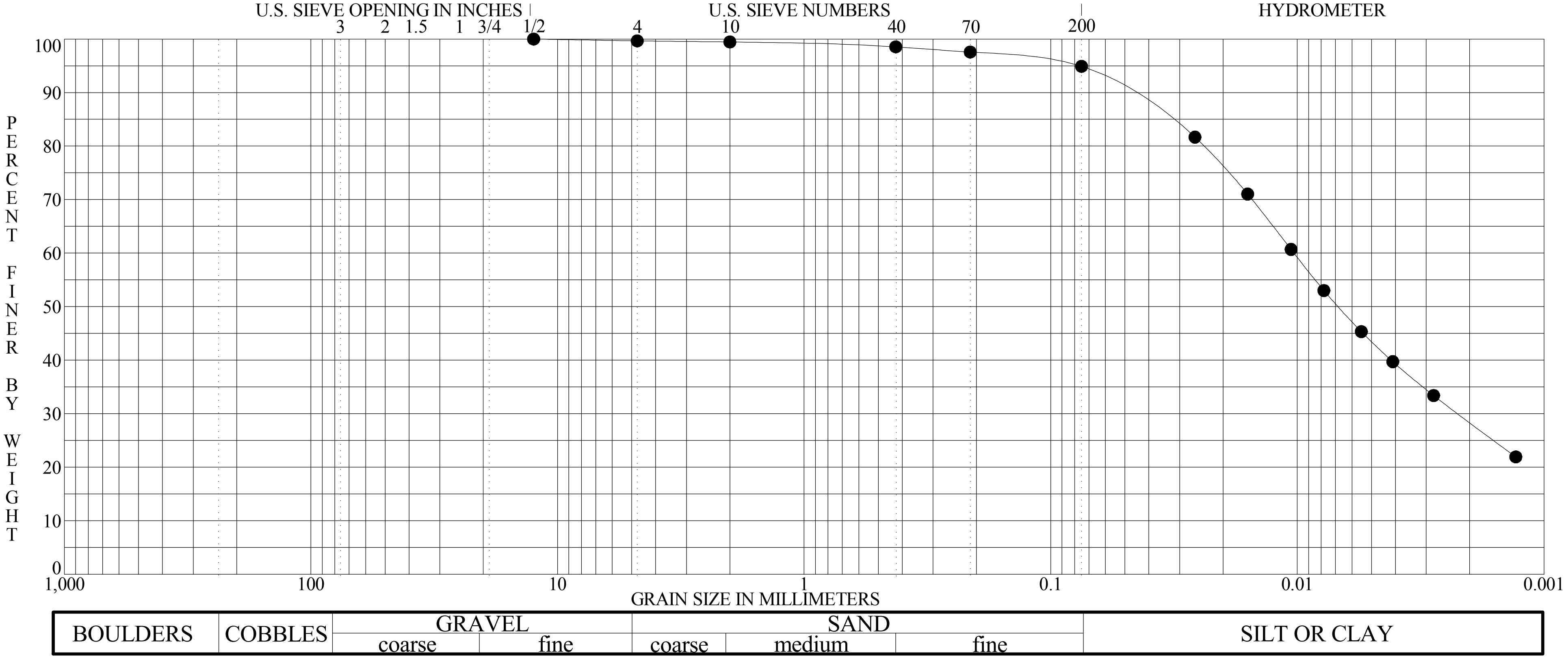
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**MW-BAP-5 S-3 4.0' to 5.1'**	**37.5000**	**32.0064**	**0.8357**	**0.2310**		**26.7**	**34.4**	**18.8**	**20.0**

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

GRN-REG W/ASTM DESC.



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● MW-BAP-5 S-11 21.0' to 22.5'	**Gray mottled with dark-gray and brown silty clay, trace fine to coarse sand, trace fine gravel, few roots and silt seams, slightly organic.** **LEAN CLAY CL**	**40**	**48**	**26**	**22**		

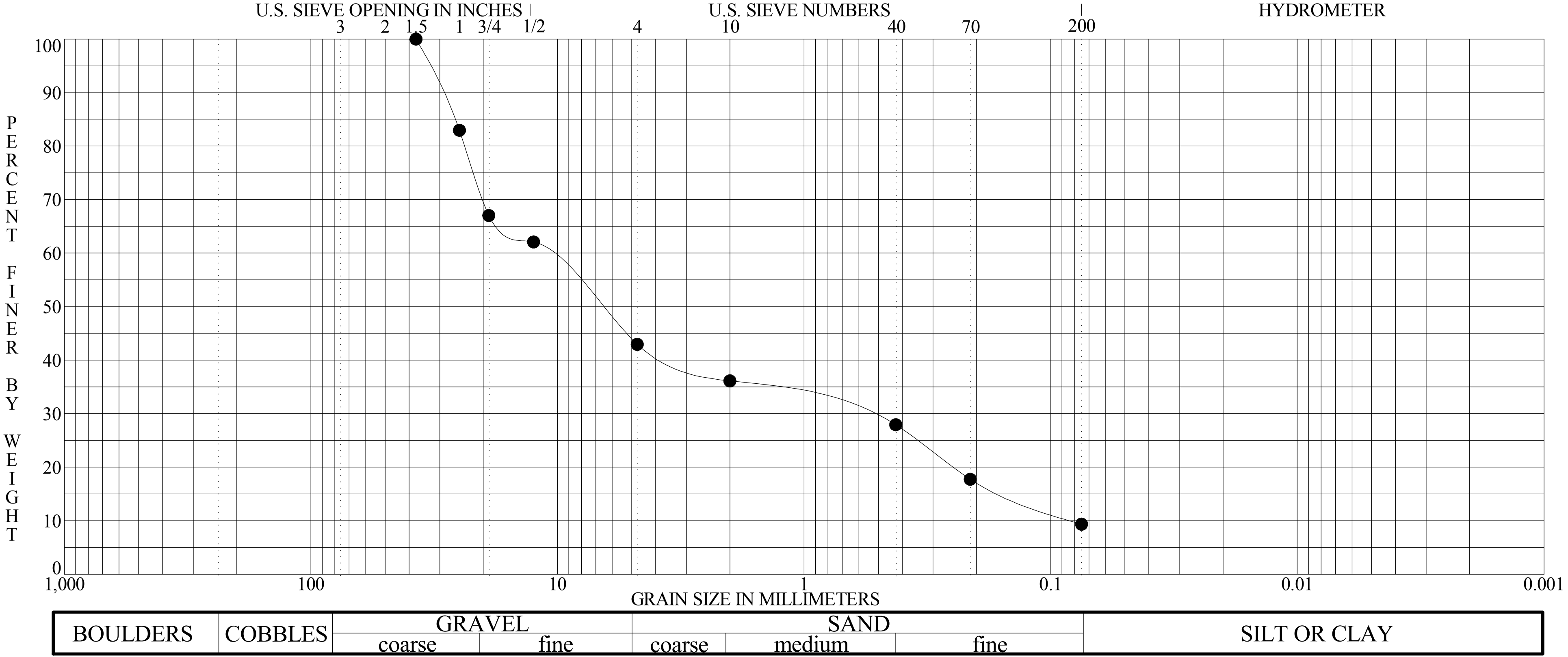
Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● MW-BAP-5 S-11 21.0' to 22.5'	**12.5000**	**0.0780**	**0.0103**	**0.0068**		**0.3**	**4.8**	**51.4**	**43.5**

ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A
DATE 12/30/15

GRN-REG W/ASTM DESC.



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**MW-BAP-5 S-21 51.0' to 51.3'**	**Gray fine to coarse gravel, some fine to coarse sand, trace silt.**					**0.432**	**138.404**

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**MW-BAP-5 S-21 51.0' to 51.3'**	**37.5000**	**33.2943**	**11.2464**	**6.7824**	**0.0813**	**57.0**	**33.6**	**9.4**	

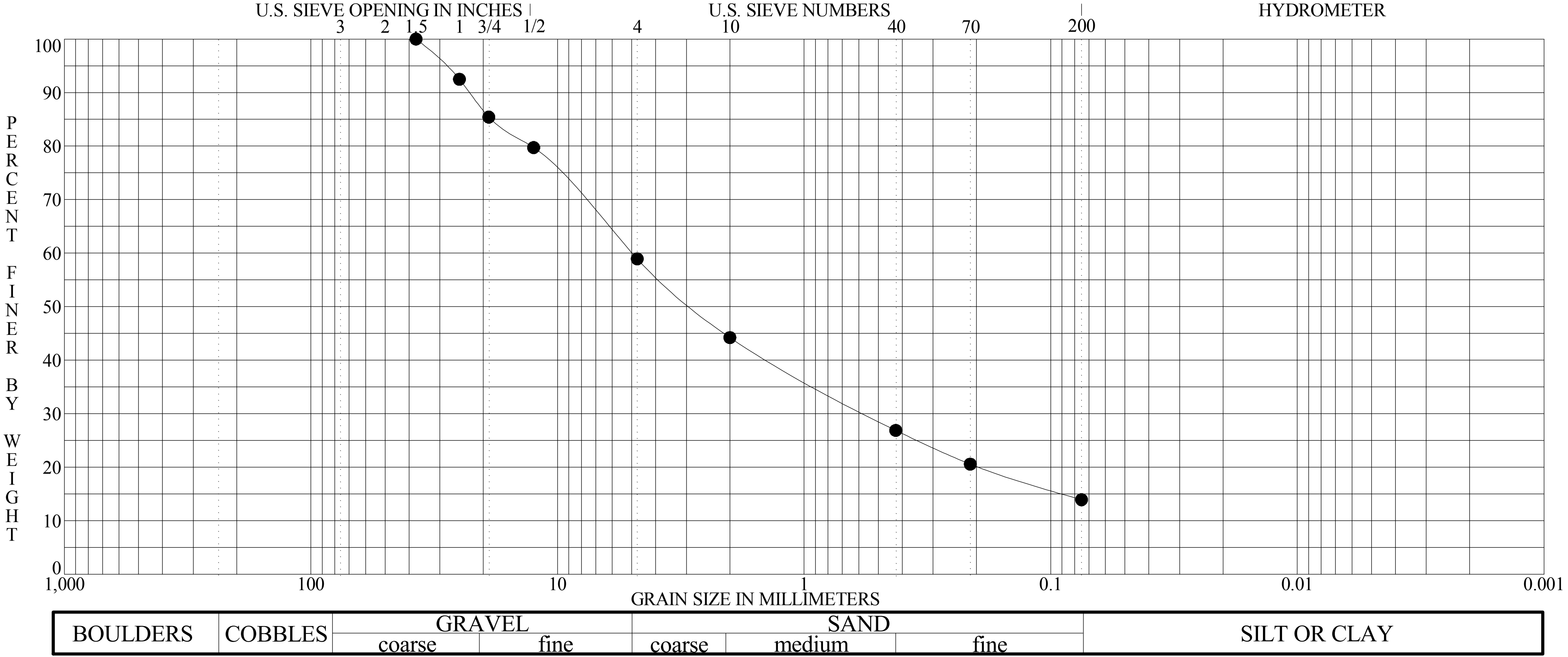
ASTM D422

GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

PLATE 26

GRN-REG W/ASTM DESC.



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**MW-BAP-5 S-24 58.5' to 59.4'**	**Gray fine to coarse sand, "and" fine to coarse gravel, little silt.**						

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**MW-BAP-5 S-24 58.5' to 59.4'**	**37.5000**	**28.6237**	**4.9922**	**2.8092**		**41.1**	**45.0**	**13.9**	

ASTM D422

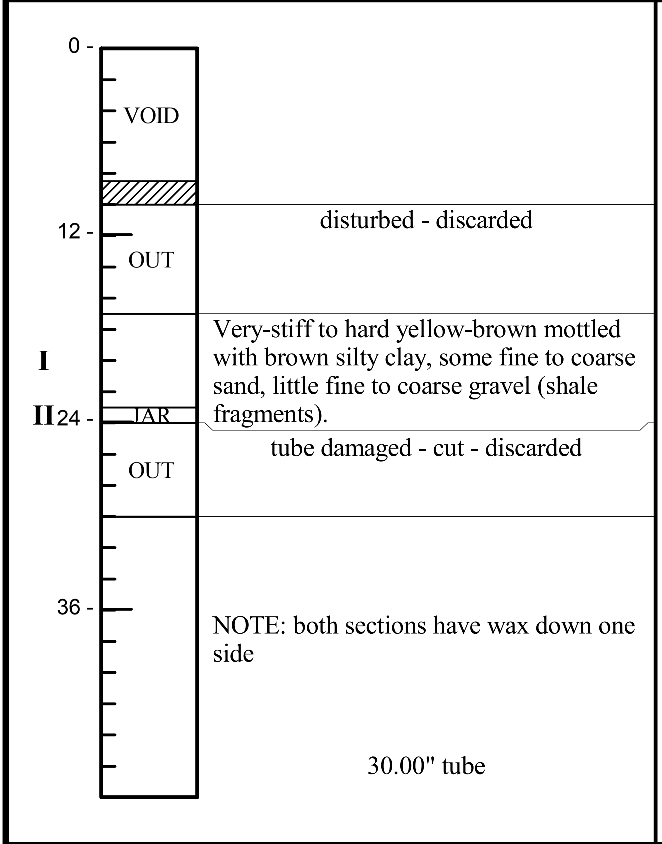
GRADATION CURVE

PROJECT BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION
LOCATION CARDINAL PLANT, BRILLIANT, OH
JOB NO. 7217-15-007A **DATE** 12/30/15

JOB NUMBER : **7217-15-007A**
PROJECT : **BOTTOM ASH POND SUPPLEMENTAL INVESTIGATION**
LOCATION : **CARDINAL PLANT, BRILLIANT, OH**

LABORATORY LOG OF SHELBY TUBES

Boring : **CD-BAP-1502** Sample : **ST-1**	Boring : **CD-BAP-1502** Sample : **ST-2**	Boring : Sample :
Depth : **20.0' to 22.0'** Recovery : **7.00"**	Depth : **32.5' to 34.5'** Recovery : **19.50"**	Depth : Recovery :



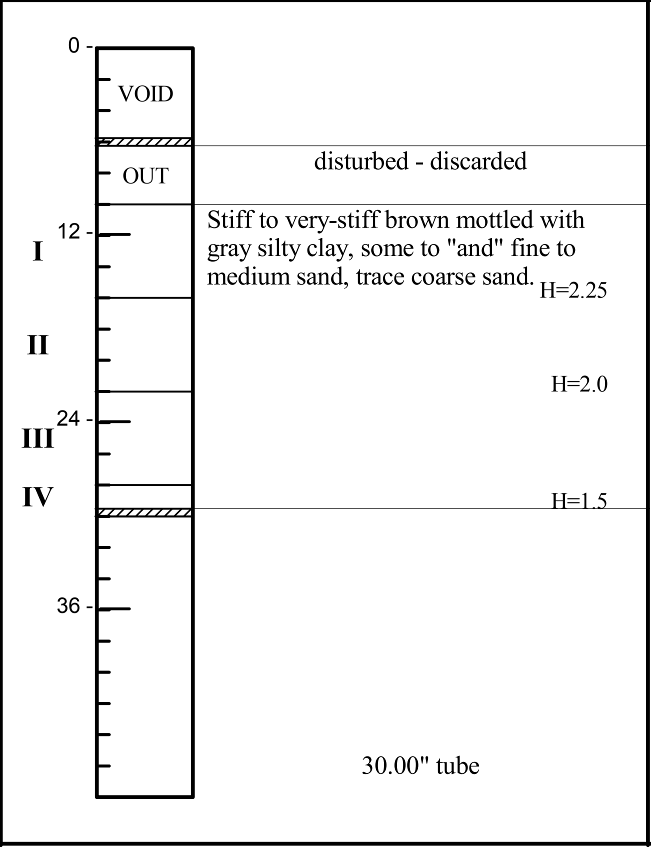
disturbed - discarded

Very-stiff to hard yellow-brown mottled with brown silty clay, some fine to coarse sand, little fine to coarse gravel (shale fragments).

tube damaged - cut - discarded

NOTE: both sections have wax down one side

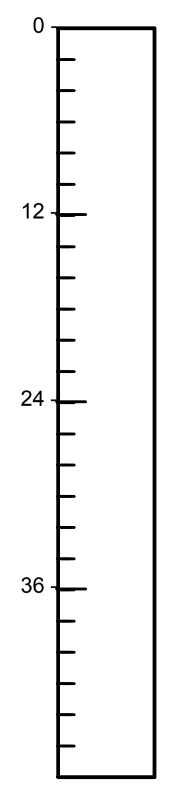
30.00" tube



disturbed - discarded

Stiff to very-stiff brown mottled with gray silty clay, some to "and" fine to medium sand, trace coarse sand.

30.00" tube



LEGEND

- ■ - Consolidation, Incremental
- C R S - Consolidation, C R S
- P P - Permeability, Vertical / Horizontal
- Swelling, Test
- In/B Sa-Cl
- ▨ - Wax
- ◪ - Unconfined Compression Test
- ☒ - Triaxial Compression Test

H - Hand Penetrometer (tsf)
Ds - Direct Shear
LOI - Loss on Ignition
AL - Atterberg Limits
MA - Sieve/Hydrometer
SG - Specific Gravity
SL - Shrinkage Limit
POR - Porosity
UDW - Unit Dry Weight
MC - Moisture Content
D_R - Relative Density
S - Sieve

2009 SITE INVESTIGATION

SUMMARY OF LABORATORY TEST RESULTS

BORING	G'int Id.	MC	LL	PL	PI	GRADATION			COMPACTION		TRIAXIAL			DIRECT SHEAR			UNCONFIN COMPRESS	CONSOLID.	SPECIFIC GRAVITY	UNIT DRY WEIGHT	REMOLDED	PERMEABILITY				RELATIVE DENSITY	LOI	ROCK CORE	SHELBY TUBE	CBR
						sieve	Hydrometer		standard	modified	uncons. undrain	consolid undrain w/pores	drained	drained	undrain	residual						cohesive	non/cohes	rigid wall	flexible wall					
							short	long																						
		%	%	%	%	* SEE INDIVIDUAL TEST CURVES														PCF						%	%			
BAP-0901	4.75	16																												
BAP-0901	7.75	16	28	18	10																									
BAP-0901	13.75	13	27	17	10																									
BAP-0901	18.25	14	37	24	13	*		*																						
BAP-0901	22.75	30	NP	NP	NP	*		*																						
BAP-0901	24.50																												*	
BAP-0901	29.25	27	37	22	15	*		*																						
BAP-0901	31.25											*																		
BAP-0901	31.75	33	35	28	7	*		*				*																	*	
BAP-0901	32.25											*																		
BAP-0901	34.25	42	34	27	7	*		*																						
BAP-0901	36.75	40	45	29	16	*																								
BAP-0901	39.25	42	40	23	17	*		*																						
BAP-0902	6.25	13	27	17	10	*		*																						
BAP-0902	10.75	20																												
BAP-0902	12.25	10	26	17	9	*		*																						
BAP-0902	16.75	24	37	19	18																									
BAP-0902	18.25	21	35	17	18	*		*																						
BAP-0902	19.75	31	29	17	12	*		*																						
BAP-0902	21.25	26	NP	NP	NP	*		*																						

Solutions To Build On

TESTING SUMMARY - STANDARD

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 DATE 7/6/09

SUM REG 111497013.GPJ BBCM.GDT 7/6/09

SUMMARY OF LABORATORY TEST RESULTS

						GRADATION			COMPACTION		TRIAXIAL			DIRECT SHEAR			UNCONFIN COMPRESS	CONSOLID.	SPECIFIC GRAVITY	UNIT DRY WEIGHT	REMOLDED	PERMEABILITY				RELATIVE DENSITY	LOI	ROCK CORE	SHELBY TUBE	CBR
BORING	G'int Id.	MC	LL	PL	PI	sieve	Hydrometer short	Hydrometer long	standard	modified	uncons. undrain	consolid undrain w/pores	drained	drained	undrain	residual						cohesive	non/cohes	rigid wall	flexible wall					
		%	%	%	%	* SEE INDIVIDUAL TEST CURVES														PCF						%	%			
BAP-0902	22.75					*																								
BAP-0902	27.25	54	NP	NP	NP	*		*																			10.4			
BAP-0902	28.75	43	NP	NP	NP	*		*																						
BAP-0902	32.25	38	36	28	8	*		*																						
BAP-0902	37.25	22				*		*																						
BAP-0902	39.75	24				*		*																						
BAP-0902	42.25					*																								
BAP-0903	3.25	24	48	24	24	*		*																						
BAP-0903	4.75	22																												
BAP-0903	7.75	20	36	20	16	*		*																						
BAP-0903	9.25	49	41	38	3	*		*																						
BAP-0903	14.25	43	NP	NP	NP	*		*																						
BAP-0903	16.75	43	37	24	13	*		*																						
BAP-0903	19.25	44	35	24	11	*		*																						
BAP-0903	21.75	35	34	21	13	*		*																						
BAP-0903	24.25					*																								
BAP-0904	4.75	13																												
BAP-0904	9.25	14	25	16	9	*		*																						
BAP-0904	13.75	16	35	21	14																									
BAP-0904	16.75					*																								

SOLUTIONS TO BUILD ON

TESTING SUMMARY - STANDARD

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 DATE 7/6/09

PLATE 2

SUM REG 111497013.GPJ BBCM.GDT 7/6/09

SUMMARY OF LABORATORY TEST RESULTS

BORING	G'int Id.	MC	LL	PL	PI	GRADATION			COMPACTION		TRIAXIAL			DIRECT SHEAR			UNCONFIN COMPRESS	CONSOLID.	SPECIFIC GRAVITY	UNIT DRY WEIGHT	REMOLDED	PERMEABILITY				RELATIVE DENSITY	LOI	ROCK CORE	SHELBY TUBE	CBR
						sieve	Hydrometer short	Hydrometer long	standard	modified	uncons. undrain	consolid undrain w/pores	drained	drained	undrain	residual						cohesive	non/cohes	rigid wall	flexible wall					
		%	%	%	%	* SEE INDIVIDUAL TEST CURVES														PCF						%	%			
BAP-0904	19.75	28	NP	NP	NP	*		*																						
BAP-0904	22.75	26	NP	NP	NP	*		*																						
BAP-0904	25.75	22	NP	NP	NP	*		*																						
BAP-0904	27.25	38	38	24	14	*		*																						
BAP-0904	28.75	47	42	30	12	*		*																						
BAP-0904	36.75					*																								
BAP-0905	4.75	17	32	18	14	*		*																						
BAP-0905	7.75	22	48	24	24																									
BAP-0905	9.85	33				*																								
BAP-0905	14.25	45	43	27	16	*		*																			8.4			
BAP-0905	16.75	42	40	25	15	*		*																						
BAP-0905	21.75	38	38	23	15	*		*																						
BAP-0905	26.75					*																								
BAP-0906	2.90	11																												
BAP-0906	4.75	15	27	17	10																									
BAP-0906	12.75					*		*																						
BAP-0906	17.25	14	31	19	12	*		*																						
BAP-0906	24.75	31	NP	NP	NP	*		*																						
BAP-0906	26.25					*																								
BAP-0906	27.25	22	NP	NP	NP	*		*																						

BBCM
SOLUTIONS TO BUILD ON

TESTING SUMMARY - STANDARD

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013
DATE 7/6/09

PLATE 3

SUMMARY OF LABORATORY TEST RESULTS

BORING	G'int Id.	MC	LL	PL	PI	GRADATION			COMPACTION		TRIAXIAL			DIRECT SHEAR			UNCONFIN COMPRESS	CONSOLID.	SPECIFIC GRAVITY	UNIT DRY WEIGHT	REMOLDED	PERMEABILITY				RELATIVE DENSITY	LOI	ROCK CORE	SHELBY TUBE	CBR
							Hydrometer																							
						sieve	short	long	standard	modified	uncons. undrain	consolid undrain w/pores	drained	drained	undrain	residual						cohesive	non/cohes	rigid wall	flexible wall					
		%	%	%	%	* SEE INDIVIDUAL TEST CURVES														PCF						%	%			
BAP-0906	31.75	34	33	22	11	*		*																						
BAP-0906	34.25	43	50	30	20	*		*																			7.9			
BAP-0906	36.75	38	43	26	17	*		*																						
BAP-0906	44.25					*																								
BAP-0907	3.25	21																												
BAP-0907	6.25	15																												
BAP-0907	7.75	23	49	26	23																									
BAP-0907	9.25	28	47	29	18	*		*														*			*				*	
BAP-0907	11.75					*		*																						
BAP-0907	14.25	43	44	28	16	*		*																						
BAP-0907	16.75	44	45	29	16	*		*																						
BAP-0907	19.25	40	48	29	19	*																								
BAP-0907	21.75	39	30	24	6	*		*																						
BAP-0907	26.75					*																								

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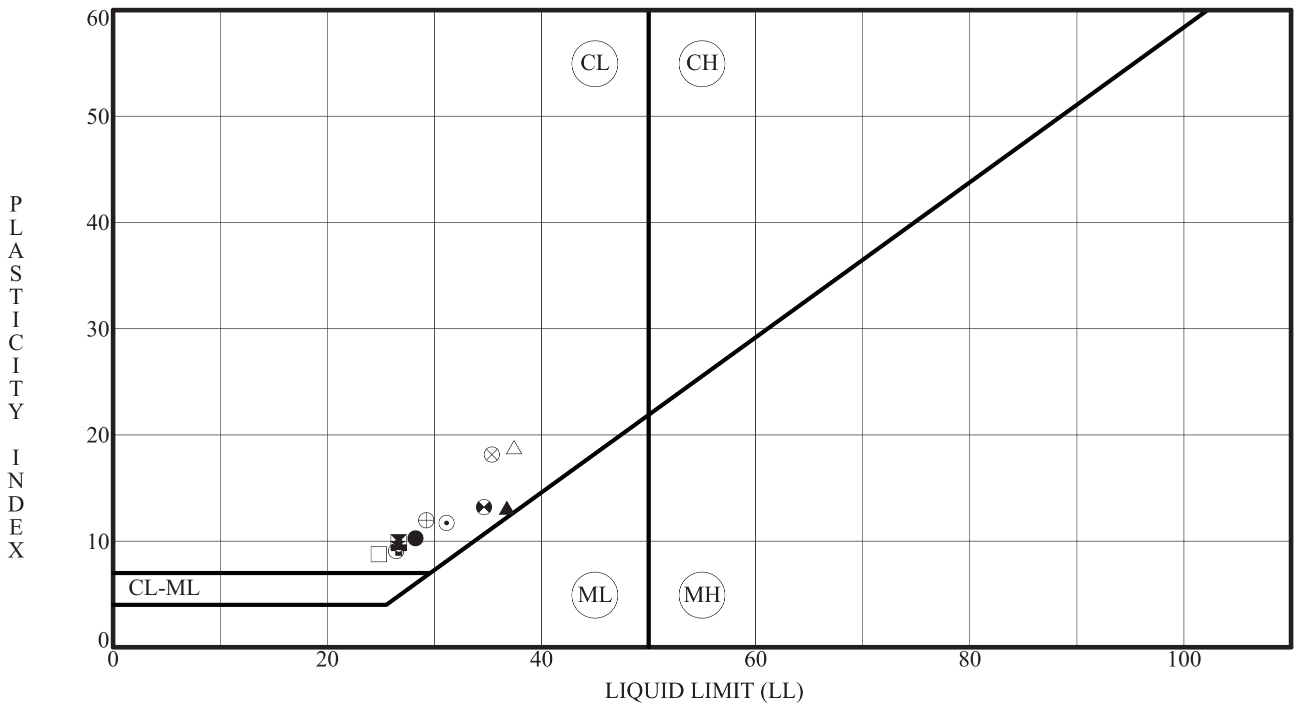
SOLUTIONS TO BUILD ON

TESTING SUMMARY - STANDARD

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 DATE 7/6/09

ATTERBERG LIMITS' RESULTS

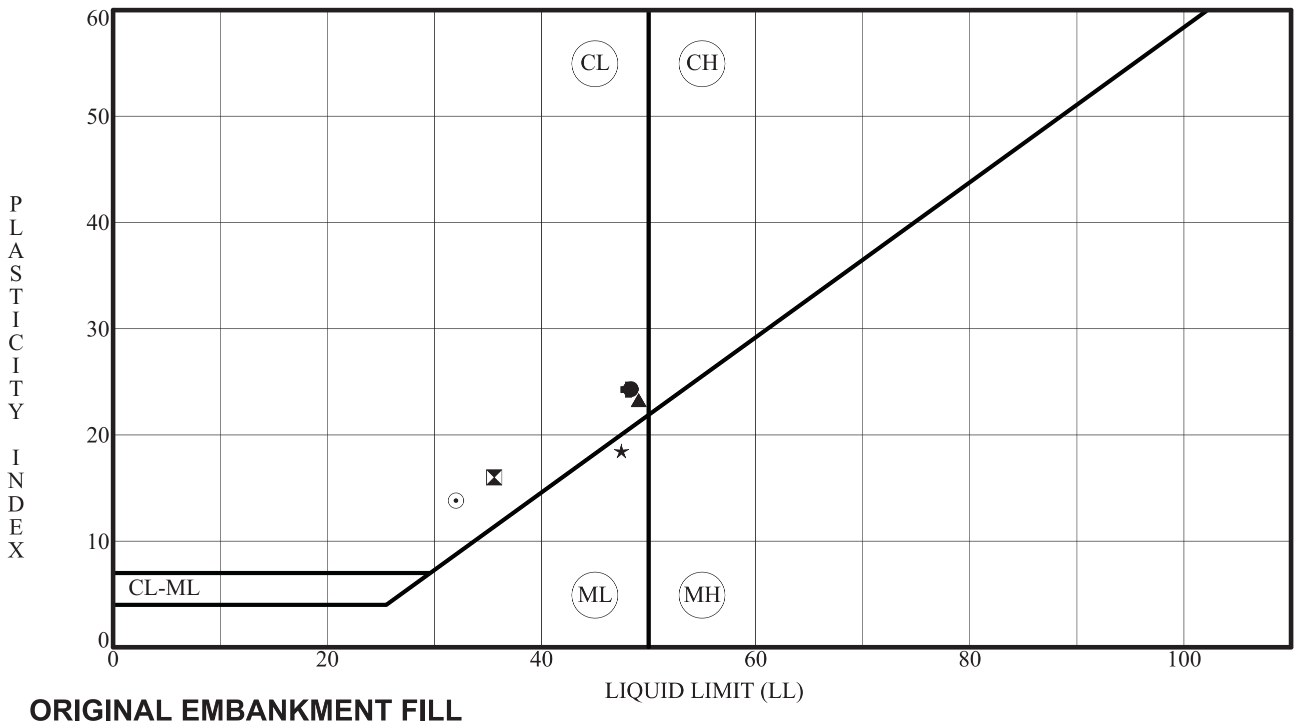
BBCM



	Specimen Id.	Depth	MC	LL	PL	PI	Fines	ASTM Classification
●	**BAP-0901**	**7.75**	**16**	**28**	**18**	**10**		
⧗	**BAP-0901**	**13.75**	**13**	**27**	**17**	**10**		
▲	**BAP-0901**	**18.25**	**14**	**37**	**24**	**13**	**60.6**	**SANDY LEAN CLAY CL**
★	**BAP-0906**	**4.75**	**15**	**27**	**17**	**10**		
⊙	**BAP-0906**	**17.25**	**14**	**31**	**19**	**12**	**38.0**	**CLAYEY SAND with GRAVEL SC**
✪	**BAP-0902**	**6.25**	**13**	**27**	**17**	**10**	**23.6**	**CLAYEY GRAVEL with SAND GC**
○	**BAP-0902**	**12.25**	**10**	**26**	**17**	**9**	**28.8**	**CLAYEY SAND with GRAVEL SC**
△	**BAP-0902**	**16.75**	**24**	**37**	**19**	**18**		
⊗	**BAP-0902**	**18.25**	**21**	**35**	**17**	**18**	**54.2**	**SANDY LEAN CLAY CL**
⊕	**BAP-0902**	**19.75**	**31**	**29**	**17**	**12**	**78.8**	**LEAN CLAY with SAND CL**
□	**BAP-0904**	**9.25**	**14**	**25**	**16**	**9**	**30.3**	**CLAYEY SAND with GRAVEL SC**
⧓	**BAP-0904**	**13.75**	**16**	**35**	**21**	**14**		

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

ATTERBERG LIMITS' RESULTS



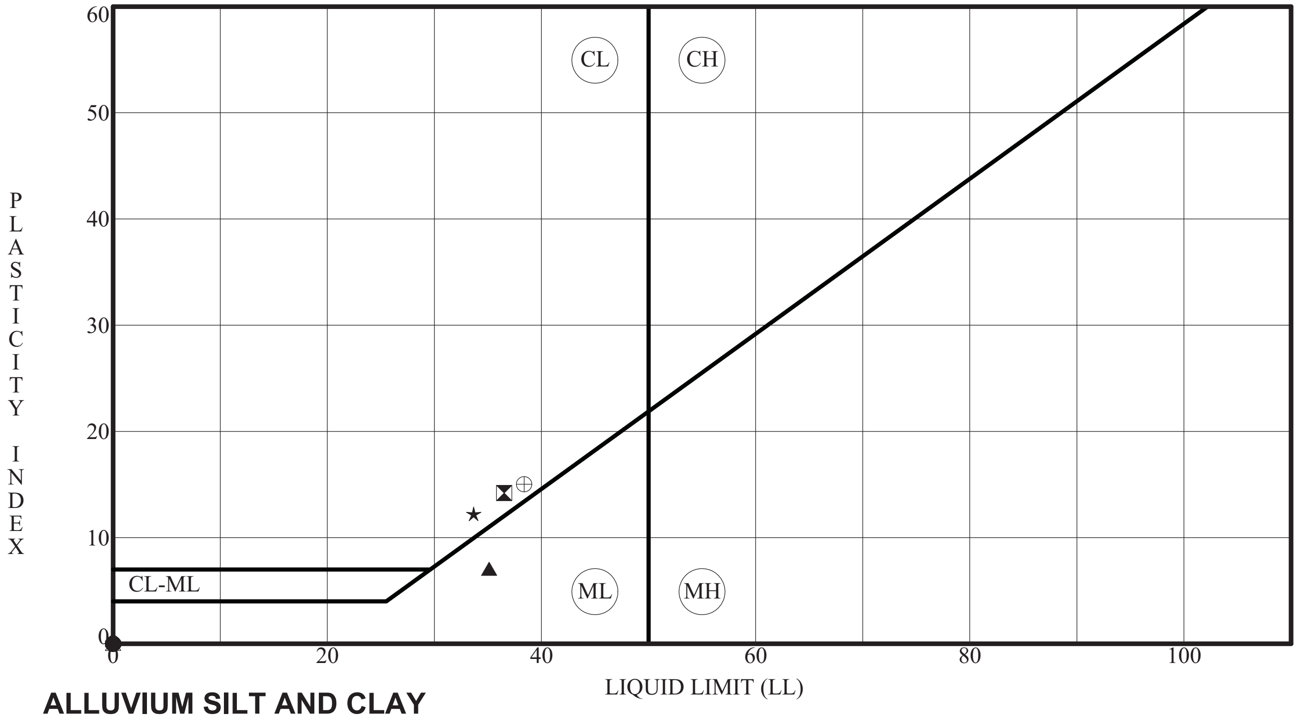
ALPI-REG 111497013.GPJ BBCM.GDT 7/6/09

ORIGINAL EMBANKMENT FILL

	Specimen Id.	Depth	MC	LL	PL	PI	Fines	ASTM Classification
●	BAP-0903	3.25	24	48	24	24	91.6	LEAN CLAY CL
⧗	BAP-0903	7.75	20	36	20	16	86.2	LEAN CLAY CL
▲	BAP-0907	7.75	23	49	26	23		
★	BAP-0907	9.25	28	47	29	18	95.2	SILT ML
☉	BAP-0905	4.75	17	32	18	14	75.2	LEAN CLAY with SAND CL
✿	BAP-0905	7.75	22	48	24	24		

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

ATTERBERG LIMITS' RESULTS



ALPI-REG 111497013.GPJ BBCM.GDT 7/6/09

ALLUVIUM SILT AND CLAY

	Specimen Id.	Depth	MC	LL	PL	PI	Fines	ASTM Classification
●	BAP-0901	22.75	30	NP	NP	NP	95.3	SILT ML
⧗	BAP-0901	29.25	27	37	22	15	91.0	LEAN CLAY CL
▲	BAP-0901	31.75	33	35	28	7	73.9	SILT with SAND ML
★	BAP-0903	21.75	35	34	21	13	70.1	LEAN CLAY with SAND CL
⊙	BAP-0906	24.75	31	NP	NP	NP	95.2	SILT ML
✿	BAP-0906	27.25	22	NP	NP	NP	75.2	SILT with SAND ML
○	BAP-0902	21.25	26	NP	NP	NP	86.8	SILT ML
△	BAP-0904	22.75	26	NP	NP	NP	47.4	SILTY SAND SM
⊗	BAP-0904	25.75	22	NP	NP	NP	91.4	SILT ML
⊕	BAP-0905	21.75	38	38	23	15	62.0	SANDY LEAN CLAY CL

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

ATTERBERG LIMITS' RESULTS

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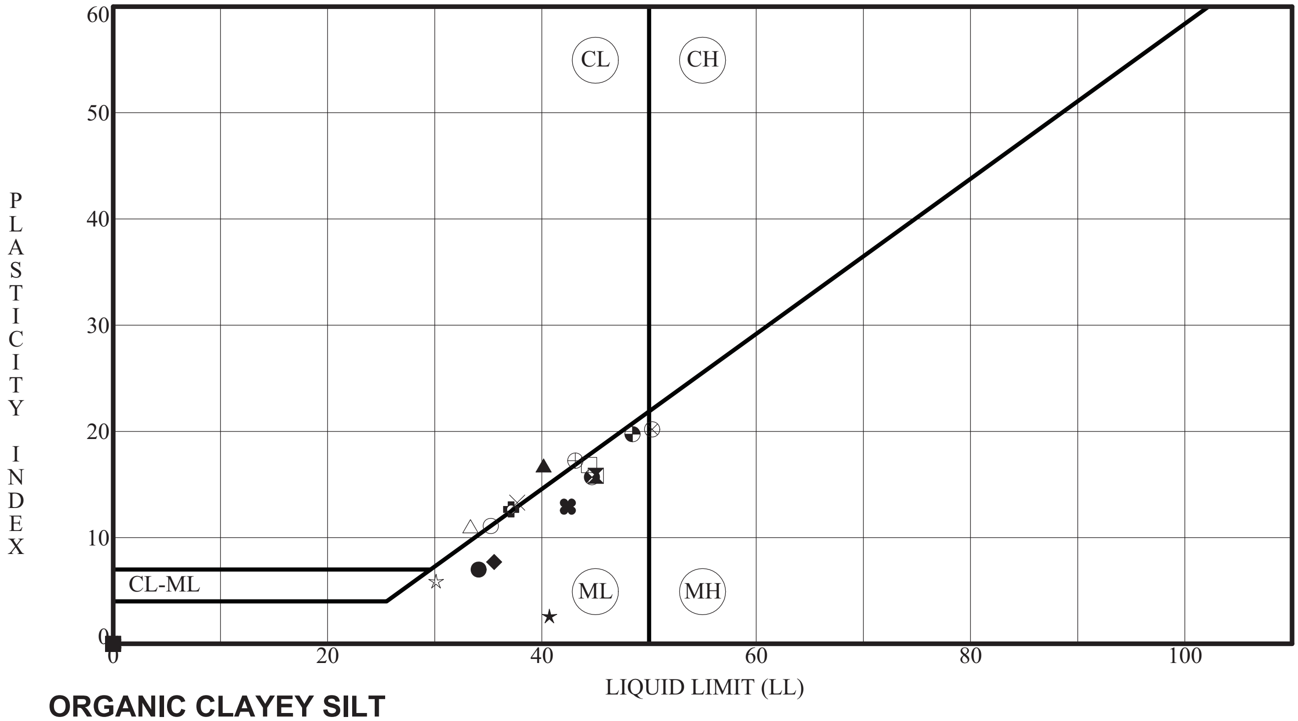


ALPI-REG 111497013.GPJ BBCM.GDT 7/6/09

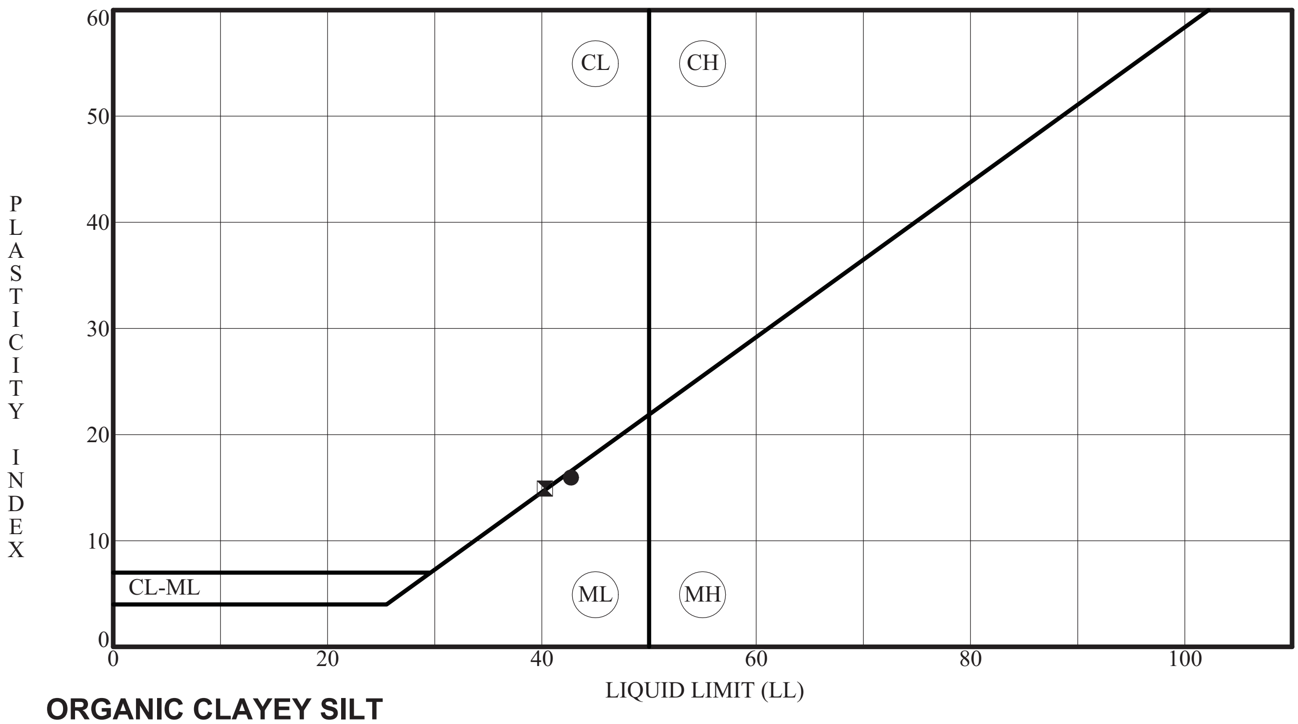
ORGANIC CLAYEY SILT

	Specimen Id.	Depth	MC	LL	PL	PI	Fines	ASTM Classification
●	BAP-0901	34.25	42	34	27	7	78.2	ORGANIC SILT with SAND OL
⧗	BAP-0901	36.75	40	45	29	16	59.2	SANDY ORGANIC SILT OL
▲	BAP-0901	39.25	42	40	23	17	81.5	ORGANIC CLAY with SAND OL
★	BAP-0903	9.25	49	41	38	3	66.6	SANDY ORGANIC SILT OL
⊙	BAP-0903	14.25	43	NP	NP	NP	71.4	ORGANIC SILT with SAND OL
✚	BAP-0903	16.75	43	37	24	13	75.9	ORGANIC CLAY with SAND OL
○	BAP-0903	19.25	44	35	24	11	61.3	SANDY ORGANIC CLAY OL
△	BAP-0906	31.75	34	33	22	11	81.3	ORGANIC CLAY with SAND OL
⊗	BAP-0906	34.25	43	50	30	20	96.9	ORGANIC SILT OH
⊕	BAP-0906	36.75	38	43	26	17	91.1	ORGANIC CLAY OL
□	BAP-0907	14.25	43	44	28	16	84.7	ORGANIC SILT with SAND OL
⊛	BAP-0907	16.75	44	45	29	16	84.9	ORGANIC SILT with SAND OL
◕	BAP-0907	19.25	40	48	29	19	90.9	ORGANIC SILT OL
☆	BAP-0907	21.75	39	30	24	6	56.3	SANDY ORGANIC SILT OL
✿	BAP-0902	27.25	54	NP	NP	NP	85.3	ORGANIC SILT OL
■	BAP-0902	28.75	43	NP	NP	NP	74.9	ORGANIC SILT with SAND OL
◆	BAP-0902	32.25	38	36	28	8	75.4	ORGANIC SILT with SAND OL
◇	BAP-0904	19.75	28	NP	NP	NP	92.1	ORGANIC SILT OL
×	BAP-0904	27.25	38	38	24	14	79.2	ORGANIC CLAY with SAND OL
✖	BAP-0904	28.75	47	42	30	12	78.4	ORGANIC SILT with SAND OL

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

ATTERBERG LIMITS' RESULTS

BBCM



ORGANIC CLAYEY SILT

	Specimen Id.	Depth	MC	LL	PL	PI	Fines	ASTM Classification
●	**BAP-0905**	**14.25**	**45**	**43**	**27**	**16**	**80.5**	**ORGANIC SILT with SAND OL**
⧗	**BAP-0905**	**16.75**	**42**	**40**	**25**	**15**	**84.5**	**ORGANIC CLAY with SAND OL**

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
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JOB NO. 011-11497-013 **DATE** 7/6/09

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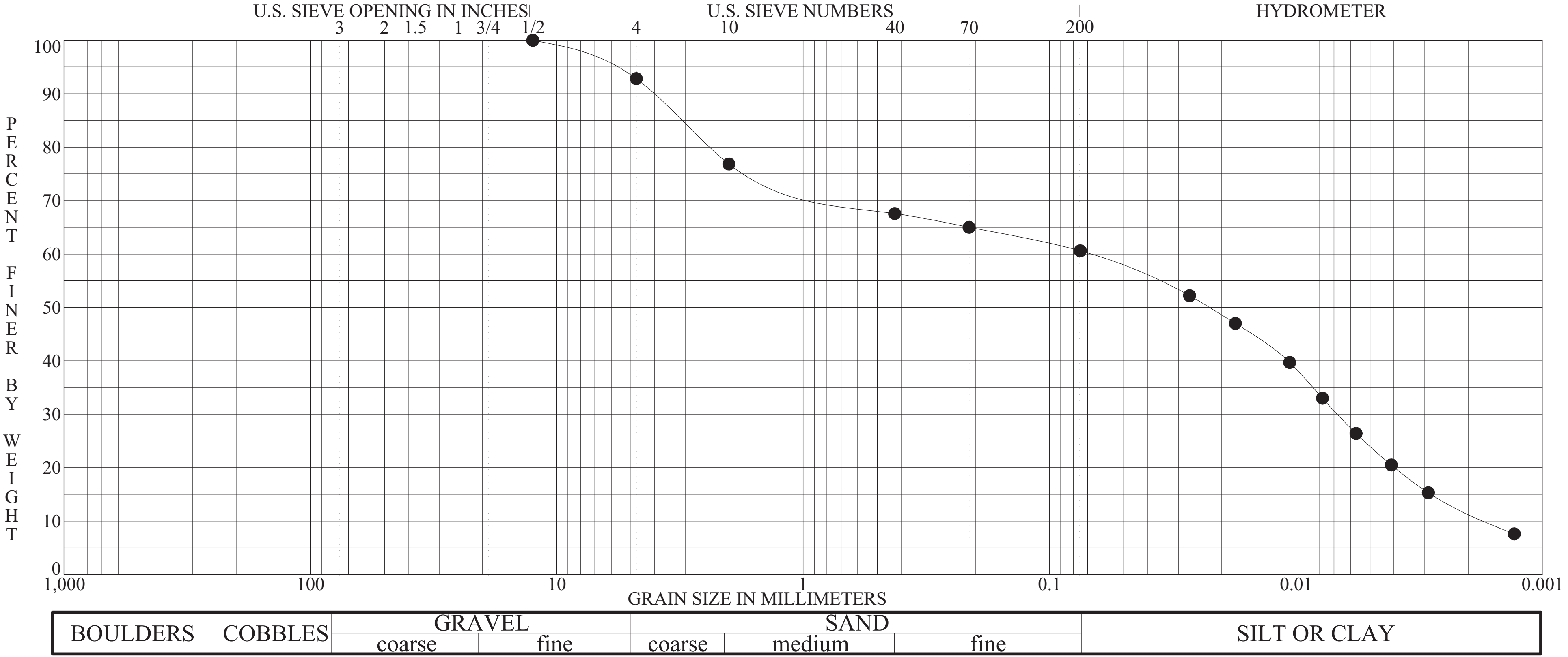
GRN-EPA W/ASTM-BBCM



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0901 S-12 17.5' to 18.3'**	**FILL: Gray and brown silty clay, some fine to coarse sand, trace fine gravel(shale fragments).** **SANDY LEAN CLAY CL**	**14**	**37**	**24**	**13**	**0.393**	**41.763**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0901 S-12 17.5' to 18.3'**	**12.5000**	**6.3655**	**0.0697**	**0.0225**	**0.0017**	**7.17**	**32.23**	**48.87**	**11.73**

ASTM D422

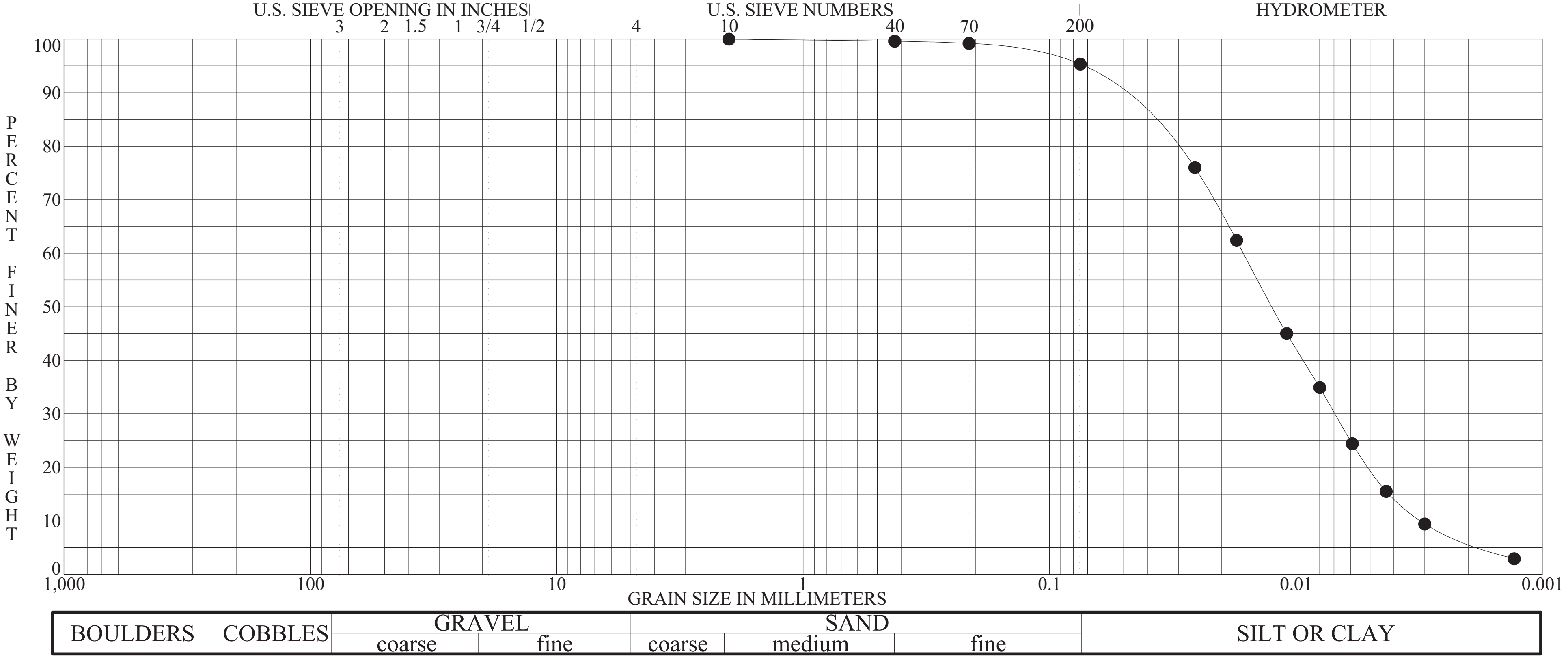
GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

PLATE 10

GRN-EPA W/ASTM-BBCM

BBCM



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0901 S-15 22.0' to 23.2'**	**Dark-gray brown silt, trace clay, trace fine to medium sand.**	**30**	**NP**	**NP**	**NP**	**0.950**	**5.248**
		SILT ML						

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0901 S-15 22.0' to 23.2'**	**2.0000**	**0.0736**	**0.0163**	**0.0125**	**0.0031**	**0.00**	**4.67**	**89.08**	**6.25**

ASTM D422

GRADATION CURVE

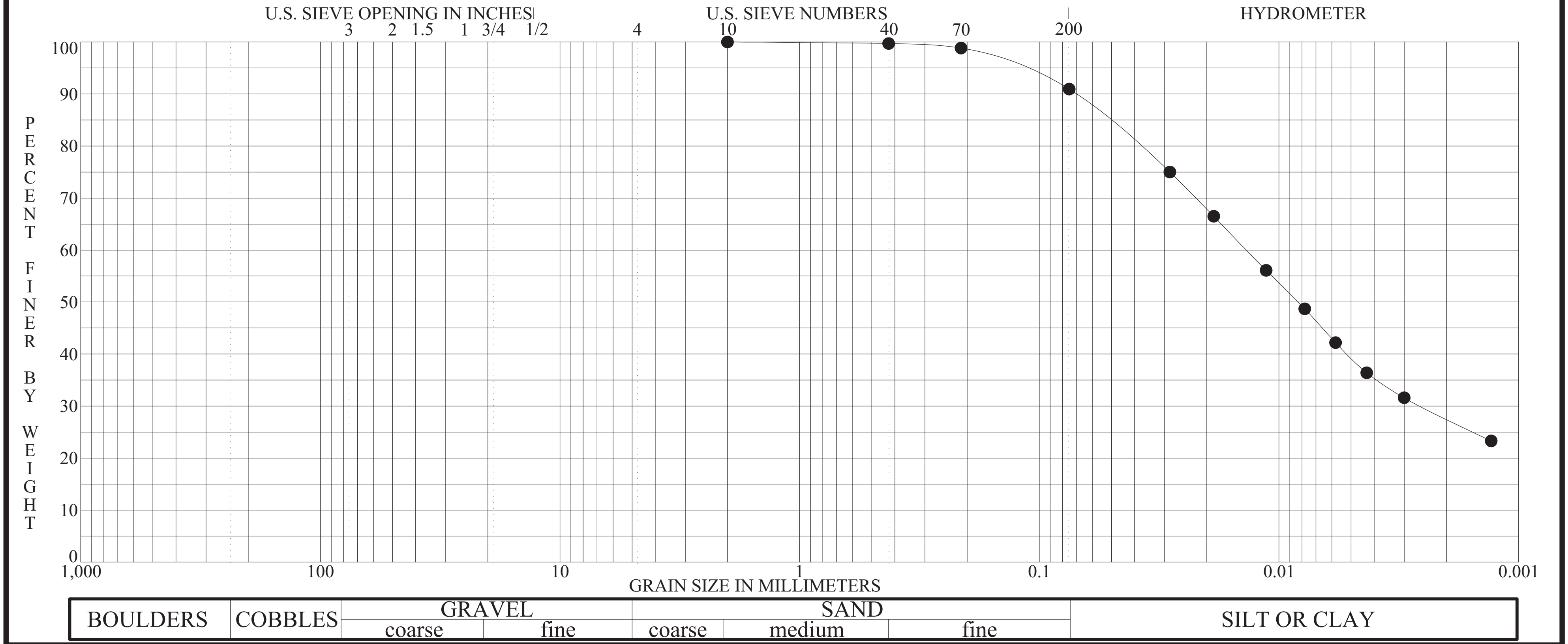
PROJECT CARDINAL PLANT ASH POND INVESTIGATION

