REPORT OF GEOTECHNICAL EXPLORATION
NASA PLUMBROOK STATION
MAIN GATE BORROW PIT

FOR:

NASA Glenn Research Center
21000 Brook Park Road, Mail Stop 60-1
Brook Park, OH 44135-3191

SUBMITTED BY:

BARR & PREVOST
ENGINEERING | TESTING | SURVEYING

2271 Scranton Road
Cleveland, Ohio 44113
Voice: 216.400.6230
Fax: 216.400.6238

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DRAFT REPORT
GEOTECHNICAL EXPLORATION
FOR THE PROPOSED
NASA PLUM BROOK STATION
MAIN GATE BORROW PIT

1. INTRODUCTION

This report presents the results of a geotechnical exploration conducted to assess the subsurface characteristics of a proposed borrow area located at NASA's Plum Brook Station located southwest of the intersection of Scheid and Patrol Roads in Erie County, Ohio. The borrow area will provide a source of fill material for construction of a proposed new Main Gate Area.

The exploration was conducted in general accordance with Barr & Prevost Inc.'s (BPI) proposal with NASA, Glenn Research Center dated November 8, 2012, as modified on December 12, 2012. The project included drilling 8 soil borings to characterize the subsurface soil, and laboratory testing to assess the suitability of the soil for use as engineered fill. In addition, consideration has been given to the design of the borrow pit so that it will function as a pond in the future.

2. GEOLOGY AND OBSERVATIONS OF THE PROJECT

2.1. Physiography

The site is located in the Erie Lake Plain district, one of the physiographic districts of the Huron-Erie Lake Plains, a flat lying Ice-Age lake basin (Brockman, 1998). The area is characterized by sand, silt and clay, and wave-planed clayey till overlying carbonate rocks and shales.

The proposed borrow pit area is flat, at an elevation of approximately 650 feet (ft) above mean sea level (msl). The terrain to the west and south rises to 700 ft msl within approximately 2.5 miles.

2.2. Geology

Bedrock is Ohio Shale overlying Prout Limestone Member and Plum Brook Shale Member of the Olentangy Shale formation (Larsen et. al., 1997). Top of bedrock, as mapped by the Ohio Department of Natural Resources (ODNR) is about 643 ft msl (Pavey et. al., 1995).

2.3. Soils

Soils at the site have been mapped by the Natural Resources Conservation Service (U.S. Department of Agriculture, 2012) as Rawson sandy loam, 2 to 6 percent slopes. These are rated as poor as a road fill source due to low strength, wetness depth and shrink swell potential.

2.4. Hydrology/Hydrogeology

Ground water resources are obtained from the carbonate rocks that underlie the Ohio shale. Shallow soils and rocks are poor producers and cannot be relied on for water supply. The relatively impermeable nature of the soils and shale create conditions that are conducive to the creation of surface water storage facilities using earth-lined ponds. Many exist in the immediate area, with several large lakes along Interstate (IR)-80 at the site of former freeway construction borrow pits. Five smaller ponds are located within a mile of the proposed borrow pit. Most of the surface drainages in the area are ephemeral indicating the lack of a permanent shallow ground water table. Some water may be available in sand stringers contained within the till, but is likely to be of limited quantity.

2.5. Site Observations

The site is located south west of the intersection of Scheid and Patrol Roads. The contract scope of work called for investigation of a 170 ft x 409 ft rectangular area, oriented length-wise east to west, roughly parallel to Scheid Road. Subsequent to drilling the first two borings (G-4 and G-5), the proposed layout was adjusted because of shallow bedrock. The revised layout was also rectangular and of similar dimensions, with a north–south orientation, positioned at the east end of the original site (see Exhibit 1).

Observations by the drilling crew describe the site as grass covered and generally level with little localized relief. It was further noted that a few mature trees were present on the site as well as what appeared to be the remnants of foundations of pre-existing structures. No surface water was noted to be standing on the site during the drilling operations.

3. EXPLORATION

3.1. Exploration Program

The subsurface exploration was originally scoped for a total of 5 borings to be drilled to bedrock, estimated to be at about 10 ft below ground surface. As mentioned, two borings were performed prior to

adjusting the study site to the east and south at NASA's direction. One of the original borings (G-1) was non-performed and four borings were added for a total of 8 borings performed at the locations indicated in Table 1 and on Exhibit 1. BPI drilled on December 11 and 12th, 2012 using an ATV-mounted Mobile B-57 rig, with 3.25-inch diameter, hollow stem augers. Soil samples were recovered at intervals of 2.5 feet, using a split spoon sampler (ASTM D-1586 "Standard Method for Penetration Test and Split Barrel Sampling of Soils") and placed in sealed jars. The standard penetration test (SPT) was conducted using an auto-hammer that has been calibrated as 95.1% efficient. All borings were advanced to or slightly into underlying shale bedrock prior to termination.

Field boring logs were prepared by field personnel, including lithological description, and standard penetration test results recorded as blows per 6-inch increment of penetration. Ground water observations, including 20 hour extended observations, were recorded during the investigation. Field penetrometer testing was conducted on suitable SPT samples prior to removal from the sampler. A total of 4 bulk samples were collected from borehole cuttings. All collected samples were then transported to BPI's soils mechanics laboratory for further evaluation.

Each boring was backfilled with a combination of bentonite grout, bentonite pellets and cuttings as indicated on the boring logs.

Table 1: Boring Summary

Boring Number	Boring Location (Northing, Easting)[1]	Surface Elevation (NGDV-ft)	Boring Depth (ft)	Bedrock Depth (ft)	Depth to Ground Water[2] (ft)
G-2	616601.07, 1928374.06	650.10	10	10.0	6.0
G-3	616432.20, 1928373.89	650.71	8.75	8.5	3.0
G-4	616432.61, 1927964.86	650.37	5	3.5	3.0
G-5	616516.76, 1928169.46	650.64	6.5	3.5	3.0
G-6	616432.00, 1928374.00	649.96	11.5	11.5	2.0
G-7	616193.00, 1928374.00	648.81	9.0	7.0	2.0
G-8	616601.00, 1928544.00	650.85	12.5	11.0	not encountered
G-9	616193.00, 1928544.00	648.72	10	8.5	8.5

(1) Ohio North State Plane coordinates.
(2) Reading after 20 hours.

3.2. Laboratory Testing

Mechanical soil classification (Plastic Limit, Liquid Limit and gradation testing) was conducted on selected samples. Moisture content was measured for most samples (ASTM D-2216). Soils not selected for testing were classified visually by comparison to soils that were. Soil classifications are presented in the boring logs using the nomenclature of the Unified Soils Classification System (USCS) in accordance with ASTM D-2487 and D-2488.

Additional testing included determination of California Bearing Ratio (CBR), in accordance with ASTM D-1883 as well as determination of Moisture–Density Relationships, in accordance with ASTM D-698. Results are presented on the Log of Borings and related test reports in Appendix A.

4. SUBSURFACE CONDITIONS

Information describing the soil conditions encountered during the subsurface investigation at each boring location is presented in the Log of Borings. The borings produced samples at discrete locations within the subsurface environment beneath the site, and test data, whether in-situ or ex-situ, are representative only of those locations.

“Topsoil” cover was noted at each of the boring locations, ranging in thickness from 7 to 12 inches. This material was described as silt-like soil containing organic matter, noticeably darker in color (brown) than the underlying materials. Lean clay soils (CL) were the predominate soil grouping encountered in the test borings, comprising 65% of all soil samples visually or mechanically classified. CL soils were noted to occur in each of the borings except G-4. Other soil types encountered in the borings were fat clay (CH) 15%, clayey sand (SC) 12%, silty sand (SM) 4% and silty clayey sand (SC-SM) 4%. Sand formations (SC, SM, SC-SM) were encountered only in borings G-2, G-8 and G-9. Cohesive samples were noted to be in a moisture condition, which ranged from the plastic limit to 9% above plastic limit. Granular samples were noted to range between damp and wet.

Shale bedrock was encountered in each of the borings at depths ranging between 3.5 feet (G-4) and 11.5 feet (G-6) below present grades. Ground water encounter during drilling was noted in only two borings (G-7 and G-9, at 8.0 and 8.5 feet below ground surface, respectively). However, ground water was measureable in borings G-2, G-3, G-4, G-5, G-6 and G-7 after 20 hours infiltration and was observed to range between 2 to 6 feet below ground surface.

5. FINDINGS AND RECOMMENDATIONS

The predominately fine-grained soils encountered in the test borings can serve as suitable embankment materials, and are commonly used for this purpose throughout Ohio. However, in general terms, they have inherent limitations in regards to structural characteristics, and moisture sensitivity. Successful performance as subgrade material and /or structural fill is heavily dependent on proper design, construction methods, adequate permanent drainage and thorough inspection and testing.

Though dependent on the fraction of coarser materials found in the soil matrix, CL and CH soils will typically exhibit relatively low unit weights and angles of internal friction (Φ). Presumptive soil support values and bearing capacities are generally at the low end of the spectrum and foundations bearing on these materials are often proportioned on the basis of ~1,500 psf allowable bearing pressure, in accordance with section 1804.2 of the Ohio Building Code.

Fine-grained soils such as those encountered at the borrow site are susceptible to volume change at varying moisture content and must be carefully compacted at controlled moisture condition. It should be anticipated that excavated materials will be difficult to dry on-site. Compaction of materials at an above optimum moisture condition will negatively affect the shear strength of the embankment material and render it susceptible to over-compaction, which can result in subgrade instability ("pumping"). Positive drainage must be maintained during embankment construction so as not to allow compacted areas to pond and become saturated or they will break down under construction traffic. Dependent on proposed improvements to the fill site, it may be prudent to consider an appropriate soil stabilization technique as a contingency in the contract documents.

Clay soils potentially exhibit a shrink/swell characteristic under variable moisture content that can adversely affect foundation performance. The soils encountered in the borrow area are, for the most part, considered of low shrink/swell potential (LL < 50 and PI < 25). The 'fat' clay mentioned above meets the 'marginal' expansion criteria (50<LL<60 and 25<PI<35), supporting the case for careful management of this soil.