LOCATION BRILLIANT, OHIO

JOB NO. 011-11497-013 **DATE** 7/6/09

PLATE 11

BBCM



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0901 S-18 28.5' to 30.0'**	**Brown mottled with gray and dark-gray siltty clay inter-bedded with organic silt, trace fine to medium sand.** **LEAN CLAY CL**	**27**	**37**	**22**	**15**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0901 S-18 28.5' to 30.0'**	**2.0000**	**0.1279**	**0.0136**	**0.0083**		**0.00**	**9.04**	**63.38**	**27.58**

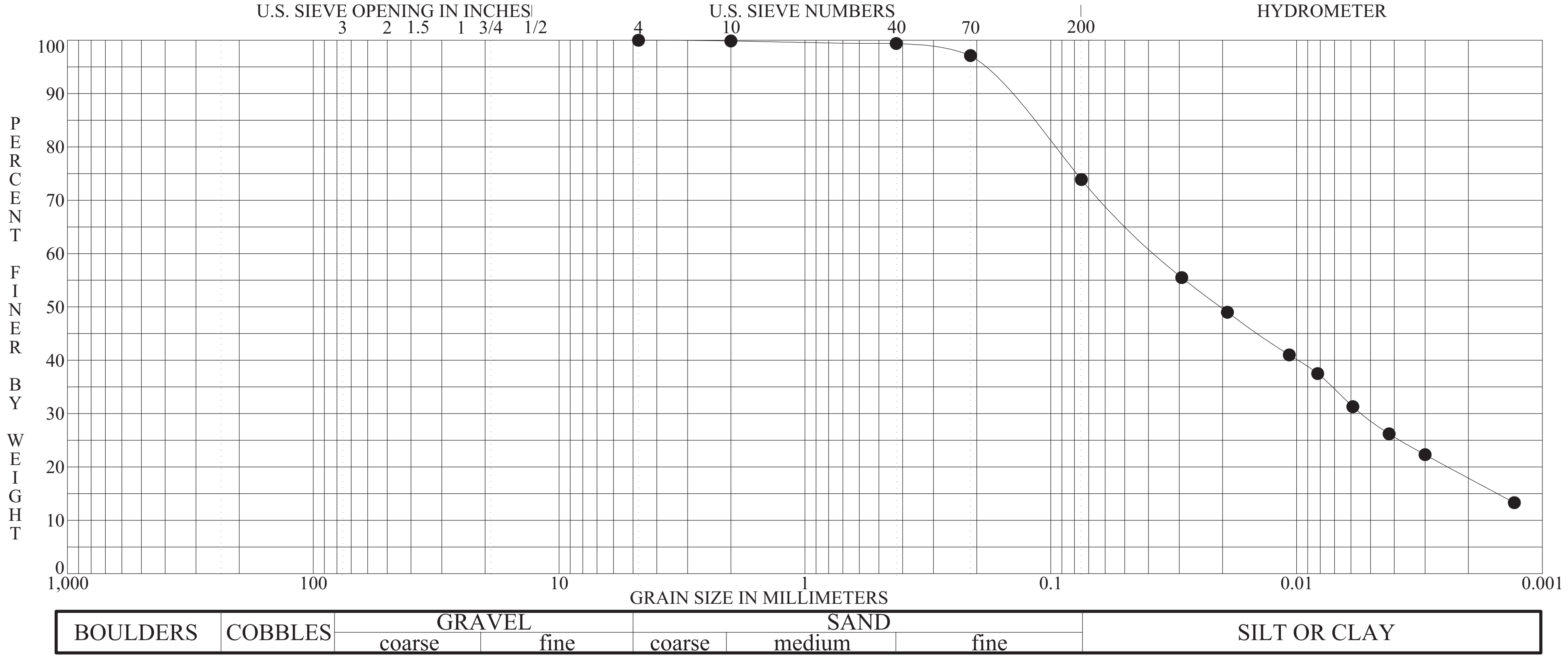
ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

GRN-EPA W/ASTM-BBCM

BBCM



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0901 ST-19A II** **31.0' to 32.8'**	**Gray mottled with dark-gray and brown clayey silt, some fine sand, trace medium to coarse sand, few seams and lenses of silty clay and fine sand.** **SILT with SAND ML**	**33**	**35**	**28**	**7**		

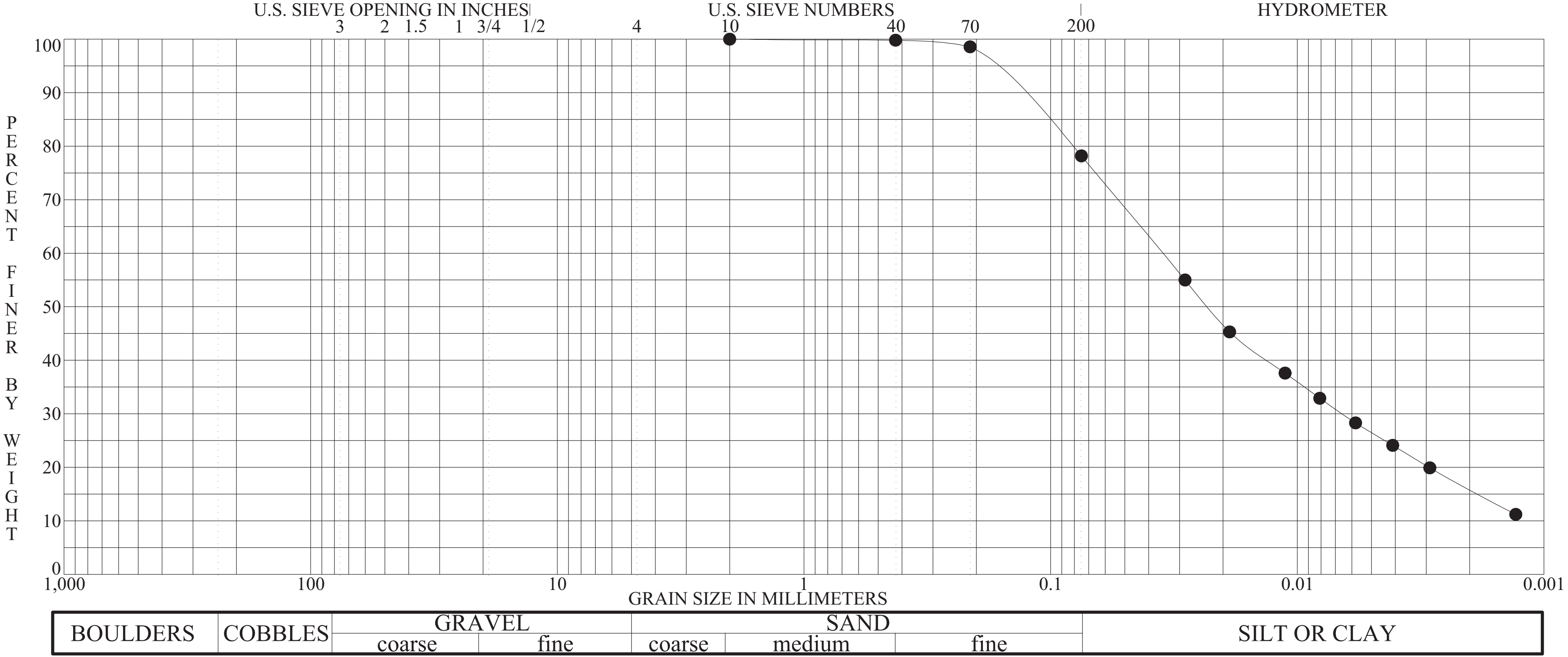
	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0901 ST-19A II** **31.0' to 32.8'**	**4.7500**	**0.1927**	**0.0369**	**0.0204**		**0.00**	**26.12**	**55.95**	**17.94**

ASTM D422

GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**

GRN-EPA W/ASTM-BBCM



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0901 S-20 33.5' to 35.0'**	**Dark-gray organic clayey silt, some fine sand, trace medium sand.** **ORGANIC SILT with SAND OL**	**42**	**34**	**27**	**7**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0901 S-20 33.5' to 35.0'**	**2.0000**	**0.1767**	**0.0351**	**0.0230**		**0.00**	**21.81**	**62.32**	**15.87**

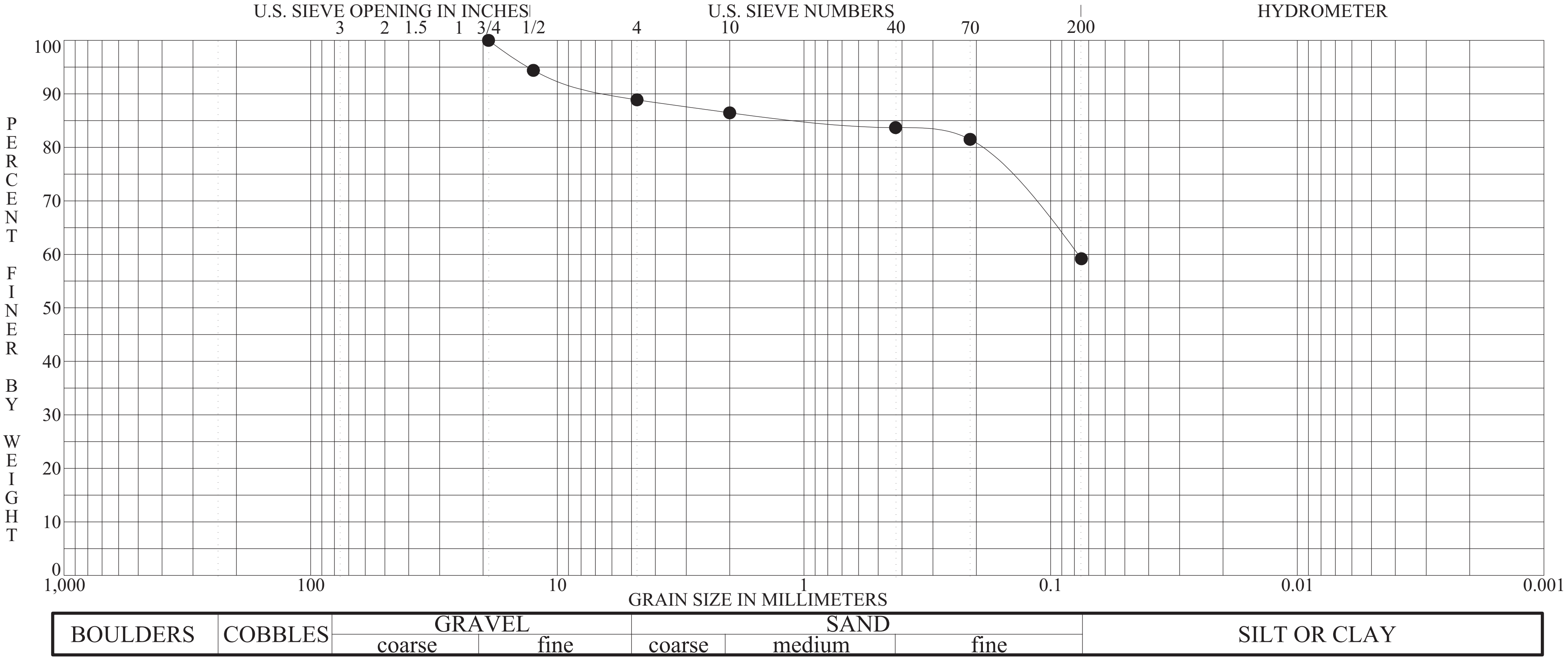
ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

PLATE 14

BBCM



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0901 S-21 36.0' to 37.5'**	**Gray mottled with dark-gray organic clayey silt inter-bedded with organic silt, some fine sand, trace medium to coarse sand, little fine gravel.** **SANDY ORGANIC SILT OL**	**40**	**45**	**29**	**16**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0901 S-21 36.0' to 37.5'**	**19.0000**	**13.0775**	**0.0779**			**11.11**	**29.71**	**59.18**	

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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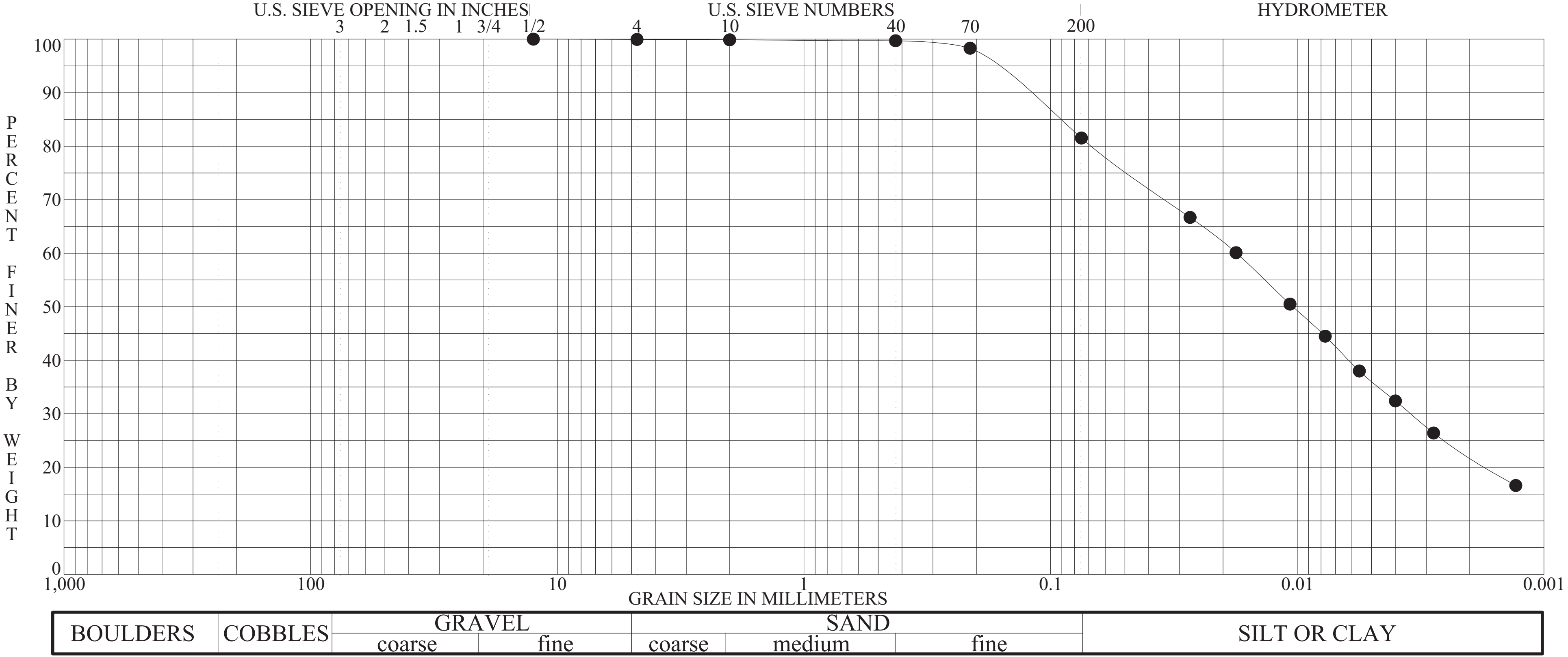

	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0901 S-22 38.5' to 40.0'**	**Gray mottled with dark-gray organic clayey silt, little fine sand, trace medium to coarse sand, trace fine gravel, few lenses of fine sand.** **ORGANIC CLAY with SAND OL**	**42**	**40**	**23**	**17**		

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0901 S-22 38.5' to 40.0'**	**12.5000**	**0.1726**	**0.0176**	**0.0104**		**0.05**	**18.42**	**59.43**	**22.10**

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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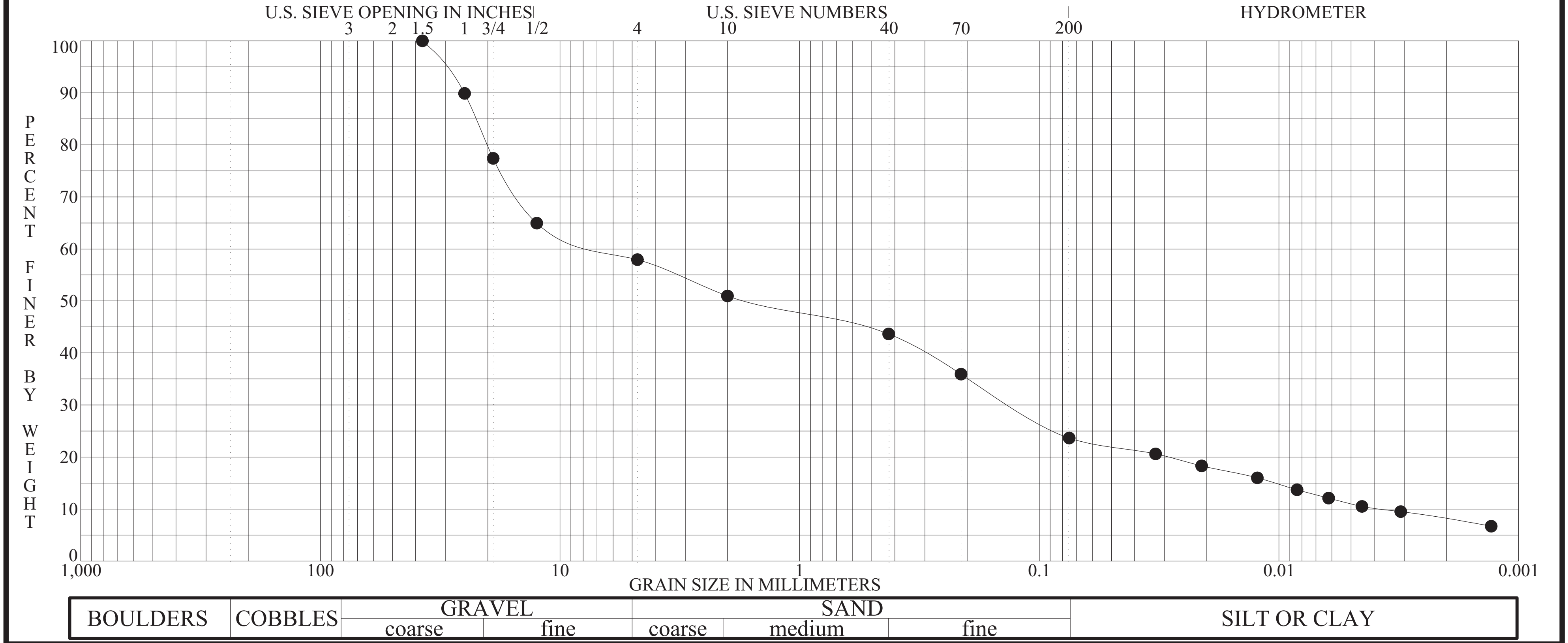


Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0902 S-4 5.5' to 6.6'**	**FILL: Brown and gray fine to coarse gravel(sandstone, siltstone and shale fragments), some fine to coarse sand, some clayey silt.** **CLAYEY GRAVEL with SAND GC**	**13**	**27**	**17**	**10**	**0.699**	**1690.044**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0902 S-4 5.5' to 6.6'**	**37.5000**	**30.6832**	**6.3123**	**1.6307**	**0.0037**	**42.06**	**34.29**	**15.56**	**8.09**

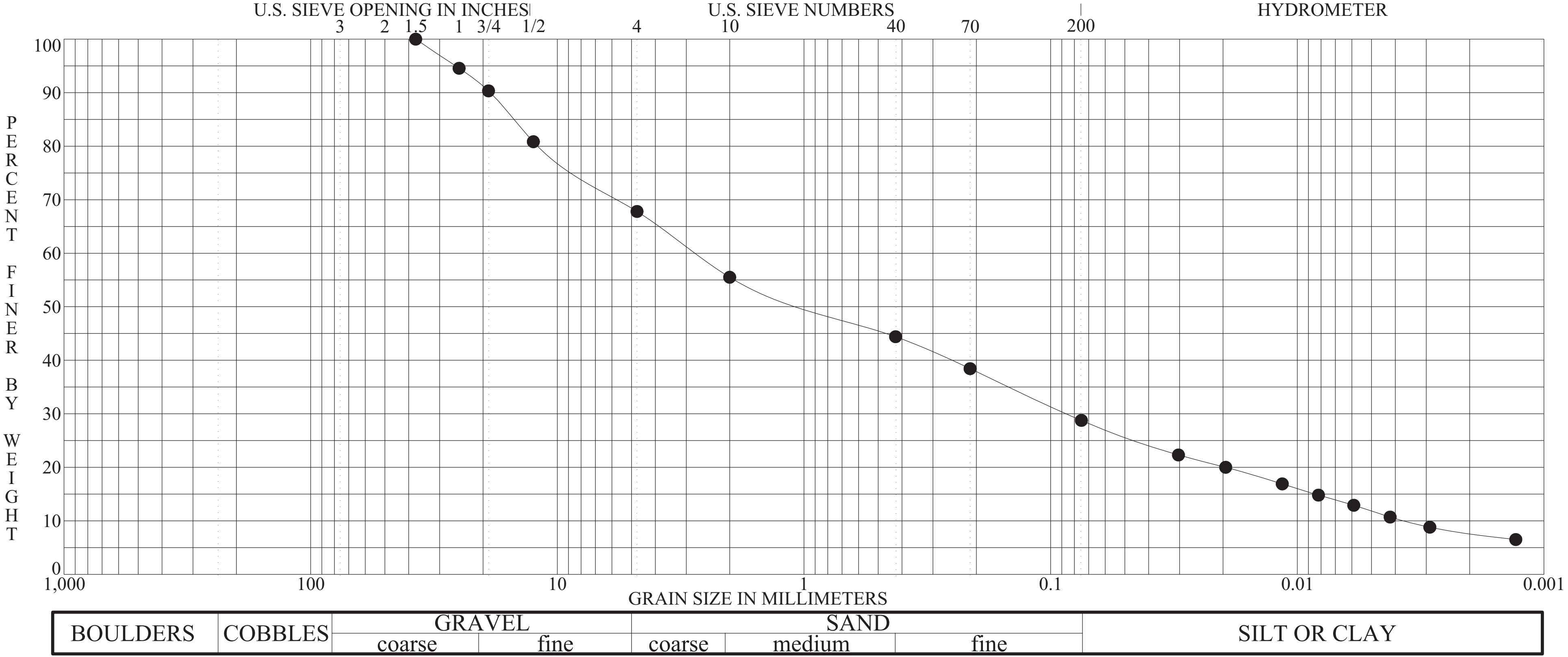
ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

PLATE 17

GRN-EPA W/ASTM-BBCM



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-PZ-BAP-0902 S-8 11.5' to 12.6'**	**FILL: Brown and gray fine to coarse sand, some fine to coarse gravel(sandstone, siltstone and shale fragments), some clayey silt.** **CLAYEY SAND with GRAVEL SC**	**10**	**26**	**17**	**9**	**0.731**	**748.575**

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-PZ-BAP-0902 S-8 11.5' to 12.6'**	**37.5000**	**25.8279**	**2.7430**	**0.9275**	**0.0037**	**32.20**	**39.04**	**21.02**	**7.73**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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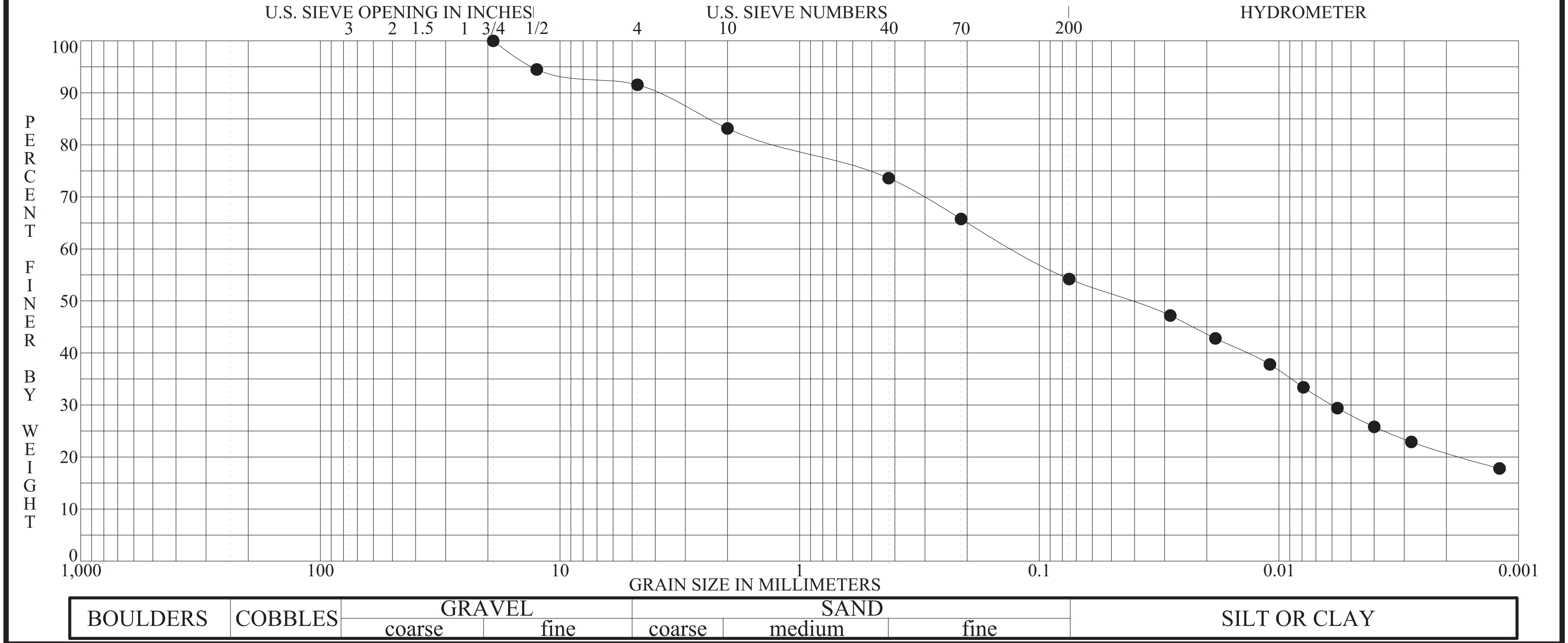

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0902 S-12 17.5' to 18.1'**	**FILL: Brown and gray silty clay, "and" fine to coarse sand, trace fine gravel(shale fragments).** **SANDY LEAN CLAY CL**	**21**	**35**	**17**	**18**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0902 S-12 17.5' to 18.1'**	**19.0000**	**12.9863**	**0.1263**	**0.0418**		**8.45**	**37.34**	**33.34**	**20.87**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION

LOCATION BRILLIANT, OHIO

JOB NO. 011-11497-013 **DATE** 7/6/09

PLATE 19

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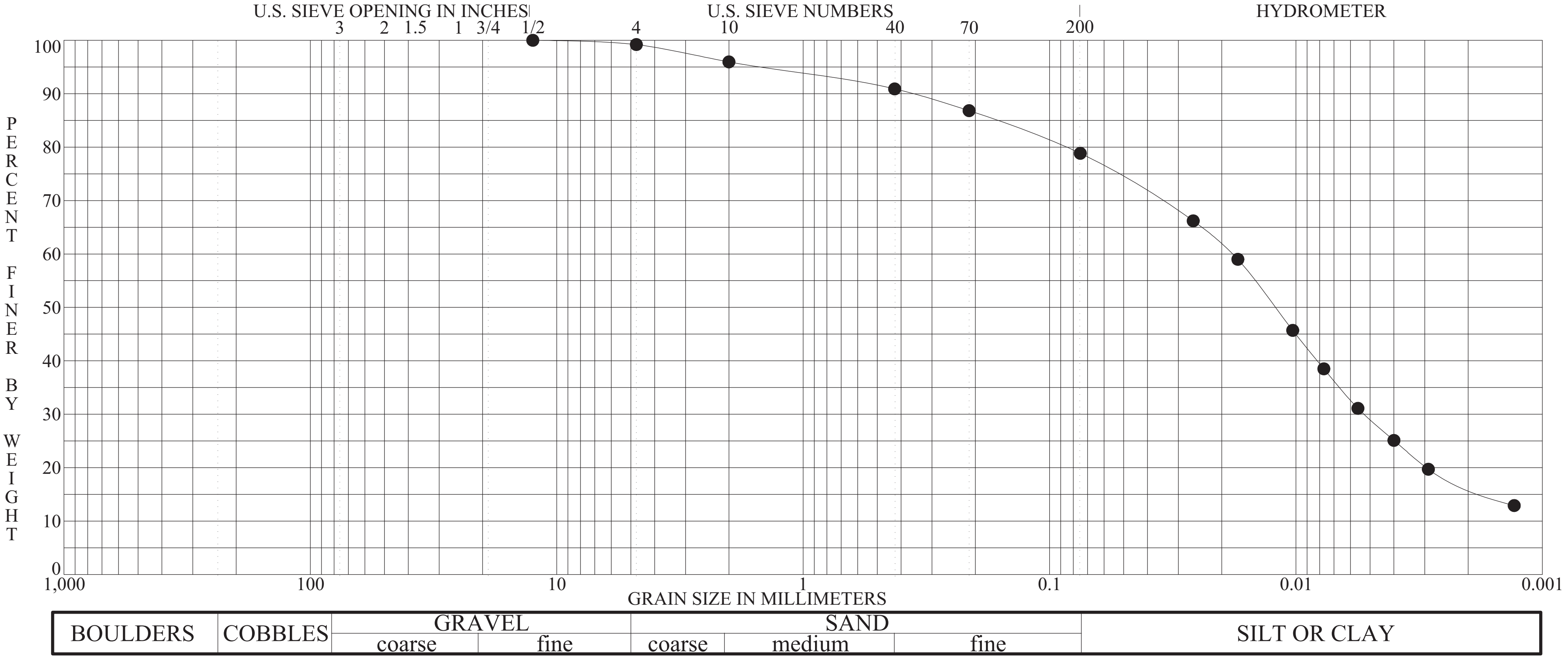

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0902 S-13 19.0' to 19.3'**	**FILL: Gray and brown silty clay, litle fine to coarse sand, trace fine gravel(shale fragments).** **LEAN CLAY with SAND CL**	**31**	**29**	**17**	**12**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0902 S-13 19.0' to 19.3'**	**12.5000**	**1.4898**	**0.0182**	**0.0122**		**0.79**	**20.36**	**62.29**	**16.55**

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

PLATE 20

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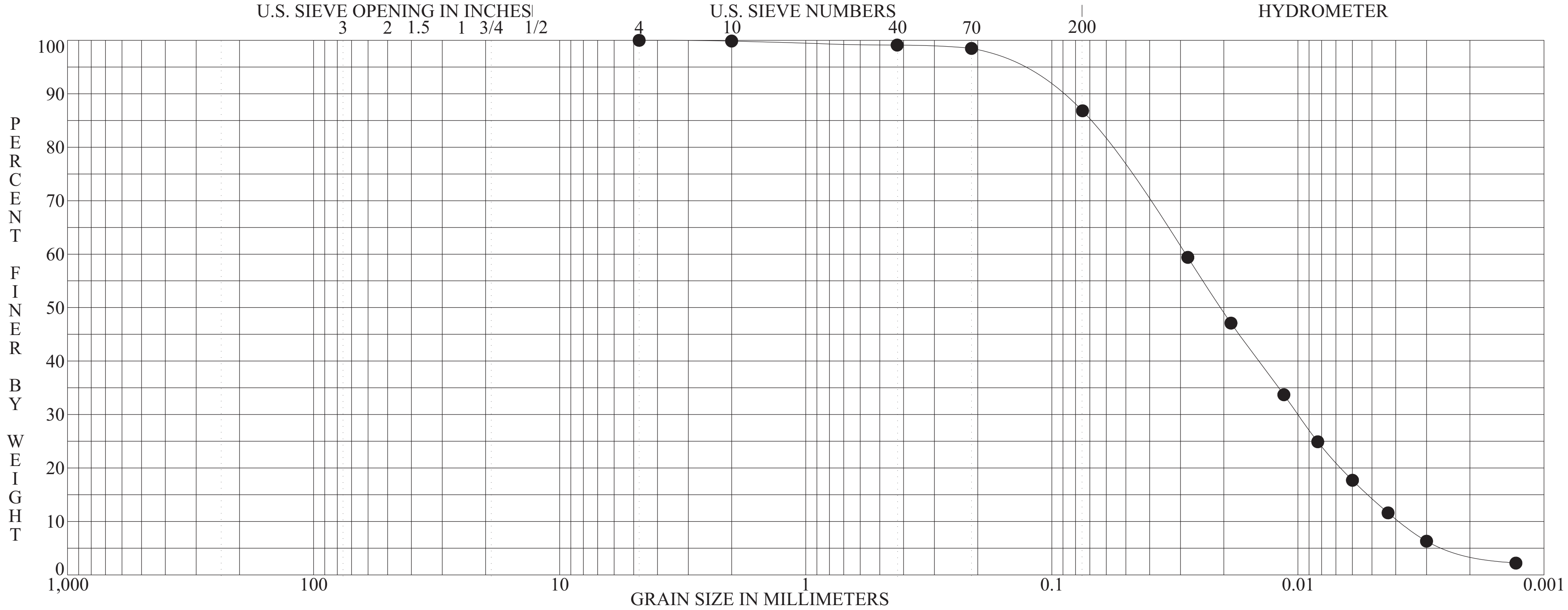

BOULDERS	COBBLES	GRAVEL		SAND			SILT OR CLAY
		coarse	fine	coarse	medium	fine	

	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-PZ-BAP-0902 S-14 20.5' to 22.0'**	**Gray and dark-gray silt, trace clay, little fine to coarse sand.**	**26**	**NP**	**NP**	**NP**	**0.902**	**7.417**
		SILT ML						

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-PZ-BAP-0902 S-14 20.5' to 22.0'**	**4.7500**	**0.1554**	**0.0286**	**0.0206**	**0.0039**	**0.00**	**13.18**	**82.51**	**4.31**

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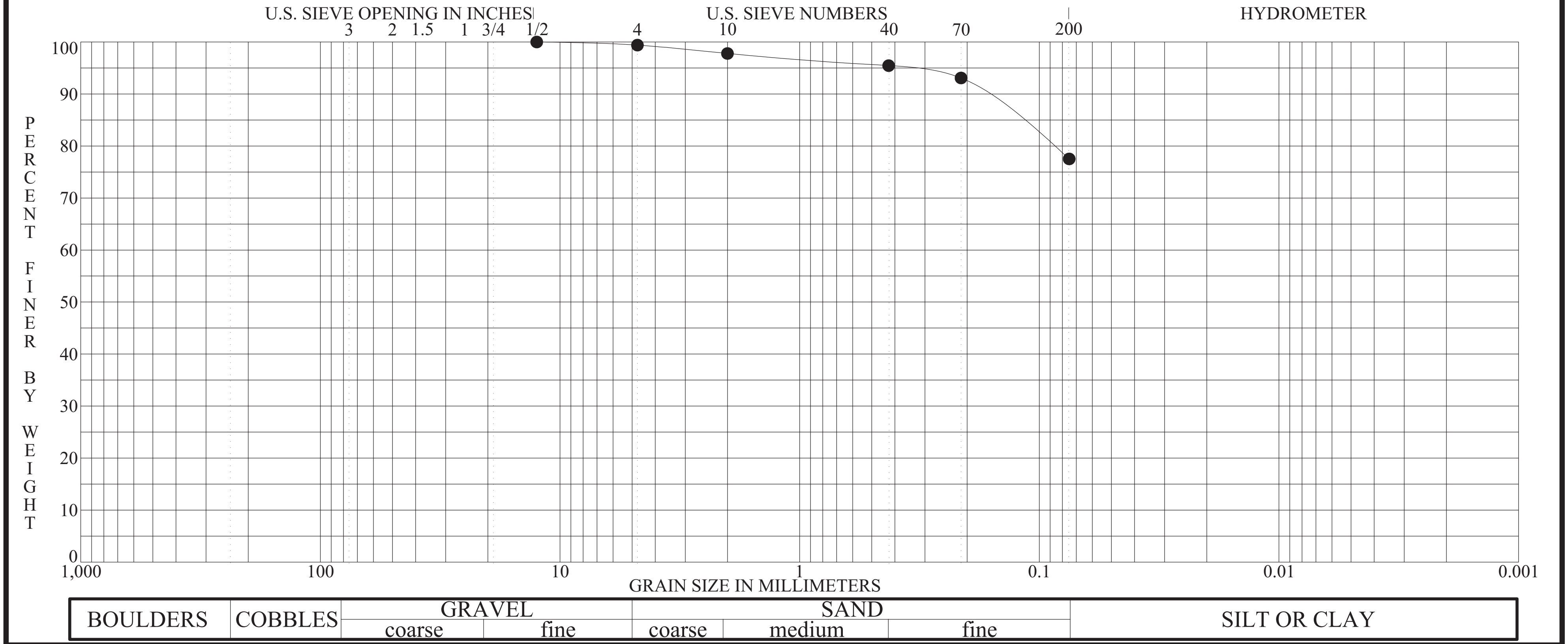
GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

PLATE 21

GRN-EPA W/ASTM-BBCM



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-PZ-BAP-0902 S-15 22.0' to 22.8'**	**Gray and dark-gray silt, some clay, little fine sand, trace medium to coarse sand, trace fine gravel.**						

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-PZ-BAP-0902 S-15 22.0' to 22.8'**	**12.5000**	**0.3717**				**0.59**	**21.88**	**77.52**	

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GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**

PLATE 22

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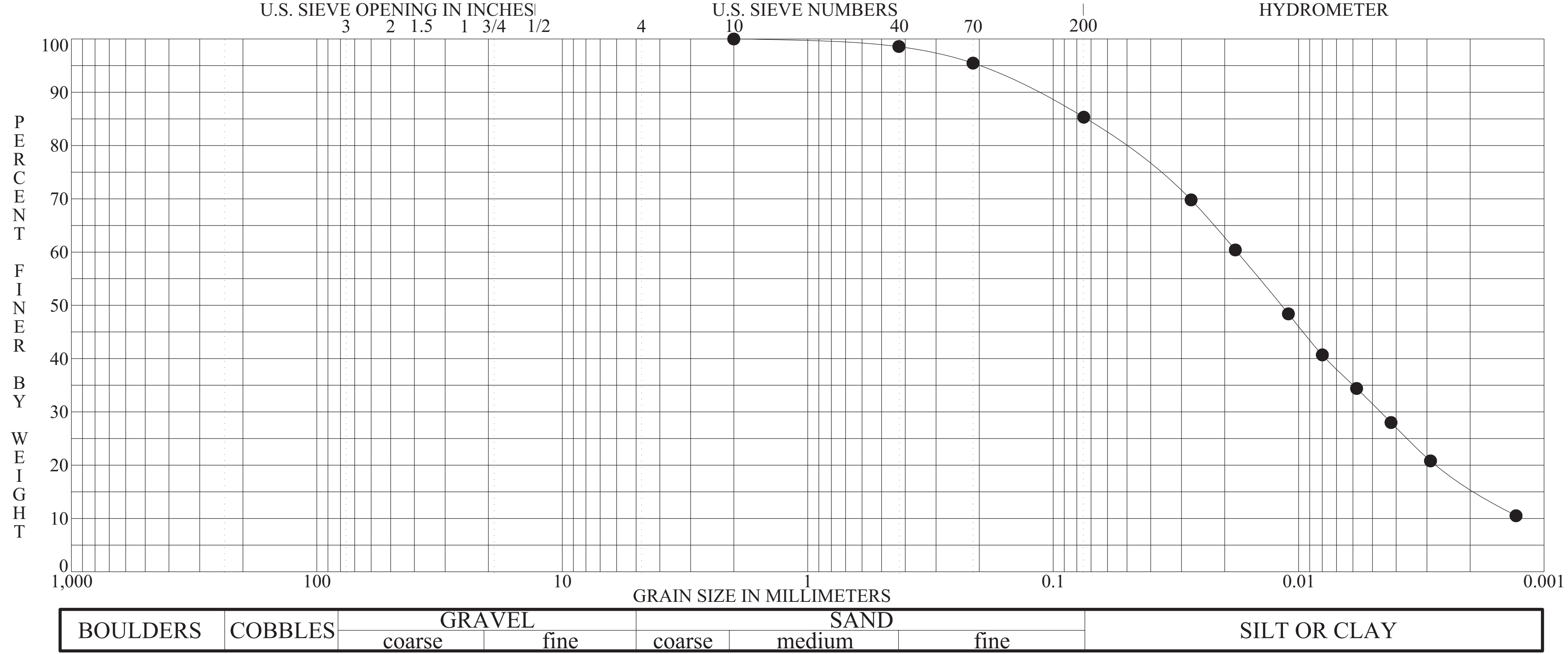

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0902 S-18 26.5' to 27.7'**	**Gray mottled with dark-gray organic silt, little clay, little fine to medium sand.** **ORGANIC SILT OL**	**54**	**NP**	**NP**	**NP**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0902 S-18 26.5' to 27.7'**	**2.0000**	**0.2020**	**0.0178**	**0.0118**		**0.00**	**14.68**	**69.29**	**16.03**

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
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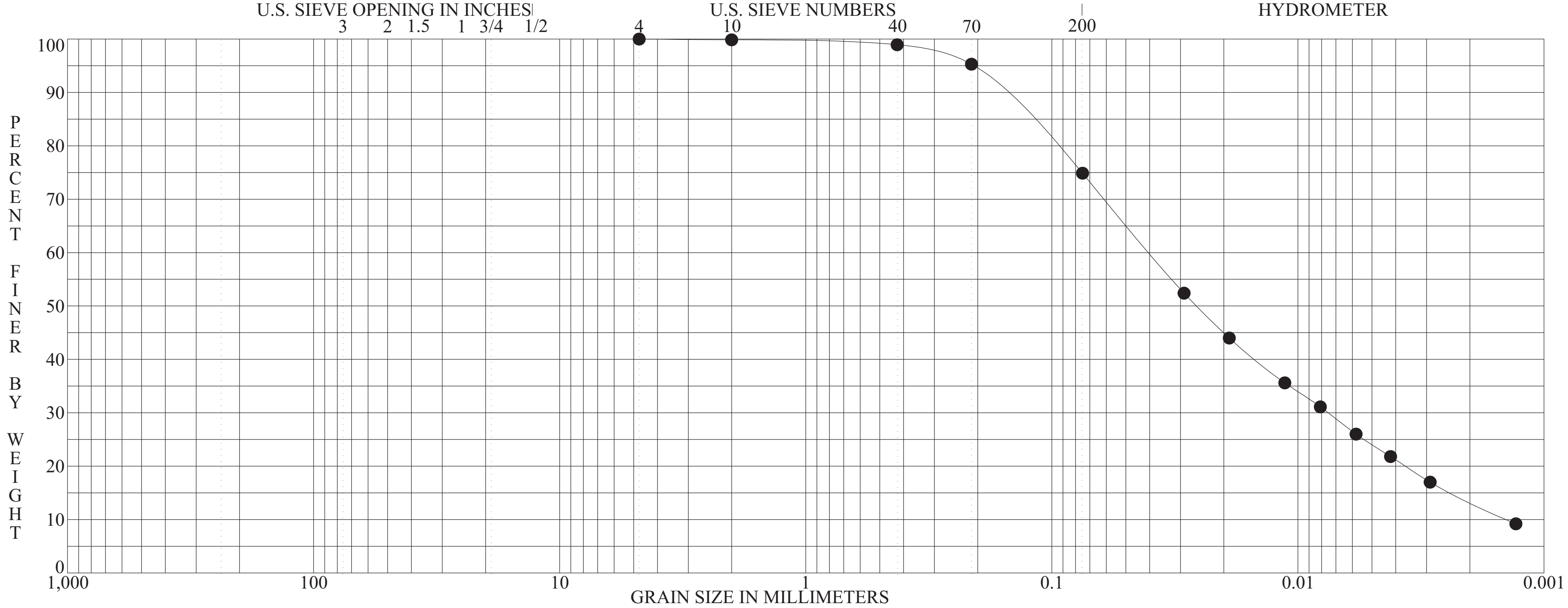

BOULDERS	COBBLES	GRAVEL		SAND			SILT OR CLAY
		coarse	fine	coarse	medium	fine	

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-PZ-BAP-0902 S-19 28.0' to 29.5'	**Gray mottled with dark-gray organic silt, little clay, some fine sand, trace medium to coarse sand.** **ORGANIC SILT with SAND OL**	**43**	**NP**	**NP**	**NP**	**1.006**	**28.333**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-PZ-BAP-0902 S-19 28.0' to 29.5'	**4.7500**	**0.2088**	**0.0400**	**0.0257**	**0.0014**	**0.00**	**25.13**	**61.48**	**13.39**

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
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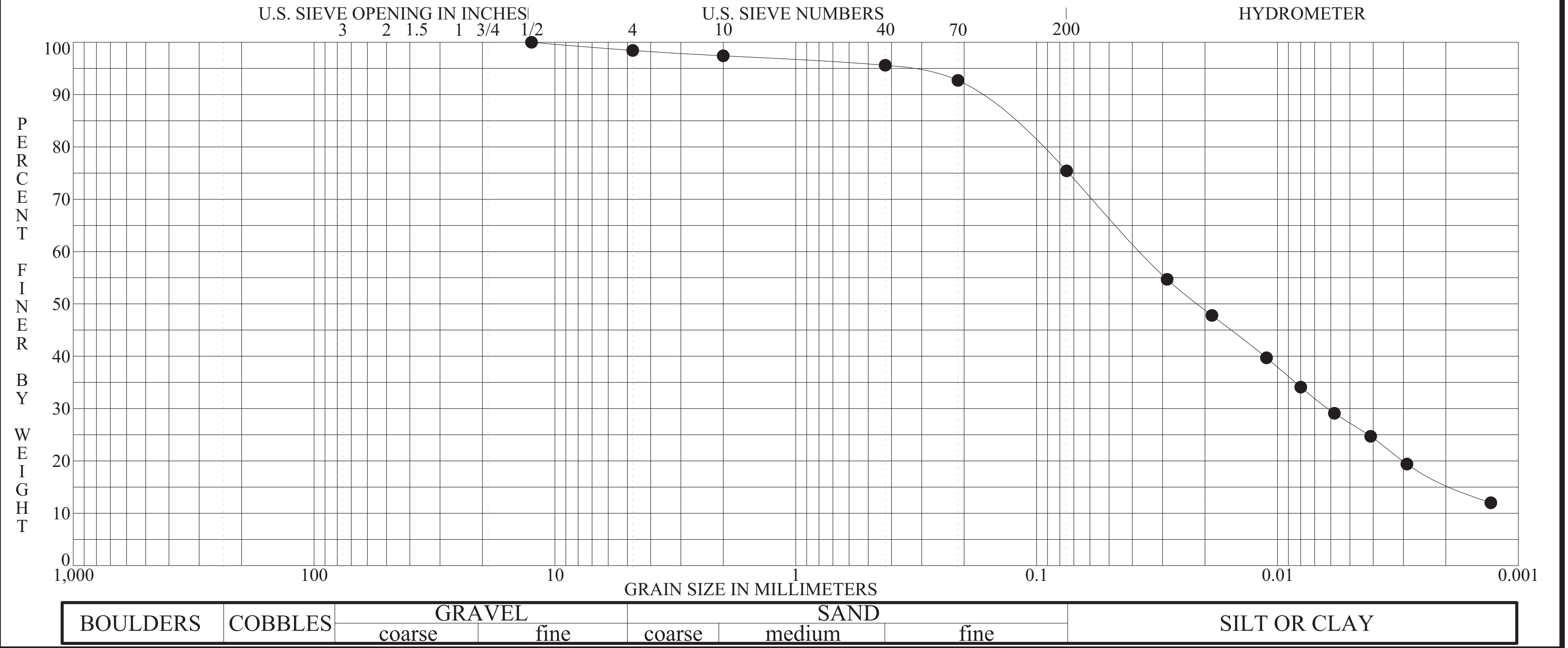

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0902 S-20 31.5' to 32.6'**	**Gray mottled with dark-gray organic clayey silt, some fine to medium sand, trace coarse sand, trace fine gravel.** **ORGANIC SILT with SAND OL**	**38**	**36**	**28**	**8**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0902 S-20 31.5' to 32.6'**	**12.5000**	**0.3667**	**0.0367**	**0.0214**		**1.56**	**23.01**	**59.45**	**15.97**

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
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PLATE 25

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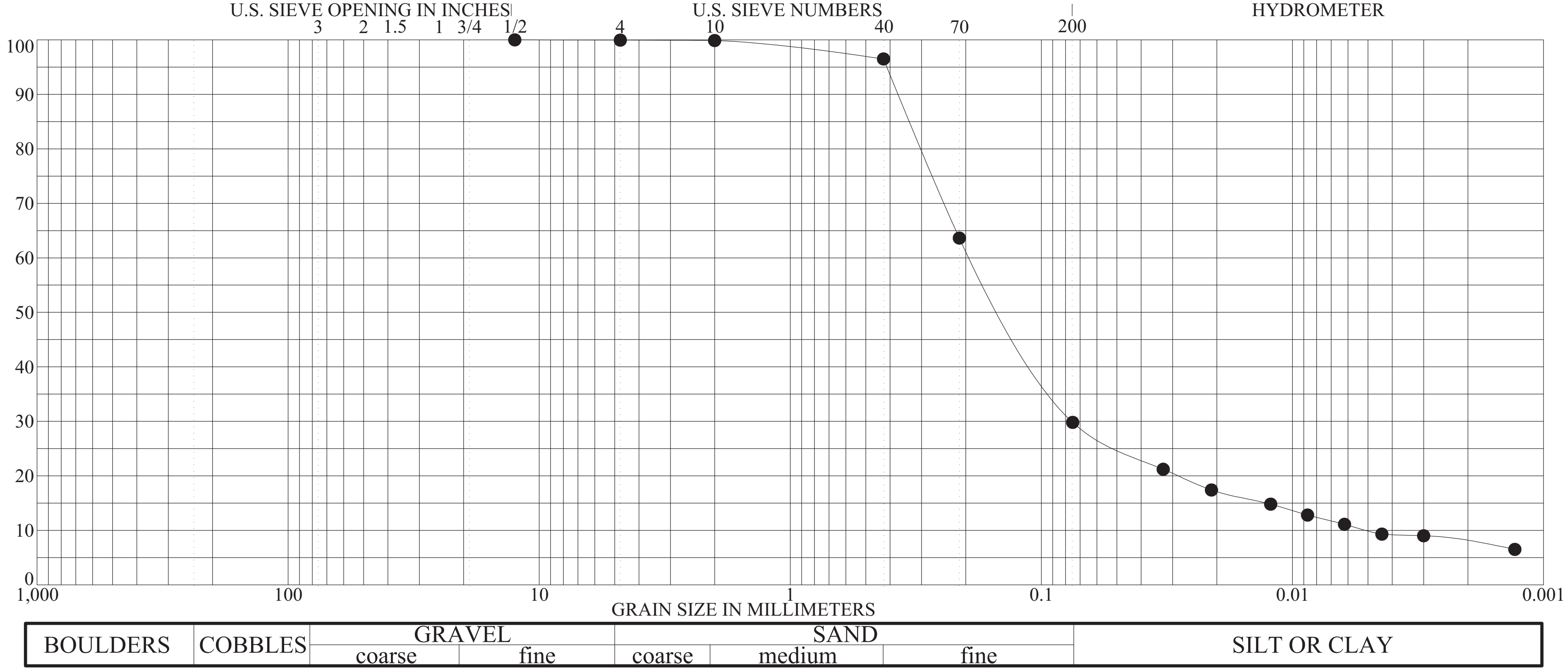

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-PZ-BAP-0902 S-22 36.5' to 37.6'	**Brown fine sand, trace medium to coarse sand, trace fine gravel, some silt, trace clay.**	**22**				**5.969**	**37.720**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-PZ-BAP-0902 S-22 36.5' to 37.6'	**12.5000**	**0.4117**	**0.1896**	**0.1395**	**0.0050**	**0.04**	**70.15**	**22.02**	**7.79**