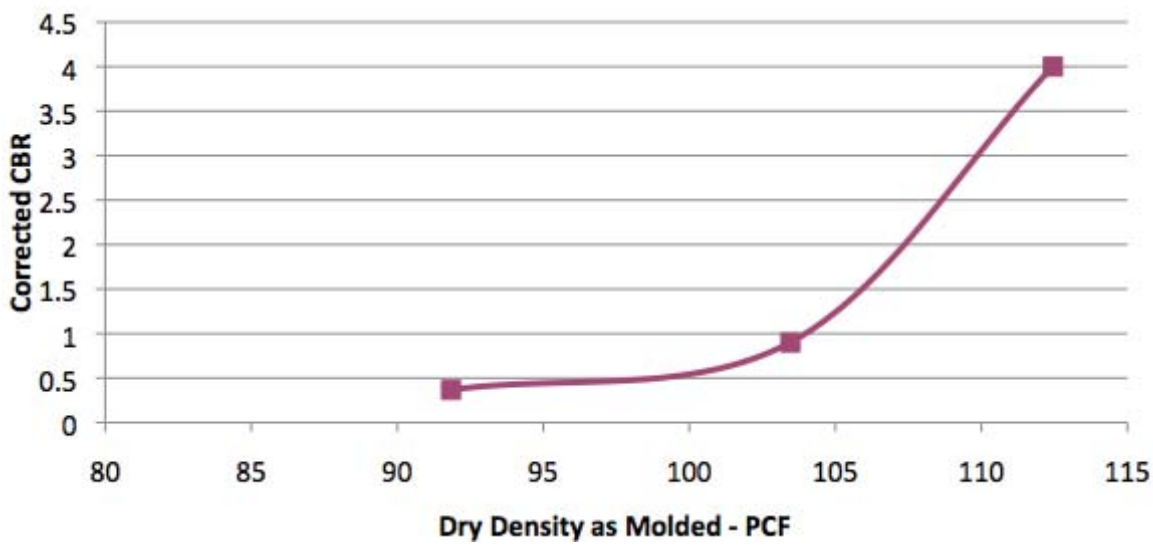
Two composite bulk samples were created to simulate soil mixtures that are likely to be created during the excavation and fill placement process. Compaction testing produced the results shown in Table 2. Both mixtures were classified as lean clay with slightly differing amounts of sand.

Table 2: Compaction Test Results (ASTM D698A)

Soil Mixture	Maximum Dry Density (pcf)	Optimum Moisture Content (%)
G2 & G8	113.7	15.2
G3 & G6	109.8	16.8

A laboratory CBR test was conducted on the sample composite G3 and G6. The results, shown in Figure 1, indicate a CBR value of 4 for a sample compacted to 100% maximum dry density. It should be noted that the laboratory CBR test includes a 96-hour soaking period that represents a fairly extreme environment for material placed under controlled conditions as part of a modern pavement design. A similar material encountered as a subgrade material on a state highway project would be assigned a CBR value of 6 when compacted to 100% of maximum dry density. As indicated above, similar soils are routinely used for construction purposes in Ohio but success depends on proper moisture control through drainage and/or chemical treatment when moisture becomes excessive.

Figure 1: Dry Density vs. CBR



It should be noted that some zones of high-moisture content, 'fat' clay were encountered in the borings (e.g. G-4, 0.6 - 3 ft). This soil is notable for its higher moisture content and plasticity, and is likely to be difficult to process. It should be discarded. Similarly, the topsoil identified at each boring location (generally ~12 inches in thickness) should not be utilized as borrow material. It may be segregated for use as the upper covering of areas to be landscaped.

6. QUALIFICATIONS

This investigation was performed in accordance with accepted geotechnical engineering practice for the purpose of characterizing soils in the proposed borrow area. No investigation of conditions at the site of the proposed construction has been requested or performed. The information submitted in this report is based upon the data obtained from borings drilled at the locations shown on Exhibit 1, and as presented on the Logs of Borings (Appendix A). This report does not reflect any variations that may occur between the borings or elsewhere on the site, or variations whose nature and extent may not become evident until a later stage of construction. In the event that any changes in location of the proposed borrow area are made, the findings contained in this report should not be considered valid until they are reviewed, and have been modified or verified in writing by a geotechnical engineer.

It has been a pleasure to be of service to NASA in performing this geotechnical exploration for the Plum Brook Station Main Gate Borrow Pit project.

Respectfully Submitted,

Barr & Prevost

James E. Prevost, P. E.
Principal

Stuart Edwards, P.E.
Geotechnical Engineer

REFERENCES

Brockman S.C., 1998. *Physiographic Regions of Ohio*. Ohio Department of Natural Resources Division of Geological Survey.

Larsen, G.E. and Vorbau, K.E. 1997. *Preliminary Bedrock Geology of the Kimball, Ohio Quadrangle.* Department of Natural Resources, Division of Geological Survey. Open-File Map. Scale 1:24,000.