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
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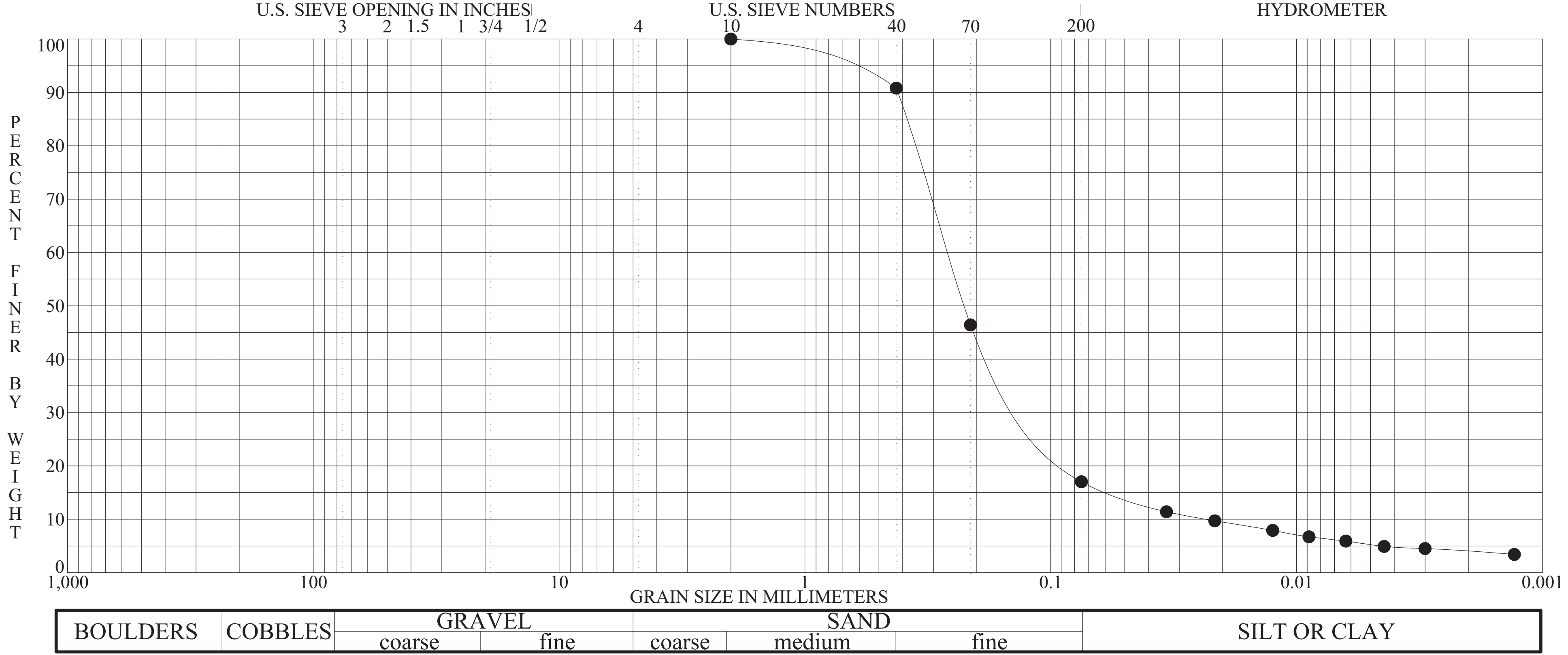

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0902 S-23 39.0' to 40.2'**	**Brown fine sand, trace medium sand, little silt, trace clay.**	**24**				**2.305**	**11.263**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0902 S-23 39.0' to 40.2'**	**2.0000**	**0.8615**	**0.2623**	**0.2242**	**0.0233**	**0.00**	**82.98**	**13.06**	**3.97**

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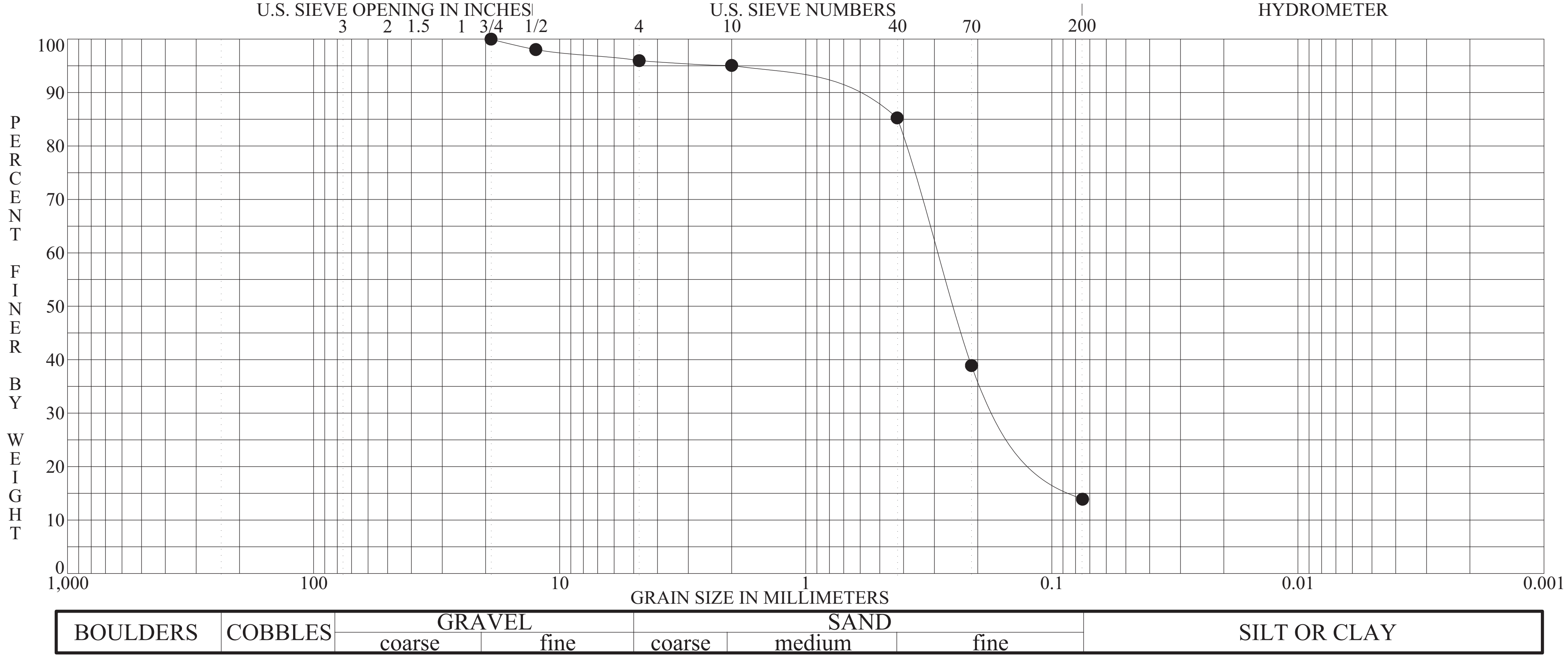

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0902 S-24 41.5' to 43.0'**	**Brown fine to medium sand, trace coarse sand, trace silt.**						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0902 S-24 41.5' to 43.0'**	**19.0000**	**1.9735**	**0.2909**	**0.2504**		**4.03**	**82.08**	**13.90**	

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
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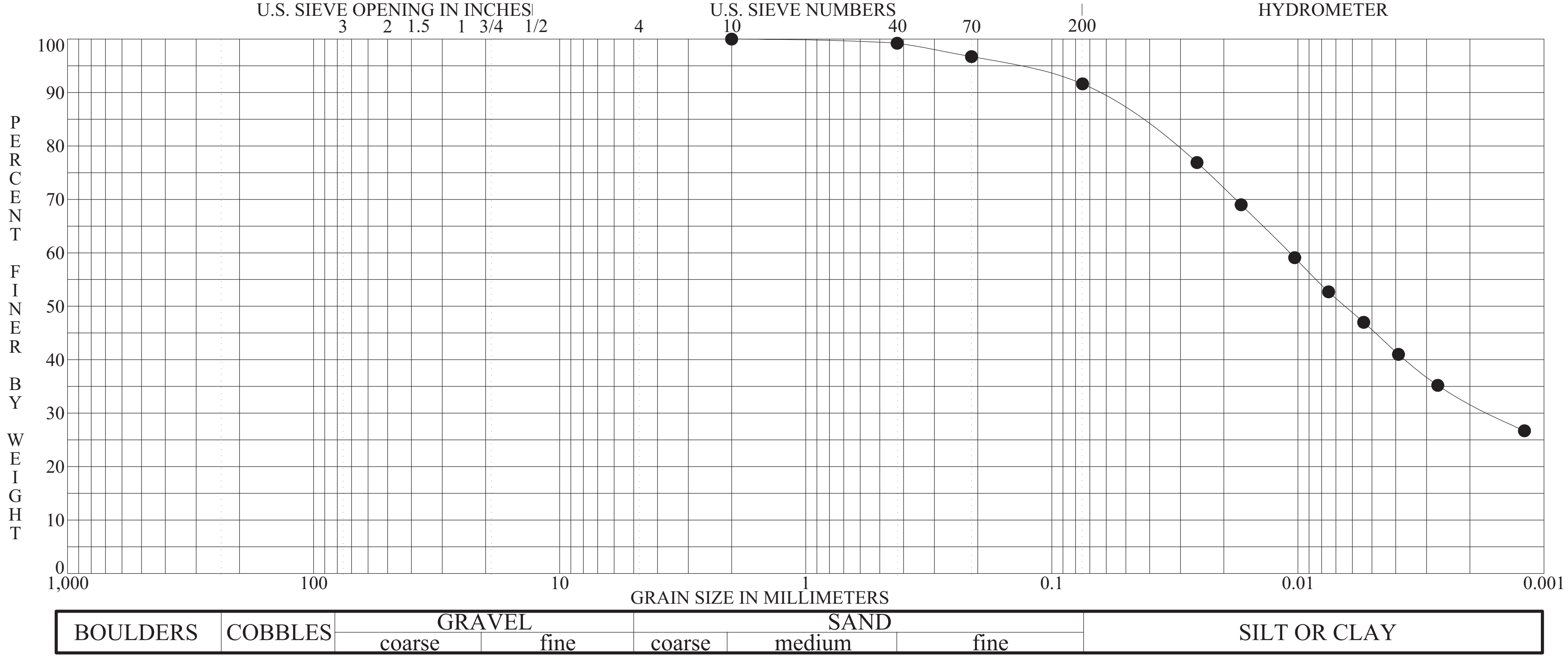

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-BAP-0903 S-2 2.5' to 3.3'	**FILL: Brown mottled with dark-brown and gray silty clay, trace fine to medium sand.** **LEAN CLAY CL**	**24**	**48**	**24**	**24**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-BAP-0903 S-2 2.5' to 3.3'	**2.0000**	**0.1492**	**0.0108**	**0.0064**		**0.00**	**8.37**	**59.57**	**32.05**

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GRADATION CURVE

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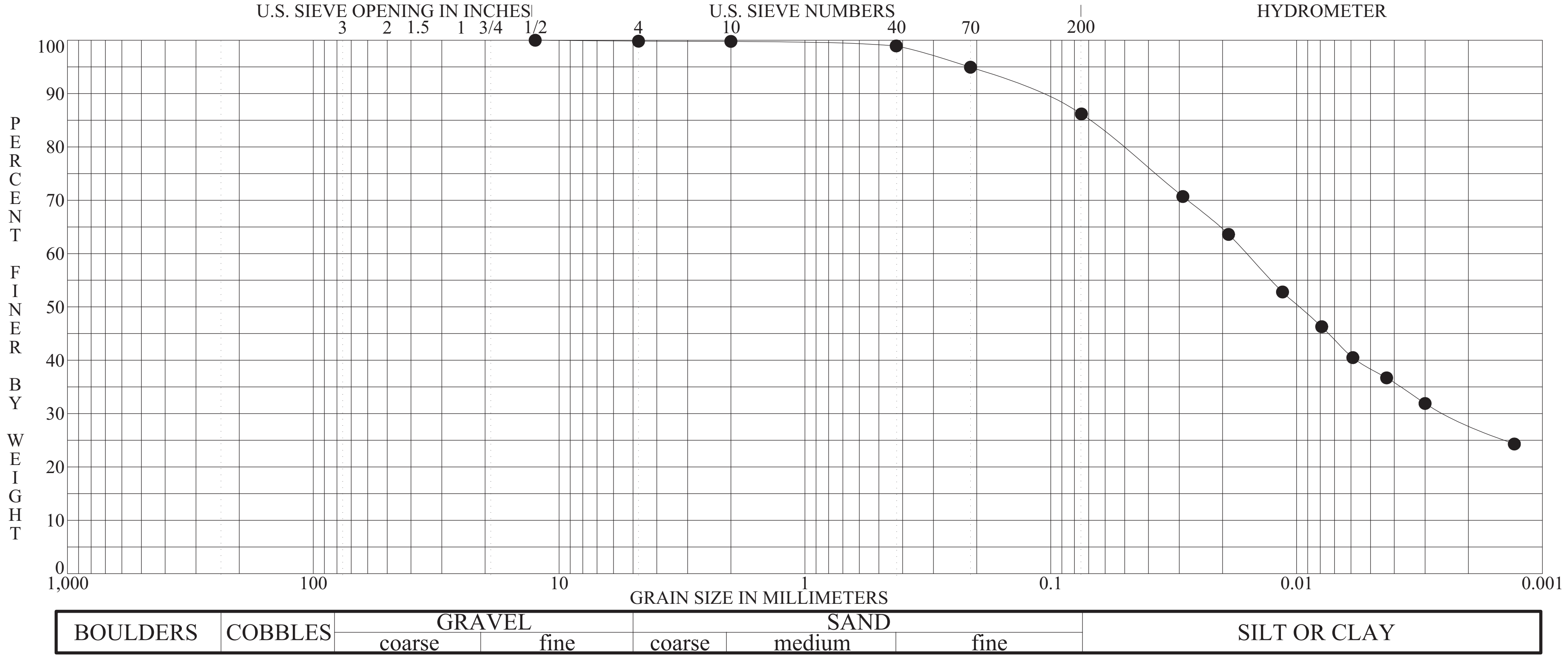

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-BAP-0903 S-5 7.0' to 8.0'	**FILL: Brown mottled with dark-brown and gray silty clay, little fine to coarse sand, trace fine gravel, few lenses of organic silt.** **LEAN CLAY CL**	**20**	**36**	**20**	**16**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-BAP-0903 S-5 7.0' to 8.0'	**12.5000**	**0.2141**	**0.0160**	**0.0097**		**0.17**	**13.64**	**57.97**	**28.22**

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
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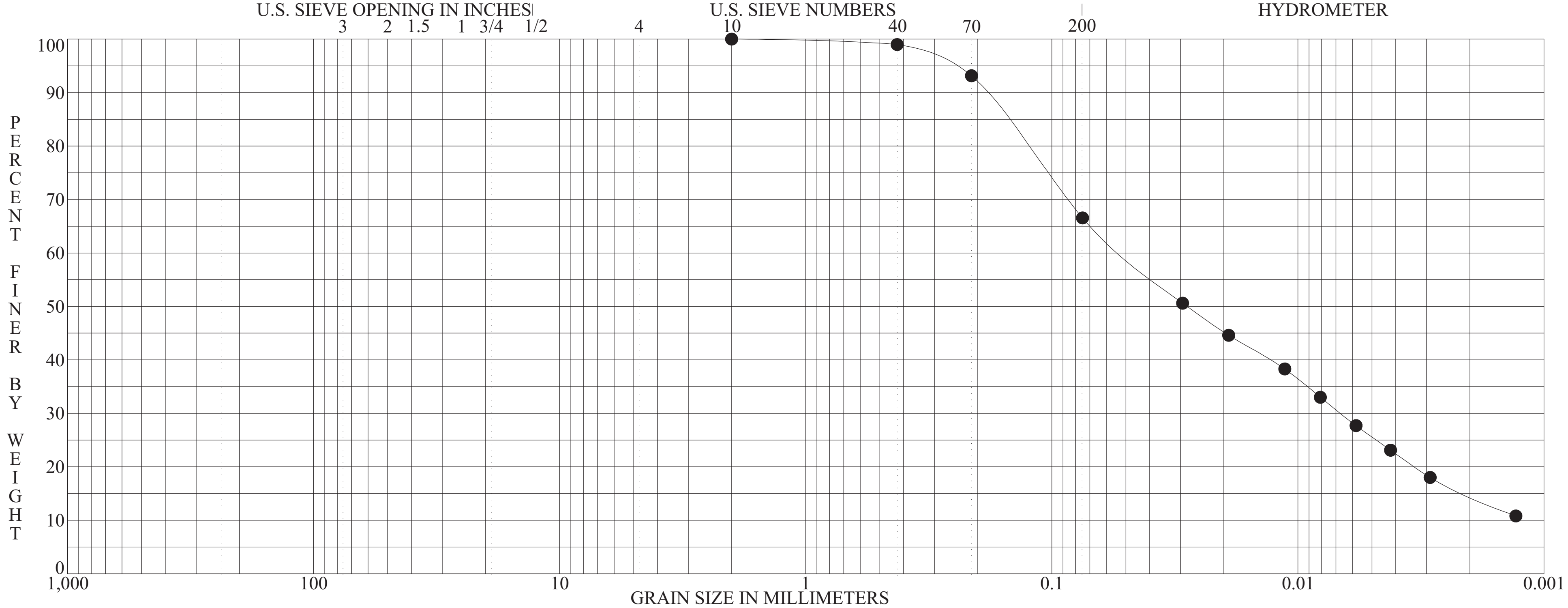

BOULDERS	COBBLES	GRAVEL		SAND			SILT OR CLAY
		coarse	fine	coarse	medium	fine	

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0903 S-6 8.5' to 9.5'**	**Dark-gray organic silt, little clay, some fine sand, trace medium sand, few lenses of fine sand.** **SANDY ORGANIC SILT OL**	**49**	**41**	**38**	**3**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0903 S-6 8.5' to 9.5'**	**2.0000**	**0.2643**	**0.0510**	**0.0282**		**0.00**	**33.45**	**51.89**	**14.67**

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GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**

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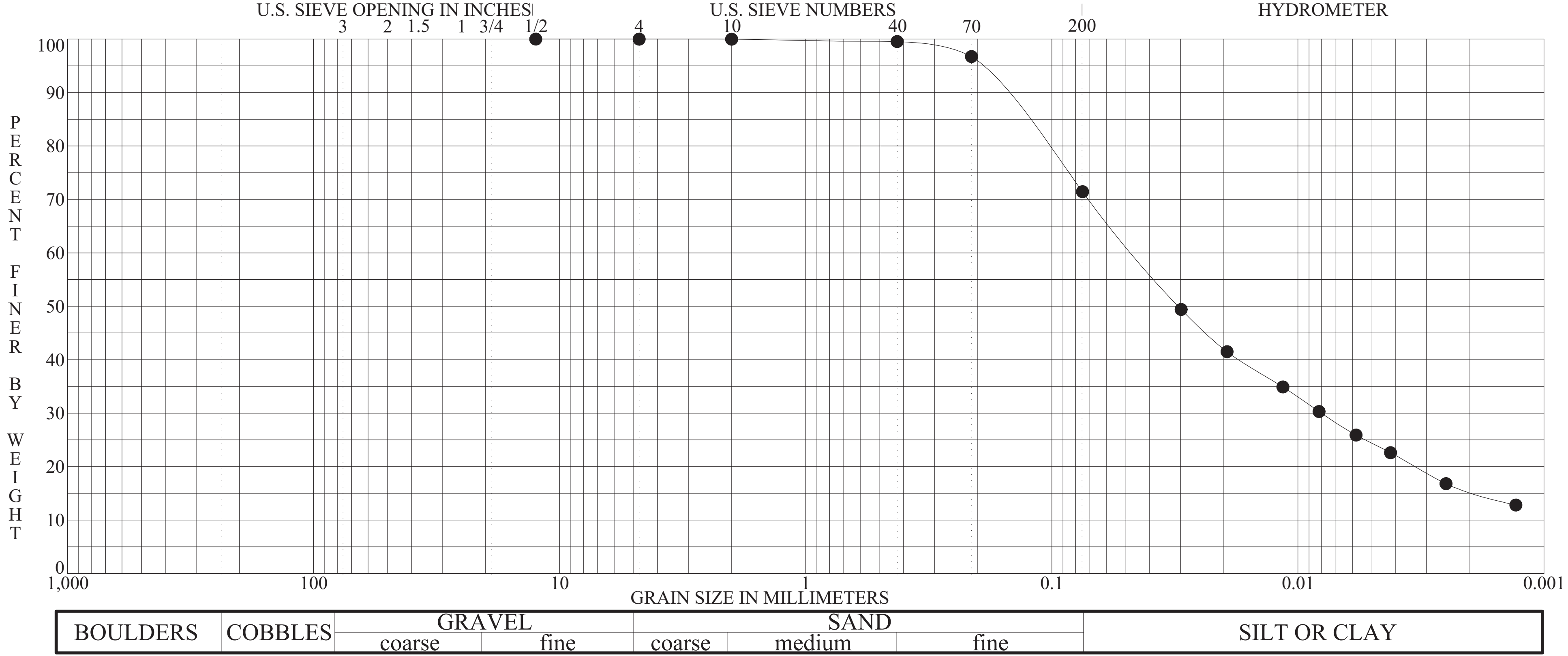

	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0903 S-7 13.5' to 14.5'**	**Gray mottled with dark-gray organic silt inter-bedded with organic clayey silt, some fine sand, trace medium to coarse sand, trace fine gravel.** **ORGANIC SILT with SAND OL**	**43**	**NP**	**NP**	**NP**		

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0903 S-7 13.5' to 14.5'**	**12.5000**	**0.1974**	**0.0464**	**0.0306**		**0.01**	**28.55**	**56.01**	**15.44**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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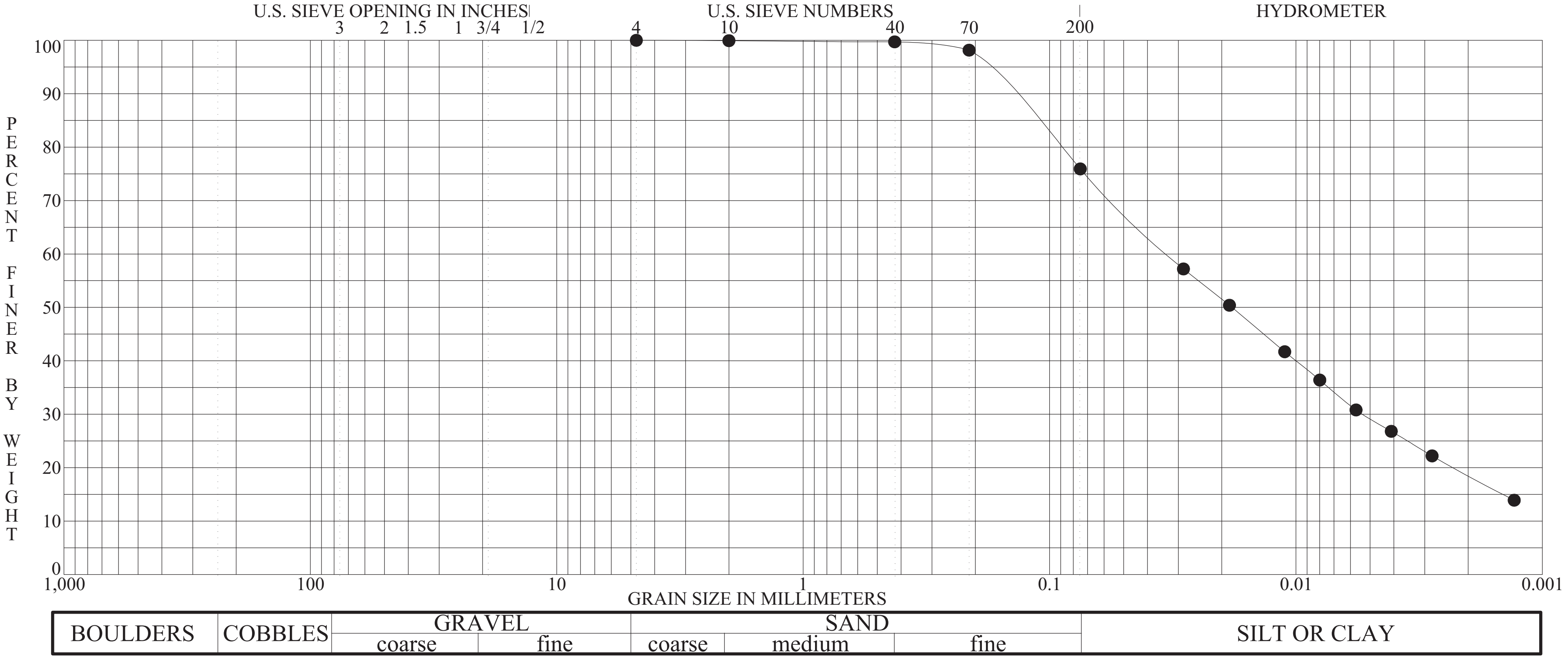


Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0903 S-8 16.0' to 17.0'**	**Gray mottled with dark-gray organic clayey silt, some fine sand, trace medium to coarse sand, few seams of silt and fine sand.** **ORGANIC CLAY with SAND OL**	**43**	**37**	**24**	**13**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0903 S-8 16.0' to 17.0'**	**4.7500**	**0.1829**	**0.0330**	**0.0182**		**0.00**	**24.07**	**57.37**	**18.56**

ASTM D422

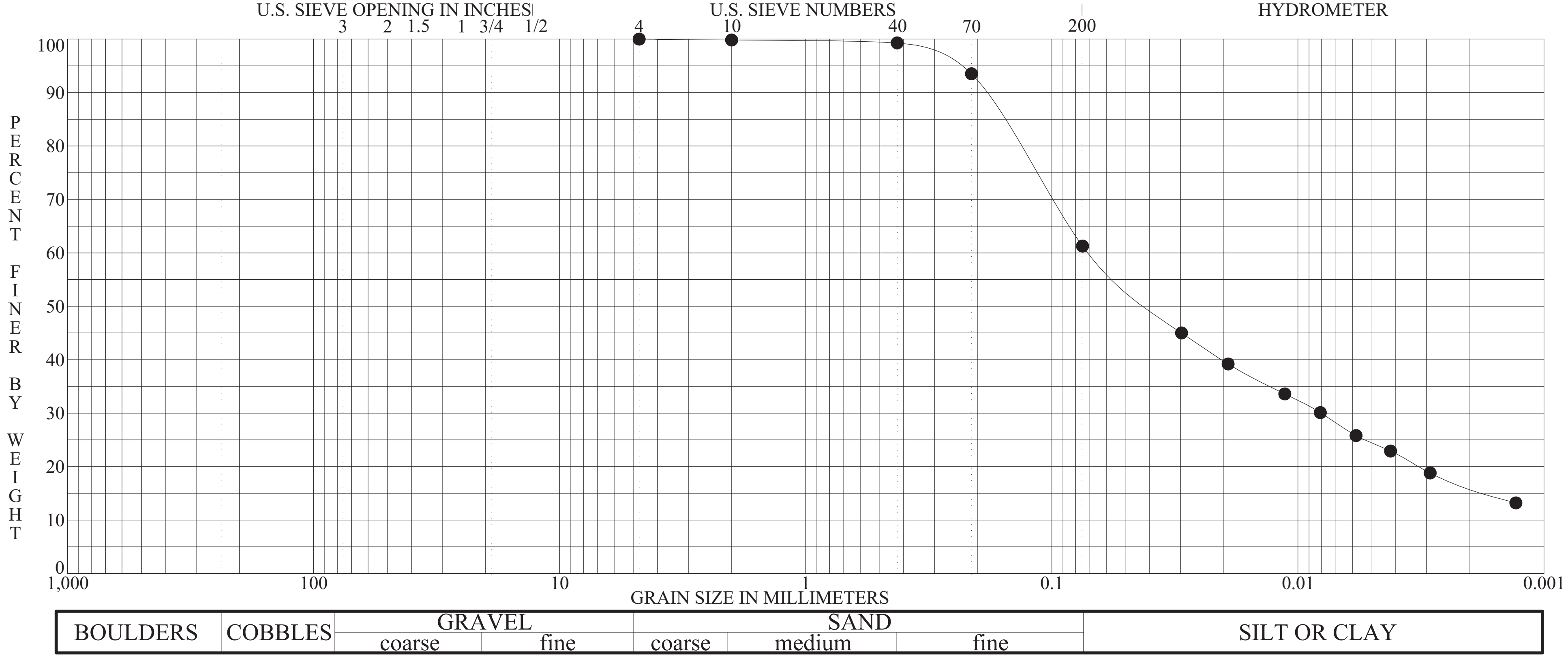
GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

PLATE 33

GRN-EPA W/ASTM-BBCM

BBCM



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0903 S-9 18.5' to 19.6'**	**Gray mottled with dark-gray organic clayey silt inter-bedded with organic silt, "and" fine sand, trace medium to coarse sand, few lenses of fine sand.** **SANDY ORGANIC CLAY OL**	**44**	**35**	**24**	**11**		

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0903 S-9 18.5' to 19.6'**	**4.7500**	**0.2536**	**0.0697**	**0.0395**		**0.00**	**38.72**	**45.07**	**16.21**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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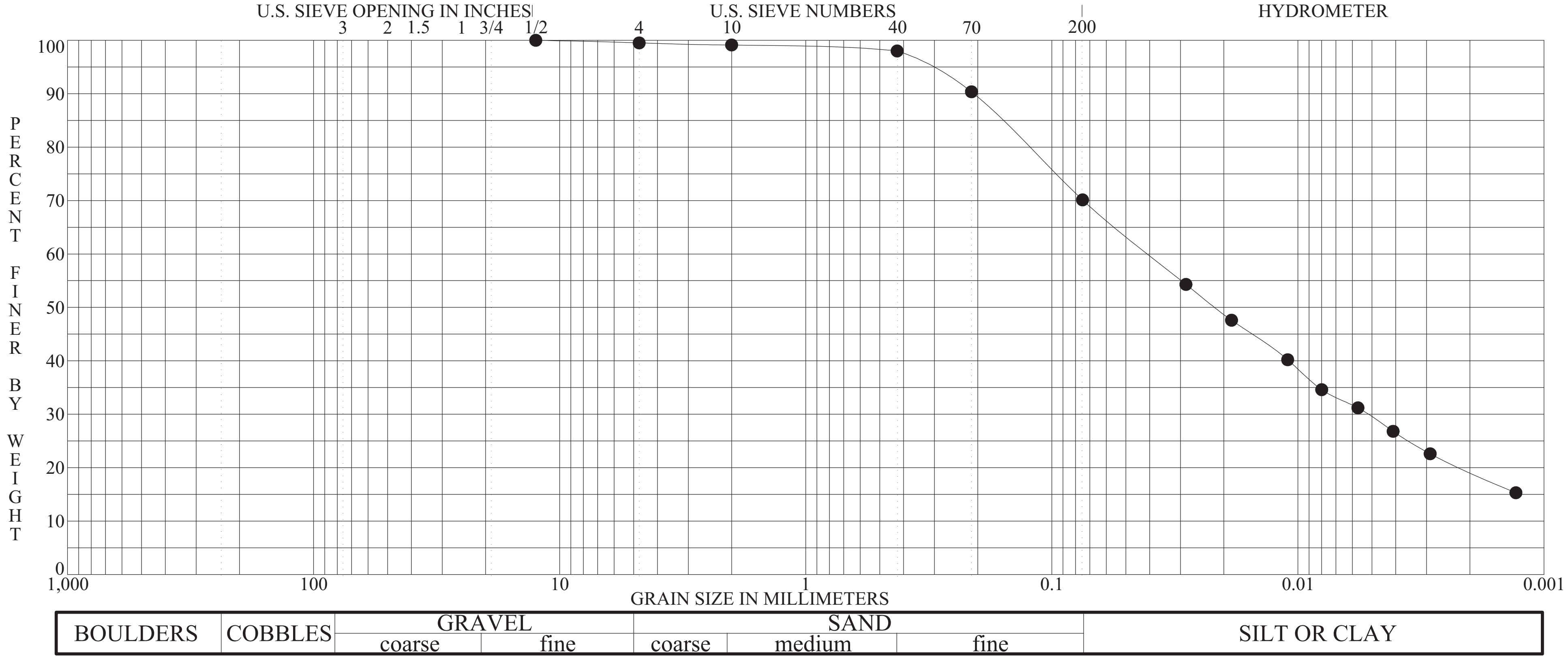

	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0903 S-10 21.0' to 21.9'**	**Gray silty clay inter-bedded with silt, some fine sand, trace medium to coarse sand, trace fine gravel, few seams of fine sand.** **LEAN CLAY with SAND CL**	**35**	**34**	**21**	**13**		

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0903 S-10 21.0' to 21.9'**	**12.5000**	**0.3233**	**0.0404**	**0.0217**		**0.48**	**29.39**	**50.91**	**19.22**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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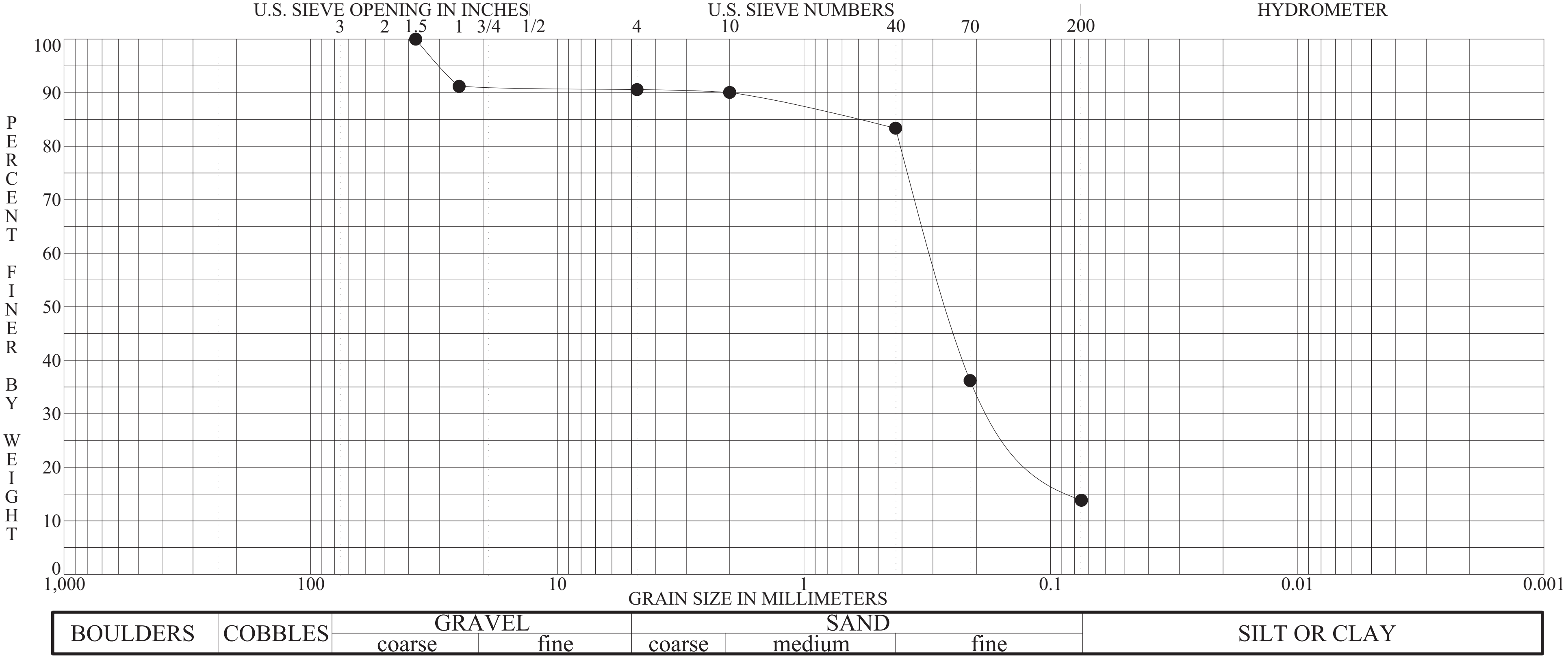

	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0903 S-11 23.5' to 24.2'**	**Brown and gray fine sand, trace medium to coarse sand, trace fine to coarse gravel, little silt, few seams of silty clay.**						

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0903 S-11 23.5' to 24.2'**	**37.5000**	**29.7874**	**0.3011**	**0.2598**		**9.42**	**76.74**	**13.84**	

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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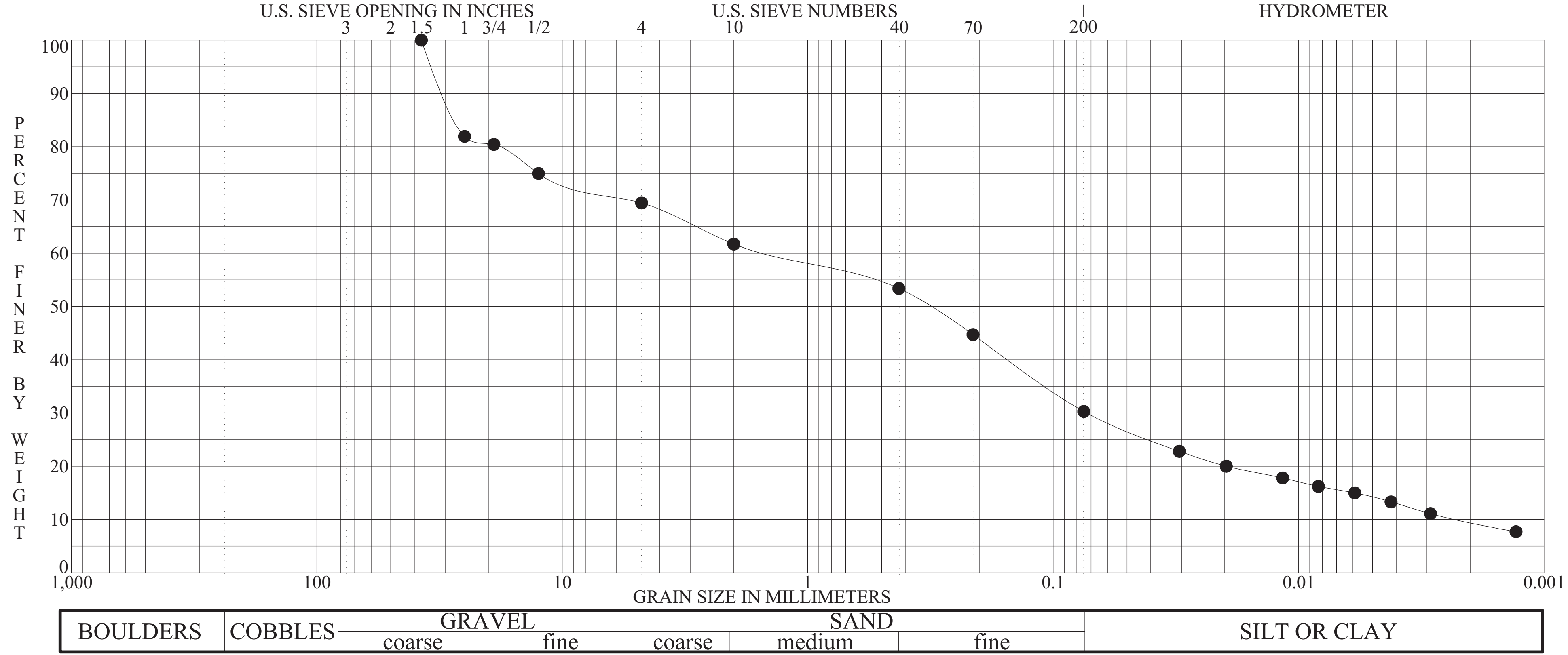

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0904 S-6 8.5' to 9.7'**	**FILL: Brown and gray fine to coarse sand, some fine to coarse gravel(sandstone, siltstone and shale fragments), some clayey silt.** **CLAYEY SAND with GRAVEL SC**	**14**	**25**	**16**	**9**	**1.616**	**650.322**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0904 S-6 8.5' to 9.7'**	**37.5000**	**33.5189**	**1.4548**	**0.3242**	**0.0022**	**30.57**	**39.15**	**20.76**	**9.53**

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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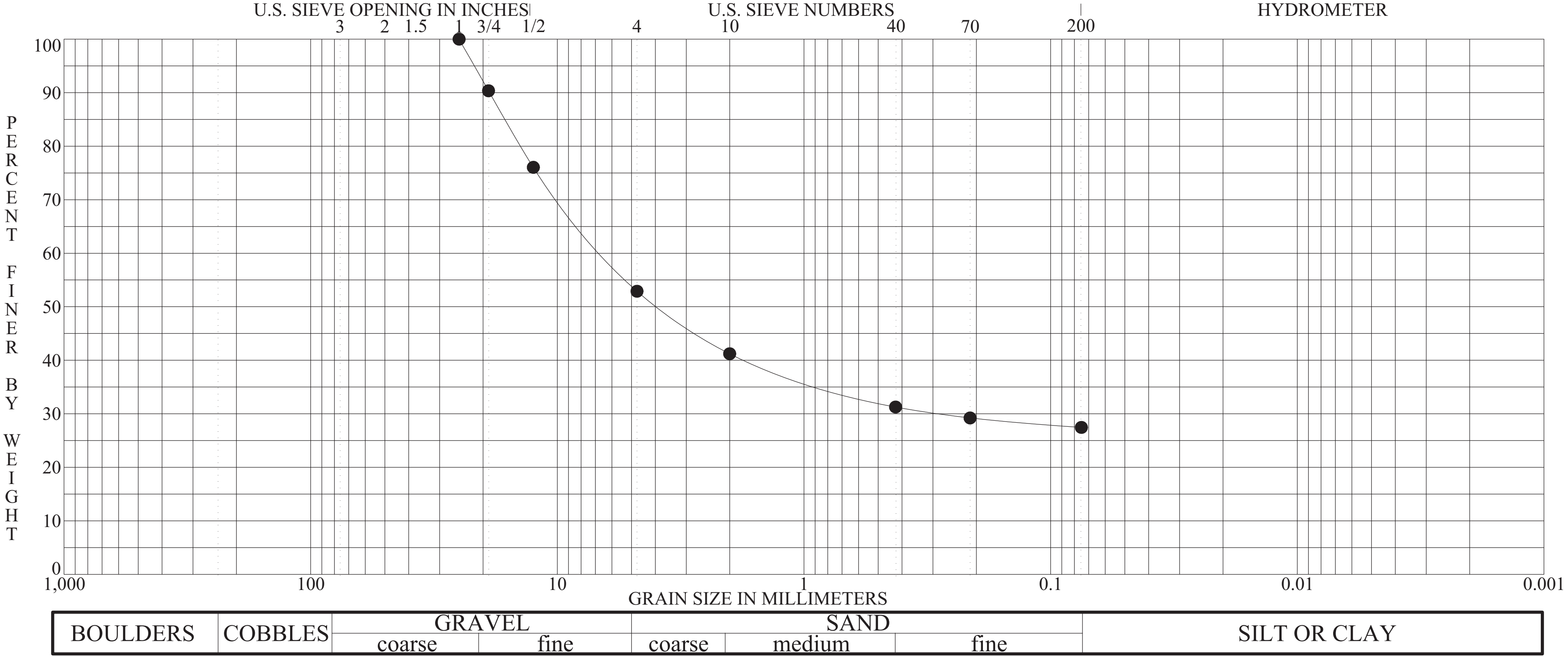

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0904 S-11 16.0' to 16.9'**	**FILL: Brown and gray fine to coarse gravel(very-soft shale fragments), some fine to coarse sand, some silty clay.**						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0904 S-11 16.0' to 16.9'**	**25.0000**	**21.6832**	**6.3914**	**3.8325**		**47.10**	**25.44**	**27.45**	

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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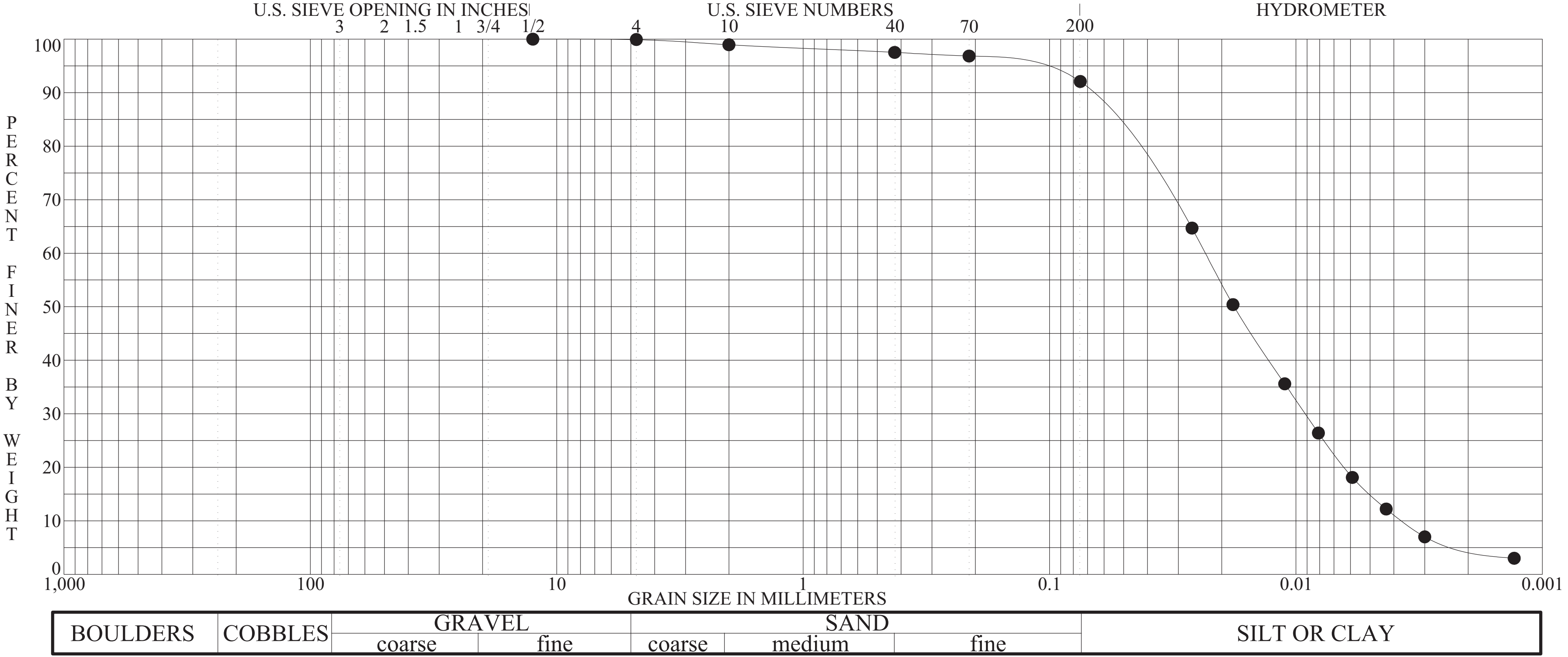

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0904 S-13 19.0' to 20.3'**	**Gray and dark-gray organic silt, trace clay, trace fine to coarse sand, trace fine gravel.** **ORGANIC SILT OL**	**28**	**NP**	**NP**	**NP**	**0.977**	**6.304**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0904 S-13 19.0' to 20.3'**	**12.5000**	**0.1414**	**0.0233**	**0.0178**	**0.0037**	**0.06**	**7.85**	**87.03**	**5.06**

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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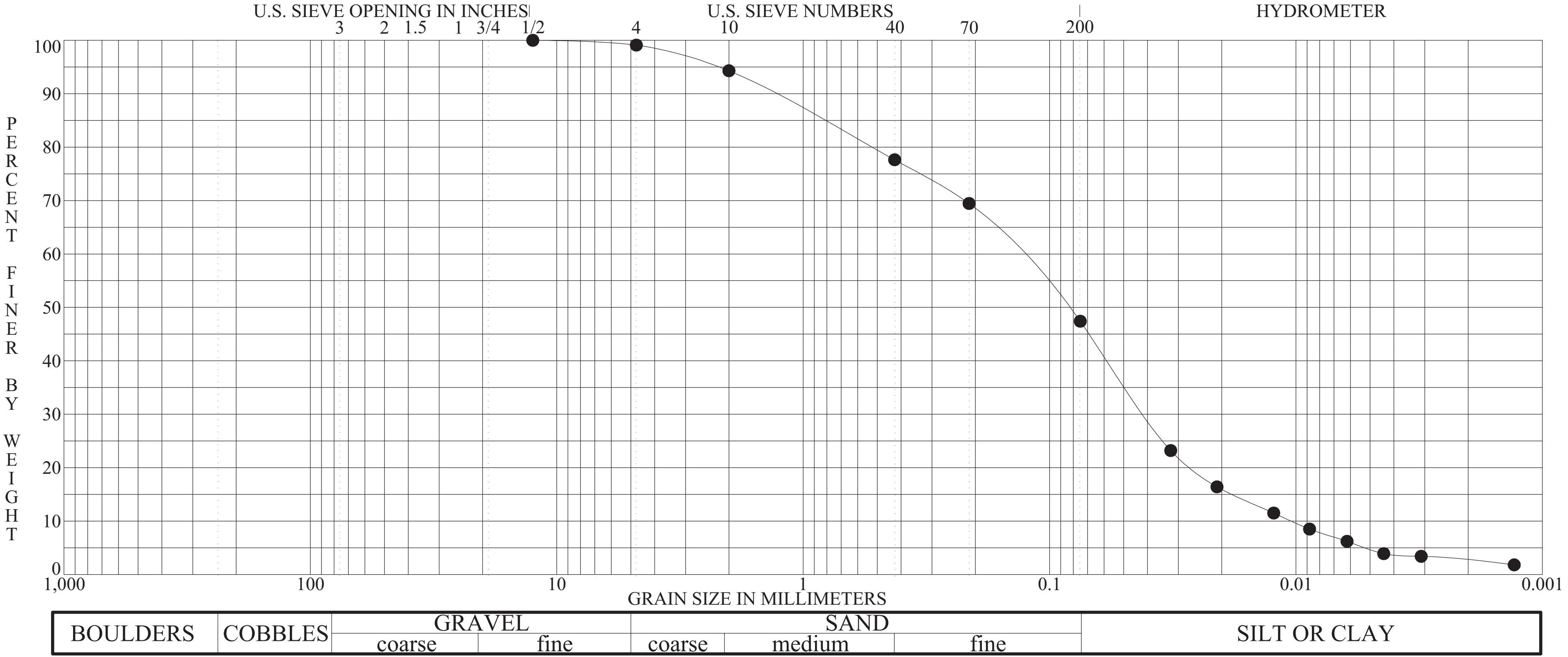

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0904 S-15 22.0' to 22.7'**	**Gray and dark-gray fine to medium sand, trace coarse sand, trace fine gravel, "and" organic silt, trace clay.** **SILTY SAND SM**	**26**	**NP**	**NP**	**NP**	**1.180**	**13.048**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0904 S-15 22.0' to 22.7'**	**12.5000**	**2.2672**	**0.1358**	**0.0847**	**0.0104**	**0.90**	**51.69**	**44.82**	**2.59**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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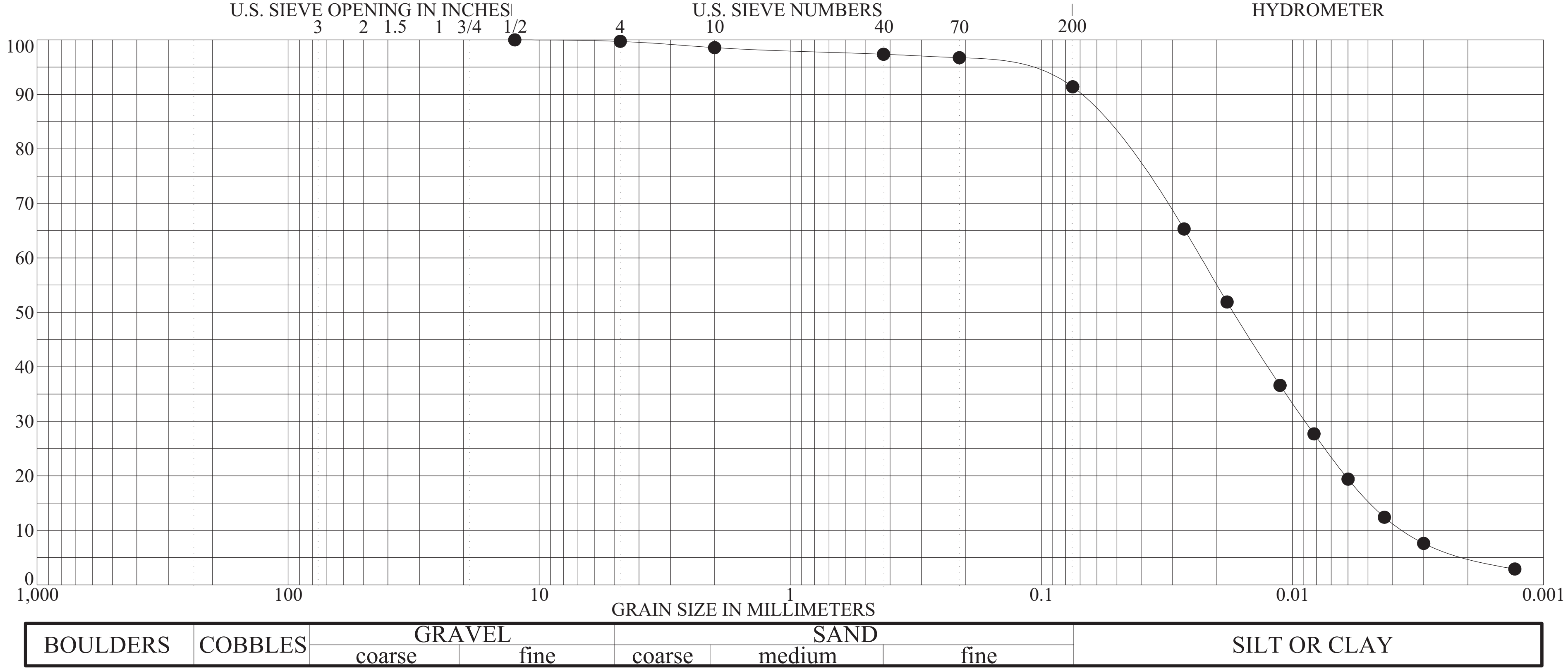

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0904 S-17 25.0' to 25.8'**	**Gray silt, trace clay, trace fine to coarse sand, trace fine gravel.** **SILT ML**	**22**	**NP**	**NP**	**NP**	**0.952**	**6.432**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0904 S-17 25.0' to 25.8'**	**12.5000**	**0.1513**	**0.0231**	**0.0171**	**0.0036**	**0.26**	**8.35**	**86.07**	**5.32**

ASTM D422

GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**

PLATE 41

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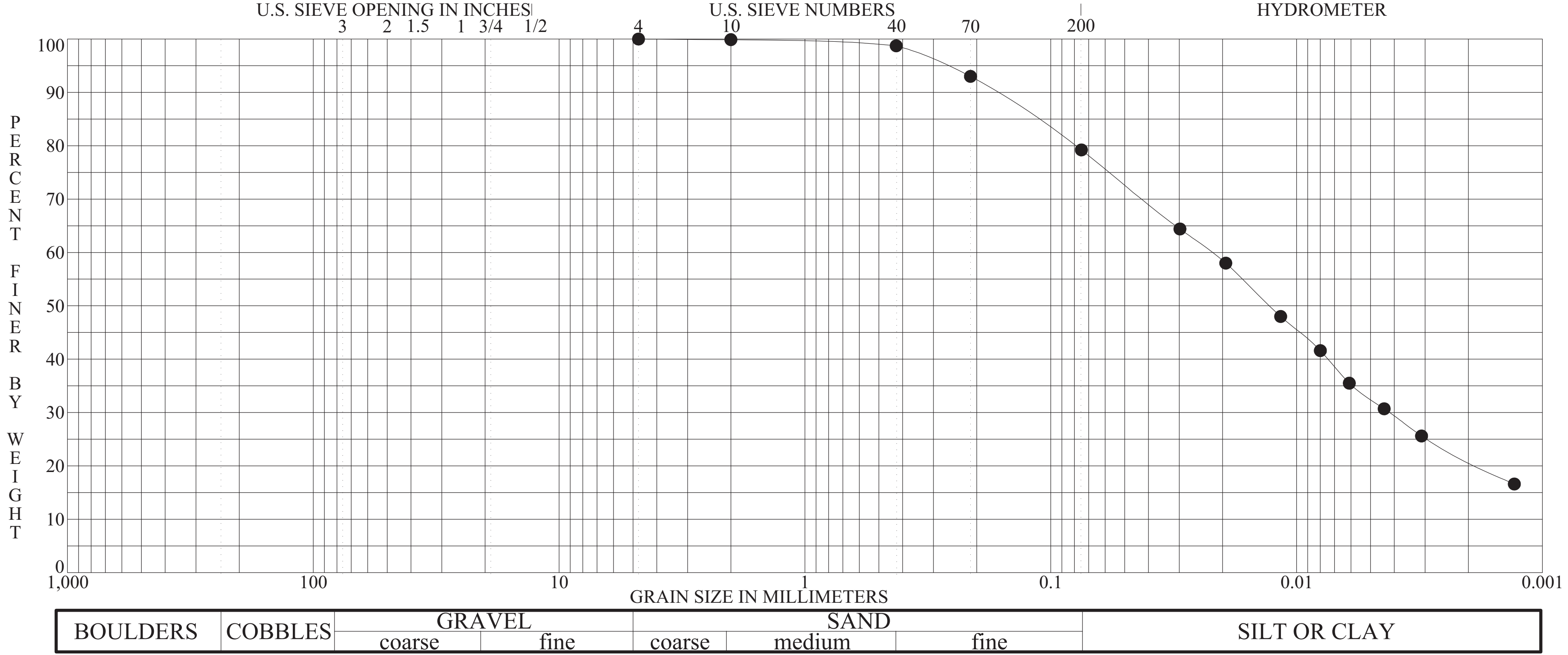

	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-PZ-BAP-0904 S-18 26.5' to 28.0'**	**Gray mottled with dark-gray organic clayey silt inter-bedded with organic silt, Little fine to coarse sand, trace fine gravel.** **ORGANIC CLAY with SAND OL**	**38**	**38**	**24**	**14**		

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-PZ-BAP-0904 S-18 26.5' to 28.0'**	**4.7500**	**0.2701**	**0.0222**	**0.0129**		**0.00**	**20.78**	**58.16**	**21.06**

ASTM D422

GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**

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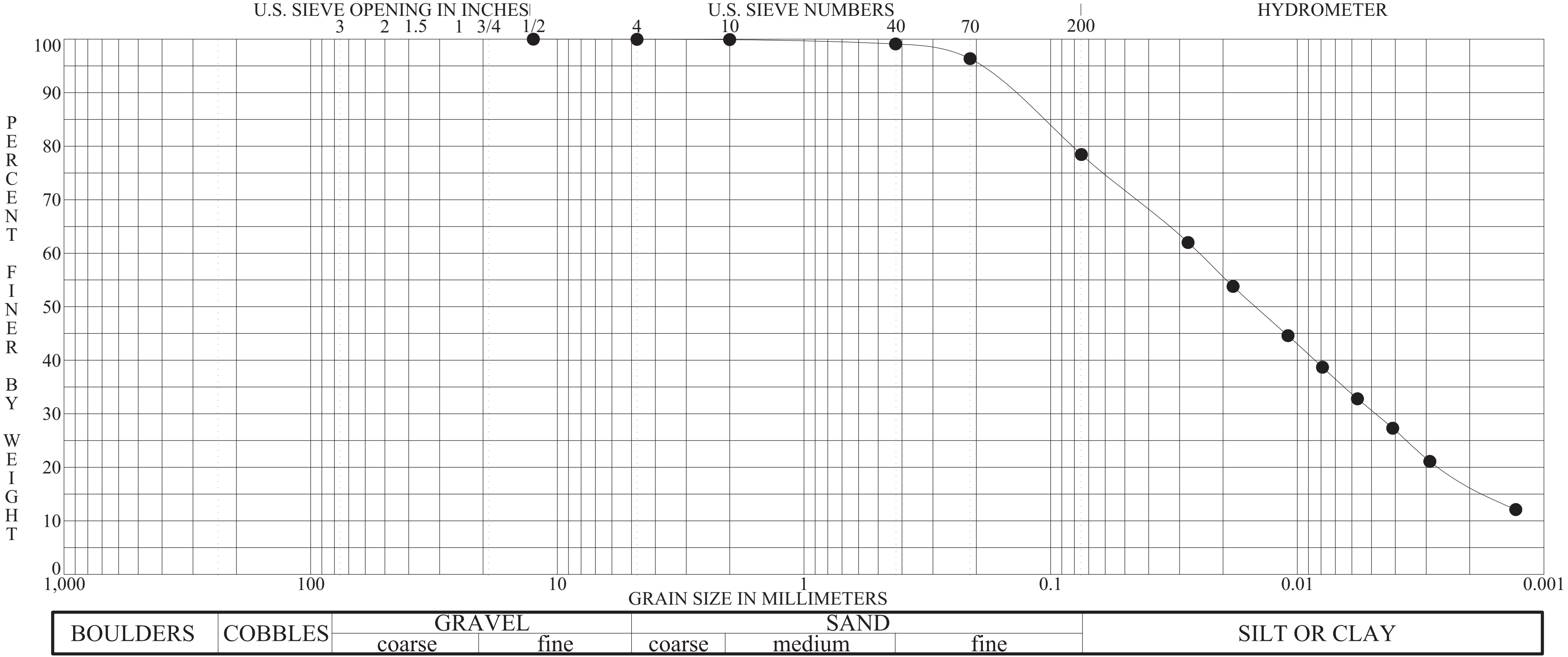

	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-PZ-BAP-0904 S-19 28.0' to 29.3'**	**Gray mottled with dark-gray organic clayey silt, some fine sand, trace medium to coarse sand, trace fine gravel.**	**47**	**42**	**30**	**12**		
		ORGANIC SILT with SAND OL						

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-PZ-BAP-0904 S-19 28.0' to 29.3'**	**12.5000**	**0.1959**	**0.0250**	**0.0147**		**0.03**	**21.53**	**61.51**	**16.93**

ASTM D422

GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**

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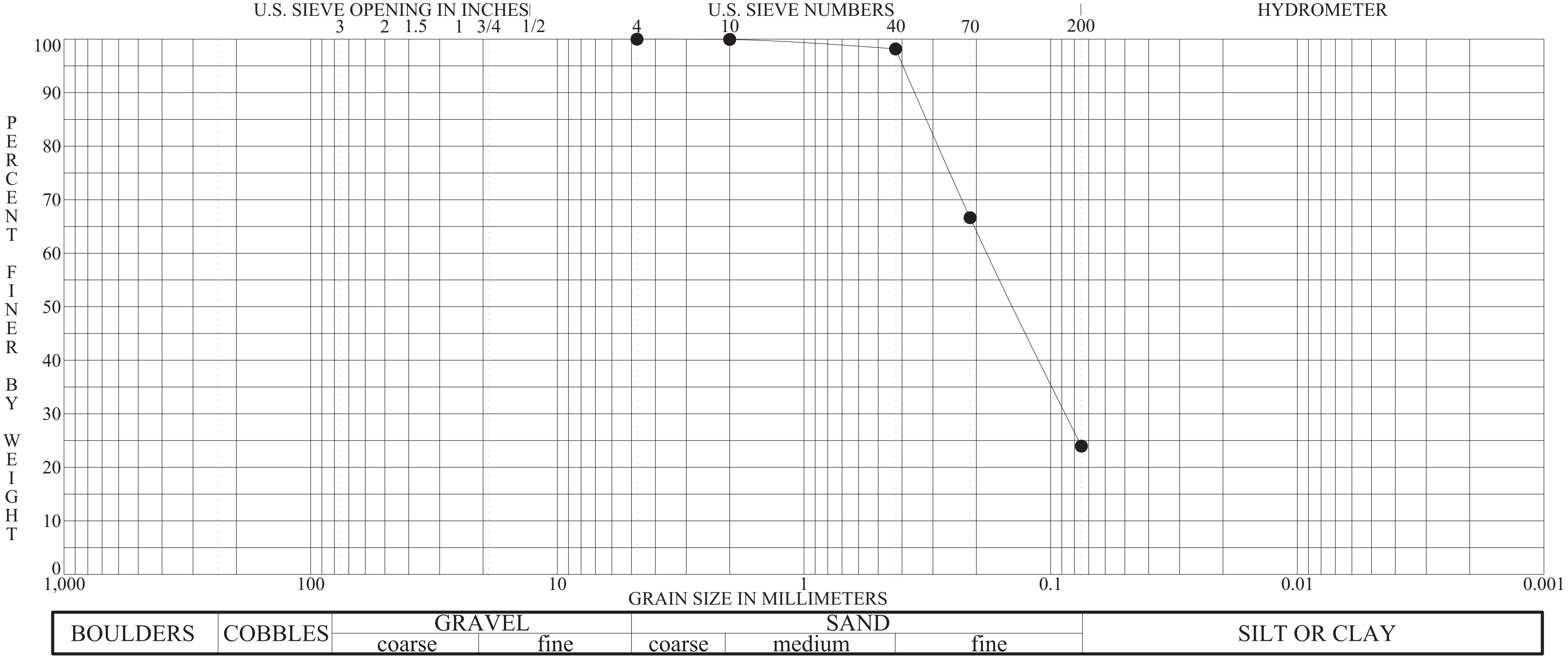

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0904 S-21 36.0' to 37.4'**	**Brown and gray fine sand, trace medium to coarse sand, some silt.**						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0904 S-21 36.0' to 37.4'**	**4.7500**	**0.3963**	**0.1804**	**0.1414**		**0.00**	**76.04**	**23.96**	

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
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PLATE 44

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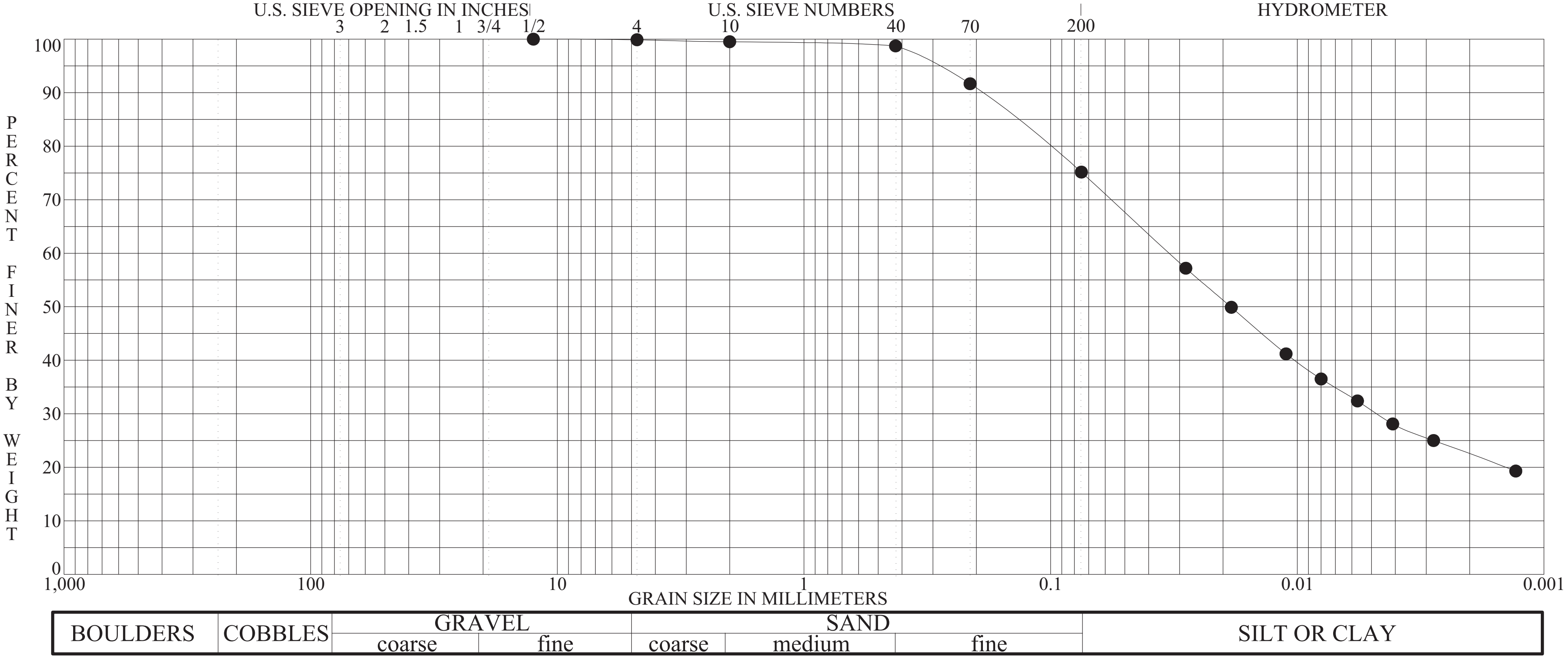

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-PZ-BAP-0905 S-3 4.0' to 5.5'	**FILL: Brown mottled with gray silty clay, some fine sand, trace medium to coarse sand, trace fine gravel.** **LEAN CLAY with SAND CL**	17	32	18	14		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-PZ-BAP-0905 S-3 4.0' to 5.5'	12.5000	0.2941	0.0329	0.0186		0.10	24.74	52.66	22.50

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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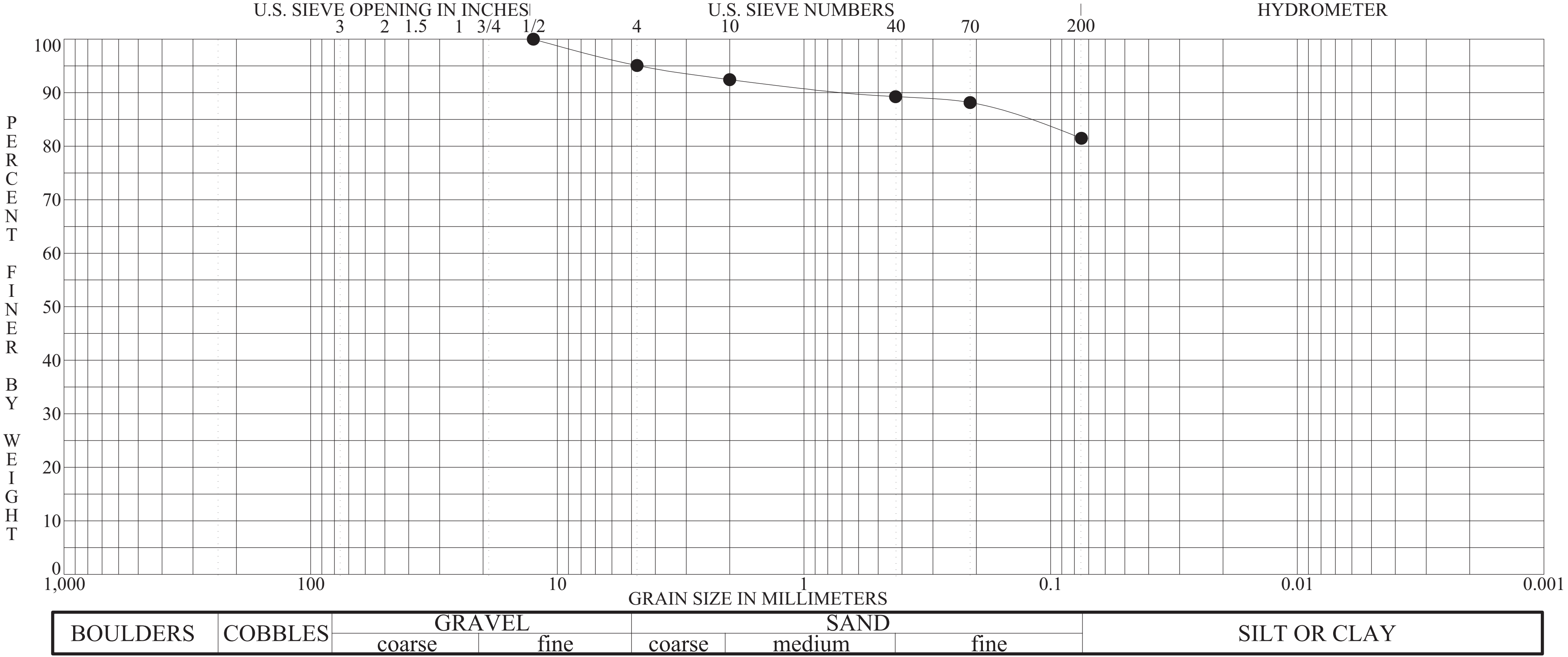

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0905 S-6B 9.7' to 10.0'**	**FILL: Brown mottled with gray silty clay inter-bedded with dark-gray organic silt, little fine to coarse sand, trace fine gravel.**	**33**					

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0905 S-6B 9.7' to 10.0'**	**12.5000**	**4.6215**				**4.92**	**13.60**	**81.48**	

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GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
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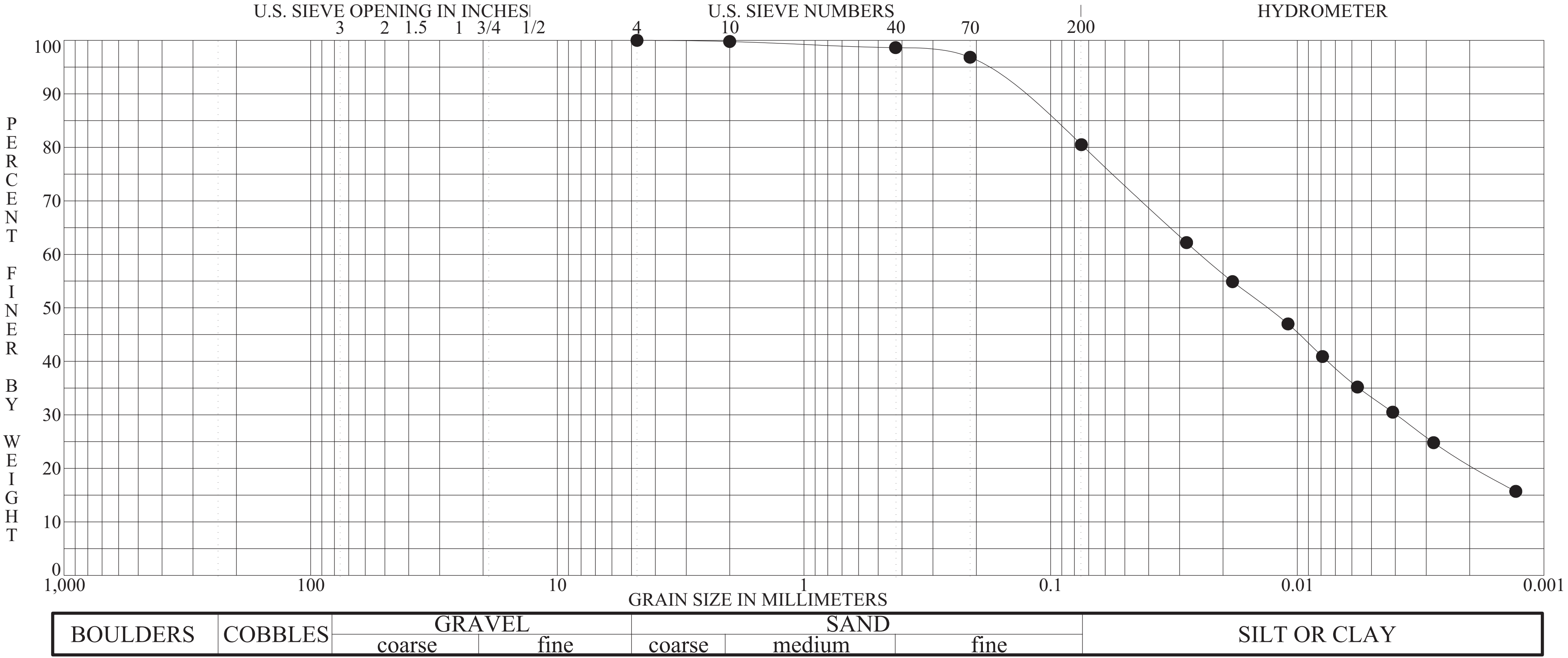


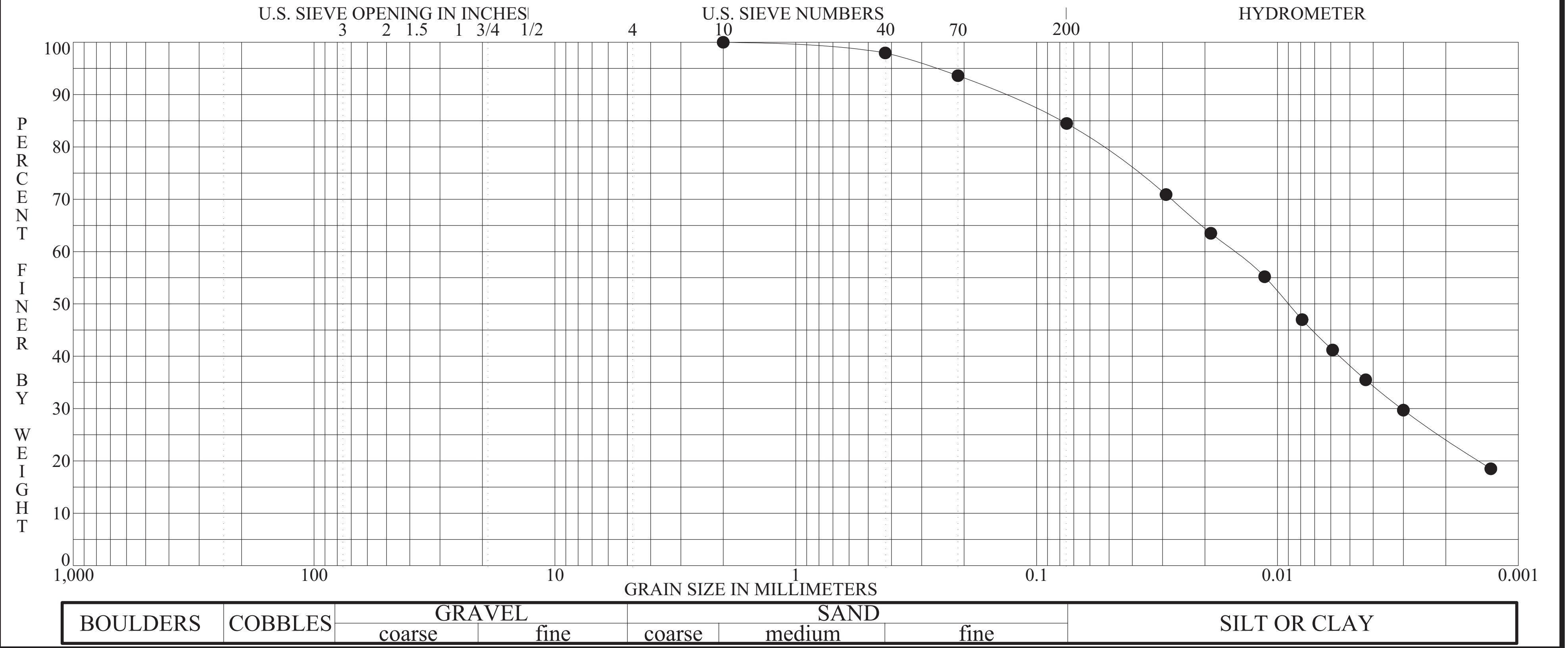
Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0905 S-8 13.5' to 15.0'**	**Gray mottled with dark-gray organic clayey silt, little fine sand, trace medium to coarse sand.**	**45**	**43**	**27**	**16**		
	ORGANIC SILT with SAND OL						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0905 S-8 13.5' to 15.0'**	**4.7500**	**0.1885**	**0.0247**	**0.0133**		**0.00**	**19.49**	**59.70**	**20.81**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0905 S-9 16.0' to 17.5'**	**Gray mottled with dark-gray organic clayey silt, little fine to medium sand.** **ORGANIC CLAY with SAND OL**	**42**	**40**	**25**	**15**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0905 S-9 16.0' to 17.5'**	**2.0000**	**0.2645**	**0.0152**	**0.0090**		**0.00**	**15.51**	**60.22**	**24.27**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
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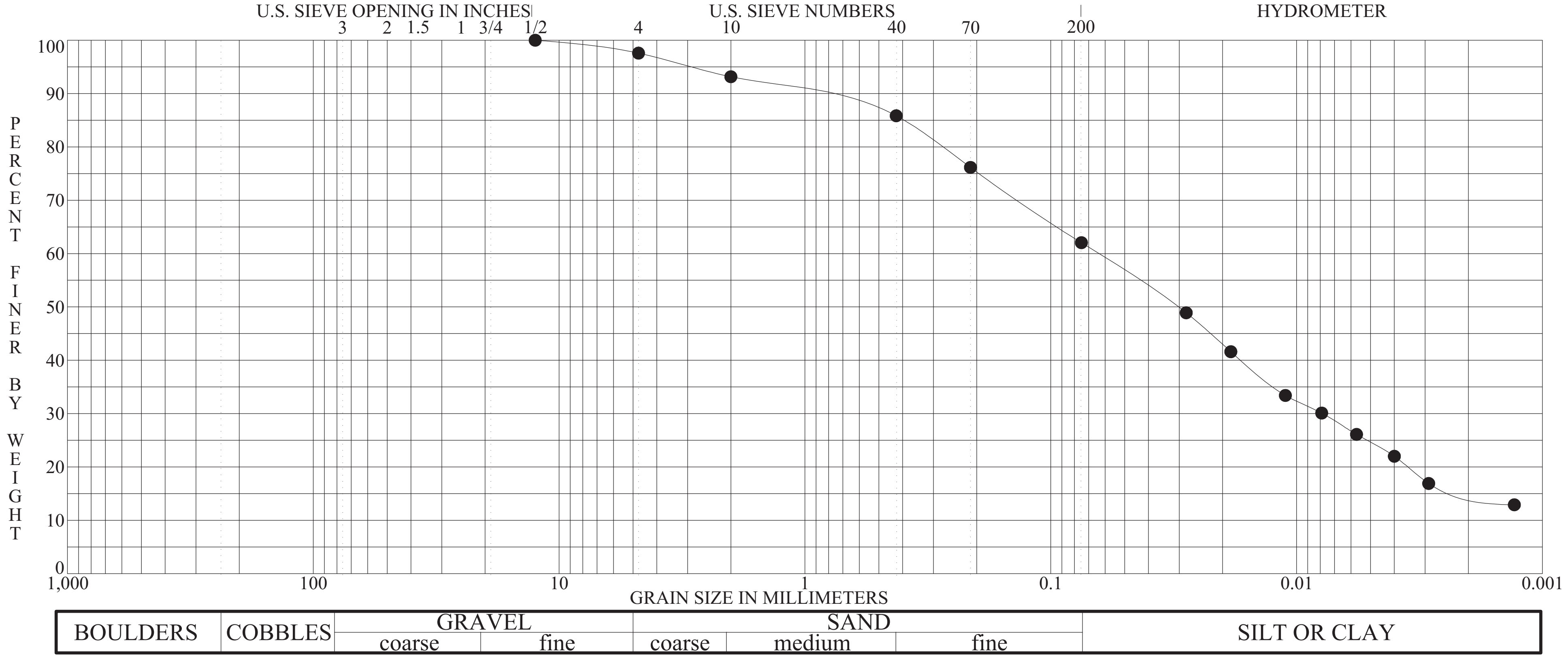

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0905 S-11 21.0' to 21.4'**	**Gray mottled with brown silty clay, some fine to medium sand, trace coarse sand, trace fine gravel, few seams of fine to medium sand.** **SANDY LEAN CLAY CL**	**38**	**38**	**23**	**15**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0905 S-11 21.0' to 21.4'**	**12.5000**	**2.8652**	**0.0644**	**0.0305**		**2.41**	**35.54**	**47.00**	**15.05**

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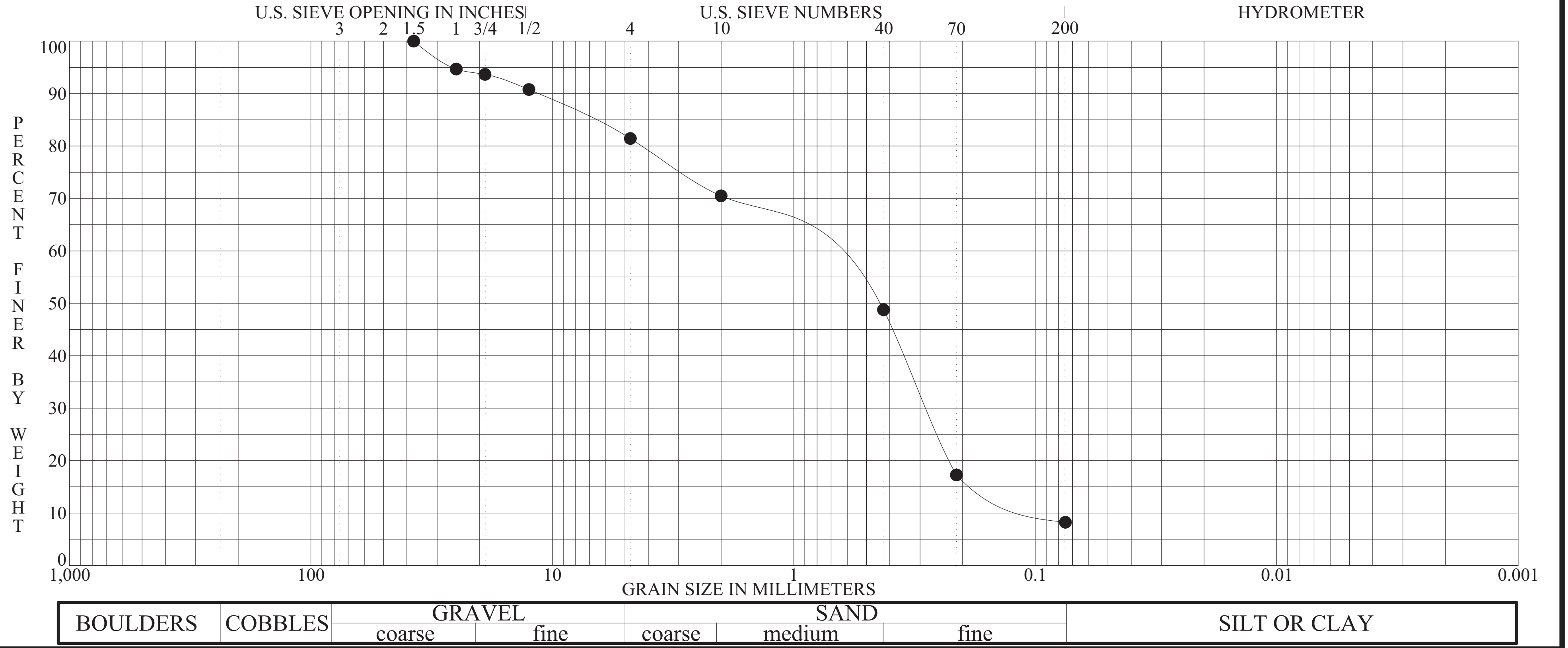
GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-PZ-BAP-0905 S-13 26.0' to 27.0'**	**Brown and gray fine to coarse sand, little fine gravel, trace silt.**					**0.907**	**10.293**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-PZ-BAP-0905 S-13 26.0' to 27.0'**	**37.5000**	**25.6140**	**0.9461**	**0.4637**	**0.0919**	**18.56**	**73.20**	**8.23**	

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GRADATION CURVE

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LOCATION BRILLIANT, OHIO
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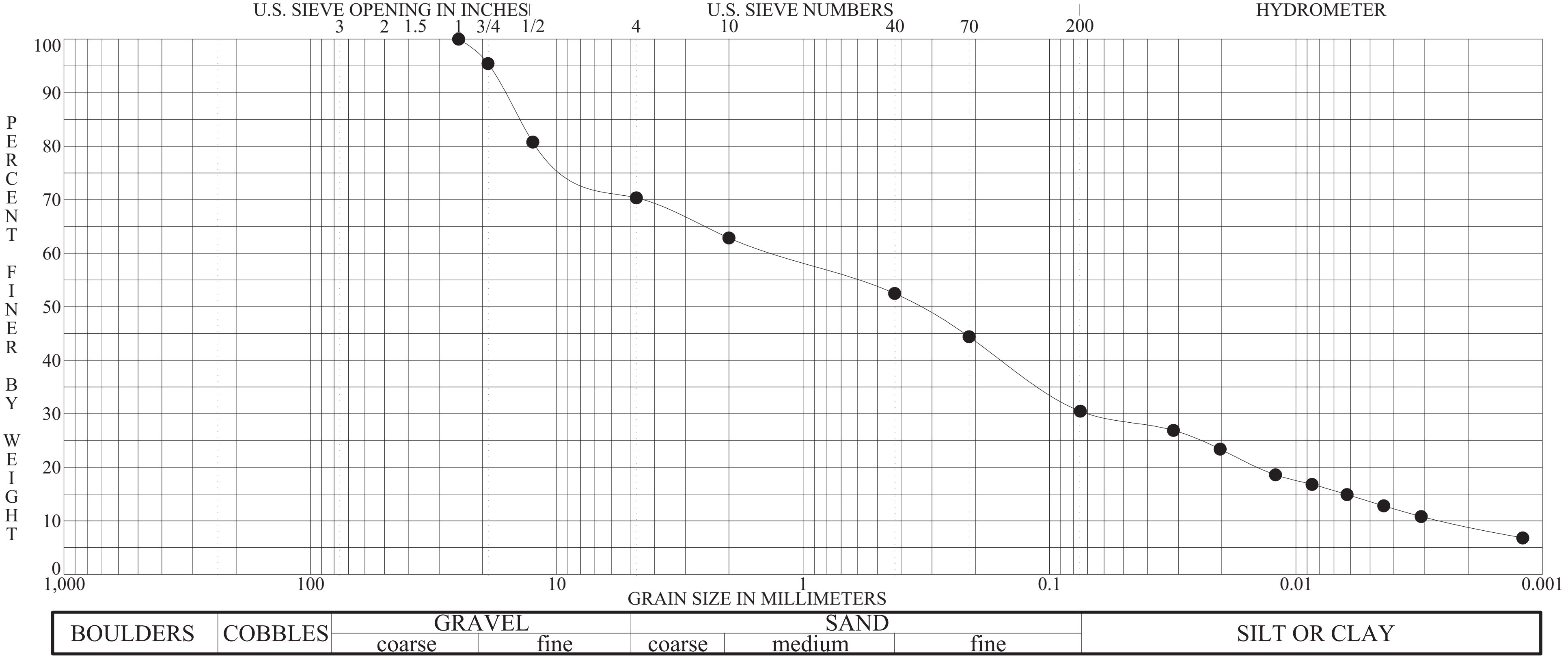

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0906 S-8 12.0' to 13.0'**	**FILL: Gray and brown fine to coarse sand, some fine to coarse gravel(sandstone fragments), some silty clay.**					**1.328**	**509.008**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0906 S-8 12.0' to 13.0'**	**25.0000**	**18.7626**	**1.3051**	**0.3431**	**0.0026**	**29.65**	**39.87**	**21.53**	**8.95**

ASTM D422

GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**

PLATE 51

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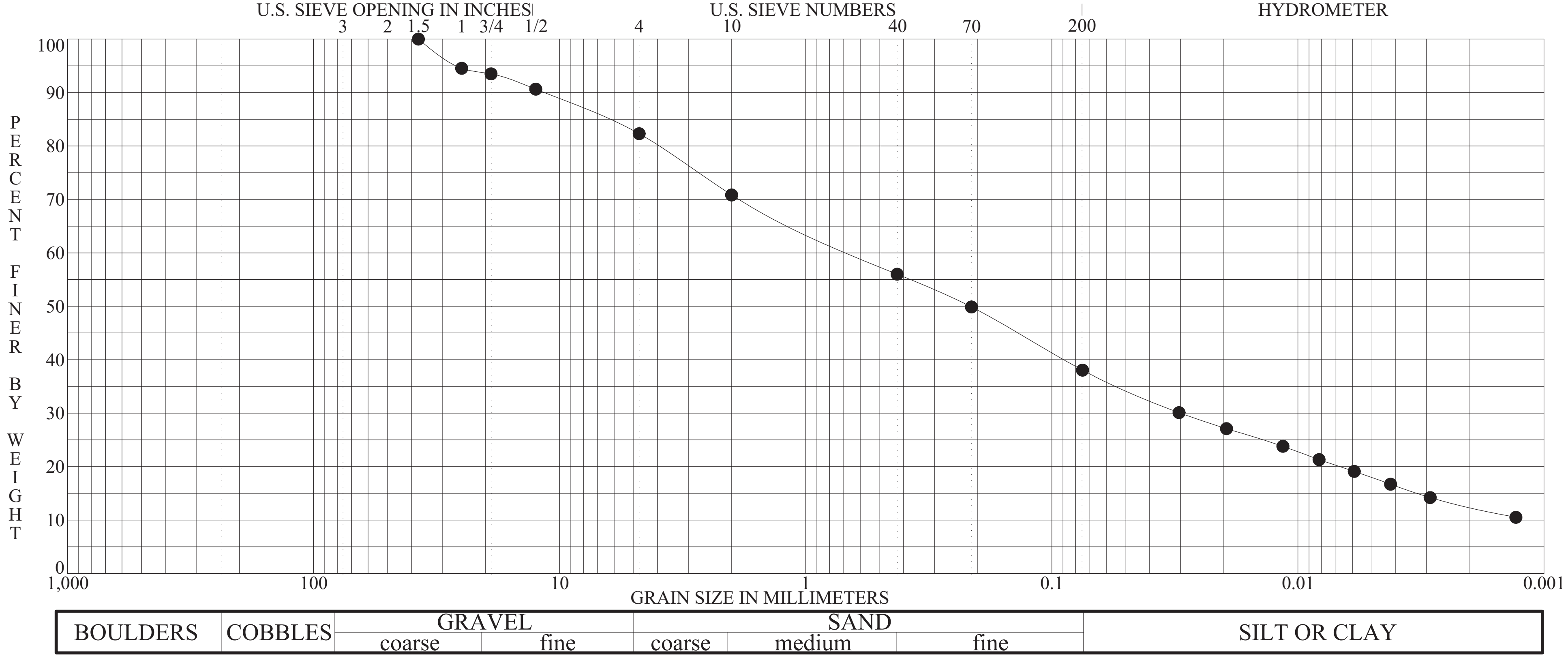


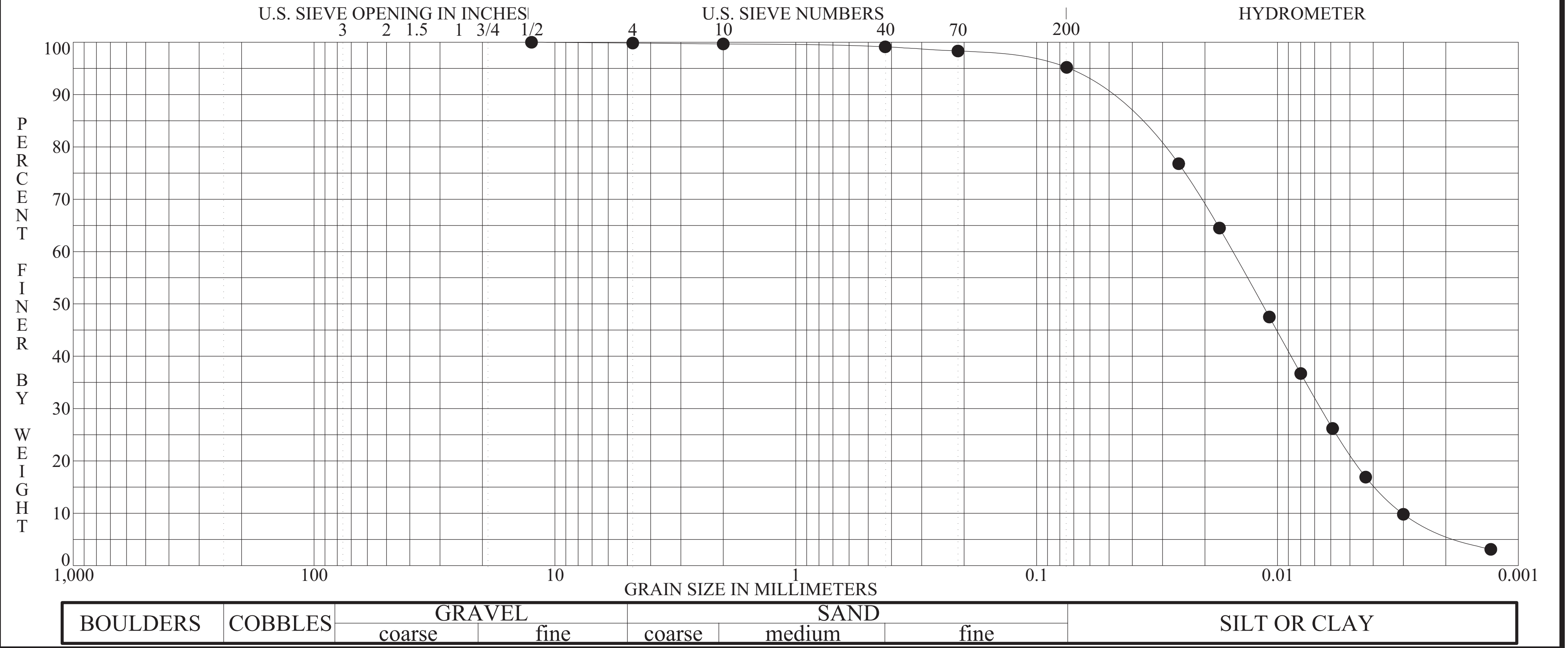
Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-BAP-0906 S-11 16.5' to 17.3'	FILL: Brown fine to coarse sand, little fine to coarse gravel, "and" silty clay.	14	31	19	12		
	CLAYEY SAND with GRAVEL SC						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-BAP-0906 S-11 16.5' to 17.3'	37.5000	25.8719	0.6448	0.2152		17.70	44.25	25.56	12.49

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 DATE 7/6/09



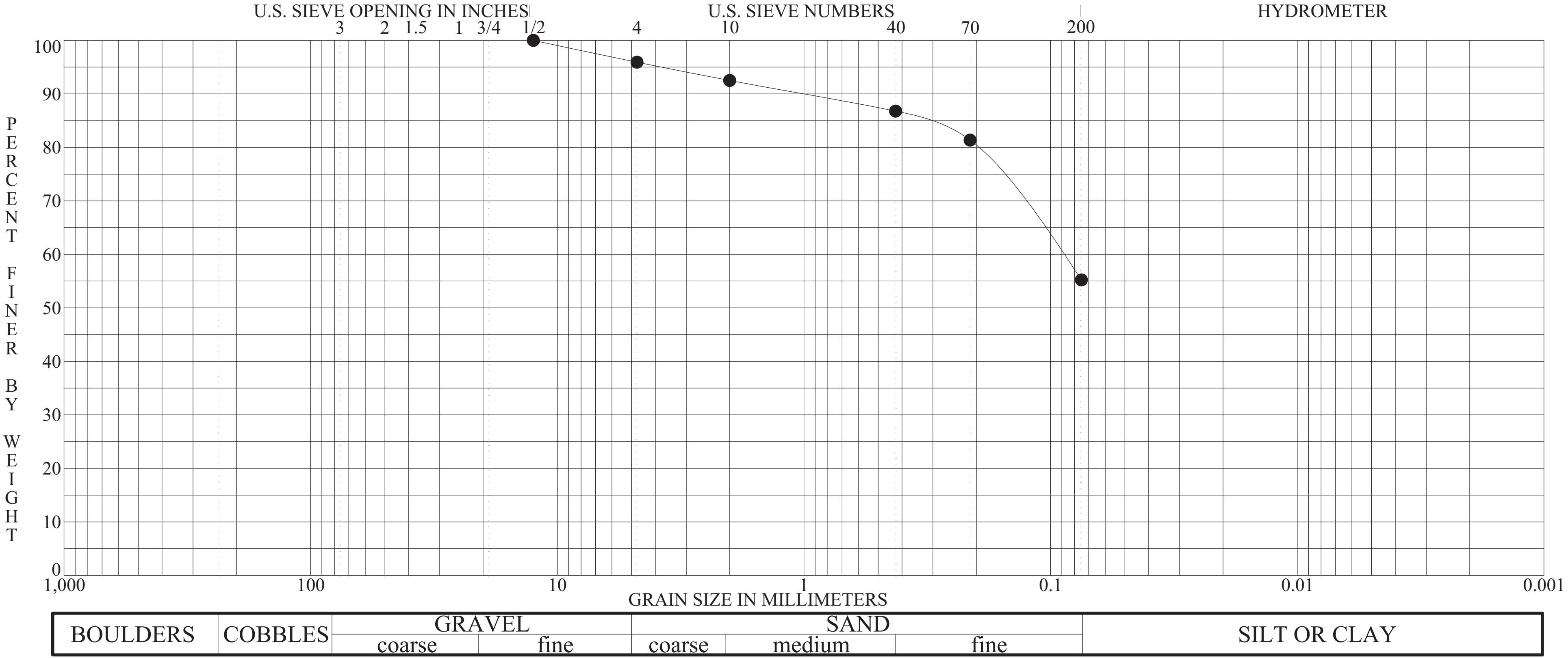
	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0906 S-15 24.0' to 25.0'**	**Gray silt, trace clay, trace fine to coarse sand, trace fine gravel.** **SILT ML**	**31**	**NP**	**NP**	**NP**	**0.934**	**5.061**

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0906 S-15 24.0' to 25.0'**	**12.5000**	**0.0741**	**0.0153**	**0.0116**	**0.0030**	**0.15**	**4.64**	**88.66**	**6.55**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0906 S-16 25.5' to 26.5'**	**Gray silt, some fine sand, trace medium to coarse sand, trace fine gravel.**						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0906 S-16 25.5' to 26.5'**	**12.5000**	**3.7584**	**0.0907**			**4.08**	**40.69**	**55.23**	

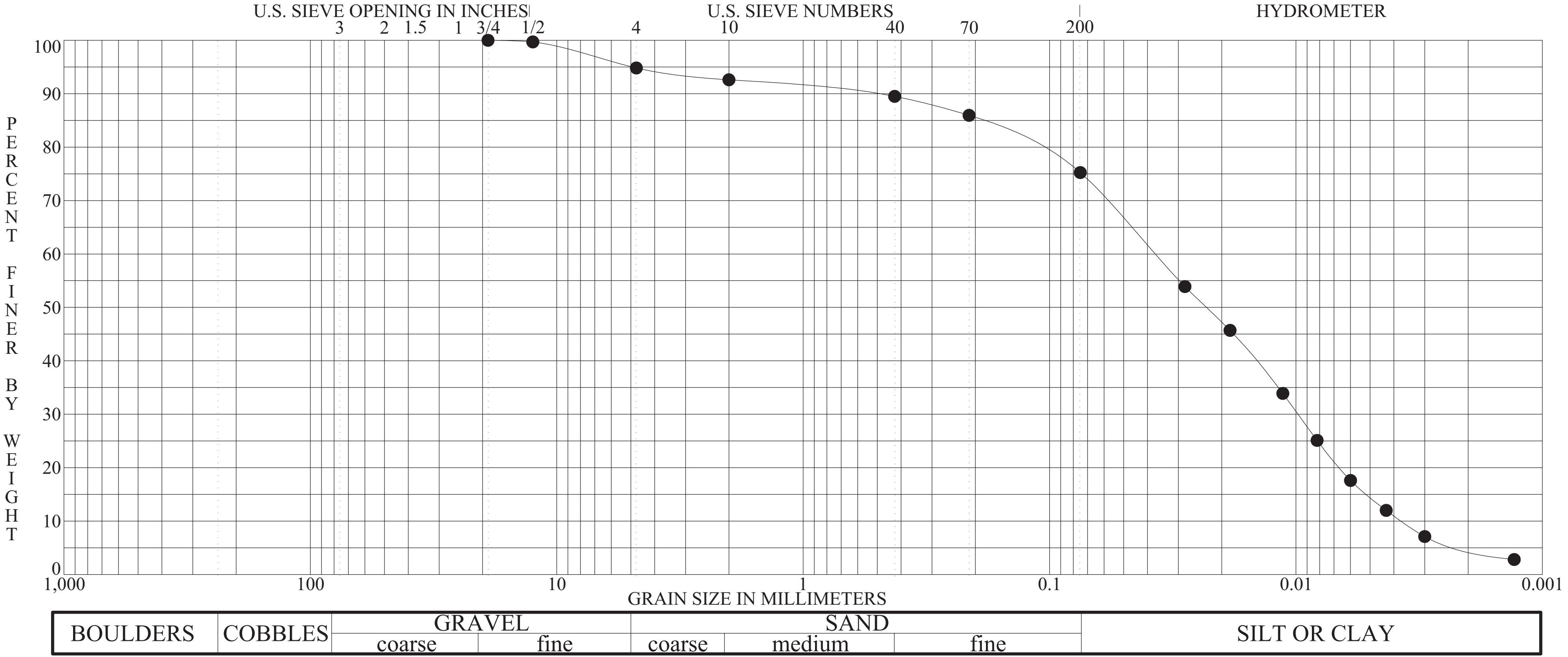
ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

GRN-EPA W/ASTM-BBCM

BBCM



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0906 S-17 27.0' to 28.2'**	**Graybrown silt, trace clay, little fine to coarse sand, trace fine gravel** **SILT with SAND ML**	**22**	**NP**	**NP**	**NP**	**0.694**	**10.046**

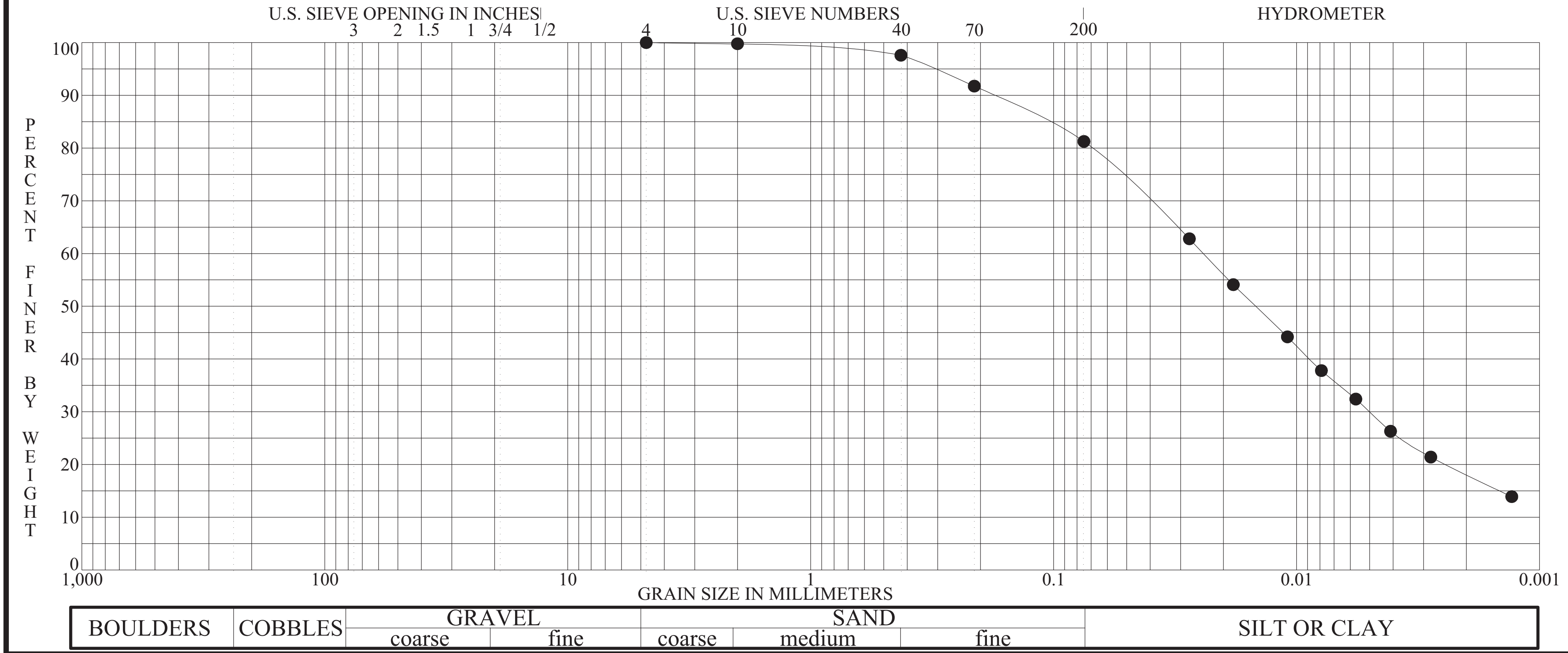
Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0906 S-17 27.0' to 28.2'**	**19.0000**	**4.9211**	**0.0373**	**0.0231**	**0.0037**	**5.18**	**19.58**	**70.23**	**5.02**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

BBCM



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0906 S-19 31.0' to 32.0'**	**Dark-gray organic clayey silt, little fine sand, trace medium to coarse sand inter-bedded with silt and silty clay.** **ORGANIC CLAY with SAND OL**	**34**	**33**	**22**	**11**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0906 S-19 31.0' to 32.0'**	**4.7500**	**0.3120**	**0.0241**	**0.0147**		**0.00**	**18.75**	**63.14**	**18.11**

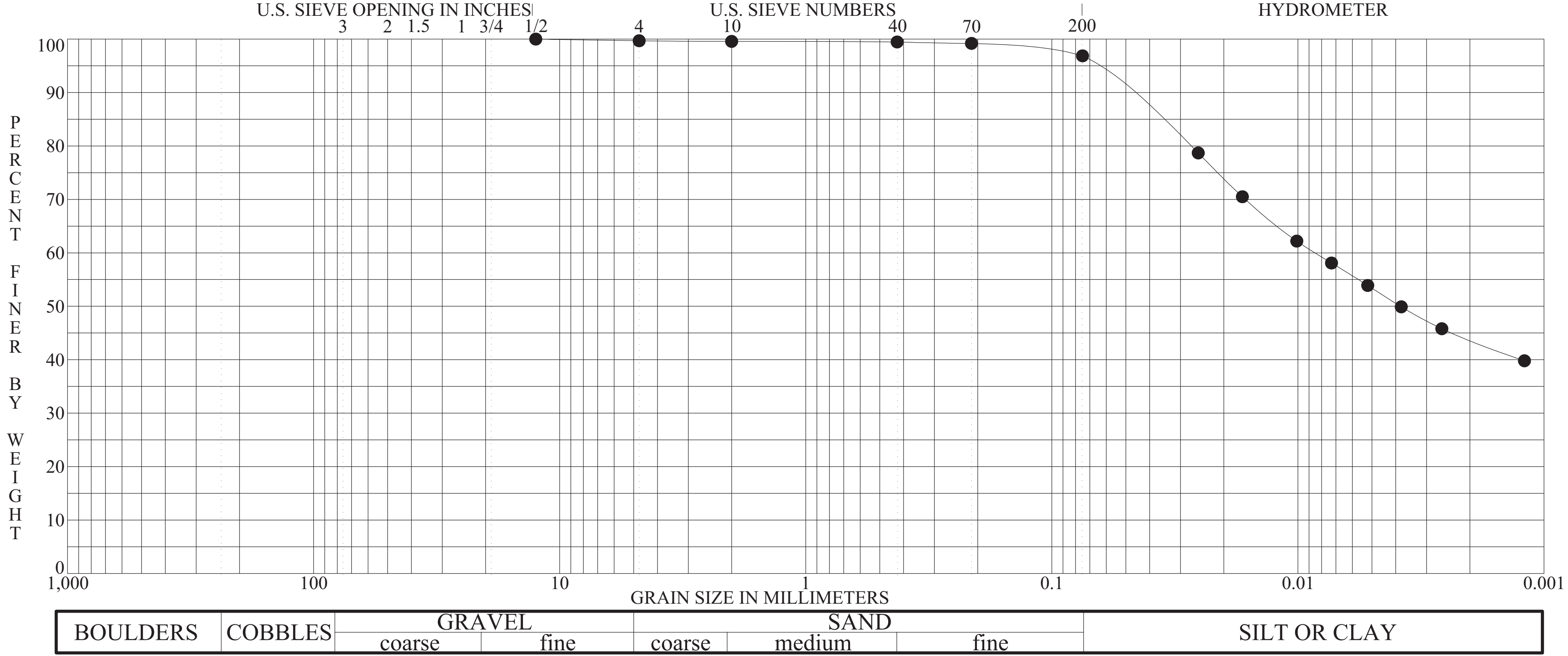
ASTM D422

GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**

GRN-EPA W/ASTM-BBCM

BBCM



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0906 S-20 33.5' to 34.4'**	**Gray organic clayey silt, trace fine to coarse sand, trace fine gravel.** **ORGANIC SILT OH**	**43**	**50**	**30**	**20**		