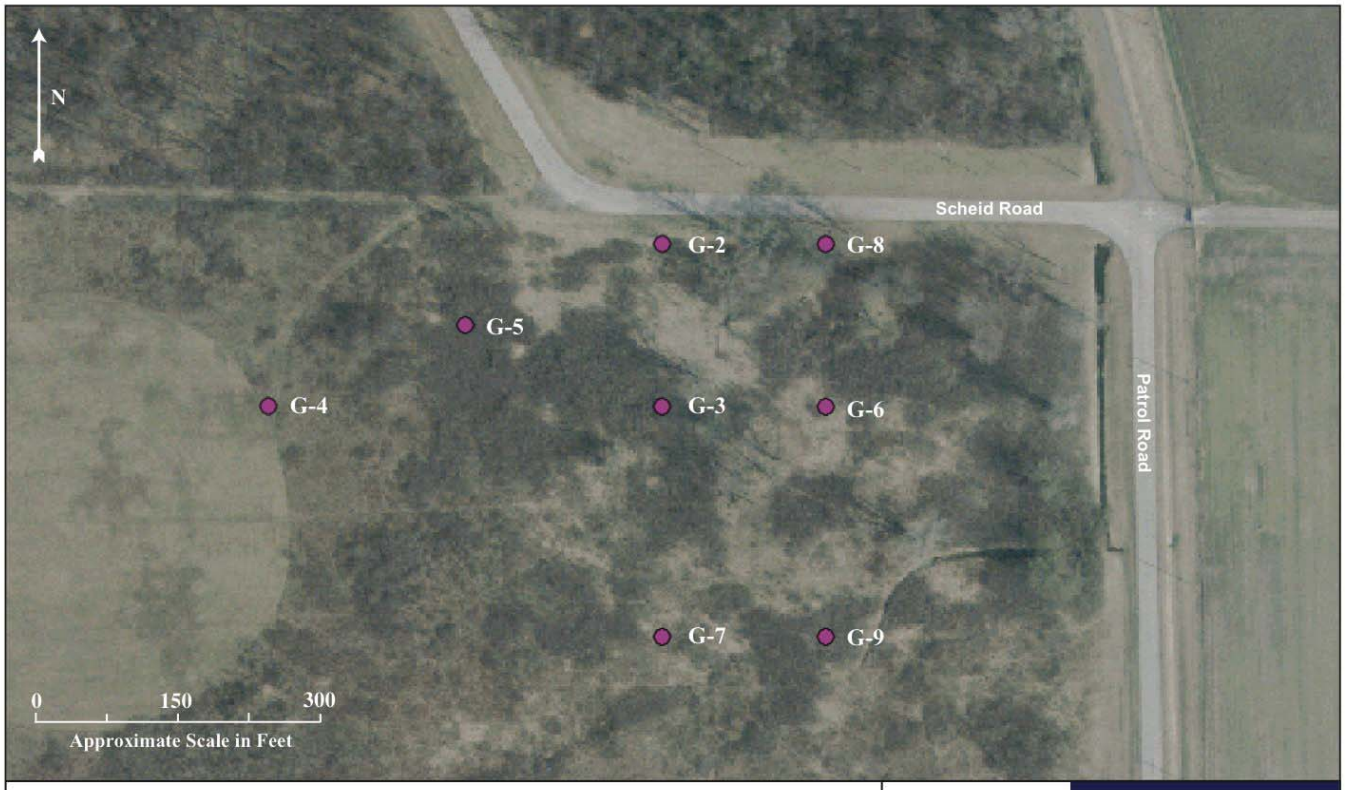
OGRIP, 2013. *Ohio Statewide Imagery Program Tile N1925615_ASCII (Digital Elevation Model) and TIF (aerial photograph).* gist3.oit.ohio.gov

Pavey, R.R. and Vorbau, K.E. 1995. *Preliminary Bedrock Topography of the Kimball, Ohio Quadrangle.* Ohio Department of Natural Resources, Division of Geological Survey. E.R. Slucher. Open-File Map. Scale 1:24,000.

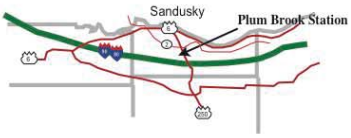
Shrake, D.L., Venteris, E.R., Swinford, E.M., Larsen, G.E. and Pavey, R.R., 2006. *Surficial Geology of the Ohio Portion of the Youngstown 30 x 60 Minute Quadrangle.* GIS compilation by Powers, D.M., 2006. Ohio Division of Geological Survey Map SG-2 Youngstown, scale 1:100,000.

U.S. Department of Agriculture, 2012. Web Soil Survey, National Cooperative Soil Survey. *Road fill Source (OH).* Natural Resource Conservation Service. 10/3/2012. http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

U.S. Department of the Interior, 1969. Kimball Quadrangle Ohio, 7.5 Minute Series (Topographic). U.S. Geological Survey. AMD 4466 I SW-Series V852. http://store.usgs.gov



Area of Detail



Prepared in GRASS 7

Exhibit 1

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Boring Locations

NASA Plum Brook Station
Main Gate Borrow Pit

APPENDIX A

LOG OF BORINGS AND LABORATORY TEST RESULTS

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/9/13 15:43 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\NASA-BROOK STATION MAIN GATE BORROW PIT 420045830\GINT FILE

PROJECT: NASA - PLUMBROOK STATION	DRILLING FIRM / OPERATOR: B&P / P. WEBB	DRILL RIG: MOBILE B57 ORV	STATION / OFFSET:	EXPLORATION ID G-2
TYPE: BORROW PIT	SAMPLING FIRM / LOGGER: B&P / R.BLASKO	HAMMER: DIEDRICH AUTOMATIC	ALIGNMENT:	
PID: Client:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 6/30/11	ELEVATION: 650.1 (MSL) EOB: 10.0 ft.	PAGE 1 OF 1
START: 12/11/12 END: 12/11/12	SAMPLING METHOD: SPT	ENERGY RATIO (%): 95.1	COORD: 616601.070 N, 1928374.060 E	

MATERIAL DESCRIPTION AND NOTES	ELEV. 650.1	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	MS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	USCS CLASS	HOLE SEALED
12.0", **TOPSOIL**	649.1																		
VERY STIFF TO HARD, BROWN MOTTLED WITH LIGHT AND DARK GRAY, **LEAN CLAY WITH SAND**, TRACE GRAVEL, CONTAINS BLACK DECAYED MATTER AND FEW ROOTS, MOIST **(FILL)**		1																	
		2	2 4 6	16	67	SS-1	3.0 - 4.5+	3	2	6	14	30	45	37	16	21	19	CL	
		3																	
		4	2 4 7	17	61	SS-2	3.0 - 4.5+	-	-	-	-	-	-	-	-	-	21	CL (V)	
	644.6	5																	
VERY STIFF TO HARD, BROWN, **CLAYEY SAND WITH GRAVEL**, CONTAINS LIGHT GRAY SHALE LAYER IN BOTTOM OF BORING, DAMP		▼ 20 hr 6																	
		7	5 8 16	38	94	SS-3	4.25 - 4.5+	23	12	13	11	19	22	31	17	14	11	SC	
		8																	
		9	4 50/5"	-	100	SS-4	3.5 - 4.5+	-	-	-	-	-	-	-	-	-	14	SC (V)	
	640.1	EOB 10																	

Bedrock Encountered at 10.0'.

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. 20 HOURS AFTER DRILLING AT 6.0'. CAVE DEPTH 7.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED .5 BAG BENTONITE CHIPS; PUMPED 16 GAL. BENTONITE GROUT

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/9/13 15:43 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\NASA-BROOK STATION MAIN GATE BORROW PIT 42004583\0\GINT FILE

PROJECT: NASA - PLUMBROOK STATION	DRILLING FIRM / OPERATOR: B&P / P. WEBB	DRILL RIG: MOBILE B57 ORV	STATION / OFFSET:	EXPLORATION ID G-3
TYPE: BORROW PIT	SAMPLING FIRM / LOGGER: B&P / R.BLASKO	HAMMER: DIEDRICH AUTOMATIC	ALIGNMENT:	
PID: Client:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 6/30/11	ELEVATION: 650.7 (MSL) EOB: 8.75 ft.	PAGE 1 OF 1
START: 12/11/12 END: 12/11/12	SAMPLING METHOD: SPT	ENERGY RATIO (%): 95.1	COORD: 616432.200 N, 1928373.890 E	

MATERIAL DESCRIPTION AND NOTES	ELEV. 650.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION(%) GR	CS	MS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	USCS CLASS	HOLE SEALED
12.0", **TOPSOIL**	649.7																		
STIFF TO HARD, BROWN MOTTLED WITH GRAY, **SANDY LEAN CLAY**, TRACE GRAVEL, MOIST		1 2 3	2 3 3	10	56	SS-1	1.25 - 3.25	1	0	1	29	27	42	37	15	22	21	CL	
		▼ 20 hr																	
@3.5'; SS-2 CHANGES TO LEAN CLAY		4 5	3 4 7	17	94	SS-2	4.0 - 4.5+	0	1	3	10	30	57	37	15	22	22	CL	
	644.2	6	5 8 9	27	100	SS-3	3.25 - 4.5+ / 4.5+	-	-	-	-	-	-	-	-	-	17	CL (V)	
HARD, GRAY MOTTLED WITH BROWN, **FAT CLAY**, TRACE SAND, DAMP		7 8						-	-	-	-	-	-	-	-	-	24	CH (V)	
	642.2																		
DARK GRAY, **SHALE FRAGMENTS**	642.0	TR. ECS	50/4"	-	86	SS-4	-	-	-	-	-	-	-	-	-	-	13	Rock (V)	

Bedrock Encountered at 8.5'

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. 20 HOURS AFTER DRILLING AT 3.0'. CAVE DEPTH 7.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED .25 BAG BENTONITE CHIPS; PUMPED 16 GAL. BENTONITE GROUT

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/9/13 15:43 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\NASA-BROOK STATION MAIN GATE BORROW PIT 420045830\GINT FILE

PROJECT: NASA - PLUMBROOK STATION	DRILLING FIRM / OPERATOR: B&P / P. WEBB	DRILL RIG: MOBILE B57 ORV	STATION / OFFSET:	EXPLORATION ID G-4
TYPE: BORROW PIT	SAMPLING FIRM / LOGGER: B&P / R.BLASKO	HAMMER: DIEDRICH AUTOMATIC	ALIGNMENT:	
PID: Client:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 6/30/11	ELEVATION: 650.4 (MSL) EOB: 5.0 ft.	PAGE 1 OF 1
START: 12/11/12 END: 12/11/12	SAMPLING METHOD: SPT	ENERGY RATIO (%): 95.1	COORD: 616432.610 N, 1927964.860 E	

MATERIAL DESCRIPTION AND NOTES	ELEV. 650.4	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION(%) GR	CS	MS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	USCS CLASS	HOLE SEALED
7.0", **TOPSOIL**	649.8																		
STIFF TO VERY STIFF, BROWN MOTTLED WITH ORANGE BROWN, **FAT CLAY WITH SAND**, TRACE GRAVEL, CONTAINS IRON STAINING, WET	647.4	1 2 ▼ 20 hr	3 3 5	13	61	SS-1	1.0 - 2.25	-	-	-	-	-	-	-	-	-	36	CH (V)	
DARK GRAY, **SHALE FRAGMENTS**	645.4	3 TR 4 5 EOB	10 20 44	101	89	SS-2	-	-	-	-	-	-	-	-	-	-	12	Rock (V)	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. 20 HOURS AFTER DRILLING AT 3.0'. CAVE DEPTH 4.5'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED .25 BAG BENTONITE CHIPS; PUMPED 10 GAL. BENTONITE GROUT

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/9/13 15:43 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\NASA-BROOK STATION MAIN GATE BORROW PIT 420045830\GINT FILE