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0906 S-20 33.5' to 34.4'**	**12.5000**	**0.0671**	**0.0085**	**0.0038**		**0.30**	**2.82**	**53.11**	**43.76**

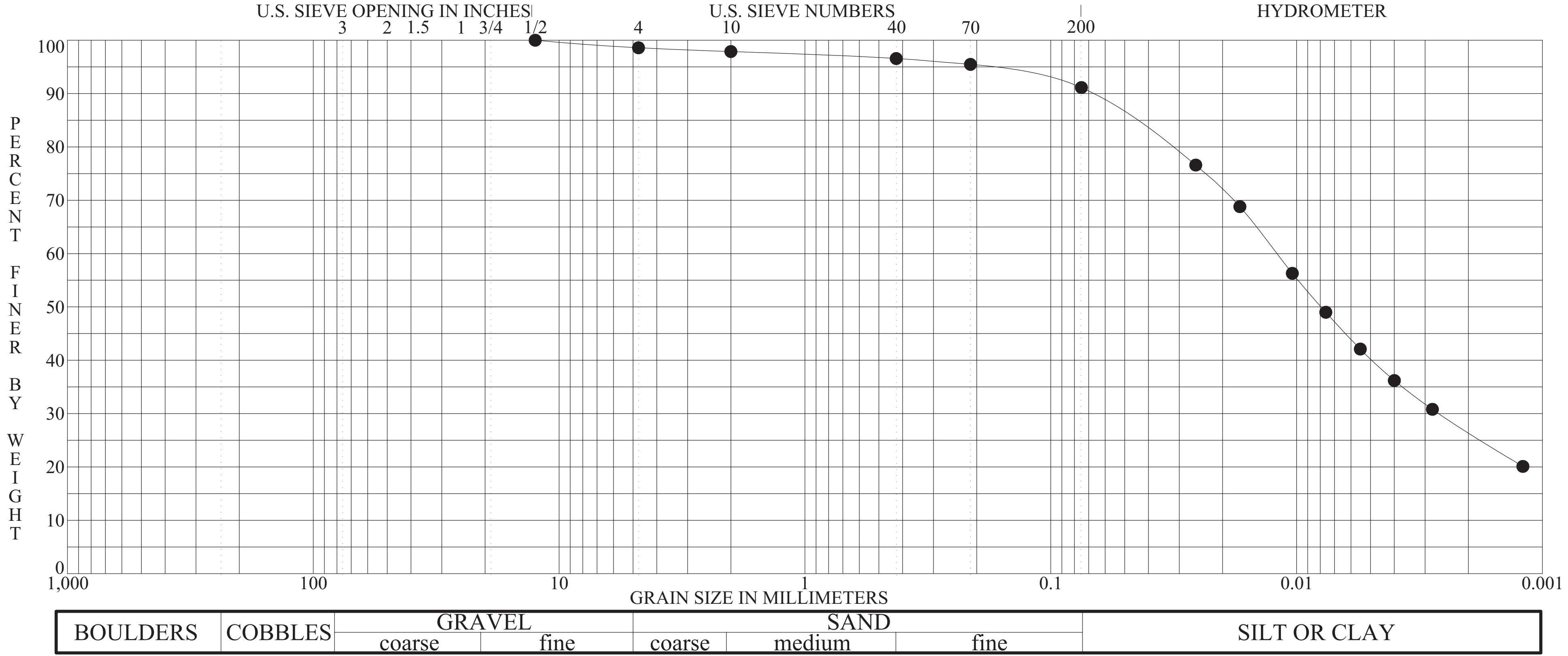
ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

GRN-EPA W/ASTM-BBCM

BBCM



	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0906 S-21 36.0' to 36.7'**	**Gray organic clayey silt, trace fine to coarse sand, trace fine gravel.** **ORGANIC CLAY OL**	**38**	**43**	**26**	**17**		

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0906 S-21 36.0' to 36.7'**	**12.5000**	**0.1891**	**0.0120**	**0.0079**		**1.41**	**7.45**	**64.58**	**26.55**

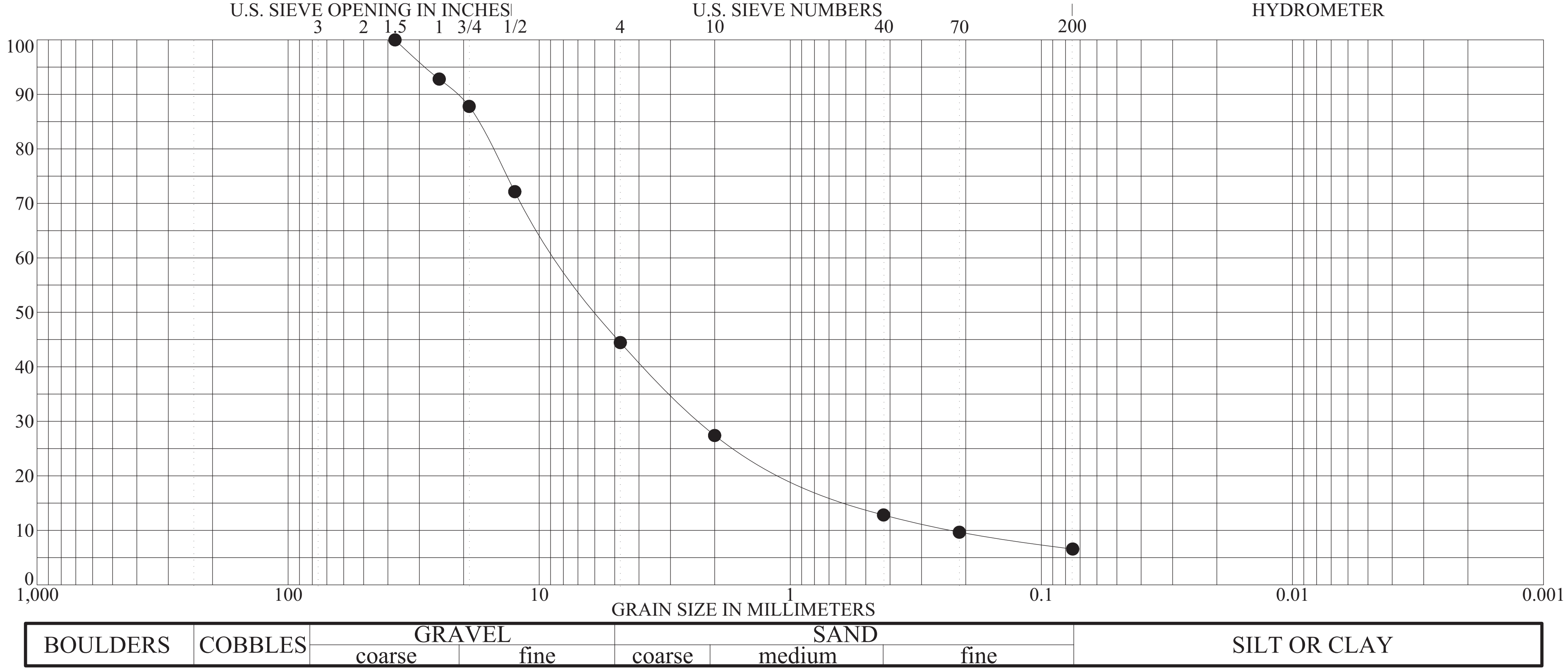
ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

GRN-EPA W/ASTM-BBCM

BBCM



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● CD-BAP-0906 S-24 43.5' to 44.2'	**Brown fine to coarse gravel, "and" fine to coarse sand, trace silt.**					**2.781**	**35.724**

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● CD-BAP-0906 S-24 43.5' to 44.2'	**37.5000**	**28.2858**	**8.1765**	**5.7650**	**0.2289**	**55.54**	**37.89**	**6.57**	

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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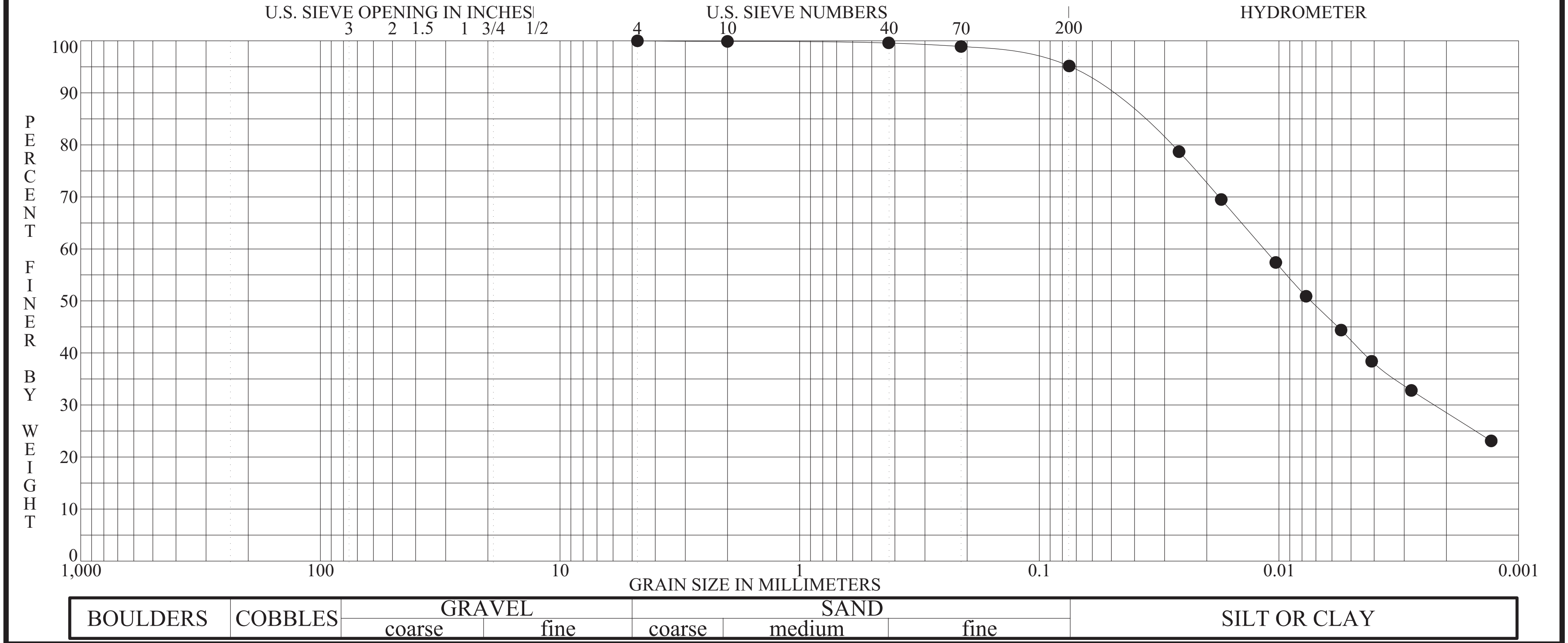


Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0907 ST-6A II 8.5' to 9.9'**	**FILL: Hard brown, gray and dark-gray silty clay inter-mixed with organic silt, trace fine to coarse sand.** **SILT ML**	**28**	**47**	**29**	**18**		

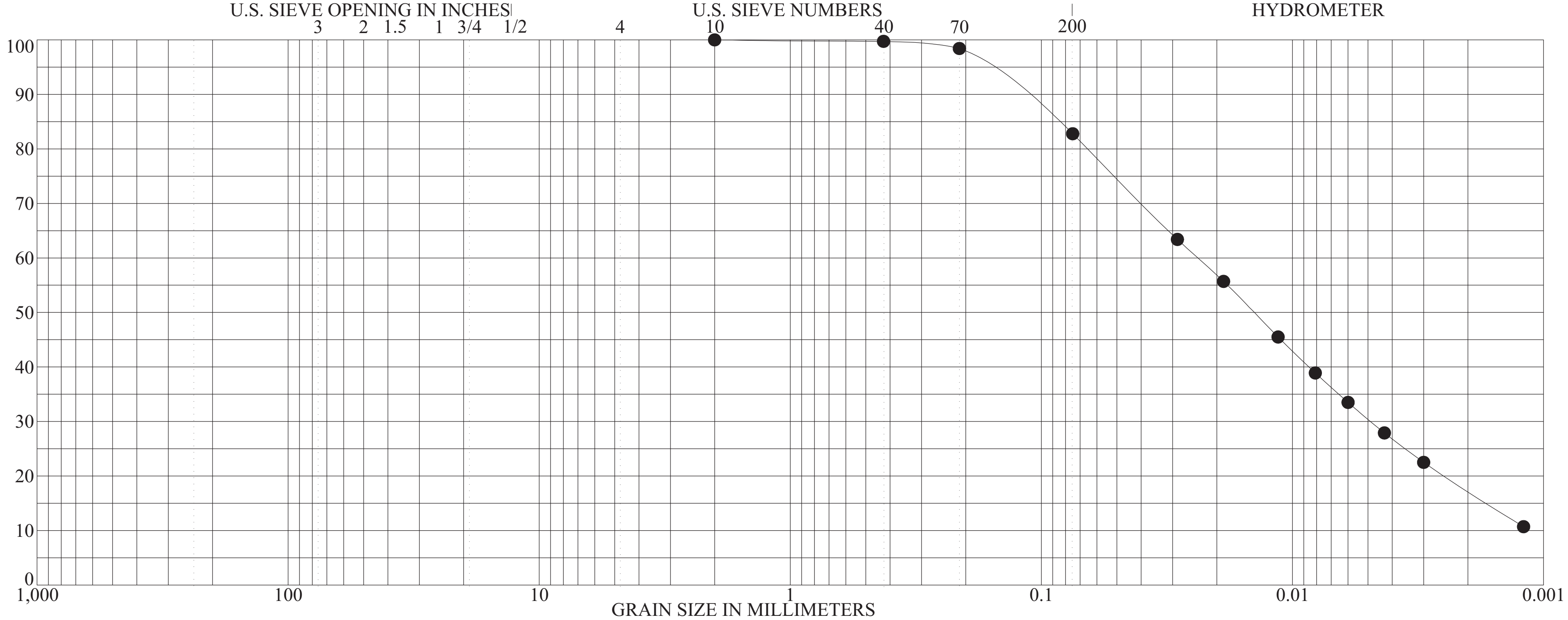
Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0907 ST-6A II 8.5' to 9.9'**	**4.7500**	**0.0742**	**0.0115**	**0.0073**		**0.00**	**4.83**	**66.62**	**28.55**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

BBCM



BOULDERS	COBBLES	GRAVEL		SAND			SILT OR CLAY
		coarse	fine	coarse	medium	fine	

	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0907 S-7 11.0' to 12.0'**	**Gray organic clayey silt, little fine to medium sand.**						

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0907 S-7 11.0' to 12.0'**	**2.0000**	**0.1688**	**0.0238**	**0.0142**		**0.00**	**17.21**	**65.51**	**17.28**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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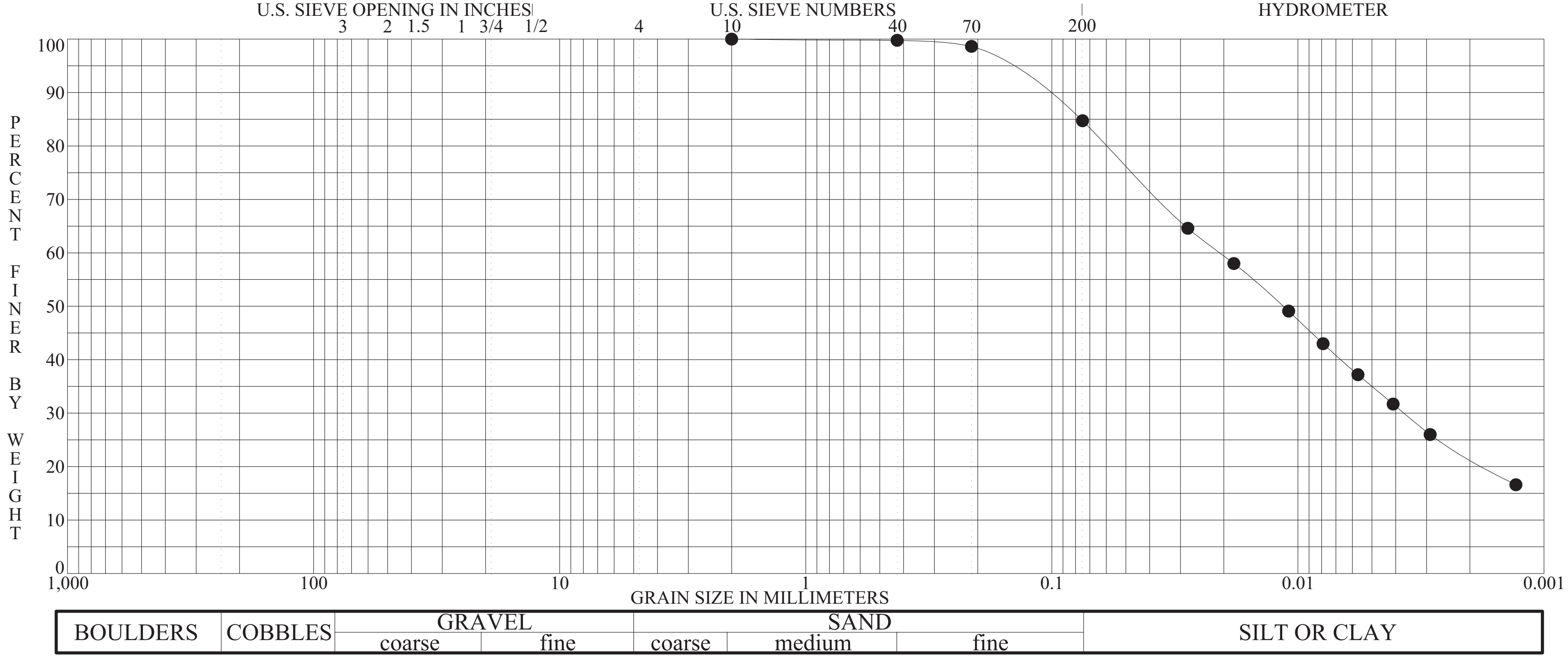

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0907 S-8 13.5' to 14.6'**	**Gray organic clayey silt, little fine to medium sand, few seams of fine sand.** **ORGANIC SILT with SAND OL**	**43**	**44**	**28**	**16**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0907 S-8 13.5' to 14.6'**	**2.0000**	**0.1615**	**0.0207**	**0.0115**		**0.00**	**15.27**	**63.08**	**21.65**

ASTM D422

GRADATION CURVE

PROJECT **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION **BRILLIANT, OHIO**
JOB NO. **011-11497-013** **DATE** **7/6/09**

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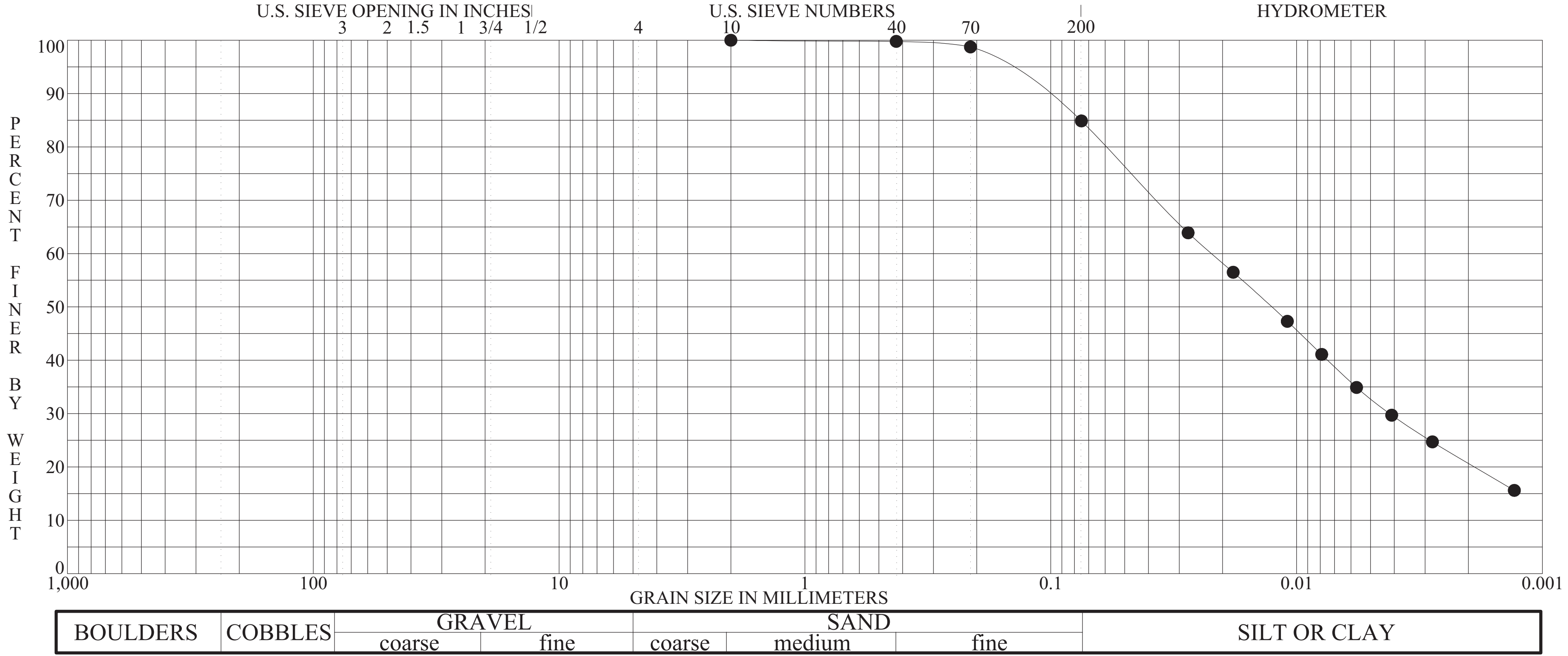

	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0907 S-9 16.0' to 17.0'**	**Gray organic clayey silt, little fine sand, trace medium sand.** **ORGANIC SILT with SAND OL**	**44**	**45**	**29**	**16**		

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0907 S-9 16.0' to 17.0'**	**2.0000**	**0.1601**	**0.0221**	**0.0126**		**0.00**	**15.12**	**64.17**	**20.71**

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

PLATE 63

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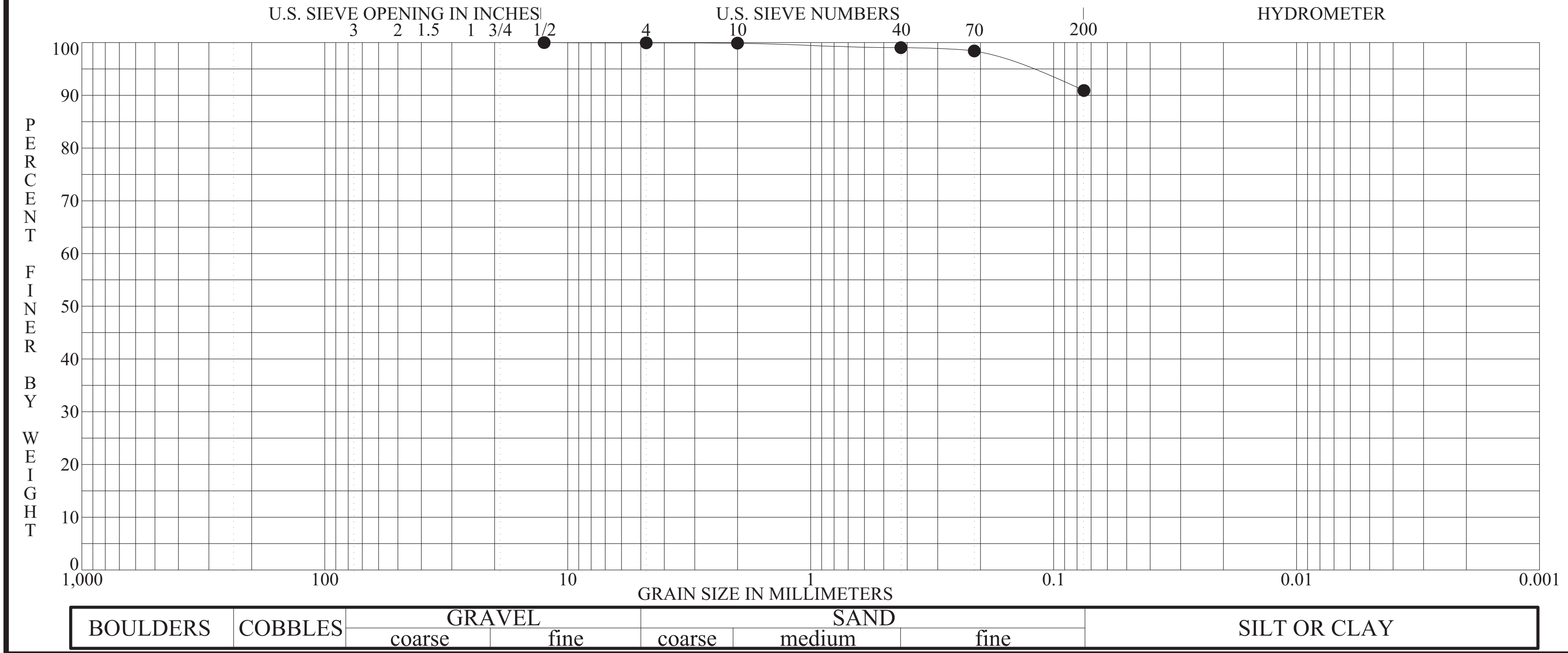
BBCM



Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0907 S-10 18.5' to 19.6'**	**Gray organic clayey silt, trace fine to coarse sand, trace fine gravel.** **ORGANIC SILT OL**	**40**	**48**	**29**	**19**		

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0907 S-10 18.5' to 19.6'**	**12.5000**	**0.1321**				**0.05**	**9.03**	**90.92**	

ASTM D422

GRADATION CURVE

PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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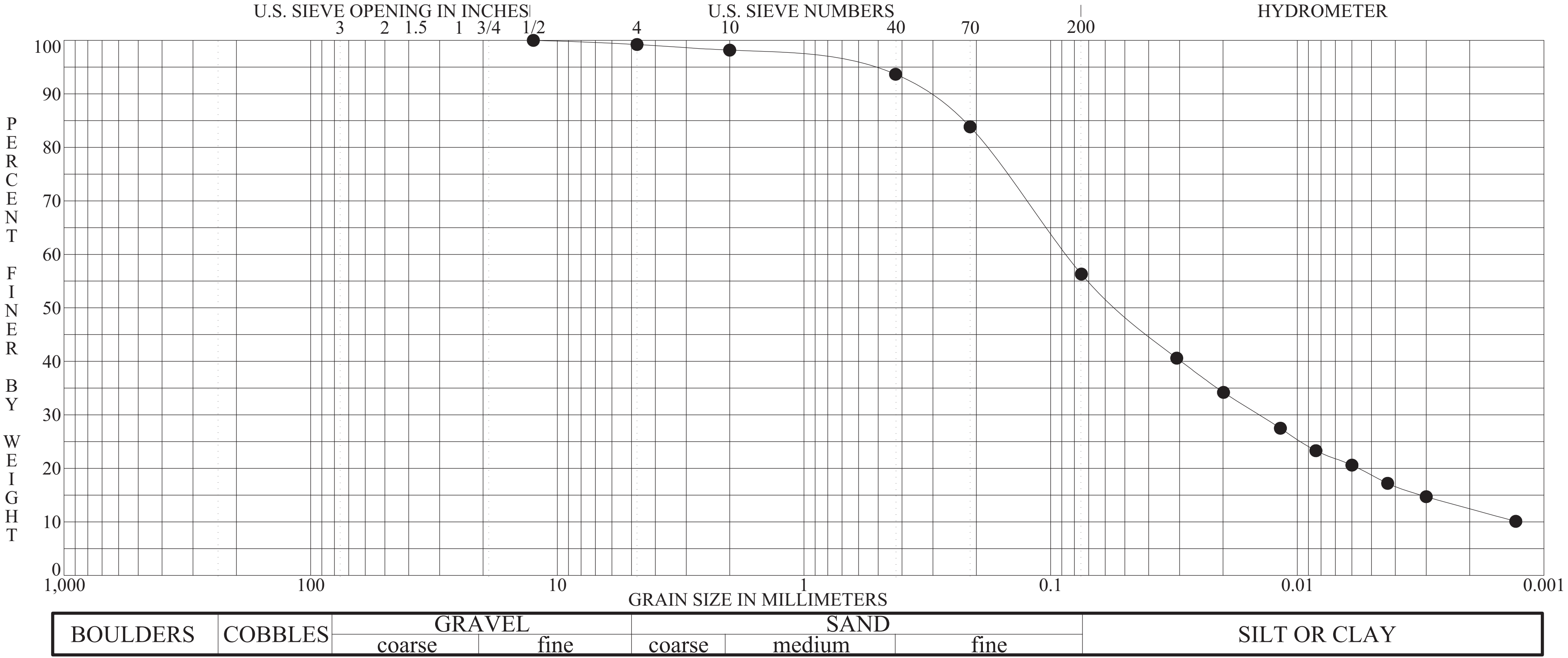

Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
● **CD-BAP-0907 S-11 21.0' to 22.0'**	**Gray organic silt, little clay, "and" fine sand, trace medium to coarse sand, trace fine gravel.**	**39**	**30**	**24**	**6**		
	SANDY ORGANIC SILT OL						

Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
● **CD-BAP-0907 S-11 21.0' to 22.0'**	**12.5000**	**0.6714**	**0.0862**	**0.0525**		**0.77**	**42.92**	**43.85**	**12.47**

ASTM D422

GRADATION CURVE

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LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

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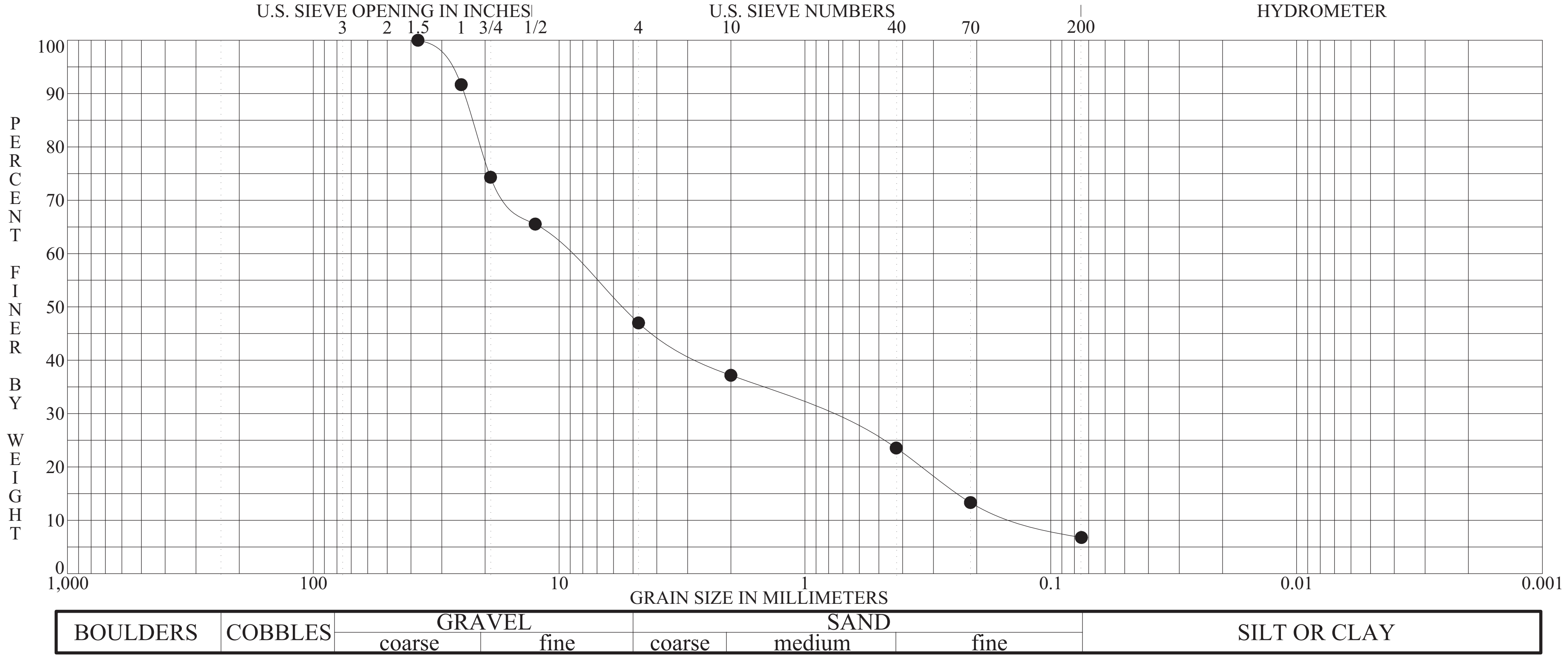


	Specimen Identification - Depth	Classification	MC%	LL	PL	PI	Cc	Cu
●	**CD-BAP-0907 S-13 26.0' to 26.6'**	**Brown fine to coarse gravel, "and" fine to coarse sand, trace silt.**					**0.668**	**74.823**

	Specimen Identification - Depth	D100	D95	D60	D50	D10	%Gravel	%Sand	%Silt	%Clay
●	**CD-BAP-0907 S-13 26.0' to 26.6'**	**37.5000**	**29.3892**	**9.3620**	**5.5538**	**0.1251**	**52.99**	**40.23**	**6.77**	

ASTM D422

GRADATION CURVE

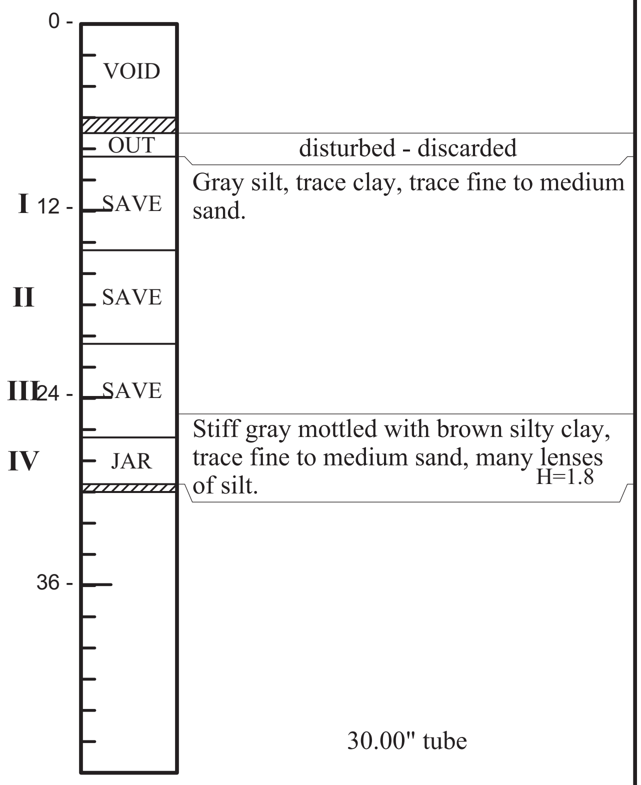
PROJECT CARDINAL PLANT ASH POND INVESTIGATION
LOCATION BRILLIANT, OHIO
JOB NO. 011-11497-013 **DATE** 7/6/09

JOB NUMBER : **011-11497-013**
PROJECT : **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION : **BRILLIANT, OHIO**

BBCM

LABORATORY LOG OF SHELBY TUBES

Boring : **CD-PZ-BAP-0901** Sample : **16A**	Boring : **CD-PZ-BAP-0901** Sample : **19A**	Boring : **CD-PZ-BAP-0906** Sample : **6A**
Depth : **23.5' to 25.3'** Recovery : **21.00"**	Depth : **31.0' to 32.8'** Recovery : **20.50"**	Depth : **8.5' to 9.4'** Recovery : **0.00"**



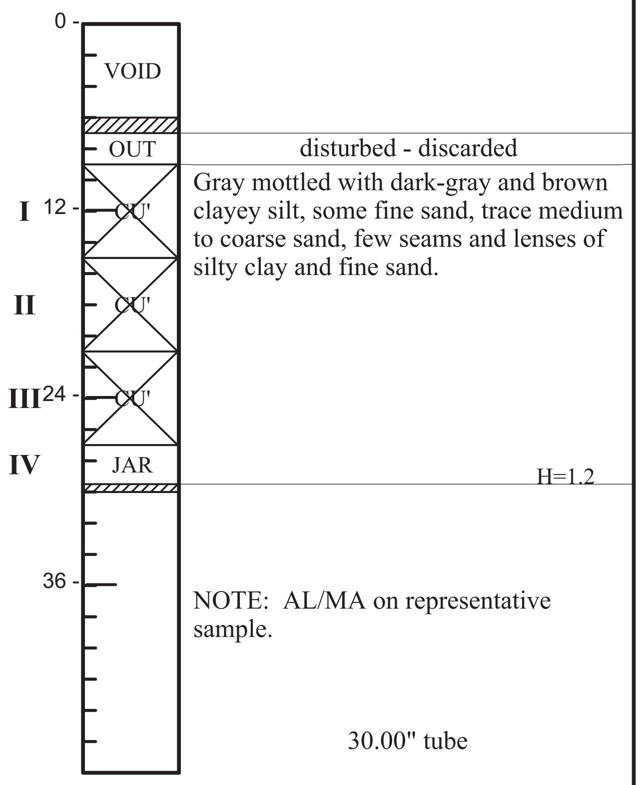
disturbed - discarded

Gray silt, trace clay, trace fine to medium sand.

Stiff gray mottled with brown silty clay, trace fine to medium sand, many lenses of silt.

H=1.8

30.00" tube



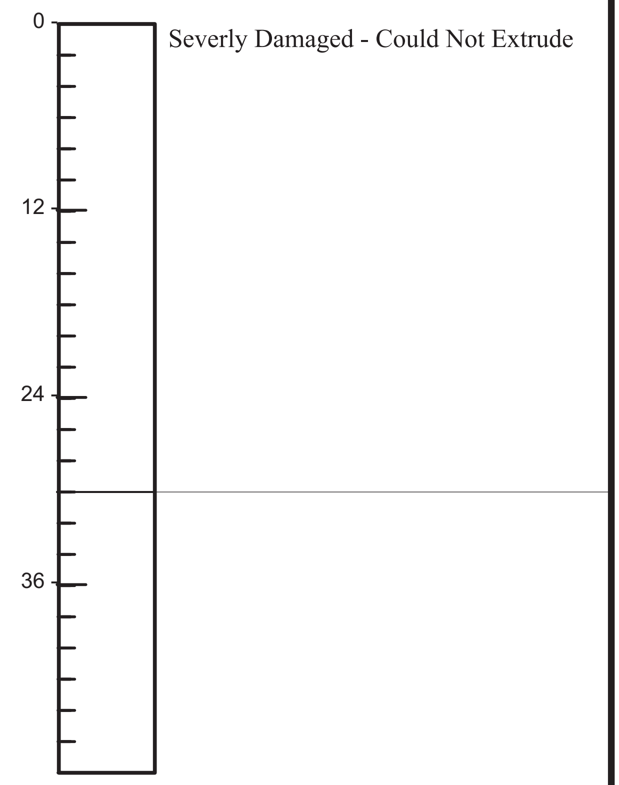
disturbed - discarded

Gray mottled with dark-gray and brown clayey silt, some fine sand, trace medium to coarse sand, few seams and lenses of silty clay and fine sand.

H=1.2

NOTE: AL/MA on representative sample.

30.00" tube



Severly Damaged - Could Not Extrude

LEGEND

■ - Consolidation, Incremental
C R S - Consolidation, C R S
P P - Permeability, Vertical / Horizontal
▭ Swelling, Test
▨ - Wax
◿ - Unconfined Compression Test
☒ - Triaxial Compression Test

H - Hand Penetrometer (tsf)
Ds - Direct Shear
LOI - Loss on Ignition
AL - Atterberg Limits
MA - Sieve/Hydrometer
SG - Specific Gravity

SL - Shrinkage Limit
POR - Porosity
UDW - Unit Dry Weight
MC - Moisture Content
D_R - Relative Density
S - Sieve

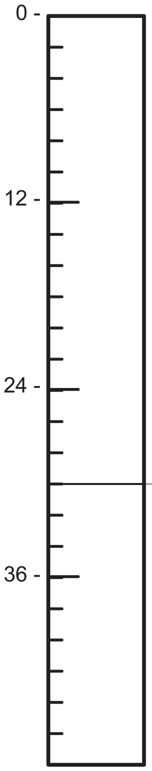
SHELBY TUBE LOG 111497013.GPJ BBCM.GDT 6/16/09

JOB NUMBER : **011-11497-013**
PROJECT : **CARDINAL PLANT ASH POND INVESTIGATION**
LOCATION : **BRILLIANT, OHIO**

BBCM

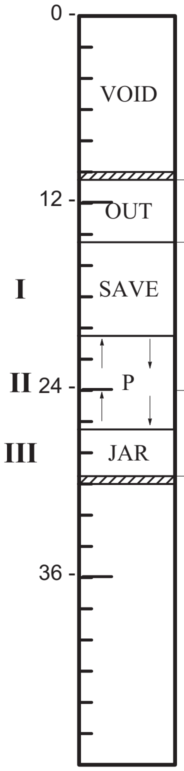
LABORATORY LOG OF SHELBY TUBES

Boring : **CD-PZ-BAP-0906** Sample : **12A**
Depth : **18.0' to 18.8'** Recovery : **0.00"**



Severly Damaged - Could Not Extrude

Boring : **CD-PZ-BAP-0907** Sample : **6A**
Depth : **8.5' to 9.9'** Recovery : **15.00"**



disturbed - discarded

FILL : Hard brown, gray and dark-gray silty clay inter-mixed with organic silt, trace fine to coarse sand.

H=4.5+

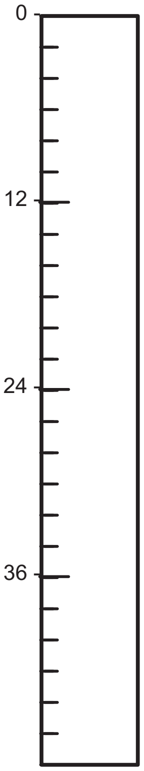
Dark-gray organic silt, little fine to medium sand, few lenses of fine sand.

H=2.2

NOTE: AL/MA on Section II

30.00" tube

Boring : Sample :
Depth : Recovery :



LEGEND

■ - Consolidation, Incremental

CRS - Consolidation, C R S

P P - Permeability, Vertical / Horizontal

Swelling, Test

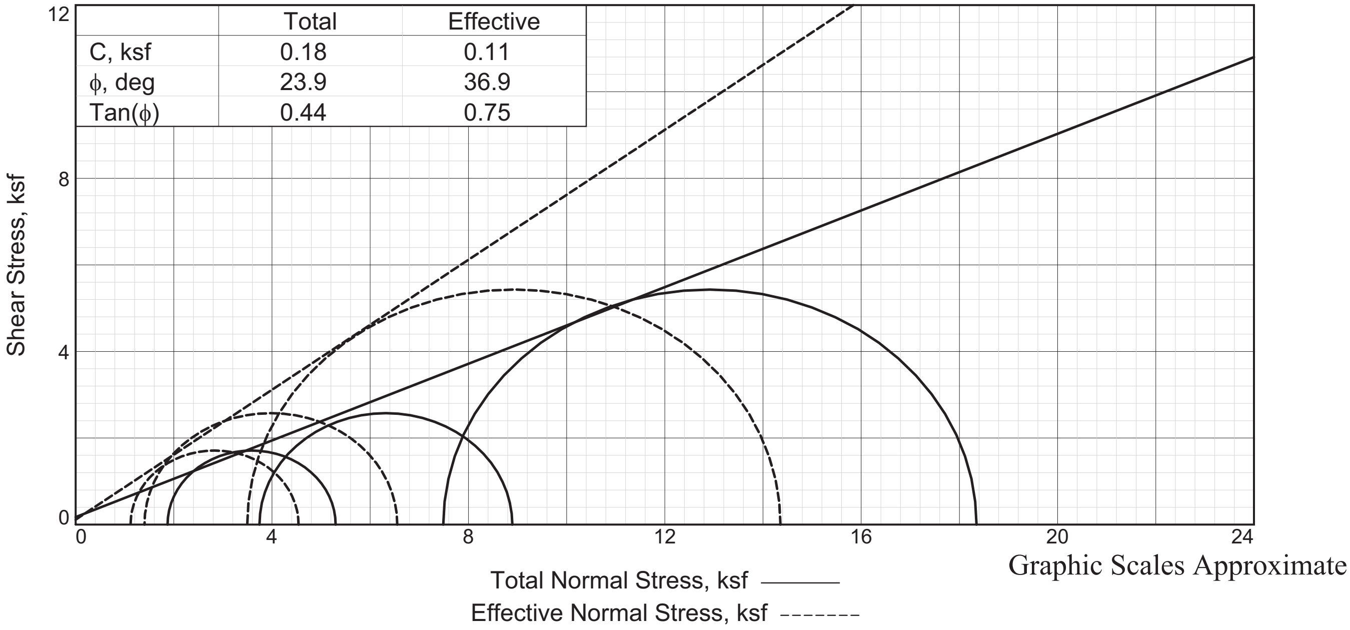
▨ - Wax

- Unconfined Compression Test

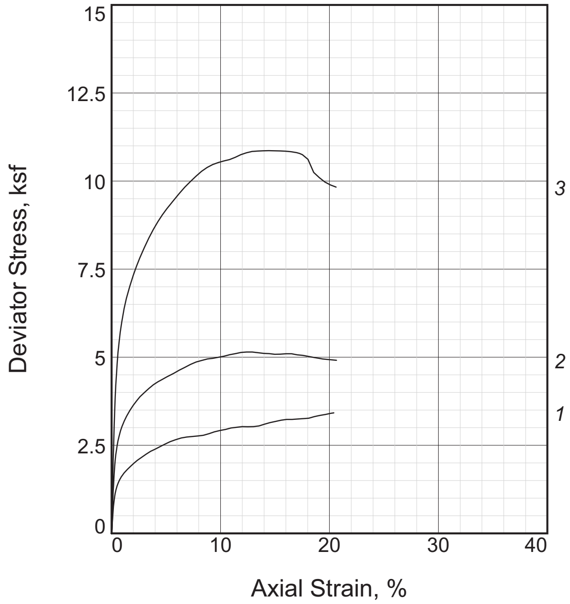
- Triaxial Compression Test

H - Hand Penetrometer (tsf)
Ds - Direct Shear
LOI - Loss on Ignition
AL - Atterberg Limits
MA - Sieve/Hydrometer
SG - Specific Gravity

SL - Shrinkage Limit
POR - Porosity
UDW - Unit Dry Weight
MC - Moisture Content
D_R - Relative Density
S - Sieve



	Total	Effective
C, ksf	0.18	0.11
ϕ, deg	23.9	36.9
Tan(ϕ)	0.44	0.75



	Sample No.	1	2	3
Initial	Water Content, %	35.1	43.8	31.9
	Dry Density, pcf	83.0	76.2	85.0
	Saturation, %	92.2	97.7	87.6
	Void Ratio	1.0297	1.2123	0.9833
	Diameter, in.	2.90	2.85	2.90
	Height, in.	5.59	5.59	5.59
At Test	Water Content, %	33.3	38.9	31.0
	Dry Density, pcf	86.9	82.6	90.3
	Saturation, %	95.6	101.0	96.5
	Void Ratio	0.9402	1.0401	0.8674
	Diameter, in.	2.86	2.78	2.85
	Height, in.	5.49	5.42	5.43
	Strain rate, in./min.	0.00	0.00	0.00
	Back Pressure, psi	40.00	40.00	40.00
	Cell Pressure, psi	53.00	66.00	92.00
	Fail. Stress, ksf	3.4	5.1	10.9
	Total Pore Pr., ksf	6.5	8.1	9.8
	Ult. Stress, ksf	3.4	4.9	9.8
	Total Pore Pr., ksf	6.5	8.0	9.9
	$\bar{\sigma}_1$ Failure, ksf	4.5	6.6	14.4
	$\bar{\sigma}_3$ Failure, ksf	1.1	1.4	3.5

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: Gray mottled with dark-gray and brown clayey silt, some fine sand, trace medium to

LL= 35 **PL=** 28 **PI=** 7

Assumed Specific Gravity= 2.7

Remarks:

1

Client:

Project: Cardinal Plant Ash Pond Investigation
Brilliant, Ohio

Location: CD-PZ-BAP-0901

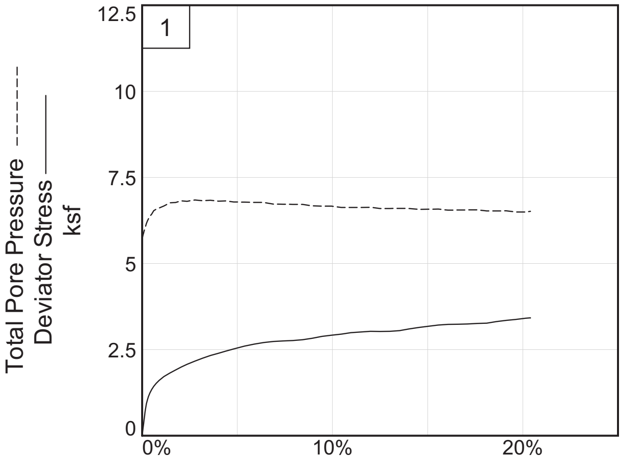
Sample Number: ST-19A **Depth:** 31.0' to 32.8'

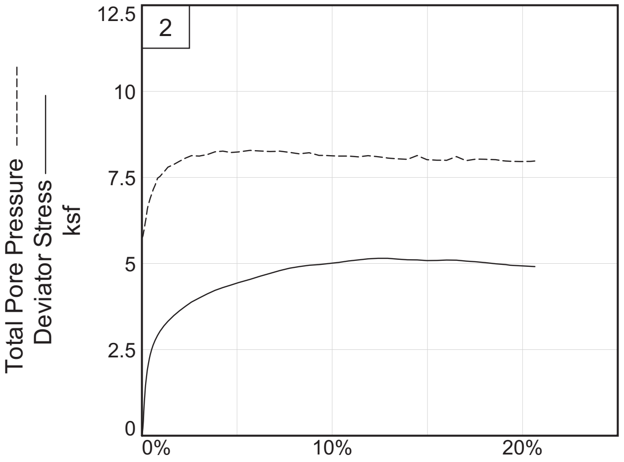
Proj. No.: 011.11497.013 **Date Sampled:** 5/1/09

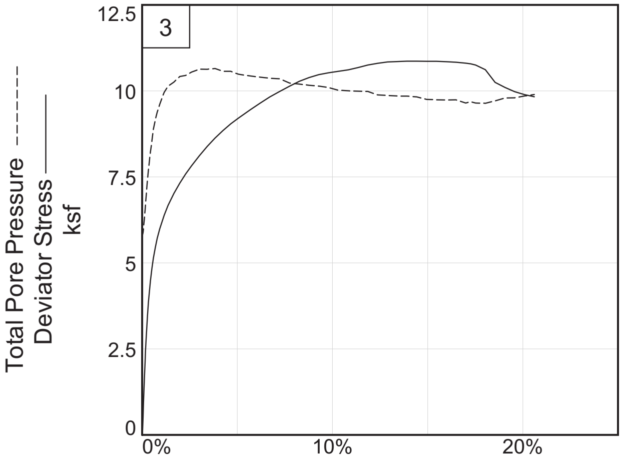
TRIAXIAL SHEAR TEST REPORT

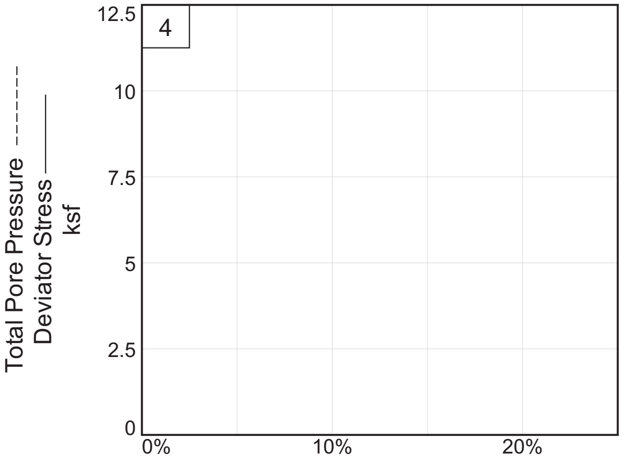
BBC&M Engineering, Inc.