PROJECT: NASA - PLUMBROOK STATION	DRILLING FIRM / OPERATOR: B&P / P. WEBB	DRILL RIG: MOBILE B57 ORV	STATION / OFFSET:	EXPLORATION ID G-5
TYPE: BORROW PIT	SAMPLING FIRM / LOGGER: B&P / R.BLASKO	HAMMER: DIEDRICH AUTOMATIC	ALIGNMENT:	
PID: Client:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 6/30/11	ELEVATION: 650.6 (MSL) EOB: 6.5 ft.	PAGE 1 OF 1
START: 12/11/12 END: 12/11/12	SAMPLING METHOD: SPT	ENERGY RATIO (%): 95.1	COORD: 616516.760 N, 1928169.460 E	

MATERIAL DESCRIPTION AND NOTES	ELEV. 650.6	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	MS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	USCS CLASS	HOLE SEALED
12.0", **TOPSOIL**	649.6																		
MEDIUM STIFF, LIGHT GRAY MOTTLED WITH ORANGE-BROWN, **SANDY LEAN CLAY**, TRACE GRAVEL, CONTAINS LIGHT GRAY-BROWN SAND POCKET, MOIST	647.1	1 2 3 ▼ 20 hr TR	2 1 3	6	-	SS-1	0.75 - 1.0	2	5	6	23	29	35	38	17	21	25	CL	
DARK GRAY, **SHALE FRAGMENTS**, CONTAINS PYRITE	644.1	4 5 6 EOB	2 9 24	52	-	SS-2	-	-	-	-	-	-	-	-	-	-	13	Rock (V)	
			50/6"	-	73	SS-3	-	-	-	-	-	-	-	-	-	-	12	Rock (V)	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. 20 HOURS AFTER DRILLING AT 3.0'. CAVE DEPTH 6.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED .25 BAG BENTONITE CHIPS; PUMPED 10 GAL. BENTONITE GROUT

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/9/13 15:43 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\NASA-BROOK STATION MAIN GATE BORROW PIT 420045830\GINT FILE

PROJECT: NASA - PLUMBROOK STATION	DRILLING FIRM / OPERATOR: B&P / P. WEBB	DRILL RIG: MOBILE B57 ORV	STATION / OFFSET:
TYPE: BORROW PIT	SAMPLING FIRM / LOGGER: B&P / R.BLASKO	HAMMER: DIEDRICH AUTOMATIC	ALIGNMENT:
PID: Client:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 6/30/11	ELEVATION: 650.0 (MSL) EOB: 11.5 ft.
START: 12/11/12 END: 12/11/12	SAMPLING METHOD: SPT	ENERGY RATIO (%): 95.1	COORD: 616432.000 N, 1928544.000 E

EXPLORATION ID G-6

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 650.0	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION(%) GR	CS	MS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	USCS CLASS	HOLE SEALED
10.0", **TOPSOIL**	649.1																		
MEDIUM STIFF TO HARD, BROWN MOTTLED WITH DARK GRAY AND RED-BROWN, **LEAN CLAY WITH SAND**, MOIST		▼ 20 hr	1 2 3	8	72	SS-1	0.5 - 1.5	0	3	7	18	39	33	34	18	16	23	CL	
@3.5'; SS-2 CHANGES TO LEAN CLAY, TRACE SAND			5 7 10	27	83	SS-2	4.5+	0	2	2	4	22	72	44	20	24	22	CL	
	643.0		4 7 10	27	78	SS-3	2.75 - 3.25	-	-	-	-	-	-	-	-	-	21	CL (V)	
HARD, DARK GRAY, **SANDY LEAN CLAY**, LITTLE GRAVEL, CONTAINS FEW ROOTS AND SHALE FRAGMENTS, DAMP							4.5+	-	-	-	-	-	-	-	-	-	10	CL (V)	
			8 7 10	27	100	SS-4	4.5+	-	-	-	-	-	-	-	-	-	10	CL (V)	
	638.5	EOB	50/5"	-	100	SS-5	4.5+	-	-	-	-	-	-	-	-	-	14	CL (V)	

Bedrock Encountered at 11.5'.

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. 20 HOURS AFTER DRILLING AT 2.0'. CAVE DEPTH 9.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED .5 BAG BENTONITE CHIPS; PUMPED 16 GAL. BENTONITE GROUT

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/9/13 15:43 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\NASA-BROOK STATION MAIN GATE BORROW PIT 420045830\GINT FILE

PROJECT: NASA - PLUMBROOK STATION	DRILLING FIRM / OPERATOR: B&P / P. WEBB	DRILL RIG: MOBILE B57 ORV	STATION / OFFSET:	EXPLORATION ID G-7
TYPE: BORROW PIT	SAMPLING FIRM / LOGGER: B&P / R.BLASKO	HAMMER: DIEDRICH AUTOMATIC	ALIGNMENT:	
PID: Client:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 6/30/11	ELEVATION: 648.8 (MSL) EOB: 9.0 ft.	PAGE 1 OF 1
START: 12/11/12 END: 12/11/12	SAMPLING METHOD: SPT	ENERGY RATIO (%): 95.1	COORD: 616193.000 N, 1928374.000 E	

MATERIAL DESCRIPTION AND NOTES	ELEV. 648.8	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION(%) GR	CS	MS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	USCS CLASS	HOLE SEALED
12.0", **TOPSOIL**	647.8																		
STIFF TO VERY STIFF, DARK GRAY MIXED WITH BROWN AND LIGHT GRAY, **LEAN CLAY WITH SAND**, TRACE GRAVEL, CONTAINS FEW ROOTS AND DECAYED ORGANICS, FUEL ODOR, MOIST **(FILL)**	645.8	20 hr	2 3 3	10	44	SS-1	1.5 - 3.0	4	3	3	14	26	50	49	19	30	27	CL	
STIFF TO VERY STIFF, BROWN MOTTLED WITH GRAY AND DARK GRAY, **FAT CLAY**, TRACE SAND, MOIST			2 3 4	11	78	SS-2	1.5 - 2.25	0	2	1	5	19	74	53	21	32	29	CH	
@6.0'; SS-3 CONTAINS TRACE GRAVEL	641.8	TR	3 5 9	22	89	SS-3	1.25 - 1.75	-	-	-	-	-	-	-	-	-	-	CH (V)	
DARK GRAY, **SHALE FRAGMENTS**	639.8	W EOB	50/3"	-	17	SS-4	-	-	-	-	-	-	-	-	-	-	-	Rock (V)	

NOTES: GROUNDWATER ENCOUNTERED AT 8.0' DURING DRILLING. 20 HOURS AFTER DRILLING AT 2.0'. CAVE DEPTH 8.5'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED .25 BAG BENTONITE CHIPS; PUMPED 16 GAL. BENTONITE GROUT

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/9/13 15:43 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\NASA-BROOK STATION MAIN GATE BORROW PIT 420045830\GINT FILE

PROJECT: NASA - PLUMBROOK STATION	DRILLING FIRM / OPERATOR: B&P / P. WEBB	DRILL RIG: MOBILE B57 ORV	STATION / OFFSET:
TYPE: BORROW PIT	SAMPLING FIRM / LOGGER: B&P / R.BLASKO	HAMMER: DIEDRICH AUTOMATIC	ALIGNMENT:
PID: Client:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 6/30/11	ELEVATION: 650.9 (MSL) EOB: 12.5 ft.
START: 12/12/12 END: 12/12/12	SAMPLING METHOD: SPT	ENERGY RATIO (%): 95.1	COORD: 616601.000 N, 1928544.000 E

EXPLORATION ID G-8

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 650.9	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION (%) GR	CS	MS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	USCS CLASS	HOLE SEALED
12.0", **TOPSOIL**	649.9																		
STIFF, BROWN, **SILTY CLAYEY SAND**, TRACE GRAVEL, MOIST **(FILL)**	647.9	1, 2	2 2 3	8	44	SS-1	1.75 - 2.0	4	6	13	31	25	21	24	17	7	18	SC-SM	
HARD, BROWN, **SANDY LEAN CLAY**, TRACE GRAVEL, DAMP		3, 4, 5	6 11 16	43	72	SS-2	4.5+	1	2	6	11	28	52	35	15	20	15	CL	
		6, 7	8 13 32	71	89	SS-3	4.5+	-	-	-	-	-	-	-	-	-	-	CL (V)	
@8.5'; SS-4 CHANGES TO DARK GRAY		8, 9, 10	8 11 12	36	50	SS-4	4.5+	-	-	-	-	-	-	-	-	-	-	CL (V)	
	639.9	TR 11																	
DARK GRAY, **SHALE FRAGMENTS**	638.4	12 EOB	6 8 50/3"	-	53	SS-5	-	-	-	-	-	-	-	-	-	-	-	Rock (V)	

NOTES: GROUNDWATER NOT ENCOUNTERED DURING DRILLING. CAVE DEPTH 10.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED .5 BAG BENTONITE CHIPS; PUMPED 20 GAL. BENTONITE GROUT

STANDARD ODOT SOIL BORING LOG (8.5 X 11) - OH DOT.GDT - 1/9/13 15:43 - X:\ACTIVE PROJECTS\ACTIVE SOIL PROJECTS\NASA-BROOK STATION MAIN GATE BORROW PIT 420045830\GINT FILE

PROJECT: NASA - PLUMBROOK STATION	DRILLING FIRM / OPERATOR: B&P / P. WEBB	DRILL RIG: MOBILE B57 ORV	STATION / OFFSET:
TYPE: BORROW PIT	SAMPLING FIRM / LOGGER: B&P / R.BLASKO	HAMMER: DIEDRICH AUTOMATIC	ALIGNMENT:
PID: Client:	DRILLING METHOD: 3.25" HSA	CALIBRATION DATE: 6/30/11	ELEVATION: 648.7 (MSL) EOB: 10.0 ft.
START: 12/12/12 END: 12/12/12	SAMPLING METHOD: SPT	ENERGY RATIO (%): 95.1	COORD: 616193.000 N, 1928544.000 E

EXPLORATION ID G-9

PAGE 1 OF 1

MATERIAL DESCRIPTION AND NOTES	ELEV. 648.7	DEPTHS	SPT/ RQD	N_{60}	REC (%)	SAMPLE ID	HP (tsf)	GRADATION(%) GR	CS	MS	FS	SI	CL	ATTERBERG LL	PL	PI	WC	USCS CLASS	HOLE SEALED
12.0", **TOPSOIL**	647.7																		
MEDIUM STIFF, BROWN MOTTLED WITH GRAY, **CLAYEY SAND**, MOIST	645.7	1 2 3	2 3 5	13	56	SS-1	0.5 - 0.75	0	0	2	53	20	25	26	15	11	19	SC	
LOOSE, BROWN WITH ORANGE-BROWN AND GRAY, **SILTY SAND**, WET	643.2	4 5	2 3 2	8	78	SS-2	-	0	0	0	64	24	12	NP	NP	NP	26	SM	
HARD, DARK BROWN, **SANDY LEAN CLAY WITH GRAVEL**, DAMP	640.2	6 7 8 W TR	3 7 10	27	67	SS-3	3.75 - 4.5+	-	-	-	-	-	-	-	-	-	-	CL (V)	
DARK GRAY, **SHALE FRAGMENTS**	638.7	9 10 EOB	4 8 29	59	56	SS-4	-	-	-	-	-	-	-	-	-	-	-	Rock (V)	

NOTES: GROUNDWATER ENCOUNTERED AT 8.5' DURING DRILLING. CAVE DEPTH 9.0'.