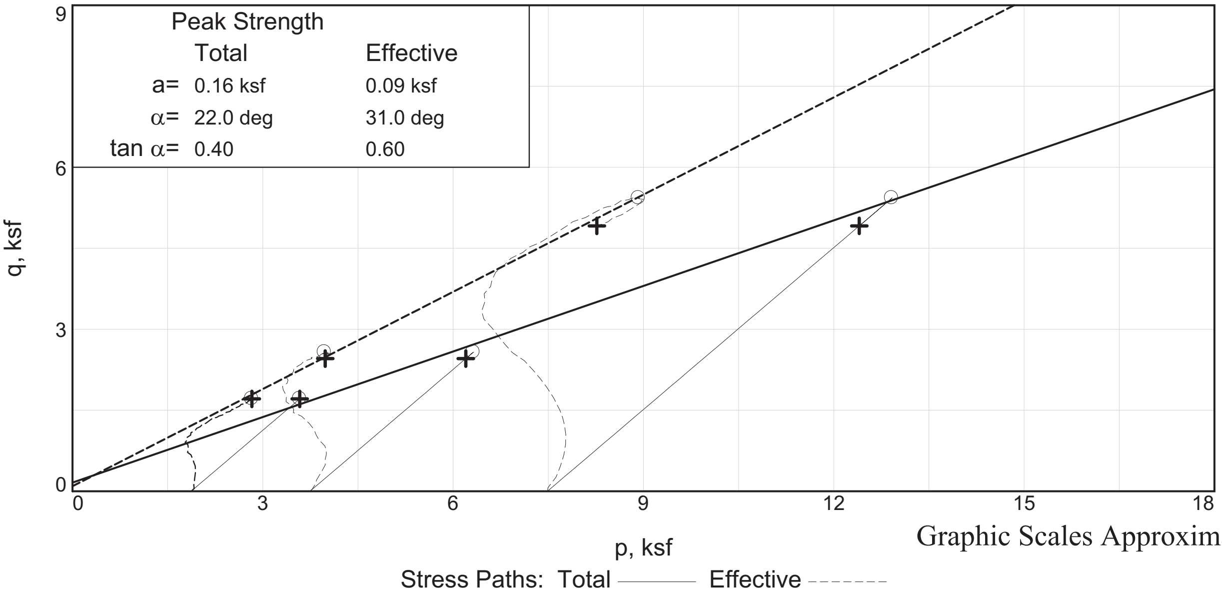
Tested By: PJM **Checked By:** JJ











Peak Strength

	Total	Effective
a=	0.16 ksf	0.09 ksf
α=	22.0 deg	31.0 deg
tan α=	0.40	0.60

Graphic Scales Approximate

Client:

Project: Cardinal Plant Ash Pond Investigation

Location: CD-PZ-BAP-0901 **Depth:** 31.0' to 32.8' **Sample Number:** ST-19A

2

Project No.: 011.11497.013

BBC&M Engineering, Inc.

Tested By: PJM **Checked By:** JJ

PLATE 70

PERMEABILITY TEST DATA AND COMPUTATION SHEET

((ASTM D-5084) FALLING HEAD, METHOD C)

Job Number: **011.11497.013**
Project Name: **Cardinal Ash Pond Investigation**
Project Location: **Brilliant, Ohio**
Tested By: **PJM**
Remarks:
Material: **FILL : Hard brown, gray and dark-gray silty clay inter-mixed with organic silt, trace fine to coarse sand.**

Date: **5/6-7/2009**
Boring: **CD-PZ-BAP-0907**
Sample: **ST-6A Sec. II**
Depth: **8.5' to 9.9'**

Maximum Dry Density:
Optimum Moisture Content:
% Compaction.:
Optimum +/-:
Natural: **X**
Remolded:

Sample:

Initial Length: 5.5945 in = 14.210 cm
Final Ave. Length (L): 5.6042 in = 14.235 cm
Diameter: 2.8765 in = 7.31 cm
Area (A): 6.499 sq in = 41.93 sq cm
Volume (V): 36.356 cu in = 595.77 cu cm
Wet Wt.: 1144.17 grams
Unit Wet Wt.: 119.90 pcf
Unit Dry Wt.: 93.99 pcf

Test Conditions:

Chamber Pressure: 62 psi
Back Pressure: 58 psi
Confining Pressure: 4 psi
Temp. @ Start: 22.5 °C
Temp. @ End: 22.5 °C
Average Temp.: 22.5 °C
B Parameter: 0.96

Moisture Content:	Before Test	After Test
Pan No. =	D	D
Wet Wt. + Pan =	1144.17	1157.03
Dry Wt. + Pan =	896.92	896.92
Wt. of Pan =	0.00	0.00
Wt. of Dry Soil =	896.92	896.92
Wt. of Water =	247.25	260.11
% Moisture =	27.57	29.00
% SATURATIOI	**93.80**	**98.30**

Pipette Pressures During Test:

Top Pipette: 60 psi = 4220.3 cm
Bottom Pipette: 58 psi = 4079.6 cm

S.G.(est) = 2.7000

Pipette:

Area (a): 0.3435 sq in = 0.8725 sq cm

Calculations:

$$k = \frac{a \cdot L}{2 \cdot A \cdot \Delta t} \ln\left(\frac{h_1}{h_2}\right)$$

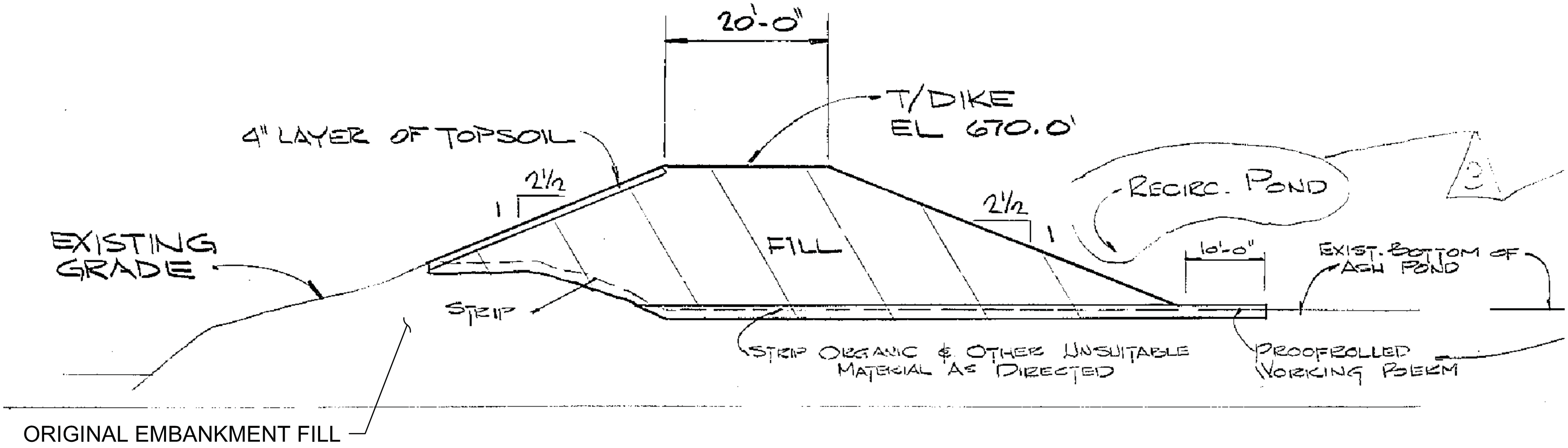
where:
k = Hydraulic Conductivity
a = Pipette Cross-Sectional Area
L = Length of Sample
A = Sample Cross-Sectional Area
Δt = Time Interval (t_2 - t_1)
h_1 = Head Loss Across Permeameter/Specimen at t_1
h_2 = Head Loss Across Permeameter/Specimen at t_2
ln = Natural Logarithm (Base e = 2.71828)

Date	Time Readings	Time Interval Δt Seconds	Top Pipette cc	Hydraulic Head Headwater H_1 cm	Bottom Pipette cc	Hydraulic Head Tailwater H_2 cm	Head Loss h = H_1-H_2 cm	ℓn (h_1/h_2)	Temp. Corr. Permeability k cm/sec
5/6/2009	9:45 AM	0.00	48.45	4092.08	14.20	4272.01	-179.93	–	–
5/6/2009	10:51 AM	3,960	48.40	4092.14	14.45	4271.73	-179.59	0.00191	6.740E-08
5/6/2009	12:15 PM	5,040	48.20	4092.36	14.65	4271.50	-179.13	0.00256	7.077E-08
5/6/2009	1:45 PM	5,400	48.05	4092.54	15.00	4271.09	-178.56	0.00320	8.280E-08
5/6/2009	3:17 PM	5,520	47.85	4092.77	15.25	4270.81	-178.04	0.00289	7.312E-08
5/7/2009	8:21 AM	61,440	45.60	4095.34	18.00	4267.66	-172.31	0.03272	7.431E-08

Time Weighted Average, k [cm/sec] = **7.423E-08**

Appendix III – Shear Strength Parameter Justification

Images: ~Cardinal Plant Aerial.jpg ~Cardinal Plant Aerial2.jpg ~Scan71615.JPG ~Scan71616.tif
Xrefs: ~94151038.dwg
File Last Updated: Jul 06, 2009
Plot Info: 7-6-2009 @ 9:20am By: MRomanello
BBC&M Filename: I:\DEPTS\CADD\Drawings\Projects\011-11497-013\EaglePoint\011-11497-013 BASE.dwg Layout: Hist Sec A-A



SECTION A-A (3-3017)

SECTION THROUGH RIVER-SIDE EMBANKMENT AT RECIRCULATION POND

0 20 40

APPROX.SCALE IN FEET

REFERENCE: SITE DEVELOPMENT PLANS - ASH STORAGE AREA SECTIONS, 1973
DRAWING NO. 3-3027-3

PLATE 1

HISTORIC SECTION A-A

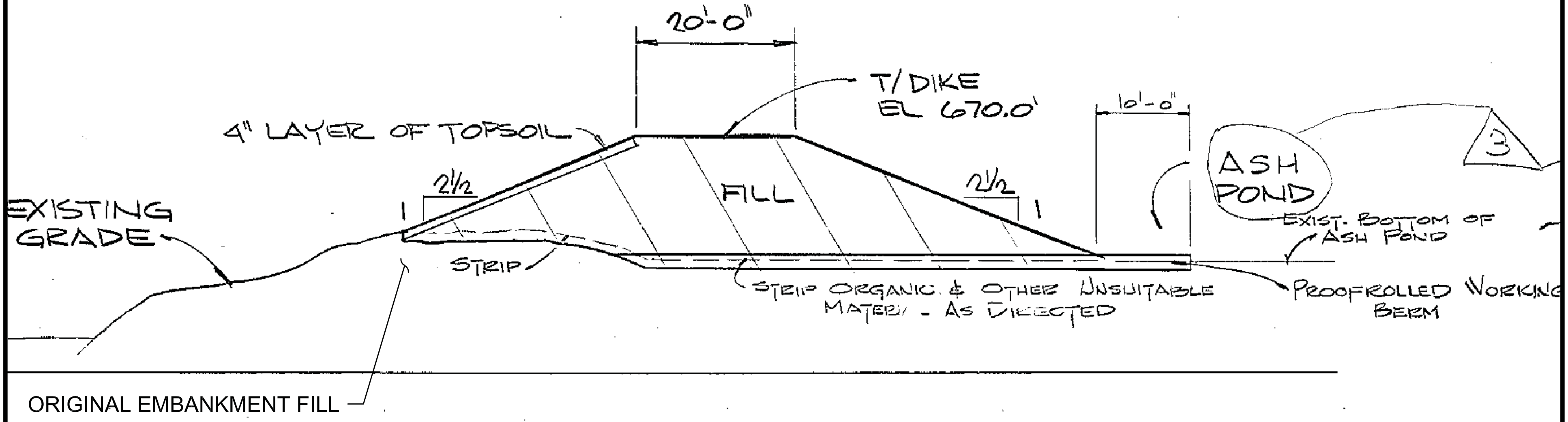
Cardinal Generating Plant
Bottom Ash Pond Investigation
Brilliant, Ohio

BBCM
SOLUTIONS TO BUILD ON

Columbus (614) 793-2226
Cleveland (216) 901-1000
Cincinnati (513) 771-8471
Dayton (937) 424-1011

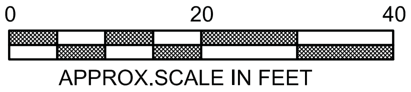
Project: 011-11497-013	Drawn By: MTR	
Drawing Date: 6-16-2009	Approved By: MGR	
Last Updated: 7-6-2009	Scale: 1" = 20'	1:1

Images: ~Cardinal Plant Aerial.jpg ~Cardinal Plant Aerial2.jpg ~Scan71615.JPG ~Scan71616.tif
Xrefs: ~94151038.dwg
File Last Updated: Jul 06, 2009
Plot Info: 7-6-2009 @ 9:21am By: MRomanello
BBC&M Filename: I:\DEPTS\CADD\Drawings\Projects\011-11497-013\EaglePoint\011-11497-013 BASE.dwg Layout: Hist Sec C-C



SECTION C-C (3-3017)

SECTION THROUGH RIVER-SIDE EMBANKMENT AT BOTTOM ASH POND



REFERENCE: SITE DEVELOPMENT PLANS - ASH STORAGE AREA SECTIONS, 1973
DRAWING NO. 3-3027-3

HISTORIC SECTION C-C

Cardinal Generating Plant
Bottom Ash Pond Investigation
Brilliant, Ohio

Project: 011-11497-013	Drawn By: MTR	
Drawing Date: 6-16-2009	Approved By: MGR	
Last Updated: 7-6-2009	Scale: 1" = 20'	1:1

BBCM
SOLUTIONS TO BUILD ON
Columbus (614) 793-2226
Cleveland (216) 901-1000
Cincinnati (513) 771-8471
Dayton (937) 424-1011

PLATE 2

Layer: NEWER EMBANKMENT FILL

BORING NUMBER	SAMPLE NUMBER	SAMPLE DEPTH	NATURAL MOISTURE CONTENT	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTIC INDEX %	GRAVEL %	SAND %	SILT %	CLAY .002 mm %	SILT/CLAY %	USCS CLASSIFICATION
BAP-0901	S-3	4.75	16									
BAP-0901	S-5	7.75	16	28	18	10						
BAP-0901	S-9	13.75	13	27	17	10						
BAP-0901	S-12	18.25	14	37	24	13	7	32	49	12	61	SANDY LEAN CLAY CL
BAP-0902	S-4	6.25	13	27	17	10	42	34	16	8	24	CLAYEY GRAVEL with SAND GC
BAP-0902	S-7	10.75	20									
BAP-0902	S-8	12.25	10	26	17	9	32	39	21	8	29	CLAYEY SAND with GRAVEL SC
BAP-0902	S-11	16.75	24	37	19	18						
BAP-0902	S-12	18.25	21	35	17	18	8	37	33	21	54	SANDY LEAN CLAY CL
BAP-0902	S-13	19.75	31	29	17	12	1	20	62	17	79	LEAN CLAY with SAND CL
BAP-0904	S-3	4.75	13									
BAP-0904	S-6	9.25	14	25	16	9	31	39	21	10	31	CLAYEY SAND with GRAVEL SC
BAP-0904	S-9	13.75	16	35	21	14						
BAP-0904	S-11	16.75					47	25			27	
BAP-0906	S-2A	2.9	11									
BAP-0906	S-3	4.75	15	27	17	10						
BAP-0906	S-8	12.75					30	40	22	9	31	
BAP-0906	S-11	17.25	14	31	19	12	18	44	26	12	38	CLAYEY SAND with GRAVEL SC

Sample Size	18	16	12	12	12	9	9	8	8	9
Minimum	3	10	25	16	9	1	20	16	8	24
Maximum	20	31	37	24	18	47	44	62	21	79
Mean	11.7	16.3	30.3	18.3	12.1	24.0	34.4	31.3	12.1	41.6
Median	13	15	29	17	11	30	37	24	11	31
Mode	5	16	27	17	10	#N/A	39	21	12	31
Std Dev	-	5.4	4.5	2.3	3.2	16.2	7.7	16.1	4.6	18.9

PLATE 3

Layer: ORIGINAL EMBANKMENT FILL

BORING NUMBER	SAMPLE NUMBER	SAMPLE DEPTH	NATURAL MOISTURE CONTENT	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTIC INDEX %	GRAVEL %	SAND %	SILT %	CLAY .002 mm %	SILT/CLAY %	USCS CLASSIFICATION
BAP-0903	S-2	3.25	24	48	24	24	0	8	60	32	92	LEAN CLAY CL
BAP-0903	S-3	4.75	22									
BAP-0903	S-5	7.75	20	36	20	16	0	14	58	28	86	LEAN CLAY CL
BAP-0905	S-3	4.75	17	32	18	14	0	25	53	23	76	LEAN CLAY with SAND CL
BAP-0905	S-5	7.75	22	48	24	24						
BAP-0905	S-6B	9.85	33				5	14			81	
BAP-0907	S-2	3.25	21									
BAP-0907	S-4	6.25	15									
BAP-0907	S-5	7.75	23	49	26	23						
BAP-0907	S-6A	9.25	28	47	29	18	0	5	67	29	96	SILT ML

Sample Size	10	10	6	6	6	5	5	4	4	5
Minimum	3	15	32	18	14	0	5	53	23	76
Maximum	10	33	49	29	24	5	25	67	32	96
Mean	6.5	22.5	43.3	23.5	19.8	1.0	13.2	59.5	28.0	86.2
Median	7	22	48	24	21	0	14	59	29	86
Mode	8	22	48	24	24	0	14	#N/A	#N/A	#N/A
Std Dev	-	5.1	7.4	4.0	4.4	2.2	7.7	5.8	3.7	8.1

Layer: ALLUVIUM SILT AND CLAY

BORING NUMBER	SAMPLE NUMBER	SAMPLE DEPTH	NATURAL MOISTURE CONTENT	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTIC INDEX %	GRAVEL %	SAND %	SILT %	CLAY .002 mm %	SILT/CLAY %	USCS CLASSIFICATION
BAP-0901	S-15	22.75	30	NP	NP	NP	0	5	89	6	95	SILT ML
BAP-0901	S-16A	24.5										
BAP-0901	S-18	29.25	27	37	22	15	0	9	63	28	91	LEAN CLAY CL
BAP-0901	S-19A	31.25										
BAP-0901	S-19B	31.75	33	35	28	7	0	26	56	18	74	SILT with SAND ML
BAP-0901		32.25										
BAP-0902	S-14	21.25	26	NP	NP	NP	0	13	83	4	87	SILT ML
BAP-0902	S-15	22.75					1	22			78	
BAP-0903	S-10	21.75	35	34	21	13	0	29	51	19	70	LEAN CLAY with SAND CL
BAP-0904	S-15	22.75	26	NP	NP	NP	1	52	45	3	48	SILTY SAND SM
BAP-0904	S-17	25.75	22	NP	NP	NP	0	8	86	5	91	SILT ML
BAP-0905	S-11	21.75	38	38	23	15	2	36	47	15	62	SANDY LEAN CLAY CL
BAP-0906	S-15	24.75	31	NP	NP	NP	0	5	89	7	96	SILT ML
BAP-0906	S-16A	26.25					4	41			55	
BAP-0906	S-17	27.25	22	NP	NP	NP	5	20	70	5	75	SILT with SAND ML

Sample Size	15	10	4	4	4	12	12	10	10	12
Minimum	21	22	34	21	7	0	5	45	3	48
Maximum	32.25	38	38	28	15	5	52	89	28	96
Mean	25.73	29.0	36.0	23.5	12.5	1.1	22.2	67.9	11.0	76.8
Median	24.75	29	36	23	14	0	21	67	7	77
Mode	22.75	26	#N/A	#N/A	15	0	5	89	5	91
Std Dev	-	5.4	1.8	3.1	3.8	1.7	15.2	17.8	8.5	15.9

NP - Non Plastic

PLATE 5

Cardinal Plant Ash Pond Investigation
Brilliant, Ohio
BBCM Engineering

INDEX TESTING SUMMARY

Layer: ORGANIC CLAYEY SILT

BORING NUMBER	SAMPLE NUMBER	SAMPLE DEPTH	NATURAL MOISTURE CONTENT	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTIC INDEX %	GRAVEL %	SAND %	SILT %	CLAY .002 mm %	SILT/CLAY %	USCS CLASSIFICATION
BAP-0901	S-20	34.25	42	34	27	7	0	22	62	16	78	ORGANIC SILT with SAND OL
BAP-0901	S-21	36.75	40	45	29	16	11	30			59	SANDY ORGANIC SILT OL
BAP-0901	S-22	39.25	42	40	23	17	0	18	59	22	81	ORGANIC CLAY with SAND OL
BAP-0902	S-18	27.25	54	NP	NP	NP	0	15	69	16	85	ORGANIC SILT OL
BAP-0902	S-19	28.75	43	NP	NP	NP	0	25	61	13	74	ORGANIC SILT with SAND OL
BAP-0902	S-20	32.25	38	36	28	8	2	23	59	16	75	ORGANIC SILT with SAND OL
BAP-0903	S-6	9.25	49	41	38	3	0	33	52	15	67	SANDY ORGANIC SILT OL
BAP-0903	S-7	14.25	43	NP	NP	NP	0	29	56	15	71	ORGANIC SILT with SAND OL
BAP-0903	S-8	16.75	43	37	24	13	0	24	57	19	76	ORGANIC CLAY with SAND OL
BAP-0903	S-9	19.25	44	35	24	11	0	39	45	16	61	SANDY ORGANIC CLAY OL
BAP-0904	S-13	19.75	28	NP	NP	NP	0	8	87	5	92	ORGANIC SILT OL
BAP-0904	S-18	27.25	38	38	24	14	0	21	58	21	79	ORGANIC CLAY with SAND OL
BAP-0904	S-19	28.75	47	42	30	12	0	22	62	17	79	ORGANIC SILT with SAND OL
BAP-0905	S-8	14.25	45	43	27	16	0	19	60	21	81	ORGANIC SILT with SAND OL
BAP-0905	S-9	16.75	42	40	25	15	0	16	60	24	84	ORGANIC CLAY with SAND OL
BAP-0906	S-19	31.75	34	33	22	11	0	19	63	18	81	ORGANIC CLAY with SAND OL
BAP-0906	S-20	34.25	43	50	30	20	0	3	53	44	97	ORGANIC SILT OH
BAP-0906	S-21	36.75	38	43	26	17	1	7	65	27	92	ORGANIC CLAY OL
BAP-0907	S-7	11.75					0	17	66	17	83	
BAP-0907	S-8	14.25	43	44	28	16	0	15	63	22	85	ORGANIC SILT with SAND OL
BAP-0907	S-9	16.75	44	45	29	16	0	15	64	21	85	ORGANIC SILT with SAND OL
BAP-0907	S-10	19.25	40	48	29	19	0	9			91	ORGANIC SILT OL
BAP-0907	S-11	21.75	39	30	24	6	1	43	44	12	56	SANDY ORGANIC SILT OL

Sample Size	23	22	18	18	18	23	23	21	21	23
Minimum	9	28	30	22	3	0	3	44	5	56
Maximum	39.25	54	50	38	20	11	43	87	44	97
Mean	23.97	41.8	40.2	27.1	13.2	0.7	20.5	60.2	18.9	78.8
Median	21.75	43	41	27	15	0	19	60	17	81
Mode	14.25	43	45	24	16	0	15	62	16	81
Std Dev	-	5.2	5.4	3.7	4.7	2.3	9.8	8.8	7.4	10.6

PLATE 6

Layer: GLACIAL OUTWASH SAND AND GRAVEL

BORING NUMBER	SAMPLE NUMBER	SAMPLE DEPTH	NATURAL MOISTURE CONTENT	GRAVEL %	SAND %	SILT %	CLAY .002 mm %	SILT/CLAY %
BAP-0902	S-22	37.25	22	0	70	22	8	30
BAP-0902	S-23	39.75	24	0	83	13	4	17
BAP-0902	S-24	42.25		4	82			14
BAP-0903	S-11	24.25		9	77			14
BAP-0904	S-21	36.75		0	76			24
BAP-0905	S-13	26.75		19	73			8
BAP-0906	S-24	44.25		56	38			7
BAP-0907	S-13	26.75		53	40			7

Sample Size	8	2	8	8	2	2	8
Minimum	24	22	0	38	13	4	7
Maximum	44.25	24	56	83	22	8	30
Mean	34.75	23.0	17.6	67.4	17.5	6.0	15.1
Median	37.00	23	7	75	18	6	14
Mode	26.75	#N/A	0	#N/A	#N/A	#N/A	14
Std Dev	-	1.4	23.7	18.0	6.4	2.8	8.4

PLATE 7

Project/Proposal No. 011.11497.013 Calculated By MTR Date 6-29-09
Project/Proposal Name CARDINAL ASH POND Checked By MHR Date 7-2-09
Subject STRENGTH & PERM. PARAMETERS Sheet 1 of 8

ONLY DRAINED STRENGTH PARAMETERS ARE REQUIRED FOR STABILITY ANALYSIS SINCE NO MODIFICATIONS HAVE BEEN MADE SINCE ~1978. – CONSTANT NORMAL POOL – NO RDD ANALYSIS AT THIS TIME

+ STRENGTH PARAMETERS

ESTIMATE EFFECTIVE ANGLE OF INTERNAL FRICTION, ϕ' OF COHESIVE LAYERS BY COMPARING RESULTS FROM THE FOLLOWING METHODS

1) CORRELATIONS TO LL, CLAY SIZED FRACTION, AND OVERBURDEN STRESS DEVELOPED BY STARK ET AL. FOR THE SECANT FULLY SOFTENED FRICTION ANGLE

2) RELATIONSHIP BETWEEN ϕ' AND PLASTICITY INDEX AS DEVELOPED BY TERZAGHI, PECK, AND MESRI, 1996

3) CORRELATION TO CLAY SIZED FRACTION FOR NORMALLY CONSOLIDATED CLAY – DISSERTATION BY G.A. HALL, WVU, 1974. (ALLUVIUM ONLY)

WHERE $\phi'_{NC} = 36 - 0.2665$ (% CLAY)

4) FOR FILL SOILS, ESTIMATE DRAINED STRENGTH VALUES FROM NAVFAC DESIGN MANUAL 7.2 USING TABLE 1 – 'TYPICAL PROPERTIES OF COMPACTED SOILS'

+ GRANULAR FOUNDATION LAYERS (GLACIAL OUTWASH SAND & GRAVEL)

ESTIMATE ϕ' BASED ON SPT CORRELATIONS AND GRAIN SIZE ANALYSIS

1) $\phi' = \sqrt{15.4 (N_{60})} + 20°$ (HANTANAKA AND UCHIDA, 1996)

2) COMPARE EQN 1) WITH TYPICAL VALUES ESTABLISHED BY SCHROEDER ET AL

TABLE 7.1 Relative Density of Cohesionless Soils

Relative Density Designation	γ_{MOIST} (PCF)	*Approximate Relative Density, %*	*N_{60} Standard Penetration Resistance*	*Approximate Angle of Friction of Soil ϕ, degrees*
Very loose	70 - 100	0–5	0–4	25–28
Loose	90 - 115	5–30	4–10	28–30
Medium	110 - 130	30–60	10–30	30–36
Dense	110 - 140	60–85	30–50	36–41
Very dense	130 - 150	>85	Over 50	>41

Project/Proposal No. 01.11497.013 Calculated By MTR Date 6-29-09
Project/Proposal Name CARDINAL ASH POND Checked By MLR Date 7-2-09
Subject STRENGTH & PERM PARAMETERS Sheet 2 of 8

+ PERMEABILITY

- EMBANKMENT FILL:
  ESTIMATE PERM BASED ON RESULTS FROM FLEX WALL PERMEABILITY TEST PERFORMED ON UNDISTURBED SAMPLE. ESTIMATE PERM. HIGHER THAN TEST VALUE TO ACCOUNT FOR PERMEABILITY ON A MACRO SCALE, AS WELL AS ACCOUNTING FOR SAMPLES WITH A HIGHER GRANULAR CONTENT.
  → ADJUST K, K_V/K_H RATIO DURING ANALYSIS TO MATCH FIELD CONDITIONS.

- ORIGINAL EMBANKMENT FILL & NATURAL COHESIVE LAYERS
  ESTIMATE PERM. BASED ON TYPICAL PUBLISHED VALUES USING SOIL DESCRIPTION & GRAIN SIZE ANALYSIS

- GRANULAR FOUNDATION LAYERS
  ESTIMATE PERMEABILITY BASED ON TYPICAL PUBLISHED VALUES BASED ON RELATIVE DENSITY & GRAIN SIZE ANALYSIS.

  AS A GUIDE, USE $K = (\underline{100}\ D_{10})^2$ μsec $(cm \times 10^{-4}/sec)$

  (HAZEN)

  ALSO USE d_{15} VALUE AND COMPARE TYPICAL RANGE OF PERMEABILITY BASED ON GRAIN SIZE (GEOSYNTEC, 1991)

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Project/Proposal No. 011.11497.013
Project/Proposal Name CARDINAL ASH POND
Subject STRENGTH & PERM. PARAMETERS
Calculated By MTR Date 6-29-09
Checked By MGR Date 7-3-09
Sheet 3 of 8

LAYER: NEWER EMBANKMENT FILL (1970s)

- DESCRIPTION: CONTAINS ZONES AND POCKETS OF THE FOLLOWING
  1) MED DENSE TO DENSE BROWN AND GRAY FINE TO COARSE GRAVEL, SOME FINE TO COARSE SAND, SOME TO "AND" SILTY CLAY
  2) SOFT TO HARD BROWN AND GRAY SILTY CLAY, SOME FINE TO COARSE SAND, SOME FINE TO COARSE GRAVEL

- N_{60} VALUES (IN GRANULAR ZONES)
  LOW: 16
  HIGH: 50
  AVG: 26

- HAND PENETROMETER (ON SAMPLES EXHIBITING COHESION)
  $H = 0.0 - 4.5^{+}$ tsf

- STRENGTH PARAMETER:

  IF CONSIDERED GRANULAR, $\phi = 34-35°$ BASED ON TABLE 7.1 USING AVERAGE N_{60}-VALUE. ADJUST FOR HIGH FINE GRAINED CONTENT, SAY $\phi' = 32°$

  1) CORRELATION TO STARK CHARTS
     - FOR CORRELATION, CONSIDER BOTH $\sigma_{vo}' = 50$ KPa AND 100 KPa TO ACCOUNT FOR PROBABLE DEPTH OF FAILURE SURFACE.
     - RESULTS: $\phi_{FS}' = 31°$ (SEE CORRELATIONS THIS APPENDIX)

  2) GRAPH OF ϕ' VRS PI:
     - RESULTS: $\phi' = 33°$ (SEE CHART THIS APPENDIX)

  3) N/A FOR FILL SOILS

  4) NAVFAC TABLE 1:

GROUP	SOIL TYPE	TYP STRENGTH	TYP K (cm/sec)
GC	CLAYEY GRAVEL	$C' = 0$, $\phi' > 31°$	$>10^{-7}$
SC	CLAYEY SANDS	$C' = 230$ psf, $\phi' = 31°$	$5x > 10^{-7}$
CL	INORG CLAYS OF LOW-MED PI	$C' = 270$ psf, $\phi' = 28°$	$>10^{-7}$

DESIGN STRENGTH: $C' = 0$ psf, $\phi' = 31°$

- PERMEABILITY: BASED ON PERMEABILITY CORRELATIONS & TYPICAL RANGE OF PERMEABILITY, USE $K_v = 1 \times 10^{-5}$ cm/sec. SEE CORRELATION THIS APPENDIX. ADJUST K_v/K_H RATIO DURING ANALYSIS TO MATCH FIELD CONDITIONS

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Project/Proposal No. 011.11497.013 Calculated By MTR Date 6-29-09
Project/Proposal Name CARDINAL ASH POND Checked By MHR Date 7-2-09
Subject STRENGTH & PERM PARAMETERS Sheet 4 of 8

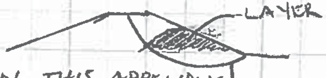
LAYER : ORIGINAL EMBANKMENT FILL (OLDER FILL)

- DESCRIPTION : STIFF TO HARD BROWN MOTTLED WITH GRAY SILTY CLAY (USCS : LEAN CLAY)

- HAND PENETROMETER RANGE : 1.5 - 4.5 tsf

- STRENGTH PARAMETER :

1) CORRELATION TO STARK CHARTS
CONSIDER $\sigma'_{v0} = 50$ KPa BASED ON RELATION OF THIS LAYER TO THE FAILURE PLANE.
- RESULTS : $\phi'_{fs} = 30°$
(SEE CORRELATION THIS APPENDIX)



2) ϕ' VRS PI
- RESULTS : FOR PI = 24 , $\phi' = 30°$ (SEE CHART THIS APPENDIX)

3) N/A FOR FILL SOILS

4) NAVFAC TABLE 1

GROUP	SOIL TYPE	TYP UNDRAINED STRENGTH	TYP K (cm/sec)
CL	INORGANIC CLAYS OF LOW TO MED PLASTICITY	$c' = 270$ psf $\phi' = 28°$	$> 10^{-7}$

DESIGN STRENGTH PARAMETER : $c' = 100$ psf , $\phi' = 30°$

- PERMEABILITY :

FLEX WALL PERMEABILITY TEST PERFORMED ON SAMPLE ST-6A OF BORING BAP-0907

- RESULTS $K_v = 7.42 \times 10^{-8}$ cm/sec

- DESIGN : USE $K_v = 1 \times 10^{-7}$ cm/sec TO ACCOUNT FOR PERM ON A MACRO SCALE.

=> K_v ADJUSTED TO 5×10^{-8} cm/sec WITH $K_H/K_v = 5$ DURING SEEPAGE ANALYSIS

PLATE 11

Project/Proposal No. 011.11497.013
Project/Proposal Name CARDINAL ASH POND
Subject STRENGTH & PERM.
Calculated By MTR Date 6-29-09
Checked By MGR Date 7-2-09
Sheet 5 of 8

LAYER: ALLUVIUM SILT & CLAY

- DESCRIPTION: VERY LOOSE TO MED DENSE GRAY SILT, CONTAINS ZONES OF STIFF TO HARD SILTY CLAY AND THIN LAYERS OF VERY LOOSE TO LOOSE FINE TO COARSE SAND

- N_{60} RANGE: 0 TO 27, AVG = 8 bpf

- HAND PENETROMETER: 0 - 3.5 tsf ON SICL SAMPLES

- STRENGTH PARAMETERS

1) STARK CORRELATION:
   - CONSIDER BOTH ϕ'_{vo} = 100 kPa AND 400 kPa WITH TENDANCY TOWARD 100 kPa
   - RESULTS: $\phi'_{FS} = 30°$ (SEE CORRELATION THIS APPENDIX)

2) ϕ' VRS PI
   - RESULTS: FOR PI = 15, $\phi' = 31.5°$ (SEE CHART THIS APPENDIX)

3) HALL'S THESIS

$$\phi'_{NC} = 36 - 0.2665\,(\%\ \text{CLAY})$$

FOR CF = 10.9, $\phi'_{NC} = 33°$

4) N/A FOR NATURAL SOILS - USE TABLE 3.28 - COMMON PROPERTIES OF COHESIONLESS SOILS (SOURCE:)
   - FOR 'LOOSE INORGANIC SILTS' $\phi' = 27°$

Design Strength Parameter: Use $\phi'_{NC} = 30°$, $c' = 0$ psf

- Permeability: Based on soil description.

$k_v = 1 \times 10^{-5}$ cm/s (typical published value)

PLATE 12

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Project/Proposal Name CARDINAL ASH POND
Subject STRENGTH & PERMEABILITY

Calculated By MTR Date 6-29-09
Checked By Date 7-2-09
Sheet 6 of 8

LAYER : <u>ORGANIC CLAYEY SILT</u>

- DESCRIPTION : VERY SOFT TO STIFF ORGANIC CLAYEY SILT, CONTAINS SEAMS OF VERY LOOSE ORGANIC SILT

* - LOSS ON IGNITION : RANGE = 7.9% TO 10.4% FROM 3 SAMPLES TESTED. ✓

- HAND PENETROMETER : 0.0 - 1.25 tsf

- STRENGTH PARAMETER :

1) STARK CORRELATION :
   - CONSIDER ϕ_{vo}' = 100 kPa AND 400 kPa WITH TENDANCY TOWARD 100 kPa
   - RESULTS : $\phi_{FS}' = 26°$ (SEE CORRELATION THIS APPENDIX)

2) ϕ' VRS PI
   - RESULTS : FOR PI = 16, $\phi' = 31°$ (SEE CHART THIS APPENDIX)

3) HALL'S THESIS

$$\phi_{NC}' = 36 - 0.2665 (\% \text{ CLAY})$$

FOR CF = 16, $\phi_{NC}' = 31.7°$

5) CU TRIAXIAL TEST - SAMPLE WAS NOT DESCRIBED AS 'ORGANIC', BUT DESCRIPTION BEST MATCHES THIS LAYER
   RESULTS : $\phi' = 36.9°$, $c' = 110$ psf

- PERMEABILITY : D_{15} -
  LOW = 0.0015
  HIGH = 0.005
  AVG = 0.0023
  } $K_v = 5 \times 10^{-6}$ cm/s (GEOSYNTEC, SEE APPENDIX)
  (4 SAMPLES TOO COARSE FOR D_{15} VALUE

* PER FHWA GEC 5, LOI < 20% SOIL PROPERTIES CONTROLLED BY NON-ORGANIC PORTION ∴ REGULAR CORRELATIONS OK

DESIGN STRENGTH PARAMETER : $\phi' = 30°$, $c' = 0$ psf

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Project/Proposal Name CARDINAL ASH POND Checked By MGR Date 7-2-09
Subject STRENGTH & PERM. Sheet 7 of 8

+ LAYER: VERY LOOSE - LOOSE GLACIAL OUTWASH SAND & GRAVEL

- DESCRIPTION: VERY LOOSE TO LOOSE BROWN AND GY FINE TO MEDIUM SAND, TRACE TO SOME SILT OR INTERBEDDED WITH SILT, FEW SEAMS OF SILTY CLAY

- N_{60} RANGE:

		ϕ'	
		EQN 72	TABLE 7.1
LOW	4	27.8	28°
HIGH	29	41.1	35°- 36°
AVG	12	33.6	30 - 31°

USE $\phi' = 29°$; $c' = 0$

- PERMEABILITY: USE GRAIN SIZE ANALYSIS

BORING CV-PZ-BAP-0904, SAMPLE 21, $D_{15} \approx 0.06$

$k_v = 1 \times 10^{-2}$ cm/s (See appendix → Geosyntec, 1991)

+ LAYER: MED DENSE GLACIAL OUTWASH SAND & GRAVEL

- DESCRIPTION: MED DENSE TO DENSE BROWN AND GRAY FINE TO COARSE GRAVEL AND FINE TO MED SAND.

- N_{60} RANGE:

		ϕ'	
		EQN 72	TABLE 7.1
LOW	14	34.7	31°- 32°
HIGH	69	52.6	>41
AVG	32	42.2	36°

USE $\phi' = 34°$; $c' = 0$

Permeability:

BORING	SAMPLE	D_{15}
0903	S-11	0.09
0905	S-13	0.19
0906	S-24	0.16
0907	S-13	0.25
0902	S-24	0.09

(See appendix)

Use $k_v = 1 \times 10^{-3}$ cm/s (Geosyntec, 1991)

PLATE 14

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Project/Proposal Name CARDINAL ASH POND Checked By ____ Date ____
Subject SEISMIC STRENGTH PARAMETERS Sheet 8 of 8

- PERFORM SEISMIC STABILITY ANALYSIS, WITH A PSEUDOSTATIC APPROACH USING LIMIT EQUILIBRIUM METHOD

⇒ APPLY HORIZONTAL LOAD TO STATIC MODEL EQUAL TO THE PEAK HORIZONTAL ACCELERATION, a, DETERMINED FROM SEISMIC HAZARD MAPPING

- ASSUMED ORIGINAL EMBANKMENT FILL LAYER WILL EXHIBIT UNDRAINED RESPONSE DURING AN EARTHQUAKE EVENT.
  ∴ USE USACE 'R' ENVELOPE TO MODEL THE STRENGTH PROPERTIES.

SINCE NO CU TEST DATA IS AVAILABLE FOR THE ORIGINAL FILL, COMPARE INDEX TESTING RESULTS TO VALUES PRESENTED BY DUNCAN AND WRIGHT (2005) FOR 'R' TEST RESULTS.

BASED ON COMPARISON, USE THE FOLLOWING STRENGTH VALUES

LAYER	C	ϕ
ORIGINAL EMBANKMENT FILL	50 psf	22°

SEE TABLE 10.3 ON FOLLOWING PG.

CU TEST PERFORMED IN ORG CLSI LAYER — USE R-ENVELOPE TO MODEL STRENGTHS FOR SEISMIC

ORG. CLSI → $c = 180$ psf, $\phi = 24°$

ALLUVIUM & GLACIAL OUTWASH FOUNDATION LAYERS WILL LIKELY EXHIBIT DRAINED STRENGTHS DURING EARTHQUAKE. ∴ USE PARAMETERS DEVELOPED FOR DRAINED ANALYSIS

NEWER EMBANKMENT FILL LAYER HAS SUFFICIENT GRANULAR MATERIAL TO ASSUME IT WILL EXHIBIT A DRAINED RESPONSE

DUNCAN & WRIGHT (2005)

Table 10.3 Summary of Soil Properties Used in Comparison of R and τ_{ff} vs. σ'_{fc} Strength Envelopes

Soil no.	Description and reference	Index properties	c' (psf)	ϕ' (deg)	c_R (psf)	ϕ_R (deg)	d^a (psf)	ψ^b (deg)
1	Sandy clay (CL) material from Pilarcitos Dam; envelope for low (0–10 psi) confining pressures. (Wong et al., 1983)	Percent minus No. 200: 60–70 Liquid limit: 45 Plasticity index: 23	0	45	60	23	64	24.4
2	Brown sandy clay from dam site in Rio Blanco, Colorado (Wong et al., 1983)	Percent minus No. 200: 25 Liquid limit: 34 Plasticity index: 12	200	31	700	15	782	16.7
3	Same as soil 1 except envelope fit to 0–100 psi range in confining pressure (Wong et al., 1983)	Percent minus No. 200: 60–70 Liquid limit: 45 Plasticity index: 23	0	34	300	15.5	327	16.8
4	Hirfanli Dam fill material (Lowe and Karafiath, 1960)	Percent minus No. 200: 82 Liquid limit: 32.4 Plastic limit: 19.4	0	35	1400	22.5	1716	26.9

ORIGINAL EMBANKMENT FILL
USE C=50psf & φ=22°
LL=48, PI=24

[a] Intercept of τ_{ff} vs. σ'_{fc} envelope—can be calculated knowing c', ϕ', c_R, and ϕ_R.

[b] Slope of τ_{ff} vs. σ'_{fc} envelope—can be calculated knowing c', ϕ', c_R, and ϕ_R.

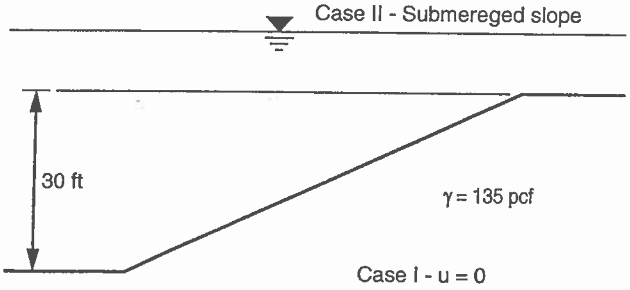

Figure 10.6 Slope used to compare simple, single-stage and rigorous, two-stage pseudostatic analyses.

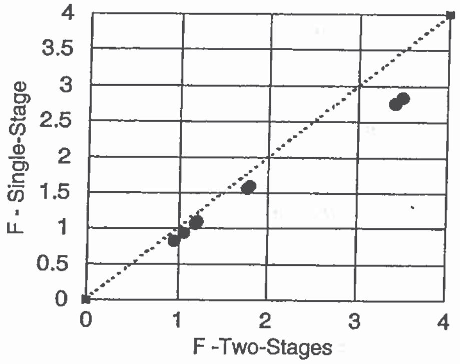

Figure 10.7 Comparison of factors of safety by simplified single-stage pseudostatic and more rigorous two-stage pseudostatic analyses.

Table 10.4 Summary of Pseudostatic Safety Factors Computed Using Simple Single-Stage and Rigorous Two-Stage Procedures

	Case I: dry slope		Case II: submerged slope	
Soil	Single-stage analysis	Two-stage analysis	Single-stage analysis	Two-stage analysis
1	0.95	1.06	0.83	0.95
2	1.56	1.77	1.59	1.79
3	1.07	1.19	1.10	1.21
4	2.76	3.42	2.83	3.49

used for cases where significant (more than 15 to 20%) strength losses are not anticipated.

POSTEARTHQUAKE STABILITY ANALYSES

Following an earthquake, the stability of a slope may be diminished because cyclic loading has reduced the shear strength of the soil. The reductions in shear strength are generally treated differently depending on whether or not liquefaction occurs. Stability follow-

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DRAINED SHEAR STRENGTH PARAMETER CORRELATION

Project No: 011-11497-014 Date: 5/29/09
Project: Gavin Plant Bottom Ash Pond Investigation

Reference:
Drained Shear Strength Parameters for Analysis of Landslides. Timothy D. Stark; Hangseok Choi; and Sean McCone. Journal of Geotechnical Engineering, May 2005. pp 575 - 588

Purpose:
Estimate effective stress, or drained, shear strength parameters of cohesive soils through emperical correlations using laboratory index testing and the effective normal stress. Secant residual and secant fully softened friction angles can be estimated from charts developed by Stark et al.

Laboratory Data

Soil Layer: Newer Embankment Fill

Statistical Results from 4 Borings

	PI	LL	MC	% Passing #200 Sieve (.075 mm)	Clay Sized Fraction (.002 mm)
Number in Statistical Sample	12	12	16	9	8
Minimum	9	25	10	24	8
Maximum	18	37	31	79	21
Mean	12.1	30.3	16.3	41.6	12.1
Median	11	28.5	14.5	31	11
Mode	10	27	16	31	12
Std Dev	3.2	4.5	5.4	18.9	4.6
Design Value	*10*	27	-	-	12

Adjustment Factor for ASTM Derived Values

$$\frac{\textit{ball-milled derived LL}}{\textit{ASTM derived LL}} = .003\ (\textit{ASTM derived LL}) + 1.23$$

LL_{ASTM} = 27
LL_{BM} = 35.4

$$\frac{\textit{ball-milled derived CF}}{\textit{ASTM derived CF}} = 0.0003\ (\textit{ASTM derived CF})2 - 0.037(\textit{ASTM derived CF}) + 2.254$$

CF_{ASTM} = 12
CF_{BM} = 22.2

where: LL = Liquid Limit
CF = Clay-sized Fraction

PLATE 17

SOLUTIONS TO BUILD ON

DRAINED SHEAR STRENGTH PARAMETER CORRELATION

Soil Layer: Newer Embankment Fill

LL_{BM} = 35.4

CF_{BM} = 22.2

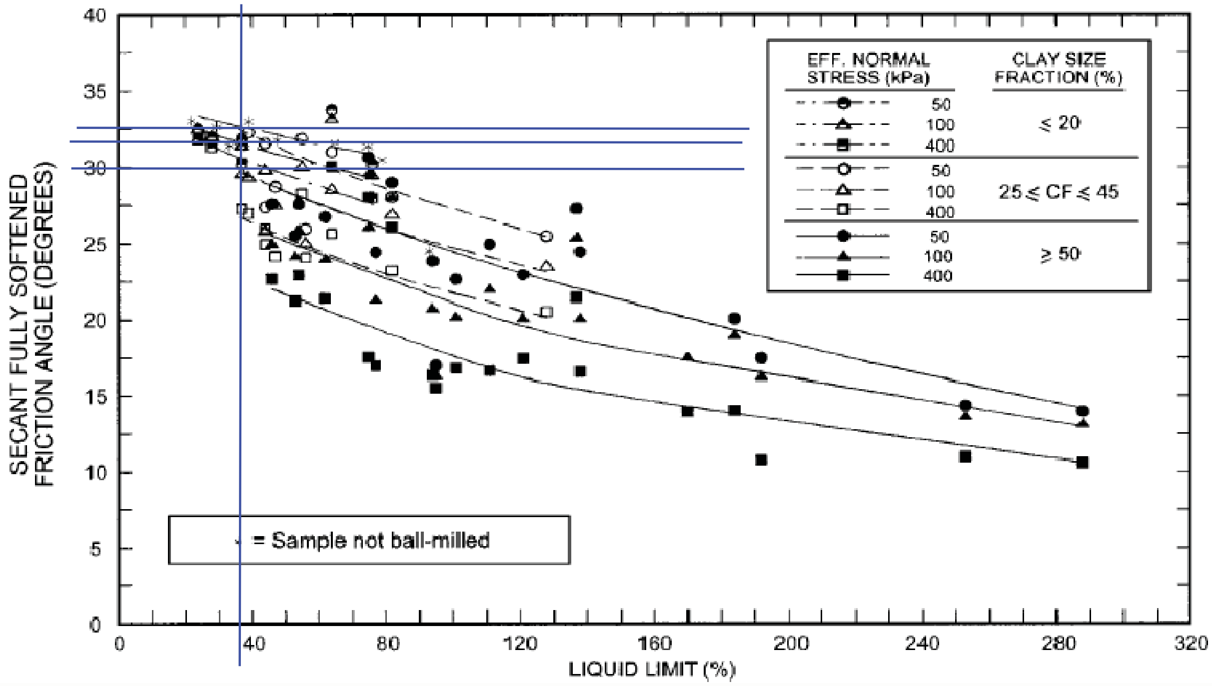

Fig. 5. Secant fully softened friction angle relationships with liquid limit, clay-size fraction, and effective normal stress

Secant Fully Softened Friction Angle

		Effective Normal Stress	
		50 kPa	*100 kPa*
Clay Sized Fraction, %	*CF ≤ 20*	32.5°	31.5°
	25 ≤ CF ≤ 45	32.5°	30°

Design Friction Angle Value	31°

PLATE 18

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DRAINED SHEAR STRENGTH PARAMETER CORRELATION

Project No: 011-11497-014 Date: 5/29/09
Project: Gavin Plant Bottom Ash Pond Investigation

Reference:
Drained Shear Strength Parameters for Analysis of Landslides. Timothy D. Stark; Hangseok Choi; and Sean McCone. Journal of Geotechnical Engineering, May 2005. pp 575 - 588

Purpose:
Estimate effective stress, or drained, shear strength parameters of cohesive soils through emperical correlations using laboratory index testing and the effective normal stress. Secant residual and secant fully softened friction angles can be estimated from charts developed by Stark et al.

Laboratory Data

Soil Layer: Original Embankment Fill

Statistical Results from 3 Borings

	PI	LL	MC	% Passing #200 Sieve (.075 mm)	Clay Sized Fraction (.002 mm)
Number in Statistical Sample	6	6	10	5	4
Minimum	14	32	15	76	23
Maximum	24	49	33	96	32
Mean	19.8	43.3	22.5	86.2	28.0
Median	20.5	47.5	22	86	28.5
Mode	24	48	22	#N/A	#N/A
Std Dev	4.4	7.4	5.1	8.1	3.7
Design Value	*24*	48	-	-	28

Adjustment Factor for ASTM Derived Values

$$\frac{\textit{ball-milled derived LL}}{\textit{ASTM derived LL}} = .003\ (\textit{ASTM derived LL}) + 1.23$$

LL_{ASTM} = 48
LL_{BM} = 66.0

$$\frac{\textit{ball-milled derived CF}}{\textit{ASTM derived CF}} = 0.0003\ (\textit{ASTM derived CF})2 - 0.037(\textit{ASTM derived CF}) + 2.254$$

CF_{ASTM} = 28
CF_{BM} = 40.7

where: LL = Liquid Limit
CF = Clay-sized Fraction

PLATE 19

DRAINED SHEAR STRENGTH PARAMETER CORRELATION

Soil Layer: Original Embankment Fill

LL_{BM} = 66.0

CF_{BM} = 40.7

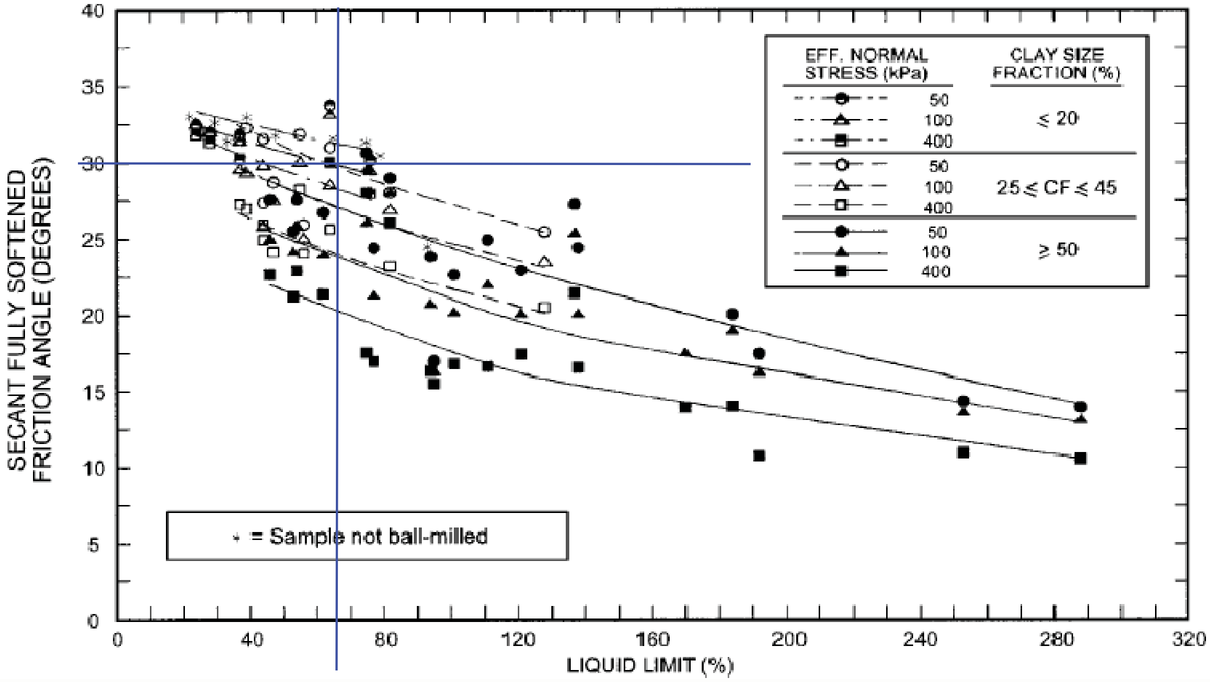

Fig. 5. Secant fully softened friction angle relationships with liquid limit, clay-size fraction, and effective normal stress

Effective Normal Stress, kPa	50
Secant Fully Softened Friction Angle	**30°**

DRAINED SHEAR STRENGTH PARAMETER CORRELATION

Project No: 011-11497-014 Date: 5/29/09
Project: Gavin Plant Bottom Ash Pond Investigation

Reference:
Drained Shear Strength Parameters for Analysis of Landslides. Timothy D. Stark; Hangseok Choi; and Sean McCone. Journal of Geotechnical Engineering, May 2005. pp 575 - 588

Purpose:
Estimate effective stress, or drained, shear strength parameters of cohesive soils through emperical correlations using laboratory index testing and the effective normal stress. Secant residual and secant fully softened friction angles can be estimated from charts developed by Stark et al.

Laboratory Data

Soil Layer: Organic Clayey Silt

Statistical Results from 7 Borings

	PI	LL	MC	% Passing #200 Sieve (.075 mm)	Clay Sized Fraction (.002 mm)
Number in Statistical Sample	17	17	20	21	19
Minimum	3	30	34	56	12
Maximum	20	50	54	97	44
Mean	13.5	40.6	42.5	78.2	19.8
Median	15	41	43	81	18
Mode	16	45	43	81	16
Std Dev	4.6	5.3	4.4	10.7	7.0
Design Value	*16*	45	-	-	20.0

Adjustment Factor for ASTM Derived Values

$$\frac{\text{ball-milled derived LL}}{\text{ASTM derived LL}} = .003\ (\text{ASTM derived LL}) + 1.23$$

LL_{ASTM} = 45
LL_{BM} = 61.4

$$\frac{\text{ball-milled derived CF}}{\text{ASTM derived CF}} = 0.0003\ (\text{ASTM derived CF})2 - 0.037(\text{ASTM derived CF}) + 2.254$$

CF_{ASTM} = 20.0
CF_{BM} = 32.7

where: LL = Liquid Limit
CF = Clay-sized Fraction

PLATE 21

DRAINED SHEAR STRENGTH PARAMETER CORRELATION

Soil Layer: Organic Clayey Silt

LL_{BM} = 61.4

CF_{BM} = 32.7

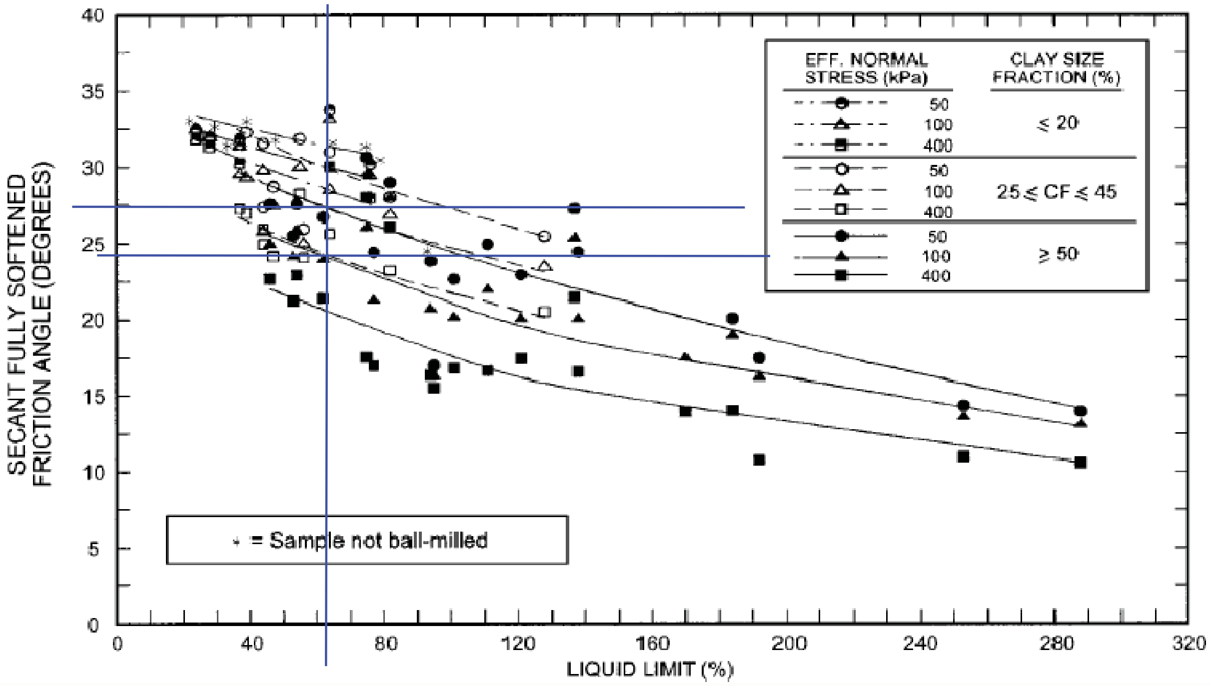

Fig. 5. Secant fully softened friction angle relationships with liquid limit, clay-size fraction, and effective normal stress

Secant Fully Softened Friction Angle

		Effective Normal Stress	
		100 kPa	*400 kPa*
Clay Sized Fraction, %	*CF ≤ 20*	27.5°	24°
	25 ≤ CF ≤ 45	-	-

Design Friction Angle Value	26°

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DRAINED SHEAR STRENGTH PARAMETER CORRELATION

Project No: 011-11497-014 Date: 5/29/09
Project: Gavin Plant Bottom Ash Pond Investigation

Reference:

Drained Shear Strength Parameters for Analysis of Landslides. Timothy D. Stark; Hangseok Choi; and Sean McCone. Journal of Geotechnical Engineering, May 2005. pp 575 - 588

Purpose:

Estimate effective stress, or drained, shear strength parameters of cohesive soils through emperical correlations using laboratory index testing and the effective normal stress. Secant residual and secant fully softened friction angles can be estimated from charts developed by Stark et al.

Laboratory Data

Soil Layer: Alluvium Silt and Clay

Statistical Results from 6 Borings

	PI*	LL*	MC	% Passing #200 Sieve (.075 mm)	Clay Sized Fraction (.002 mm)
Number in Statistical Sample	4	4	10	12	10
Minimum	7	34	22	48	3
Maximum	15	38	38	96	28
Mean	12.5	36.0	29.0	76.8	11.0
Median	14	36	28.5	76.5	6.5
Mode	15	#N/A	26	91	5
Std Dev	3.8	1.8	5.4	15.9	8.5
*Does not include results from 'Non-Plastic' samples.					
Design Value	*15*	36	-	-	10.0

Adjustment Factor for ASTM Derived Values

$$\frac{\textit{ball-milled derived LL}}{\textit{ASTM derived LL}} = .003\ (\textit{ASTM derived LL}) + 1.23$$

LL_{ASTM} = 36
LL_{BM} = 48.2

$$\frac{\textit{ball-milled derived CF}}{\textit{ASTM derived CF}} = 0.0003\ (\textit{ASTM derived CF})2 - 0.037(\textit{ASTM derived CF}) + 2.254$$

CF_{ASTM} = 10.0
CF_{BM} = 19.1

where: LL = Liquid Limit
CF = Clay-sized Fraction

PLATE 23

DRAINED SHEAR STRENGTH PARAMETER CORRELATION

Soil Layer: Alluvium Silt and Clay

LL_{BM} = 48.2

CF_{BM} = 19.1

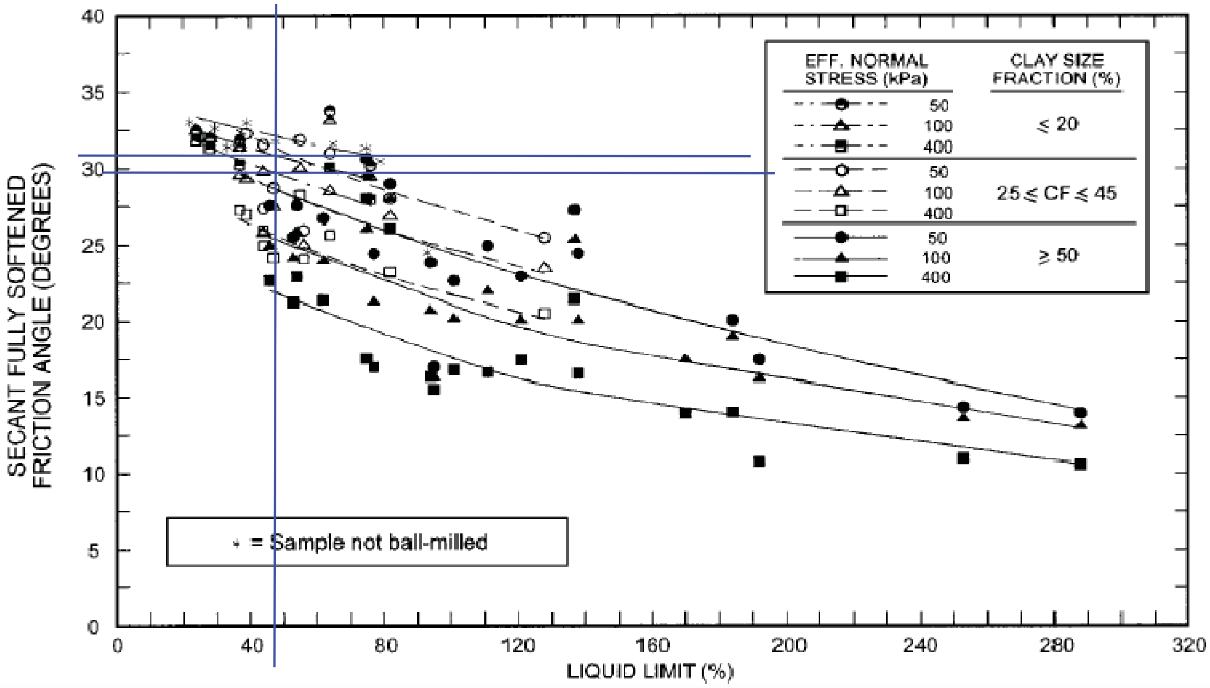


Fig. 5. Secant fully softened friction angle relationships with liquid limit, clay-size fraction, and effective normal stress

Secant Fully Softened Friction Angle

Clay Sized Fraction, %		Effective Normal Stress 100 kPa	Effective Normal Stress 400 kPa
	CF ≤ 20	31°	29.5°
	25 ≤ CF ≤ 45	-	-

Design Friction Angle Value	30°

PLATE 24

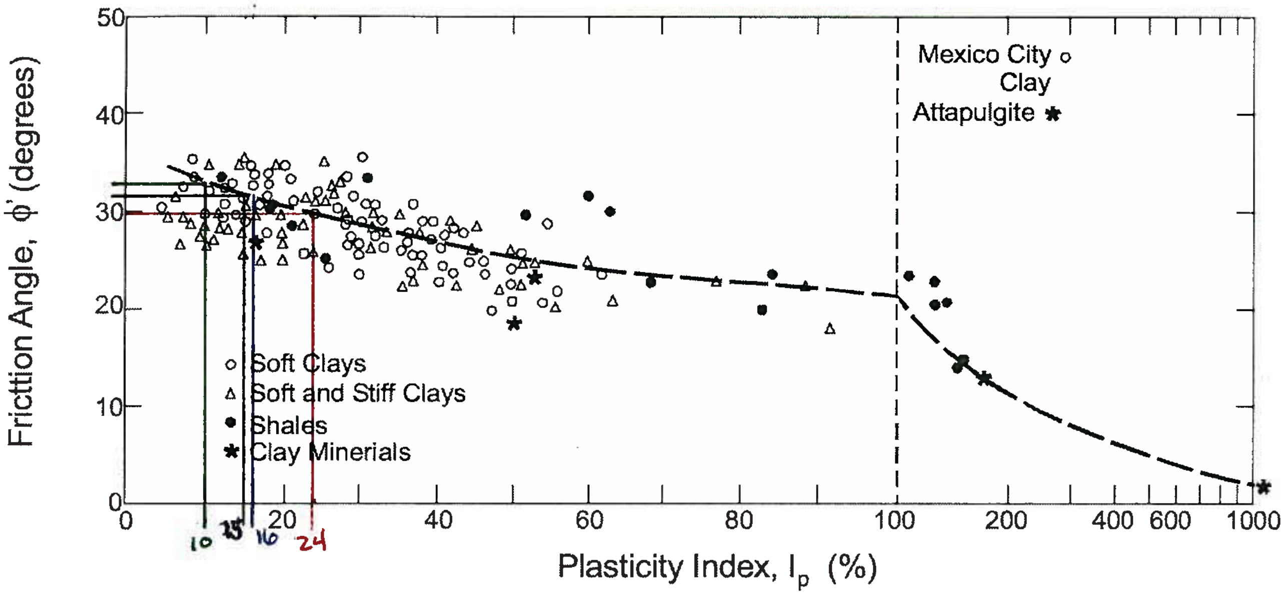


Figure 74. Relationship between ϕ' and PI (Terzaghi, Peck, and Mesri, 1996).

Report No. FHWA-IF-02-034
Geotechnical Engineering Circular No. 5
Evaluation of Soil and Rock Properties
April, 2002

	LAYER	P.I.	ϕ'
🟩	EMBANKMENT EXPANSION FILL	10	33°
🟥	ORIGINAL EMBANKMENT FILL	24	30°
⬛	ALLUVIUM SILT AND CLAY	15	31.5°
🟦	ORGANIC CLAYEY SILT	16	31°

TABLE 3.28
COMMON PROPERTIES OF COHESIONLESS SOILS

1 g/cm³ = $\frac{\text{pcf}}{62.427}$

Material	Compactness	D_R, %	N*	γ dry,† g/cm³	γ_{dry} (pcf)	Void ratio e	γ_{SAT} (pcf)	Strength‡ ϕ
GW: well-graded gravels, gravel-sand mixtures	Dense	75	90	2.21	138	0.22	149	40
	Medium dense	50	55	2.08	129.8	0.28	143.5	36
	Loose	25	<28	1.97	123	0.36	139.5	32
GP: poorly graded gravels, gravel-sand mixtures	Dense	75	70	2.04	127.4	0.33	143	38
	Medium dense	50	50	1.92	120	0.39	137.5	35
	Loose	25	<20	1.83	114.2	0.47	134	32
SW: well-graded sands, gravelly sands	Dense	75	65	1.89	118	0.43	136.8	37
	Medium dense	50	35	1.79	111.7	0.49	132.2	34
	Loose	25	<15	1.70	106.1	0.57	128.8	30
SP: poorly graded sands, gravelly sands	Dense	75	50	1.76	109.9	0.52	131.3	36
	Medium dense	50	30	1.67	104.2	0.60	127.6	33
	Loose	25	<10	1.59	99.3	0.65	124	29
SM: silty sands	Dense	75	45	1.65	103	0.62	127	35
	Medium dense	50	25	1.55	97	0.74	123.5	32
	Loose	25	<8	1.49	93	0.80	120.7	29
ML: inorganic silts, very fine sands	Dense	75	35	1.49	93	0.80	120.7	33
	Medium dense	50	20	1.41	88	0.90	117.6	31
	Loose	25	<4	1.35	84.3	1.0	115.5	27

*N is blows per foot of penetration in the SPT. Adjustments for gradation are after Burmister (1962).[13] See Table 3.23 for general relationships of D_R vs. N.

†Density given is for G_s = 2.65 (quartz grains).

‡Friction angle ϕ depends on mineral type, normal stress, and grain angularity as well as D_R and gradation (see Fig. 3.63).

1 g/cm³ = 9.81 kN/m³

$$\gamma_{SAT} = \frac{(G_s + e)\gamma_w}{1 + e}$$

$$\gamma_{SAT} = \gamma_d + \frac{e\gamma_w}{(1+e)}$$

Newer Embankment Fill: Permeability

D_{15} Range = 0.002 - 0.080

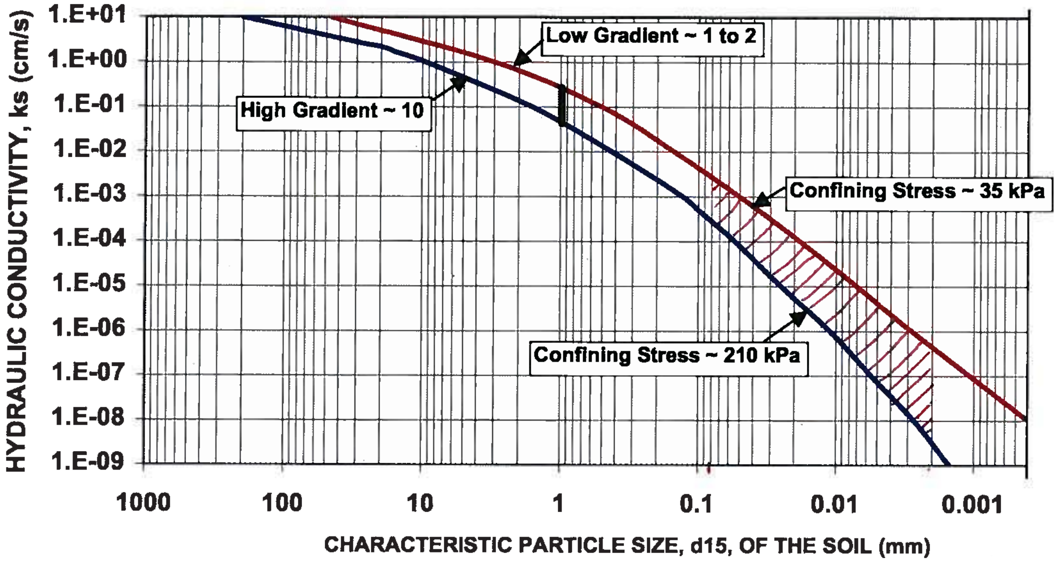


Figure 91. Range of hydraulic conductivity based on grain size (after GeoSyntec, 1991).

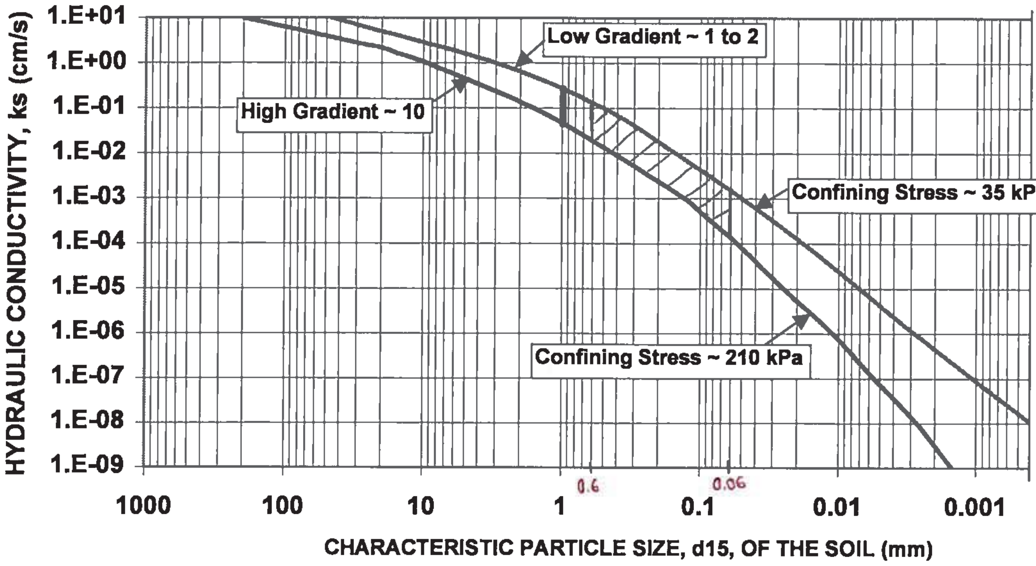
Considering the site geology, the laboratory and field data should be tabulated with other known data for the sample/test location and with depth, soil/rock type, grain size distribution, Atterberg limits, and water content. This table should also include important test information such as: stress conditions, gradients, and test method. Once this table is constructed it will be much easier to group like soil types and k values, to delineate distinct areas within the site, and to eliminate potentially erroneous data. Once these values have been grouped together and potentially erroneous values eliminated, it may be useful to compute an average value for each grouping. When averaging, the log of the hydraulic conductivity value must be taken before performing an arithmetic mean or incorrect results will be produced. First, the logarithm of each value should be taken. Second, an average value should be calculated from these logarithmic values. Finally, the antilog of this average value should be taken to calculate the average hydraulic conductivity value. Table 35 illustrates how to calculate the mean of the log of k data and compares this value with an incorrect direct arithmetic mean.

K_s range: $1 \times 10^{-8} - 1 \times 10^{-3}$ cm/s

Geotechnical Engineering Circular No. 5
Evaluation of Soil and Rock Properties.

PLATE 27

Glacial outwash sand and gravel.



Loose:
$k_v = 1 \times 10^{-2}$ cm/s

Medium-dense:
$k_v = 1 \times 10^{-3}$ cm/s

Figure 91. Range of hydraulic conductivity based on grain size (after GeoSyntec, 1991).

Considering the site geology, the laboratory and field data should be tabulated with other known data for the sample/test location and with depth, soil/rock type, grain size distribution, Atterberg limits, and water content. This table should also include important test information such as: stress conditions, gradients, and test method. Once this table is constructed it will be much easier to group like soil types and k values, to delineate distinct areas within the site, and to eliminate potentially erroneous data. Once these values have been grouped together and potentially erroneous values eliminated, it may be useful to compute an average value for each grouping. When averaging, the log of the hydraulic conductivity value must be taken before performing an arithmetic mean or incorrect results will be produced. First, the logarithm of each value should be taken. Second, an average value should be calculated from these logarithmic values. Finally, the antilog of this average value should be taken to calculate the average hydraulic conductivity value. Table 35 illustrates how to calculate the mean of the log of k data and compares this value with an incorrect direct arithmetic mean.

Geotechnical Engineering Circular No. 5
Evaluation of Soil and Rock Properties.

Method: Geosyntec
Source: FHWA GEC No 5: pg 184

Equation: Graphic

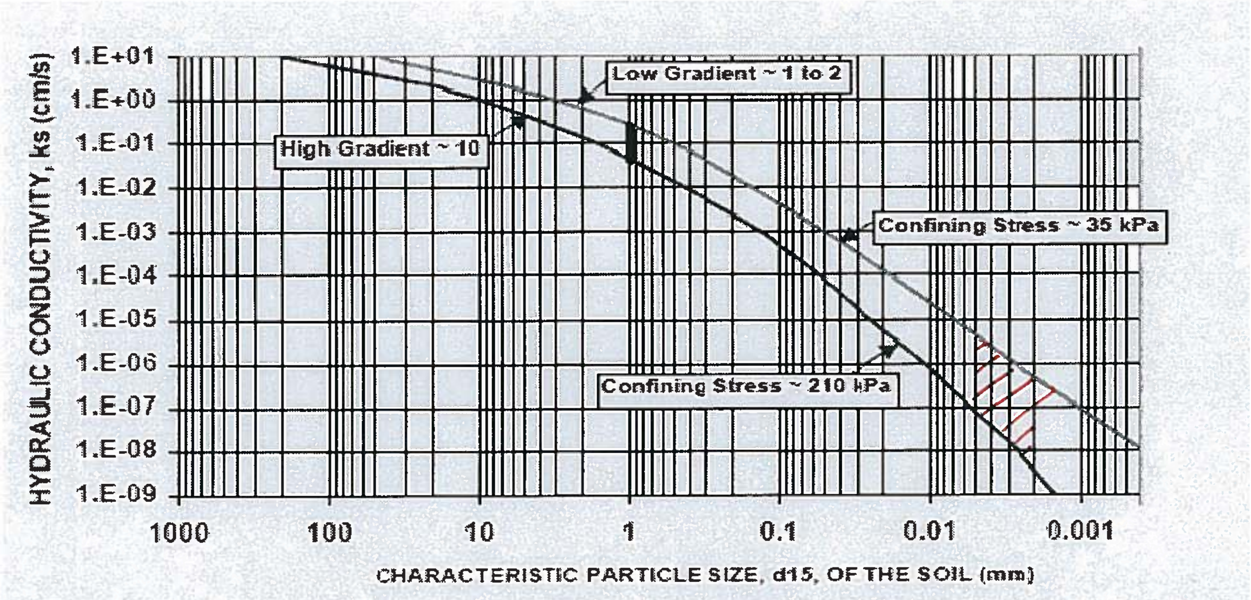


Figure 91. Range of hydraulic conductivity based on grain size after GeoSyntec, 1991).

LAYER: ORGANIC CLAYEY SILT

d_{15} RANGE = 0.0015 mm - 0.005 mm

AVG d_{15} = 0.002 mm

USE $K_v = 5 \times 10^{-6}$ cm/SEC BASED ON INCLUSION OF SILT SEAMS

PERMEABILITY TEST DATA AND COMPUTATION SHEET

((ASTM D-5084) FALLING HEAD, METHOD C)

Job Number: **011.11497.013**
Project Name: **Cardinal Ash Pond Investigation**
Project Location: **Brilliant, Ohio**
Tested By: **PJM**
Remarks:
Material: **FILL : Hard brown, gray and dark-gray silty clay inter-mixed with organic silt, trace fine to coarse sand.**

Date: **5/6-7/2009**
Boring: **CD-PZ-BAP-0907**
Sample: **ST-6A Sec. II**
Depth: **8.5' to 9.9'**

Maximum Dry Density:
Optimum Moisture Content:
% Compaction.:
Optimum +/-:
Natural: **X**
Remolded:

Sample:

Initial Length: 5.5945 in = 14.210 cm
Final Ave. Length (L): 5.6042 in = 14.235 cm
Diameter: 2.8765 in = 7.31 cm
Area (A): 6.499 sq in = 41.93 sq cm
Volume (V): 36.356 cu in = 595.77 cu cm
Wet Wt.: 1144.17 grams
Unit Wet Wt.: 119.90 pcf
Unit Dry Wt.: 93.99 pcf

Test Conditions:

Chamber Pressure: 62 psi
Back Pressure: 58 psi
Confining Pressure: 4 psi
Temp. @ Start: 22.5 °C
Temp. @ End: 22.5 °C
Average Temp.: 22.5 °C
B Parameter: 0.96

Moisture Content:	Before Test	After Test
Pan No. =	D	D
Wet Wt. + Pan =	1144.17	1157.03
Dry Wt. + Pan =	896.92	896.92
Wt. of Pan =	0.00	0.00
Wt. of Dry Soil =	896.92	896.92
Wt. of Water =	247.25	260.11
% Moisture =	27.57	29.00
% SATURATIOI	**93.80**	**98.30**
S.G.(est) =	2.7000	

Pipette Pressures During Test:

Top Pipette: 60 psi = 4220.3 cm
Bottom Pipette: 58 psi = 4079.6 cm

Pipette:

Area (a): 0.3435 sq in = 0.8725 sq cm

Calculations:

$$k = \frac{a \cdot L}{2 \cdot A \cdot \Delta t} \ln\left(\frac{h_1}{h_2}\right)$$

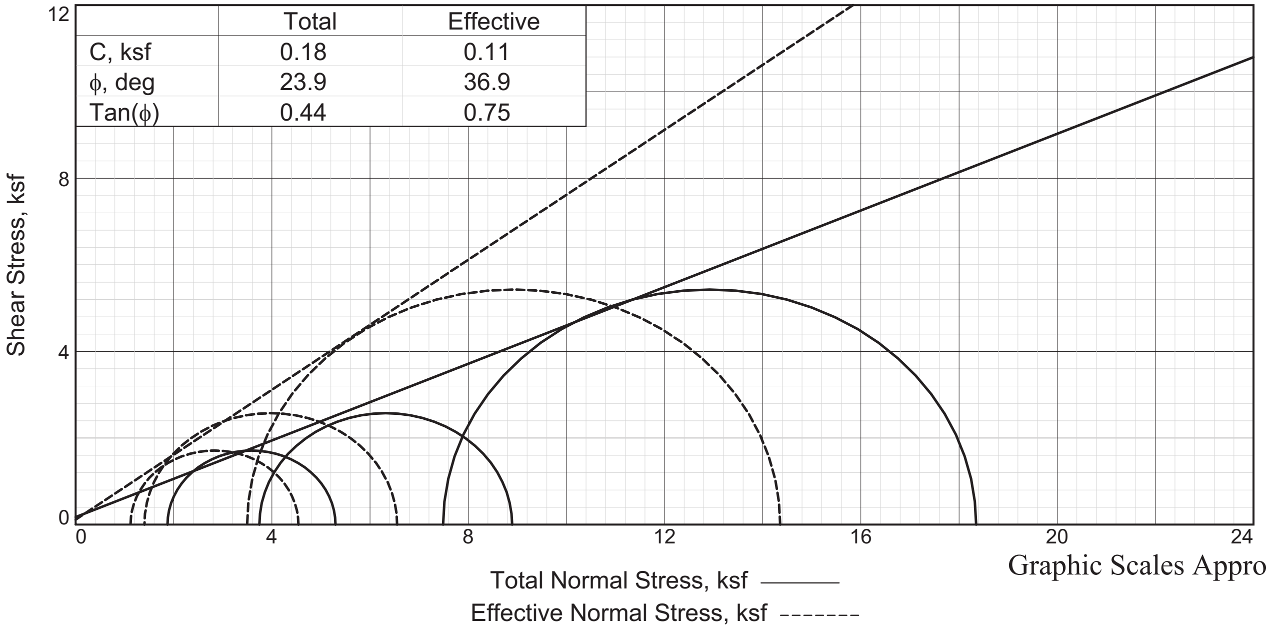
where:

k = Hydraulic Conductivity
a = Pipette Cross-Sectional Area
L = Length of Sample
A = Sample Cross-Sectional Area

Δt = Time Interval (t_2 - t_1)
h_1 = Head Loss Across Permeameter/Specimen at t_1
h_2 = Head Loss Across Permeameter/Specimen at t_2
ln = Natural Logarithm (Base e = 2.71828)

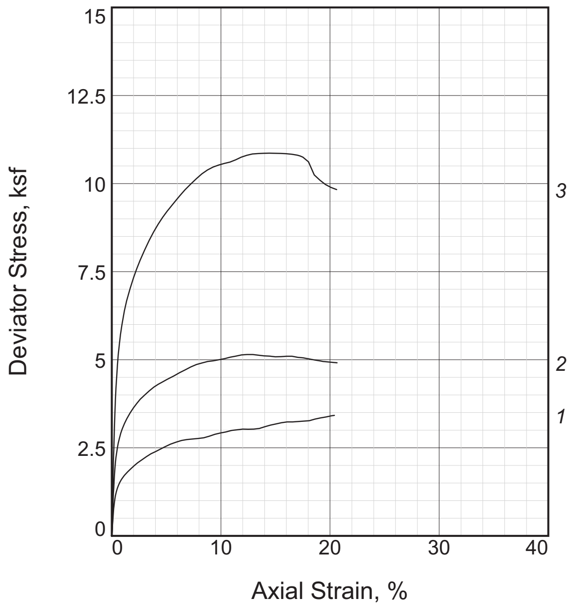
Date	Time Readings	Time Interval Δt Seconds	Top Pipette cc	Hydraulic Head Headwater H_1 cm	Bottom Pipette cc	Hydraulic Head Tailwater H_2 cm	Head Loss h = H_1-H_2 cm	ℓn (h_1/h_2)	Temp. Corr. Permeability k cm/sec
5/6/2009	9:45 AM	0.00	48.45	4092.08	14.20	4272.01	-179.93	–	–
5/6/2009	10:51 AM	3,960	48.40	4092.14	14.45	4271.73	-179.59	0.00191	6.740E-08
5/6/2009	12:15 PM	5,040	48.20	4092.36	14.65	4271.50	-179.13	0.00256	7.077E-08
5/6/2009	1:45 PM	5,400	48.05	4092.54	15.00	4271.09	-178.56	0.00320	8.280E-08
5/6/2009	3:17 PM	5,520	47.85	4092.77	15.25	4270.81	-178.04	0.00289	7.312E-08
5/7/2009	8:21 AM	61,440	45.60	4095.34	18.00	4267.66	-172.31	0.03272	7.431E-08

Time Weighted Average, k [cm/sec] = **7.423E-08**



	Total	Effective
C, ksf	0.18	0.11
ϕ, deg	23.9	36.9
Tan(ϕ)	0.44	0.75

Graphic Scales Approximate



	Sample No.	1	2	3
Initial	Water Content, %	35.1	43.8	31.9
	Dry Density, pcf	83.0	76.2	85.0
	Saturation, %	92.2	97.7	87.6
	Void Ratio	1.0297	1.2123	0.9833
	Diameter, in.	2.90	2.85	2.90
	Height, in.	5.59	5.59	5.59
At Test	Water Content, %	33.3	38.9	31.0
	Dry Density, pcf	86.9	82.6	90.3
	Saturation, %	95.6	101.0	96.5
	Void Ratio	0.9402	1.0401	0.8674
	Diameter, in.	2.86	2.78	2.85
	Height, in.	5.49	5.42	5.43
	Strain rate, in./min.	0.00	0.00	0.00
	Back Pressure, psi	40.00	40.00	40.00
	Cell Pressure, psi	53.00	66.00	92.00
	Fail. Stress, ksf	3.4	5.1	10.9
	Total Pore Pr., ksf	6.5	8.1	9.8
	Ult. Stress, ksf	3.4	4.9	9.8
	Total Pore Pr., ksf	6.5	8.0	9.9
	$\bar{\sigma}_1$ Failure, ksf	4.5	6.6	14.4
	$\bar{\sigma}_3$ Failure, ksf	1.1	1.4	3.5

Type of Test:
CU with Pore Pressures

Sample Type: Shelby Tube

Description: Gray mottled with dark-gray and brown clayey silt, some fine sand, trace medium to

LL= 35 **PL=** 28 **PI=** 7

Assumed Specific Gravity= 2.7

Remarks:

1

Client:

Project: Cardinal Plant Ash Pond Investigation
Brilliant, Ohio

Location: CD-PZ-BAP-0901

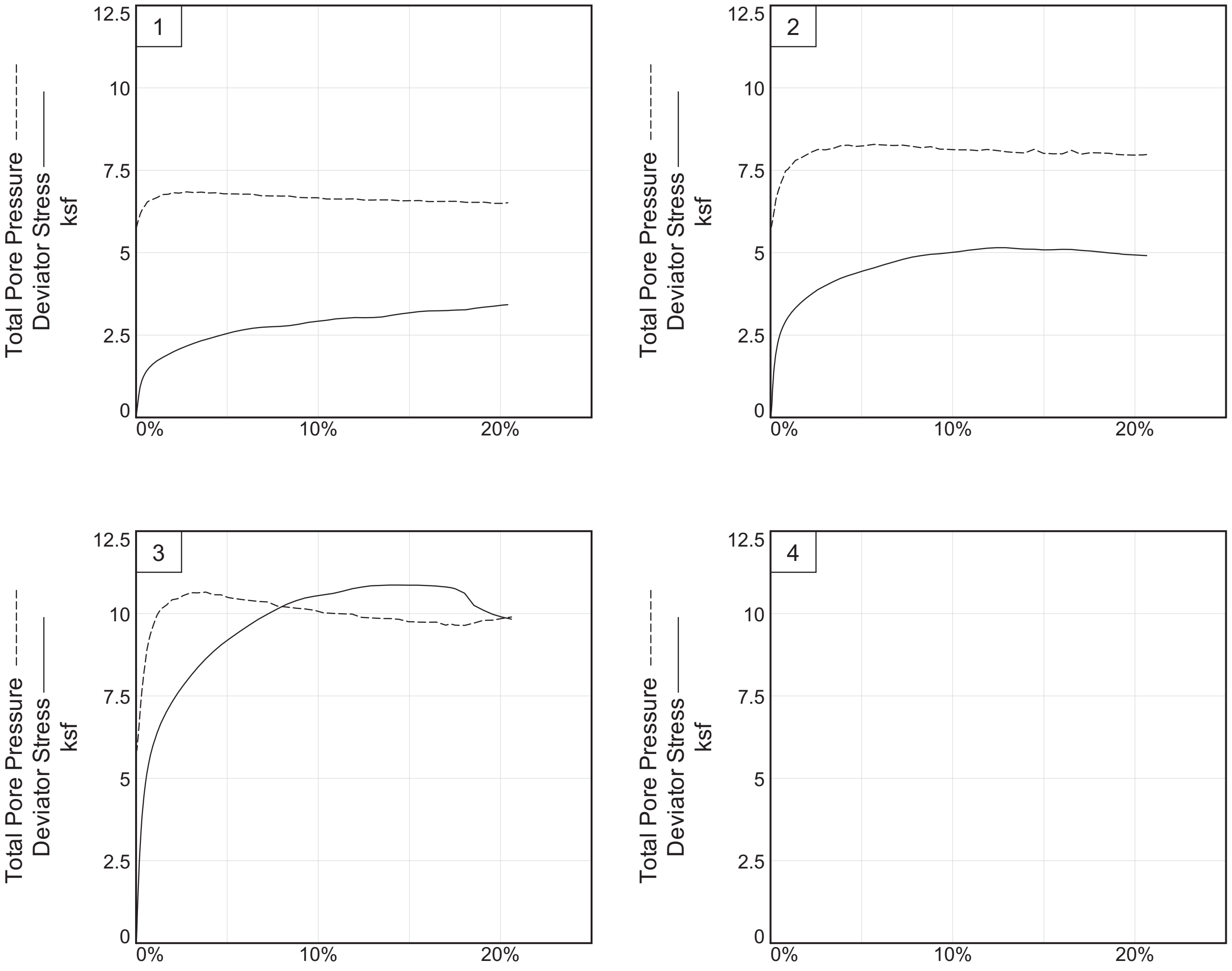
Sample Number: ST-19A **Depth:** 31.0' to 32.8'

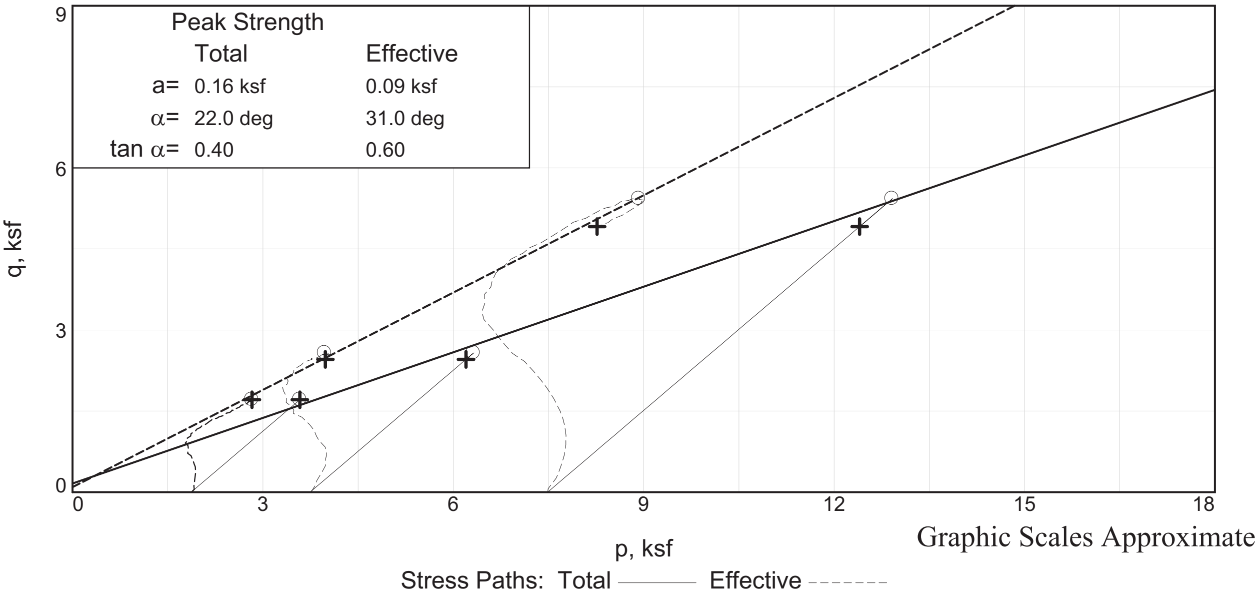
Proj. No.: 011.11497.013 **Date Sampled:** 5/1/09

TRIAXIAL SHEAR TEST REPORT

BBC&M Engineering, Inc.

Tested By: PJM **Checked By:** JJ





Peak Strength

	Total	Effective
a=	0.16 ksf	0.09 ksf
α=	22.0 deg	31.0 deg
tan α=	0.40	0.60

Graphic Scales Approximate

Client:

Project: Cardinal Plant Ash Pond Investigation

Location: CD-PZ-BAP-0901 **Depth:** 31.0' to 32.8' **Sample Number:** ST-19A

2

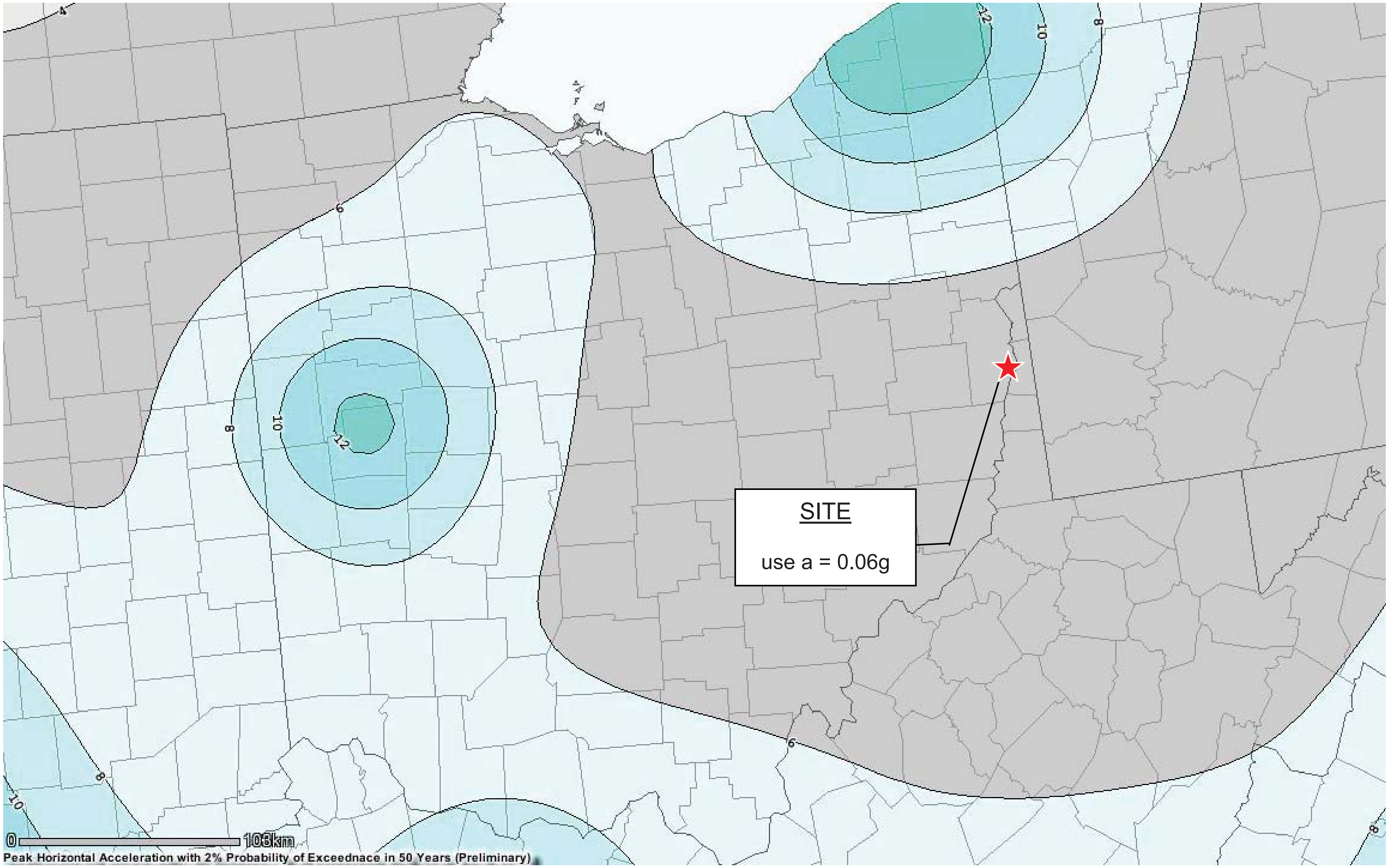
Project No.: 011.11497.013

BBC&M Engineering, Inc.

Tested By: PJM **Checked By:** JJ

USGS National Seismic Hazard Maps - 2008

Peak Horizontal Acceleration with 2% Probability of Exceedence in 50 Years

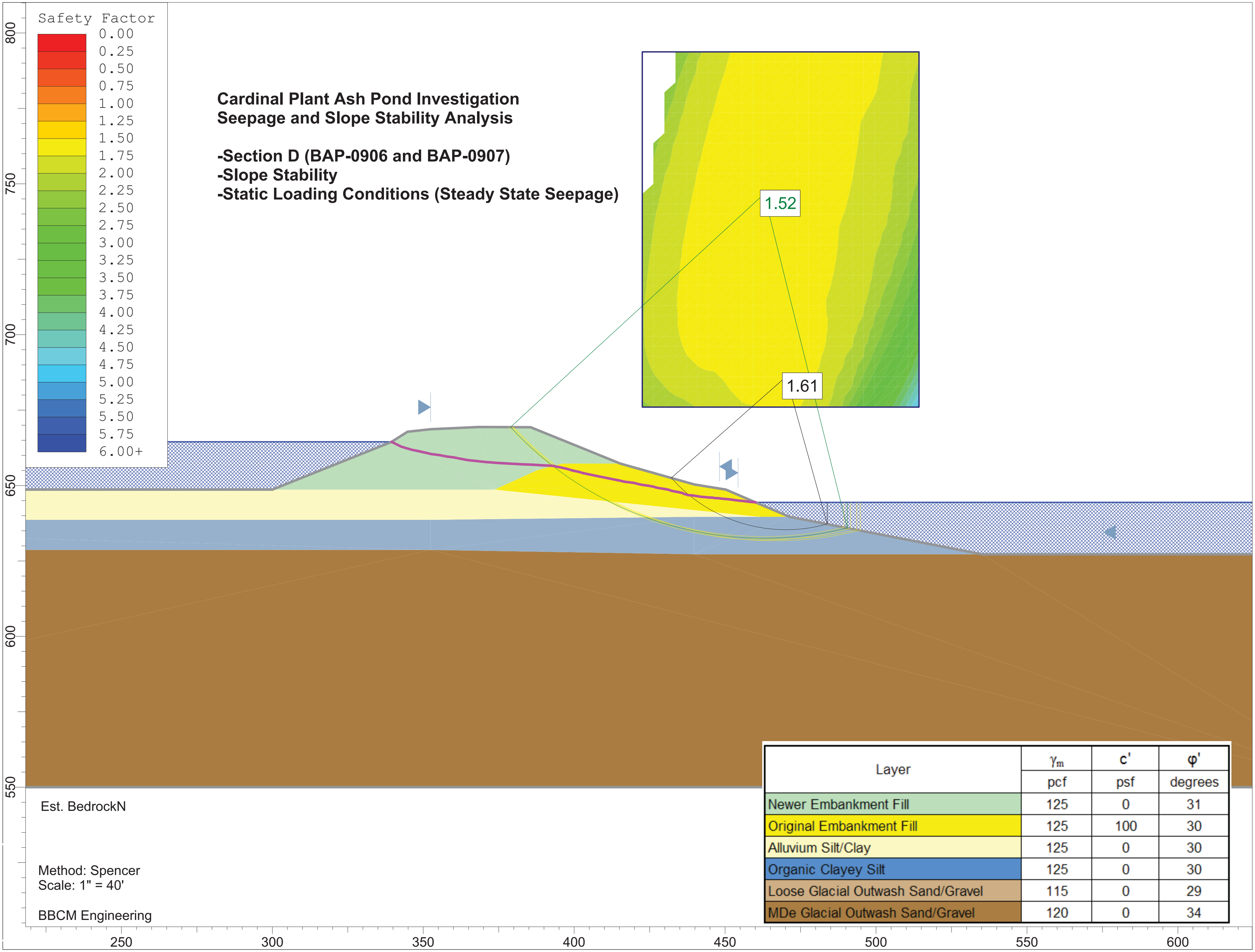


SITE

use a = 0.06g

PLATE 33

Appendix IV – Limit Equilibrium Analysis



Cardinal Plant Ash Pond Investigation
Seepage and Slope Stability Analysis

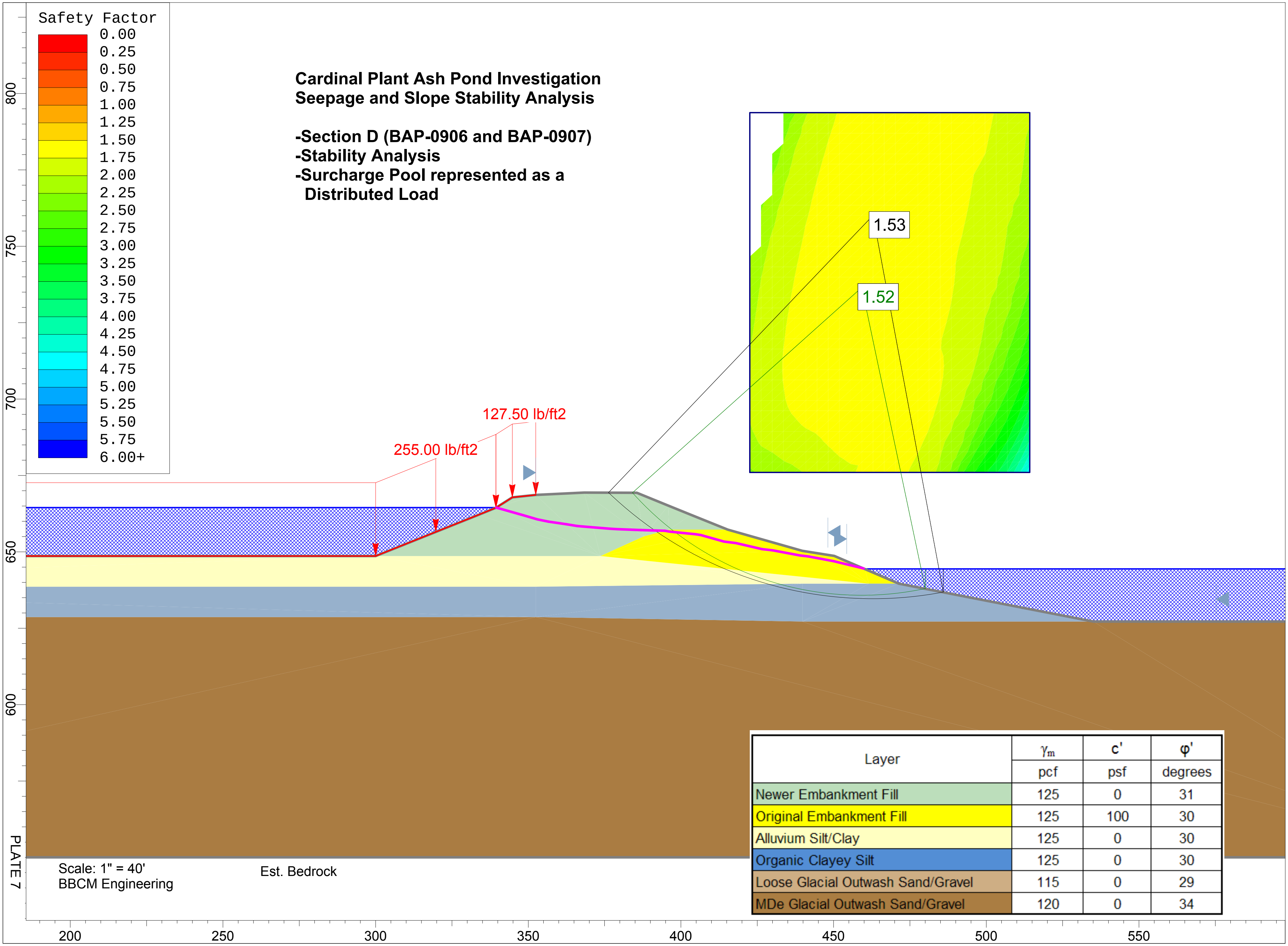
-Section D (BAP-0906 and BAP-0907)
-Slope Stability
-Static Loading Conditions (Steady State Seepage)

Layer	γ_m	c'	φ'
	pcf	psf	degrees
Newer Embankment Fill	125	0	31
Original Embankment Fill	125	100	30
Alluvium Silt/Clay	125	0	30
Organic Clayey Silt	125	0	30
Loose Glacial Outwash Sand/Gravel	115	0	29
MDe Glacial Outwash Sand/Gravel	120	0	34

Method: Spencer
Scale: 1" = 40'

BBCM Engineering

PLATE 10



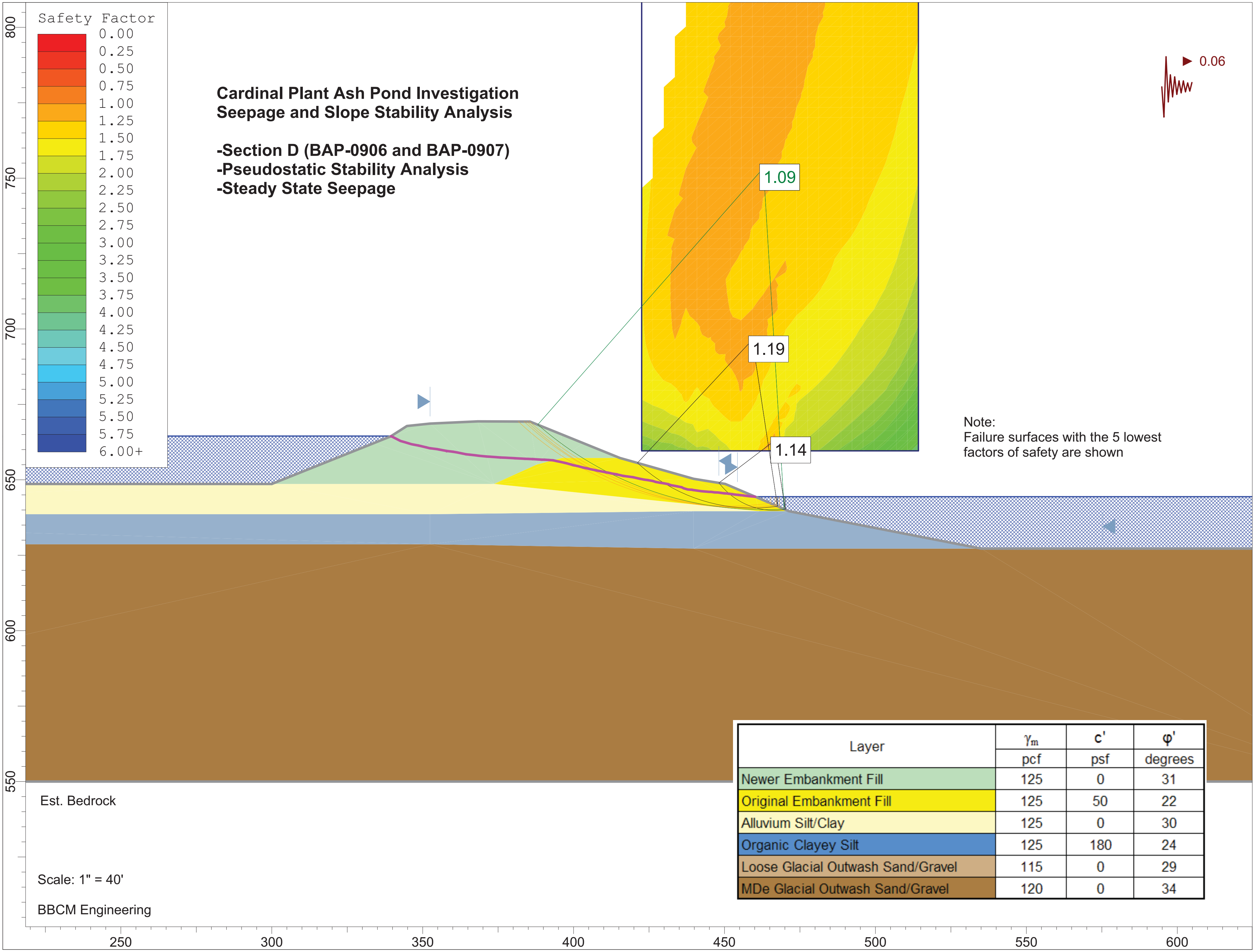
Cardinal Plant Ash Pond Investigation
Seepage and Slope Stability Analysis

-Section D (BAP-0906 and BAP-0907)
-Stability Analysis
-Surcharge Pool represented as a
Distributed Load

Layer	γ_m	c'	φ'
	pcf	psf	degrees
Newer Embankment Fill	125	0	31
Original Embankment Fill	125	100	30
Alluvium Silt/Clay	125	0	30
Organic Clayey Silt	125	0	30
Loose Glacial Outwash Sand/Gravel	115	0	29
MDe Glacial Outwash Sand/Gravel	120	0	34

Scale: 1" = 40'
BBCM Engineering

PLATE 7



Cardinal Plant Ash Pond Investigation
Seepage and Slope Stability Analysis

-Section D (BAP-0906 and BAP-0907)
-Pseudostatic Stability Analysis
-Steady State Seepage

Note:
Failure surfaces with the 5 lowest factors of safety are shown

Layer	γ_m	c'	φ'
	pcf	psf	degrees
Newer Embankment Fill	125	0	31
Original Embankment Fill	125	50	22
Alluvium Silt/Clay	125	0	30
Organic Clayey Silt	125	180	24
Loose Glacial Outwash Sand/Gravel	115	0	29
MDe Glacial Outwash Sand/Gravel	120	0	34

Est. Bedrock

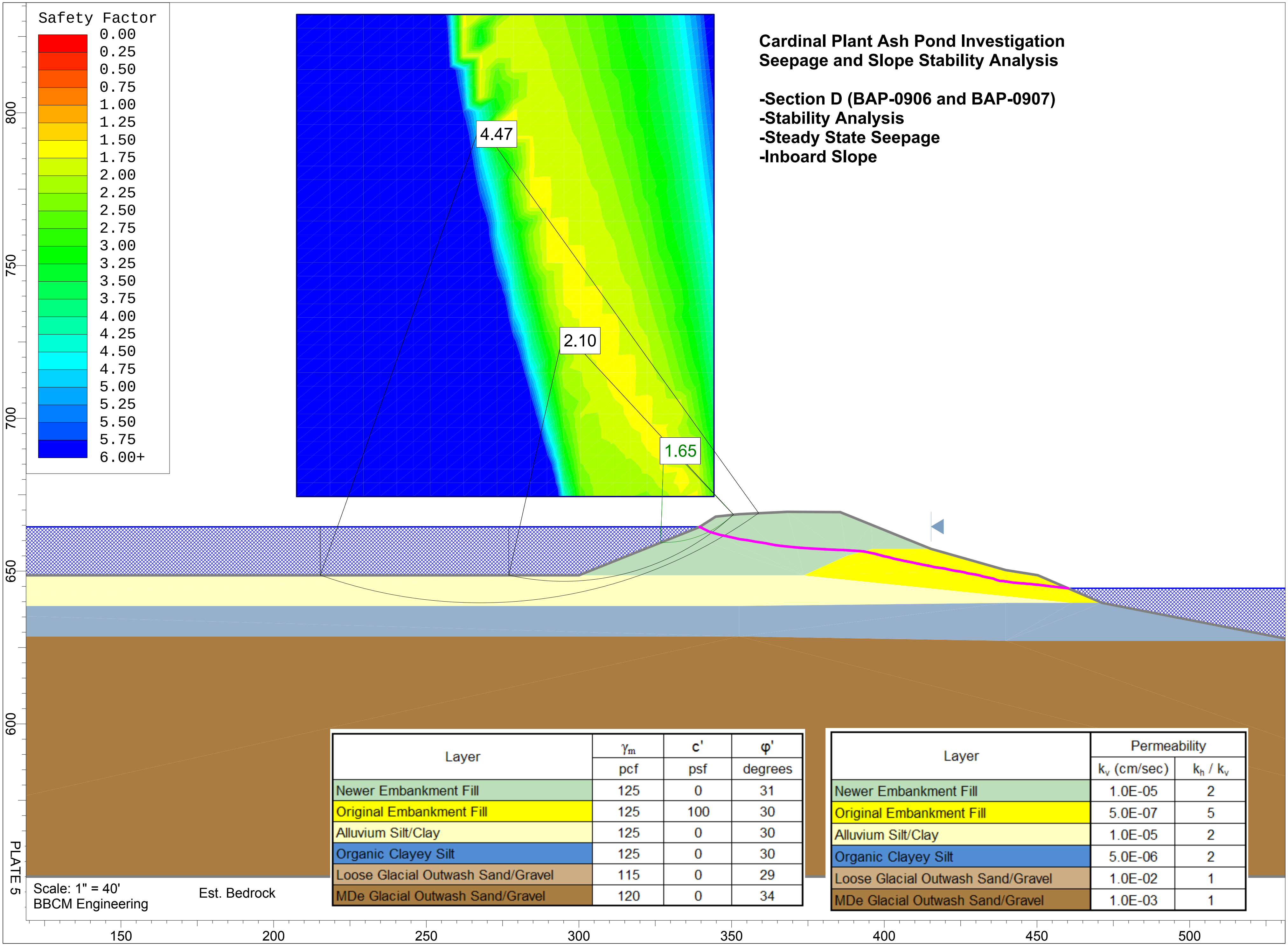
Scale: 1" = 40'

BBCM Engineering

PLATE 11

Cardinal Plant Ash Pond Investigation
Seepage and Slope Stability Analysis

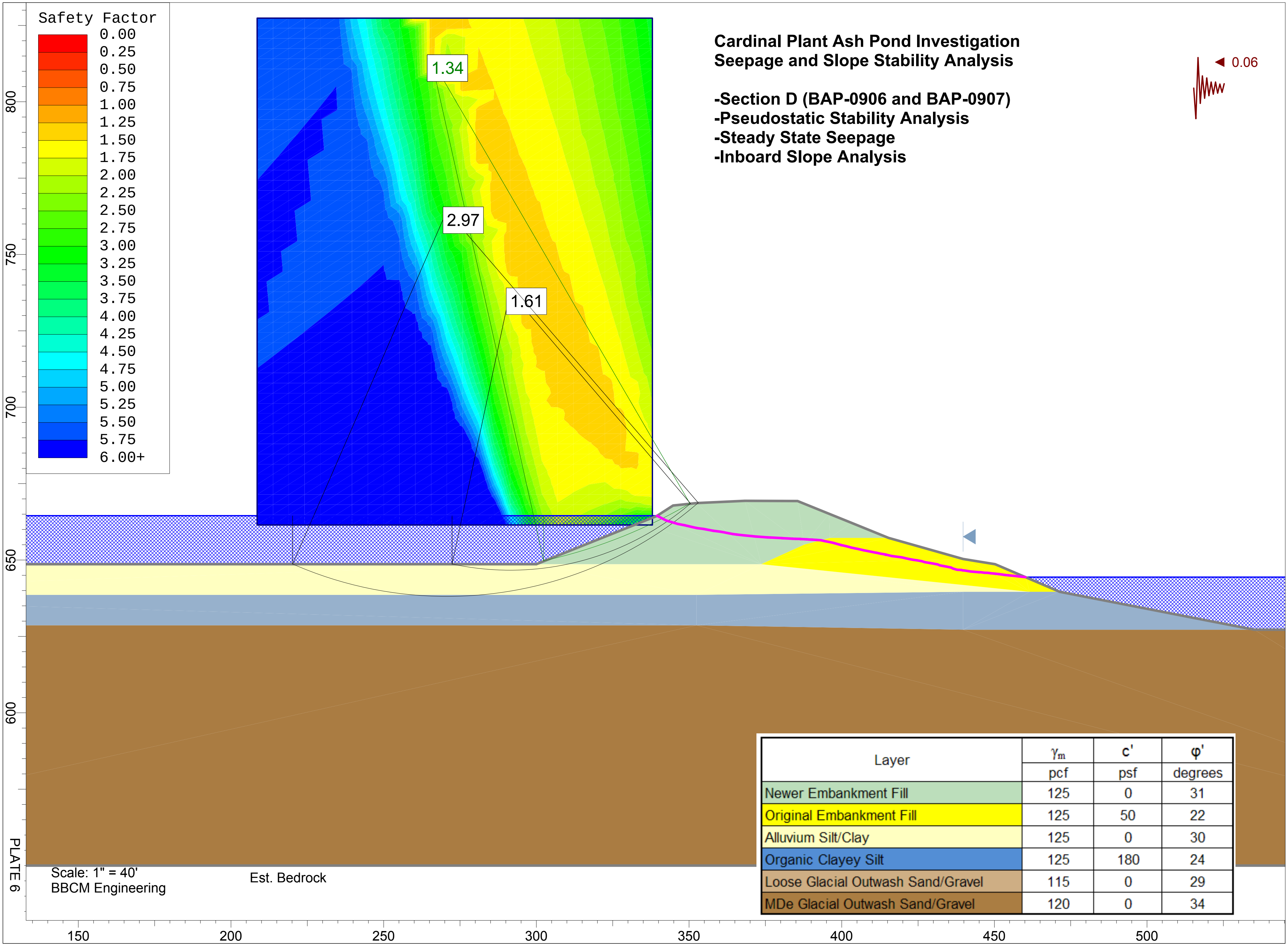
-Section D (BAP-0906 and BAP-0907)
-Stability Analysis
-Steady State Seepage
-Inboard Slope



Scale: 1" = 40'
BBCM Engineering

Layer	γ_m	c'	φ'
	pcf	psf	degrees
Newer Embankment Fill	125	0	31
Original Embankment Fill	125	100	30
Alluvium Silt/Clay	125	0	30
Organic Clayey Silt	125	0	30
Loose Glacial Outwash Sand/Gravel	115	0	29
MDe Glacial Outwash Sand/Gravel	120	0	34

Layer	Permeability	
	k_v (cm/sec)	k_h / k_v
Newer Embankment Fill	1.0E-05	2
Original Embankment Fill	5.0E-07	5
Alluvium Silt/Clay	1.0E-05	2
Organic Clayey Silt	5.0E-06	2
Loose Glacial Outwash Sand/Gravel	1.0E-02	1
MDe Glacial Outwash Sand/Gravel	1.0E-03	1



Cardinal Plant Ash Pond Investigation
Seepage and Slope Stability Analysis

-Section D (BAP-0906 and BAP-0907)
-Pseudostatic Stability Analysis
-Steady State Seepage
-Inboard Slope Analysis

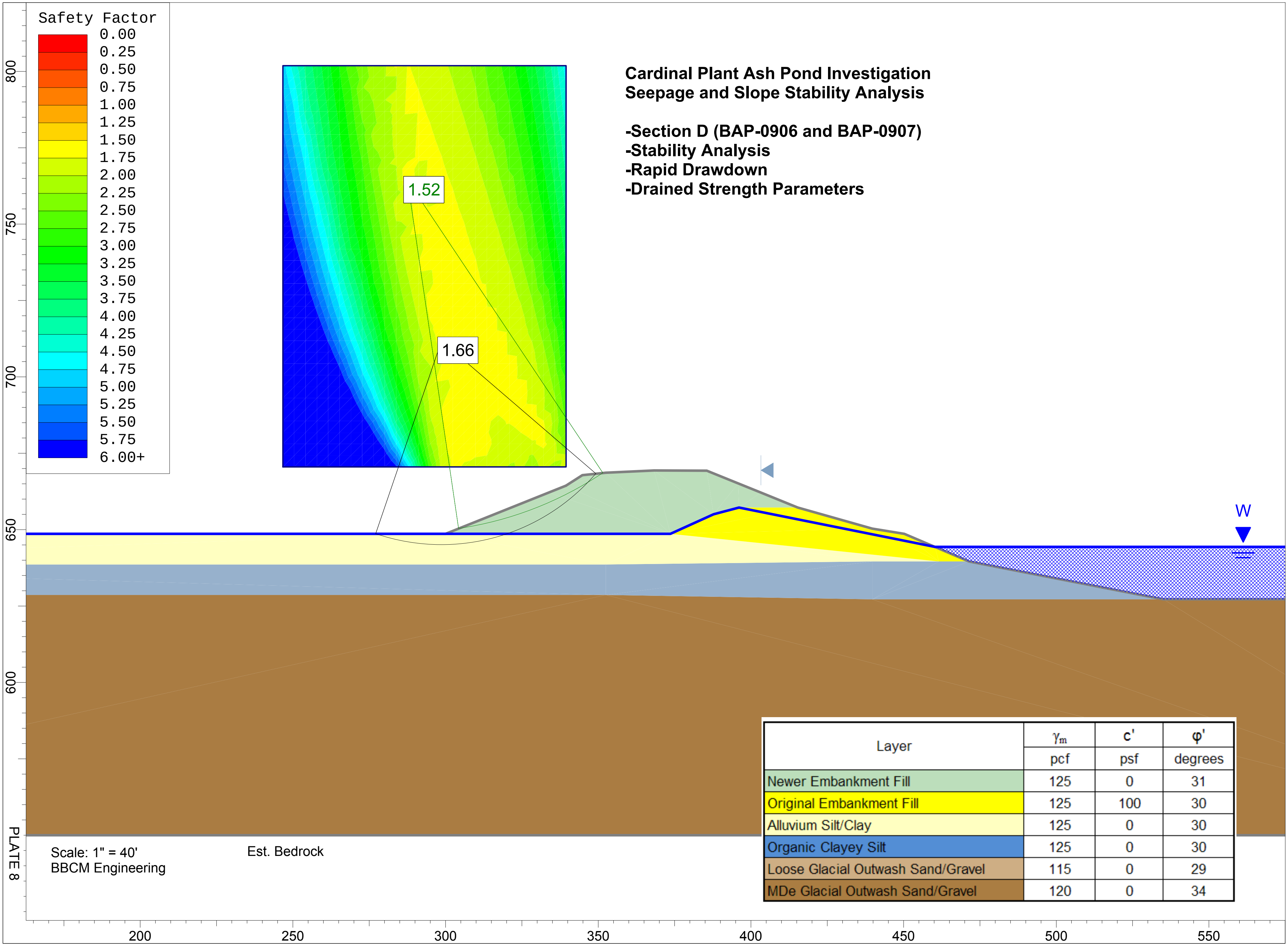
Layer	γ_m	c'	φ'
	pcf	psf	degrees
Newer Embankment Fill	125	0	31
Original Embankment Fill	125	50	22
Alluvium Silt/Clay	125	0	30
Organic Clayey Silt	125	180	24
Loose Glacial Outwash Sand/Gravel	115	0	29
MDe Glacial Outwash Sand/Gravel	120	0	34

Scale: 1" = 40'
BBCM Engineering

PLATE 6

Cardinal Plant Ash Pond Investigation
Seepage and Slope Stability Analysis

-Section D (BAP-0906 and BAP-0907)
-Stability Analysis
-Rapid Drawdown
-Drained Strength Parameters



Layer	γ_m	c'	φ'
	pcf	psf	degrees
Newer Embankment Fill	125	0	31
Original Embankment Fill	125	100	30
Alluvium Silt/Clay	125	0	30
Organic Clayey Silt	125	0	30
Loose Glacial Outwash Sand/Gravel	115	0	29
MDe Glacial Outwash Sand/Gravel	120	0	34

Scale: 1" = 40'
BBCM Engineering

Est. Bedrock

PLATE 8

INDEX TESTING SUMMARY
LIQUEFACTION SCREENING

Fine Grained Soil Liquefaction Screening
Cardinal Bottom Ash Pond

Layer: NEWER EMBANKMENT FILL

BORING NUMBER	SAMPLE NUMBER	SAMPLE DEPTH	NATURAL MOISTURE CONTENT	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTIC INDEX %	GRAVEL %	SAND %	SILT %	CLAY .005 mm %	CLAY .002 mm %	SILT/CLAY %	USCS CLASSIFICATION	Fines Content and Plasticity Index Screening			Is Soil Sample Liquefiable (meets all three criteria)
															% Passing		
														LL < 35	0.005 < 15	WC < 0.9LL	
BAP-0901	S-5	7.75	16	28	18	10								Yes	-	Yes	-
BAP-0901	S-9	13.75	13	27	17	10								Yes	-	Yes	-
BAP-0901	S-12	18.25	14	37	24	13	7	32	49	23	12	61	SANDY LEAN CLAY CL	No	No	Yes	No
BAP-0902	S-11	16.75	24	37	19	18								No	-	Yes	No
BAP-0902	S-12	18.25	21	35	17	18	8	37	33	28	21	54	SANDY LEAN CLAY CL	No	No	Yes	No
BAP-0902	S-13	19.75	31	29	17	12	1	20	62	28	17	79	LEAN CLAY with SAND CL	Yes	No	No	No
BAP-0904	S-9	13.75	16	35	21	14								No	-	Yes	No
BAP-0906	S-3	4.75	15	27	17	10								Yes	-	Yes	-
BAP-0906	S-8	12.75					30	40	22	13	9	31		-	Yes	-	-
BAP-0906	S-11	17.25	14	31	19	12	18	44	26	18	12	38	CLAYEY SAND with GRAVEL SC	Yes	No	Yes	No

Layer: ORIGINAL EMBANKMENT FILL

BORING NUMBER	SAMPLE NUMBER	SAMPLE DEPTH	NATURAL MOISTURE CONTENT	LIQUID LIMIT %	PLASTIC LIMIT %	PLASTIC INDEX %	GRAVEL %	SAND %	SILT %	CLAY .005 mm %	CLAY .002 mm %	SILT/CLAY %	USCS CLASSIFICATION	Fines Content and Plasticity Index Screening			Is Soil Sample Liquefiable (meets all three criteria)
															% Passing		
														LL < 35	0.005 < 15	WC < 0.9LL	
BAP-0903	S-2	3.25	24	48	24	24	0	8	60	45	32	92	LEAN CLAY CL	No	No	Yes	No
BAP-0903	S-5	7.75	20	36	20	16	0	14	58	38	28	86	LEAN CLAY CL	No	No	Yes	No
BAP-0905	S-3	4.75	17	32	18	14	0	25	53	30	23	76	LEAN CLAY with SAND CL	Yes	No	Yes	No
BAP-0905	S-5	7.75	22	48	24	24								No	-	Yes	No
BAP-0907	S-5	7.75	23	49	26	23								No	-	Yes	No
BAP-0907	S-6A	9.25	28	47	29	18	0	5	67	43	29	96	SILT ML	No	No	Yes	No

Appendix V – 2009 Investigation Report Text

August 4, 2009
011-11497-013

BBCM
SOLUTIONS TO BUILD ON

Mr. Pedro Amaya, P.E.
American Electric Power
1 Riverside Plaza
Columbus, OH 43215

Re: Subsurface Investigation and Analysis
Bottom Ash Pond Embankments
AEP Cardinal Plant
Brilliant, Ohio

Dear Mr. Amaya:

In accordance with our proposal dated March 23, 2009, and our signed contract dated March 25, 2009, BBC&M Engineering, Inc. (BBCM) has completed a geotechnical assessment of the embankment separating the Bottom Ash Complex from the Ohio River at the Cardinal Generating Plant in Brilliant, Ohio.

BBCM's scope of work, as developed by AEP, consisted of obtaining subsurface data at a total of four cross-sections through the bottom ash pond an recirculation pond embankments, and performing seepage and slope stability analyses to provide an indication as to the level of safety provided by the embankments. The following report is a summary of our investigation.

We appreciate having been given the opportunity to be of service on this project. If you have any questions, please do not hesitate to contact this office.

Respectfully submitted,

BBC&M ENGINEERING, INC.
Columbus, Ohio

Michael T. Romanello, E.I.
Staff Engineer

Michael G. Rowland, P.E.
Senior Engineer

Submitted: 4 bound copies
1 electronic copy on CDROM

6190 Enterprise Court • Dublin, OH 43016 - 3293 • Phone 614.793.2226 • Fax 614.793.2410

Cardinal Generating Plant
Bottom Ash Pond Investigation

Brilliant, Ohio

Report to

American Electric Power Service Corp.
Columbus, Ohio

Prepared by

BBCM Engineering, Inc.
Dublin, Ohio

August, 2009

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APPENDIX B

APPENDIX C

APPENDIX D

INTRODUCTION

The Cardinal Generating Plant is located along the Ohio river between Brilliant, Ohio and Tiltonsville, Ohio, as shown on the Vicinity Map, included as Plate 1 of Appendix A. The Bottom Ash Pond Complex is located along the west bank of the river just to the south of the main plant area. The Bottom Ash Complex consists of two components: the Bottom Ash Pond and the Recirculation Pond. The Bottom Ash Pond is located north of the Recirculation Pond and they are separated by an earthen embankment. The crest elevation for all of the embankments is approximately the same, but vary in Elevation from 668.6' to 669.4' at the surveyed cross sections. The total length of the exterior embankment along the Ohio River is approximately 2,000 feet. For comparison, the normal pool for this stretch of the Ohio River is El. 644. Both ponds are isolated from exterior surface water inflow.

SCOPE OF WORK

The purpose of this Geotechnical Assessment was to provide an indication as to the level of safety provided by the dam separating the ponds from the Ohio River. The work which was performed as part of the limited subsurface investigation consisted of 1) review of the original plans; 2) the performance of two soil borings each at four different locations (one at the crest and one at the toe); 3) conversion of four soil borings into observation wells; 4) the completion of laboratory testing on the recovered samples; and, 5) engineering analyses of the existing embankments with consideration to seepage, steady-state slope stability and seismic slope stability.

REVIEW OF HISTORICAL PLANS

The Site Development Plan for the Ash Storage Area and the corresponding Sections Plan (drawings numbers 3-3017-5 and 3-3027-3, respectively) from the ash pond vertical expansion in the 1970s were made available for review. The plans were developed in 1973 and include 'Record Drawing' information through 1978. The ash pond complex is believed to have been originally constructed in the 1960s when the plant was first brought online. BBCM also received an electronic drawing file of the plant, including topographic data, as depicted in the Plan of Borings presented as Plate 2 in Appendix A. The aerial survey used to develop the drawing file was performed in 1994.

Based on the historical cross-sections extending through both the Bottom Ash Pond and the Recirculation Pond from the vertical expansion, the original ash pond embankments along the Ohio River ranged in height from 4 to 6 feet above the bottom of the ash pond. Historical Sections 'A-A' and 'C-C' detail the vertical expansion plans for the embankment which was assessed during this investigation. These cross-sections are presented as Plates 1 and 2 of Appendix C. Based on the sections, the original embankment was raised by approximately 10 to 12 feet by constructing an earthen embankment on the inboard slope of the original embankments. The construction was intended to raise the crest from an approximate elevation of 658.0 feet to Elevation 670.0 feet. The approximate boundary of the original ash pond embankment is depicted on the historical cross-sections as well as the seepage and stability analysis graphic output.

GEOLOGY

The natural soils at the site generally consist of a layer of alluvium silt, clay and fine sand over glacial outwash deposits of variable thickness overlying the bedrock surface. The alluvium clays and silts were deposited in the backwater of the Ohio River, while the outwash materials typically consist of sand, gravel and silt deposits deposited during the last ice age. Based on geological literature, the glacial outwash extends to the bedrock surface, estimated to be roughly 60 feet below the natural ground surface at the pond. The upper most bedrock most likely consists of shale and/or sandstone belonging to the Conemaugh Group of Pennsylvanian Age.

FIELD WORK

Site Reconnaissance

On March 20, 2009, a Senior Engineer and a Project Engineer from our office performed a Dam and Dike Condition Survey and results were presented in the 2009 Inspection Report for the Ash Impoundment. During the condition survey, the locations of the critical cross sections determined by AEP were observed, and the proposed borings were staked in these areas. Additional information concerning the visual condition of the dam may be found in this report.

Soil Borings

During the period of April 6 through April 10, 2009, BBCM was on site and performed a total of seven (7) soil borings, designated CD-BAP-0901 through CD-BAP-0907, that were extended to depths ranging from 30.0 to 60.5 feet below existing grade. A 'PZ' designation was added to Borings CD-PZ-BAP-0902, 0904, and 0905 to indicate an observation well was installed within the borehole. For simplicity throughout this report, the borings are typically referred to with the 'BAP' (Bottom Ash Pond) designation only. Borings BAP-0901, 0902, 0904 and 0906 were located at the crest of the pond embankments and Borings BAP-0903, 0905, and 0907 were located at the outboard toe of the embankment slopes, and were placed to correspond with the crest borings. The boring location areas were selected by AEP and field located by BBCM. The boring locations are shown on the 'Plan of Borings' presented on a full size drawing as Plate 2 in Appendix A. All boring locations and elevations, as well as additional ground surface points near the borings were surveyed by AEP personnel to create surface profiles.

All borings were performed with either a truck-mounted drill rig or an all-terrain-vehicle (ATV) mounted drill rig and were advanced between sampling attempts using 3¼-inch or 4¼-inch I.D. hollow-stem augers. Disturbed, but representative samples were obtained by lowering a 2-inch O.D. split-barrel sampler to the bottom of the hole and driving it into the soil by blows from a 140-pound automatic hammer freely falling 30 inches (Standard Penetration Test, ASTM D1586). The automatic hammer used to advance the SPT sampler had previously been calibrated for energy transmission using dynamic pile monitoring methods. The energy calibration factor is included on the boring logs. SPT sampling was performed continuously through the embankment fill and at 2½-foot intervals once the native soil was encountered. Split barrel samples were examined immediately after recovery and representative portions of each sample were placed in air tight jars and retained for subsequent laboratory testing.

Undisturbed Soil Samples

In addition to the disturbed samples, thin-walled press tube samples (“Shelby” tubes) were also attempted at various depths in order to obtain relatively undisturbed soil samples for strength testing. The samples were collected by hydraulically pressing a 3-inch diameter thin-walled steel (Shelby) tube at the end of the drill rod stem into the soil at a uniform rate. The samples were preserved inside the Shelby tube sampler and sealed with wax. The sample collection was completed in accordance with ASTM D 1587 Method for Thin-Walled Tube Geotechnical Sampling of Soils. Two Shelby tube samples were obtained in Boring BAP-0901 and one Shelby tube sample was obtained in each of borings BAP-0903 and BAP-0906. It should be noted that several other attempts were made to obtain additional undisturbed samples but resulted in crushing the tube or no recovery.

Borehole Backfilling and Observation Wells

During and at the completion of drilling, groundwater readings were measured and recorded in each boring. In Borings CD-PZ-BAP-0902, 0904, and 0905, wells were installed to permit future groundwater readings. The wells consist of 2-inch diameter PVC, well casings and screens. Screens are nominal 10-foot lengths with 10-slotted openings. Quartz sand was used as a filter (where the surrounding soil does not consist of sand and gravel) and was placed to a level approximately 2 feet above the top of the well screen. A well seal consisting of approximately 2 feet of granular bentonite (3/8-inch hole plug) was set above the filter pack and the remainder of the annular space was filled with a bentonite slurry (benseal). A lockable steel cover was installed over the well and a 3 foot by 3 foot concrete pad was constructed to protect the exposed portion of the well which extends above the ground surface. Three to four steel bollards were installed around each concrete pad to protect the well.

During the installation of the wells, a surge block was used to densify the sand pack. Upon completion, each well was developed. Well development includes an attempt to hand bail 10 well volumes of groundwater from each well. Well Completion Diagrams are presented as Plates 23 though 25 of Appendix A. BBCM understands that all follow up groundwater level measurements will be obtained by AEP personnel. It is also understood that AEP will formally survey in the top of pipe for the three wells.

Recording of Field Data

In the field, the following procedures and specific duties were performed by a Staff Engineer or a Field Geologist from our office:

- examined all samples recovered from the borings;
- cleaned soil samples of cuttings and preserved representative portions in airtight glass jars;
- made seepage observations and measured the water levels in the borings;
- prepared a log of each boring;
- made hand-penetrometer measurements in soil samples exhibiting cohesion; and,
- provided liaison between the field personnel and the Project Manager so that the field investigation could be modified in the event that unexpected subsurface conditions were encountered.

At the completion of drilling, all samples were transported to the BBCM laboratory for further examination and testing.

LABORATORY TESTING

Index Testing

Laboratory testing was performed on selected representative soil samples obtained during the field investigations to determine natural moisture content (ASTM D2216), liquid and plastic limits (BBCM adjustment to ASTM D4318), and grain size analyses (ASTM D422). The results of these and other tests permit an evaluation of the strength, compressibility and permeability characteristics of the soils encountered at this site.

The results of the moisture content testing and of the liquid and plastic limits are graphically displayed on the individual boring logs presented in Appendix A. The results of all grain size analyses are also displayed graphically and presented as Plates 10 through 66 in Appendix B. All laboratory test results and a summary of laboratory test results are presented in Appendix B.

Table 1 summarizes the results of the index testing for the each layer except for the glacial outwash sand and gravel, where only a limited number of index testing was performed. For a comprehensive summary of all index testing performed, see Plates 3 through 7 of Appendix C.

Table 1. Summary of index values

Newer Embankment Fill

Statistic	*MC*	*LL*	*PL*	*PI*	*CF*
Sample Size	16	12	12	12	8
Minimum	10	25	16	9	8
Maximum	31	37	24	18	21
Mean	16.3	30.3	18.3	12.1	12.1
Median	15	29	17	11	11
Mode	16	27	17	10	12
Standard Deviation	5.4	4.5	2.3	3.2	4.6

Original Embankment Fill

Statistic	*MC*	*LL*	*PL*	*PI*	*CF*
Sample Size	10	6	6	6	4
Minimum	15	32	18	14	23
Maximum	33	49	29	24	32
Mean	22.5	43.3	23.5	19.8	28.0
Median	22	48	24	21	29
Mode	22	48	24	24	N/A
Standard Deviation	5.1	7.4	4.0	4.4	3.7

Alluvium Silt and Clay

Statistic	*MC*	*LL*	*PL*	*PI*	*CF*
Sample Size	10	4	4	4	10
Minimum	22	34	21	7	3
Maximum	38	38	28	15	28
Mean	29.0	36.0	23.5	12.5	11.0
Median	29	36	23	14	7
Mode	26	N/A	N/A	15	5
Standard Deviation	5.4	1.8	3.1	3.8	8.5

Organic Clayey Silt

Statistic	*MC*	*LL*	*PL*	*PI*	*CF*
Sample Size	22	18	18	18	21
Minimum	28	30	22	3	5
Maximum	54	50	38	20	44
Mean	41.8	40.2	27.1	13.2	18.9
Median	43	41	27	15	17
Mode	43	45	24	16	16
Standard Deviation	5.2	5.4	3.7	4.7	7.4

MC = Moisture Content; LL = Liquid Limit; PL = Plastic Limit; PI = Plasticity Index;
CF = Clay-sized Fraction (% finer than 0.002 mm)

Specialty Testing

In addition to the above index tests, a three-point isotropically consolidated-undrained (CU) triaxial shear test (ASTM D4767) and a flex wall permeability test was performed on undisturbed soil samples obtained from Shelby Tube sampling. Results of all laboratory testing are included in Appendix B. Difficulties were encountered in obtaining undisturbed samples within the newer embankment fill due to the granular nature of the material. The CU triaxial test and permeability test were performed on undisturbed samples obtained within the alluvium and original embankment fill layers, respectively.

GENERAL SUBSURFACE CONDITIONS

Stratigraphy

Based on the descriptions of the samples recovered in the borings and laboratory testing, the subsurface stratigraphy for each section can generally be described in descending order from the top of the embankment as follows:

- The four borings which were performed from the crest of the embankments encountered 1.0 to 3.0 feet of roadway base consisting of bottom ash/boiler slab at the ground surface overlying 18.0 to 22.0 feet of embankment fill consisting of very stiff to hard silty clay and medium-dense to dense fine to coarse sand and gravel. Hand penetrometer measurements on samples exhibiting cohesion within this layer ranged from 2.5 to 4.5+ tons per square foot (tsf), while SPT N-values (corrected for 60% energy) ranged from 6 to 50 with an average of 26. Index testing results, including liquid limit and plasticity index of samples tested within this stratum are summarized in Table 1 of the previous section. The material was predominantly classified as Lean Clay (CL) to Clayey Gravel with Sand (GC) under the Unified Soil Classification System. Boring CD-PZ-BAP-0901 encountered a 4.5 foot thick zone of very-soft to very-stiff silty clay at the bottom of the fill. Hand penetrometer measurements within this zone ranged from 0.0 to 2.25 tsf.

- The three borings which were performed from the outboard toe of the embankments encountered 8.5 to 11.5 feet of embankment fill consisting of very-stiff to hard brown mottled with gray silty clay. The fill encountered in these borings is believed to be associated with the original pond embankments, and is denoted throughout this report as the 'Original Embankment Fill'. Hand penetrometer measurements on samples within this layer ranged from 1.6 to 4.5+ tons per square foot (tsf), while SPT N-values (corrected for 60% energy) ranged from 11 to 48 with an average of 22. Index testing results, including liquid limit and plasticity index of samples tested within this stratum are summarized in Table 1 of the previous section. The material was predominantly classified as Lean Clay (CL) under the Unified Soil Classification System.

- Underlying the embankments, the borings encountered 4.5 to 10.5 feet of alluvium consisting of very-loose to loose silt with few zones of stiff to hard silty clay and thin seams of very loose to loose fine to coarse sand. Hand penetrometer measurements on samples exhibiting cohesion within this layer ranged from 1.6 to 4.5+ tons per square foot (tsf), while SPT N-values (corrected for 60% energy) ranged from 0 to 33, with an average of 8. Index testing results, including liquid limit and plasticity index of samples tested within this stratum are summarized in Table 1 of the previous section.

- Beneath the alluvium silt and clay, the borings encountered 3.5 to 14.5 feet of very-soft to stiff organic clayey silt. Hand penetrometer measurements on samples exhibiting cohesion within this layer ranged from 0.0 to 1.25 tons per square foot (tsf), while SPT N-values (corrected for 60% energy) ranged from 0 to 20, with an average of 5. Index testing results, including liquid limit and plasticity index of samples tested within this stratum are summarized in Table 1 of the previous section. Loss on Ignition (LOI) values ranged from 7.9 to 10.4%. The material is predominantly classified as organic clay with sand (OL) under the Unified Soil Classification System. Throughout the report, this layer was identified as a clayey silt based on its consistency even though the PI often indicated the material would be classified as a silty clay

- All borings were terminated after penetrating 7.0 to 30.0 into feet very-loose to loose fine to coarse sand and/or medium-dense to dense brown fine to coarse sand and gravel. SPT N_{60}-values in the very-loose to loose sand ranged from 4 to 29 bpf with an average of 12. SPT N_{60}-values in the medium-dense to dense sand and gravel ranged from 14 to 69 bpf with an average of 32. The percent passing the 200 sieve ranged between 6 and 24, with an average of 12.2.

The newer embankment fill consisted of silty clay, sand, and gravel and was considered as a uniform stratum although the main descriptor varied based on the small variations in the percent by weight of each material. Strength parameters associated with this layer are discussed in the **Seepage and Stability Analysis** section. For a more detailed description of the stratigraphy, including the presence of minor variations and inclusions, the logs of the individual borings should be examined in conjunction with the summary above.

Groundwater

Groundwater observations were made as each boring was being advanced and measurements were made at the completion of drilling. The groundwater observations are graphically displayed on the boring logs and also noted at the bottom of the log. All water level readings indicated on the borings logs are referenced from the ground surface, as the top of pipes have not yet been formally surveyed. Extended groundwater measurements were made in the observation wells while on site and are summarized in Table 2.

Table 2: Extended Groundwater Measurements.

Boring	*Elevation During Drilling*	*Elevation at Completion*	*Elevation on 4-7/8-09*	*Elevation on 4-10-09*
CD-BAP-0901	635.2	654.9		-
CD-PZ-BAP-0902	655.0	657.3	657.3	659.6
CD-BAP-0903	627.6	633.6		-
CD-PZ-BAP-0904	652.1	652.1		652.2
CD-PZ-BAP-0905	632.1	642.1	642.1	644.7
CD-BAP-0906	648.6	658.3		-
CD-BAP-0907	627.3	634.0		-

Elevation Datum: NAD 27 / NGVD 29

SEEPAGE AND STABILITY ANALYSIS

Embankment dams must exhibit adequate factors of safety against a slope stability failure for static and seismic conditions. As part of this project, BBCM considered four areas of the ash pond embankment along the river as deemed critical by AEP to analyze for stability. Each section was developed by performing one boring through the crest of the embankment and one boring at the outboard toe, with the exception of the southernmost section through the recirculation pond embankment, where the location of the proposed boring at the toe was inaccessible. The following sections of this report discuss the analyses that were performed, explain the rational supporting parameter selection and present the results.

Based on visual observations, the Recirculation Pond embankments appeared to be in 'Fair' condition while the Bottom Ash Pond appeared to be in "Good' Condition. The principal item which came out of this inspection relative to this report is that no evidence of slope failure or seepage was observed on the embankment slope between the pond and the river. It should be noted however, that the toe of the slope is inundated by the ordinary high water level of the Ohio River. The 2009 Inspection Report should be consulted for the complete assessment of the visual observations made for the Bottom Ash Complex.

Methodology

The seepage and stability analyses were performed with the aid of the computer program Slide (Version 5.0) developed by Rocscience, Inc. The program performs 2-D limit equilibrium slope stability analyses and steady-state unsaturated seepage analysis; the latter using the finite element method. Pore pressure values produced from the seepage analysis are used in the slope stability computations for each model.

Static and seismic slope stability analyses were performed on the outboard embankment slopes for Cross-Sections B and D using Spencer's method (Spencer, 1973) with a deterministic approach. Both methods provide solutions for given cross sections based on limit equilibrium theory. The five critical slip surfaces corresponding to the lowest factor-of-safety are shown in the graphical output. Seismic slope stability analyses were performed based on a pseudo-static slope stability approach. Stability calculations were performed in general accordance with the US Army Corps of Engineer's Engineering Manual 1110-2-1902 entitled *Slope Stability*.

Cross Sections

Cross-sections showing the general subsurface conditions encountered in the borings were developed based on the survey data provided by AEP. Table 3 summarizes the borings used to develop the four cross sections, which are shown individually on the Subsurface Cross Sections shown on a full size plan sheet as Plate 3 of Appendix A. Two cross-sections were chosen to carry out the seepage and stability analysis, and are considered representative of the cross-sections not used. It should be noted that no bathymetric data was available. As such, the portion of the slope located below the Ohio River normal pool was estimated. If bathymetric information becomes available in the future, it is recommended that the analysis cross-sections be reviewed.

Table 3: Cross Section Data

Cross-Section	*Location*	*Crest Boring*	*Toe Boring*
Section A	Recirculation Pond	CD-BAP-0901	-
Section B	Recirculation Pond	CD-PZ-BAP-0902	CD-BAP-0903
Section C	Bottom Ash Pond	CD-PZ-BAP-0904	CD-PZ-BAP-0905
Section D	Bottom Ash Pond	CD-BAP-0906	CD-BAP-0907

Although four separate cross-sections were examined, the parameters selected to represent the permeability and strength of both the original and newer embankment fill layers were kept the same between sections. Although there are minor differences when comparing the two layers between borings, it is believed that there is insufficient evidence to support delineating the parameters from section to section. Therefore, for the purposes of the seepage and slope stability analyses, the permeability and shear strength parameters used to represent the fill layers were based on the totality of test data available for the embankment across the entire site.

The natural alluvium soils underlying the pond embankments are somewhat variable, consistent with the depositional environment of such soils. As with the embankment fill, it is difficult to justify developing specific parameters for an individual cross-section, as the properties of this stratum may vary over short distances. As such, the parameters used to represent the alluvium, and similarly the organic clayey silt and glacial outwash layers, were based on the totality of test data available for these layers across the entire site.

At the time of the survey performed March 27, 2009, the pool levels in the recirculation pond and bottom ash pond were at EL. 663.1, and EL. 664.4, respectively. The resulting freeboard from the surveyed pool levels range from 4.3 - 5.1 feet and 5.6 - 5.8 feet for the recirculation and bottom ash ponds, respectively. It is understood that these levels represent the approximate normal operating pool level. The pool level in the Ohio River was recorded as Elevation 644.4 feet. The ordinary high water level of the river is believed to be EL. 644 at the site.

Seepage Analysis

The location of the groundwater table within the embankments was estimated based on extended groundwater readings taken from the observations wells and conditions encountered during drilling. Groundwater conditions used in the finite element model were then calibrated to match the observed conditions. Results from the seepage analysis provided pore pressure values within the model to be used in the Stability Analysis.

Hydraulic Properties

As previously indicated, the same modeled permeability values for the various soil layers were taken for both cross-sections based on the totality of information available for the site. A flex wall permeability test was performed on an undisturbed sample obtained within the original embankment fill layer yielding a vertical permeability of $7.4\text{x}10^{-8}$ cm/sec. The design value for permeability was increased to $5\text{x}10^{-7}$ cm/sec as a result of the calibration of the seepage models. Permeability values for the other strata were estimated from typical published values based on material description or correlations to grain size. Permeability values and anisotropic ratios were then adjusted during the seepage analysis to best match the observed groundwater conditions. Supporting calculations for the development of the permeability values are included in the *Slope Stability Shear Strength and Permeability Parameter Justification* section of Appendix C.

Permeability values assigned to the model layers are shown in the table below. Several layers were modeled with anisotropic permeability functions. The horizontal permeability (k_h) of the original embankment fill soils were estimated as 10 times the vertical permeability (h_v), to best model the stratification of the soil as a result of compacting the fill in horizontal lifts (Casagrande, 1937), but was adjusted to a ratio of 5 times during the analysis. Similarly, a k_h/k_v ratio of 2 was used for the newer embankment fill soils. The alluvium and organic clayey silt foundation layer were modeled with a horizontal permeability twice the vertical permeability to simulate the natural stratification and inclusion of fine sand seams. The remaining soil layers were defined as a granular material and were assigned isotropic permeability functions.

Table 4: Permeability Values

Material Description	Permeability		Reference
	k_v (cm/sec)	k_h / k_v	
Newer Embankment Fill	$1\text{x}10^{-5}$	2	Grain Size Correlation
Original Embankment Fill	$5\text{x}10^{-7}$	5	Permeability Test
Alluvium Silt and Clay	$1\text{x}10^{-5}$	2	Typical Published Values
Organic Clayey Silt	$5\text{x}10^{-6}$	2	Typical Published Values
Loose to Med Dense Glacial Outwash Sand and Gravel	$1\text{x}10^{-2}$	1	Grain Size Correlation
Med Dense - Dense Glacial Outwash Sand and Gravel	$1\text{x}10^{-3}$	1	Grain Size Correlation

Hydraulic Boundary Conditions

Topographic contours from the most recent survey as well as from historical construction drawings were used to expand the surface profile created from the AEP survey in order to develop a full scale model. The following boundary conditions were assigned to the finite element based models.

- A 'Constant Head' boundaries of 663.0 and 664.5' were used to represent the level of water in the recirculation pond and ash pond, respectively.
- The model was extended on the downstream side to the approximate middle of the Ohio River, and a 'Constant Head' boundary of 644.4' was used to represent the normal flow level of the river at this point (water level recorded by AEP).
- A 'No-Flow' boundary was placed on the upstream end of the model, as flow should become predominantly downward near the middle of the pond.
- A ‘No-Flow’ boundary was placed on the bottom of the model at Elevation 550' representing the approximate bedrock surface, which is assumed impermeable for this analysis.
- 'Unknown' boundary conditions were set on the remainder of the model to allow the program freedom to calculate values at these locations. These locations include the downstream slope face and the downstream ground surface.
- For Section D, the Constant Head Boundary of 644.4' was extended up the downstream slope to the location of the toe boring in an effort to model the observed groundwater conditions within the original embankment fill.

Finite Element Discretization and Mesh

The following steps were performed during the development of the seepage model:

- 6 Noded Triangles were used to generate the finite element mesh for the models (see Plates 2 and 7 of Appendix D).
- The density of nodes was manually increased to minimize the number of ‘Poor Quality Elements’ based on the Mesh Quality function available in Slide.
- Poor quality elements were defined as elements with one of the following characteristics:
    1. Maximum side length to minimum side length ratio greater than 10.
    2. Minimum interior angle less than 20 degrees.
    3. Maximum interior angle greater than 120 degrees.
- Prior to final computational runs, a sensitivity analysis was performed to determine if an adequate number of total finite element nodes were used in the analysis.
- A sensitivity analysis was performed on the tolerance of the computational iteration.

Seepage Analysis Models and General Results

Graphical output from the seepage analyses for Sections B and D are presented in Appendix D as Plates 3 and 4 for Section and B and Plates 8 and 9 for Section D. The calibrated seepage models produced phreatic surface shapes close to what was expected based on the water levels measured in the observation wells.

Although a typical phreatic surface extending from the ash pond level to the Ohio River was generated, much of the seepage emanating from the ponds is moving downward through the newer embankment fill and thin stratum of alluvium soils and into the glacial outwash sand and gravel stratum.

Stability Analyses

Shear Strength Parameters

In order to perform slope stability analyses, it was necessary to estimate appropriate parameters to represent the existing soils. The shear strength and unit weight values used for the slope stability analyses were based on a combination of the laboratory index test results, triaxial shear tests, published values and judgment, and are intended to be representative of long-term conditions. Table 5 lists the strength parameters used in both static and seismic analyses for each stratum. Supporting calculations for the development of these strength values are presented in the *Slope Stability Shear Strength Parameter Justification* section of Appendix C.

The percent of organic content in the Organic Clayey Silt layer was determined by performing Loss on Ignition (LOI) tests; results ranged from 7.9 to 10.4 percent. For LOI-values of less than 20 percent, the soil properties are controlled by the non-organic portion of the soil (FHWA, 2002).

Table 5: Strength Values for Static Conditions

Material Description	γ_{wet} (pcf)	Strength		Reference
		ϕ'	c' (psf)	
Newer Embankment Fill	125	31°	0	SPT and Index Testing Correlations
Original Embankment Fill	125	30°	100	Index Testing Correlations
Alluvium Silt and Clay	125	30°	0	Index Testing Correlations
Organic Clayey Silt	125	30°	0	Index Testing Correlations and CU Triaxial Test (BBCM 2009)
Very Loose to Loose Glacial Outwash Sand and Gravel	115	29°	0	SPT and Grain Size Correlations
Medium Dense Glacial Outwash Sand and Gravel	120	34°	0	SPT and Grain Size Correlations

In addition to the static steady-state stability analyses, strength parameters were developed for use with the pseudo-static seismic analyses. With respect to seismic loading, it is believed that the newer embankment fill soil is sufficiently granular that drained strengths values will be exhibited during seismic loading. However, as the original embankment fill is more cohesive in nature, it will likely exhibit an undrained response. As the embankment fill has come to equilibrium under the present steady-state seepage conditions, the shear strength envelope used in the analysis was based on the "R" test, as recommended in the Army Corps of Engineer's Manual 1110-2-1906 "Laboratory Soils Testing," and suggested by Duncan and Wright in their 2005 publication. This is essentially the slope and y intercept of the CU strength envelope. Unfortunately, CU triaxial tests were not performed in the newer embankment fill layer as all Shelby tubes attempted in this layer failed to recover an adequate sample size (however, a permeability test was performed). The seismic strength values for the newer embankment fill layer has been estimated based on values given by Duncan and Wright (2005) for soils with similar index properties (See Plate 16 of Appendix D). CU Triaxial test data was available for the Organic Clayey Silt layer, and the corresponding R envelope was used to model the shear strength. As there is a significant amount of sand within the alluvium strata, drained strength values were used for seismic loading.

Table 6: Strength Values for Seismic Conditions

Material Description	γ_{wet} (pcf)	Strength		Reference
		ϕ	c (psf)	
Newer Embankment Fill	125	31°	0	SPT and Index Testing Correlations
Original Embankment Fill	125	22°	50	Duncan and Wright (2005)
Alluvium Silt and Clay	125	30°	0	Index Testing Correlations
Organic Clayey Silt	125	24°	180	CU Triaxial Test (BBCM 2009)
Very Loose to Loose Glacial Outwash Sand and Gravel	115	29°	0	SPT and Grain Size Correlations
Medium Dense Glacial Outwash Sand and Gravel	120	34°	0	SPT and Grain Size Correlations

Analysis and Results

Static and seismic analyses were performed on Sections B and D to determine the factor of safety against rotational failure for the outboard slopes using drained soil strength parameters. The graphical computer outputs for these analyses have been included with this report in Appendix D.

Seismic analyses were performed using a pseudo-static analysis with a horizontal seismic coefficient of 0.06g. This coefficient was determined from the 2008 USGS National Seismic Hazard Maps for the "Peak Acceleration (%g) with 2% Probability of Exceedance in 50 Years". This chart is provided as Plate 33 of Appendix C.

Graphical results of the slope stability analysis for static and seismic conditions are shown in Appendix D. Table 7 summarizes the lowest factors of safety determined for each analysis case.

Table 7: Stability Analysis Summary

Analysis Case	Required Minimum Factor of Safety	Computed FS	
		Section B	Section D
Static (Steady-State Seepage)	1.50	1.57	1.52
Pseudo-Static	1.00	1.05	1.09

The critical failure surfaces were located through a deterministic search, with no limitations on failure depth. The failure surface locations were restricted to find only surfaces associated with a global failure through the composite embankment (original plus newer embankment fill) or through the original embankment only. Shallow sloughing failures along the river bank were not considered for this analysis. The results are based on the pool level recorded at the time of the survey, extrapolated bathymetric data, and the groundwater measurements recorded from the observation wells.

CONCLUSIONS

As part of this report, BBCM examined the stability of the outboard embankment slopes at 4 locations under steady-state seepage and seismic loading conditions using the results of 7 soil borings. The analyses suggest that at the four cross sections examined, the embankments exhibit adequate factors of safety relative to those recommended by the US Army Corps of Engineers (COE).

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Appendix VI – Excerpt from 2010 Follow-Up Investigation Report

INTRODUCTION

BBCM previously performed a limited subsurface investigation and slope stability analyses of the Cardinal Bottom Ash Pond Complex, the report of which was dated August 4, 2009. This report consisted of obtaining subsurface data at a total of four cross-sections through the bottom ash pond and recirculation pond embankments, and performing seepage and slope stability analyses to provide an indication as to the level of safety provided by the embankments.

The purpose of this follow-up work was to supplement the analyses performed as part of the original work in an attempt to fulfill the AEP action plan requirements in response to the USEPA inspection report. The follow-up slope stability analyses are solely based on existing subsurface data, as no additional field or laboratory work was performed as part of this project. Also as part of this follow-up work, hydraulic and hydrologic (H&H) analyses were performed to determine the capacity and freeboard of the Bottom Ash Pond related to current requirements. A summary of the work performed is contained in this report. This report should be considered an addendum to our August 4, 2009 Bottom Ash Pond Complex report.

SLOPE STABILITY ANALYSIS

Follow-Up Embankment Stability Analysis

Additional slope stability analyses were performed on Sections B and D to determine the factor of safety against rotational failure for the following conditions:

1.) Inboard slopes under steady-state seepage conditions;
2.) Pseudo-static seismic analyses under steady-state seepage conditions for the inboard slopes;
3.) Surcharge pool conditions (outboard slopes); and,
4.) Rapid drawdown analyses for the inboard slope.

The previously developed cross-section (B and D) geometry, permeability values, and shear strength parameters were used in the follow-up analysis. Please refer to the '*Subsurface Investigation and Analysis – Bottom Ash Pond Embankments'* report by BBCM dated August, 2009 for a complete discussion of these parameters.

Seismic analyses for the inboard slopes were performed using a pseudo-static analysis with a horizontal seismic coefficient of 0.06g, consistent with the original report. The surcharge pool was modeled using a distributed line surcharge load, as it is not expected that the phreatic surface within the embankment will change during this temporary loading condition.

A rapid drawdown analysis was also completed for the bottom ash pond inboard embankment slopes utilizing the previously developed cross-sections. It is the understanding of BBCM that the ponds are typically filled with ash which would tend to support the inboard slopes. However, on an occasional basis, during times of ash removal and subsequent re-filling, a full pool of water could be established and a rapid drawdown scenario could occur if the pond were suddenly emptied. While not impossible, a large scale rapid drawdown event with unsupported interior slopes is unlikely. Notwithstanding, a rapid drawdown analysis was completed using the conventional method whereby the phreatic surface is positioned at the ground surface (inside the pond) and extended up into the slowly-draining embankment layers to the normal pool elevation. Drained strength parameters are used in this scenario. The drawdown level for the analysis was considered to occur from the normal operating pool El. 664.4 down to the natural ground surface on the inboard side of the embankment. During the subsurface investigation it was determined that there are two types of fill present in the embankments, identified as *newer embankment fill* and *original embankment fill*. The *newer embankment fill* contains a high percentage of sand and gravel (58%), as determined from previous laboratory testing. While pockets of this layer are cohesive and will exhibit a slowly-draining response during a rapid drawdown event, the layer as a whole likely will not maintain a consistent phreatic surface on the inboard slope. As a result, the phreatic surface was modeled to maintain its elevated level only within the *original embankment fill* and not within the *newer embankment fill*. Please see the analysis of the *newer embankment fill* layer submitted in Appendix B.

Graphical results of the slope stability analysis for static and seismic conditions are shown in Appendix A. Table 1 summarizes the lowest factors of safety determined for each analysis case.

Table 1: Stability Analysis Summary

Analysis Case	Required Minimum Factor of Safety	Computed FS	
		Section B	Section D
Static (Steady-State Seepage) – Inboard Slope	1.50	1.70	1.65
Pseudo-Static – Inboard Slope	1.00	1.39	1.34
Maximum Surcharge Pool – Outboard Slope	1.40	1.55	1.52
Rapid Drawdown – Inboard Slope	1.30	1.55	1.52

The critical failure surfaces were located through a deterministic search, with no limitations on failure depth. The failure surface locations were restricted to find only surfaces associated with a global failure through the embankment. Shallow sloughing failures along the river bank were not considered for these analyses.

Liquefaction of Foundation Alluvium

A liquefaction screening analysis was performed for the soft alluvium soils underlying the embankments. There is concern that areas of this layer could potentially liquefy during seismic excitation and ultimately cause a failure of the embankments. The screening analysis was performed using the five techniques listed in the Federal Highway GEC No. 3:

1.) Geologic Age and Origin,
2.) Fines Content and Plasticity Index,
3.) Saturation,
4.) Depth Below Ground Surface, and
5.) Soil Penetration Resistance.

The five screening techniques are described in detail in the hand calculations provided in Appendix B. Due to the fines content and plasticity index, as well as the geologic age and origin, the screening analysis suggests that liquefaction will not occur for the alluvium silt and clay layer.