ABANDONMENT METHODS, MATERIALS, QUANTITIES: POURED .5 BAG BENTONITE CHIPS; PUMPED 16 GAL. BENTONITE GROUT

BARR & PREVOST
ENGINEERING | TESTING | SURVEYING

Barr and Prevost, Inc.
2800 Corporate Exchange Drive, Suite 240
Columbus, Ohio 43231
Telephone: (614) 714-0270
Fax: (614) 714-0323

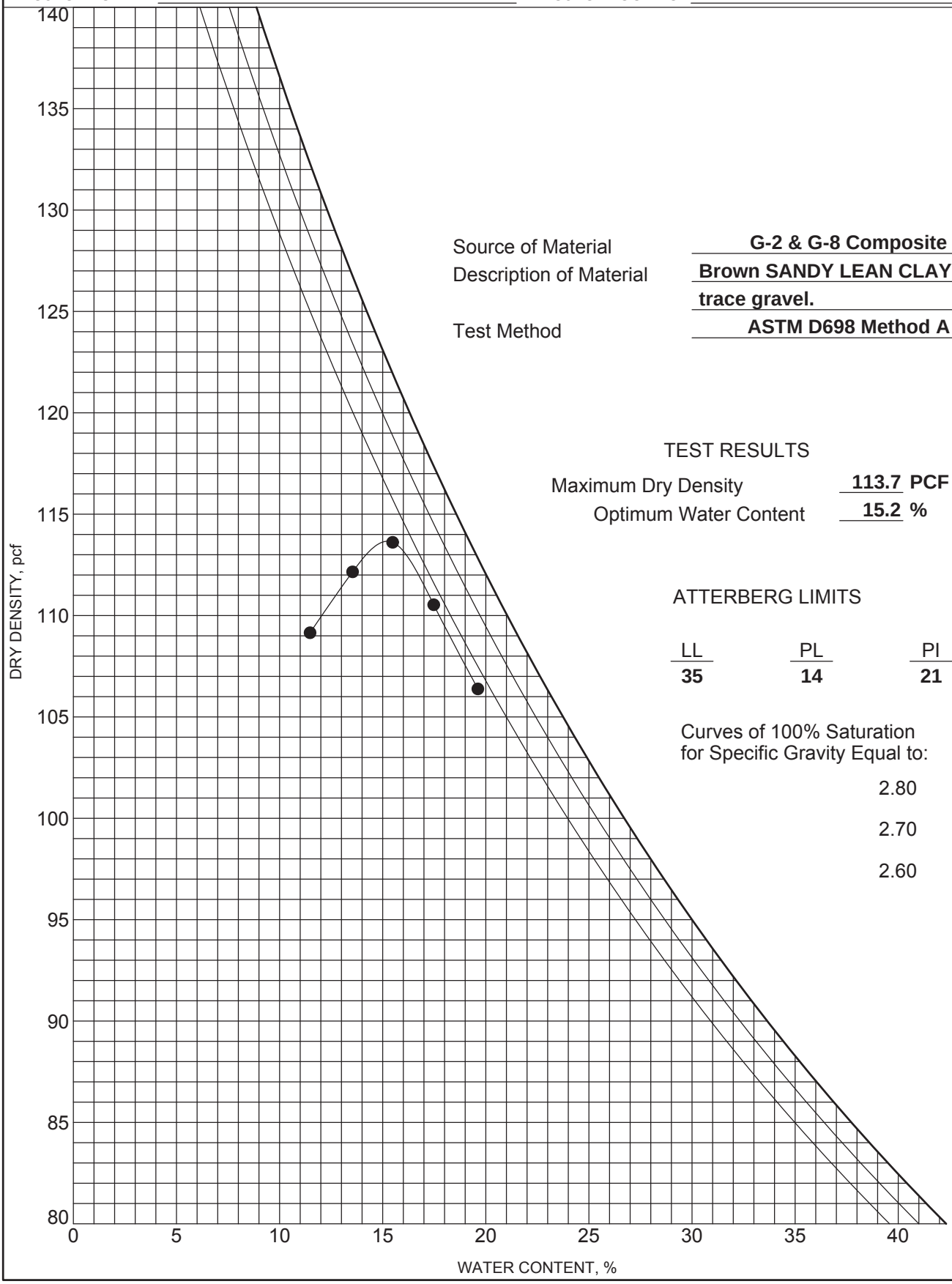
MOISTURE-DENSITY RELATIONSHIP

CLIENT NASA

PROJECT NAME Plum Brook Station Main Gate Borrow Pit

PROJECT NUMBER

PROJECT LOCATION



Source of Material **G-2 & G-8 Composite**

Description of Material **Brown SANDY LEAN CLAY, trace gravel.**

Test Method **ASTM D698 Method A**

TEST RESULTS

Maximum Dry Density **113.7** **PCF**

Optimum Water Content **15.2** **%**

ATTERBERG LIMITS

LL	PL	PI
35	**14**	**21**

Curves of 100% Saturation for Specific Gravity Equal to:

2.80

2.70

2.60

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Fax: (614) 714-0323

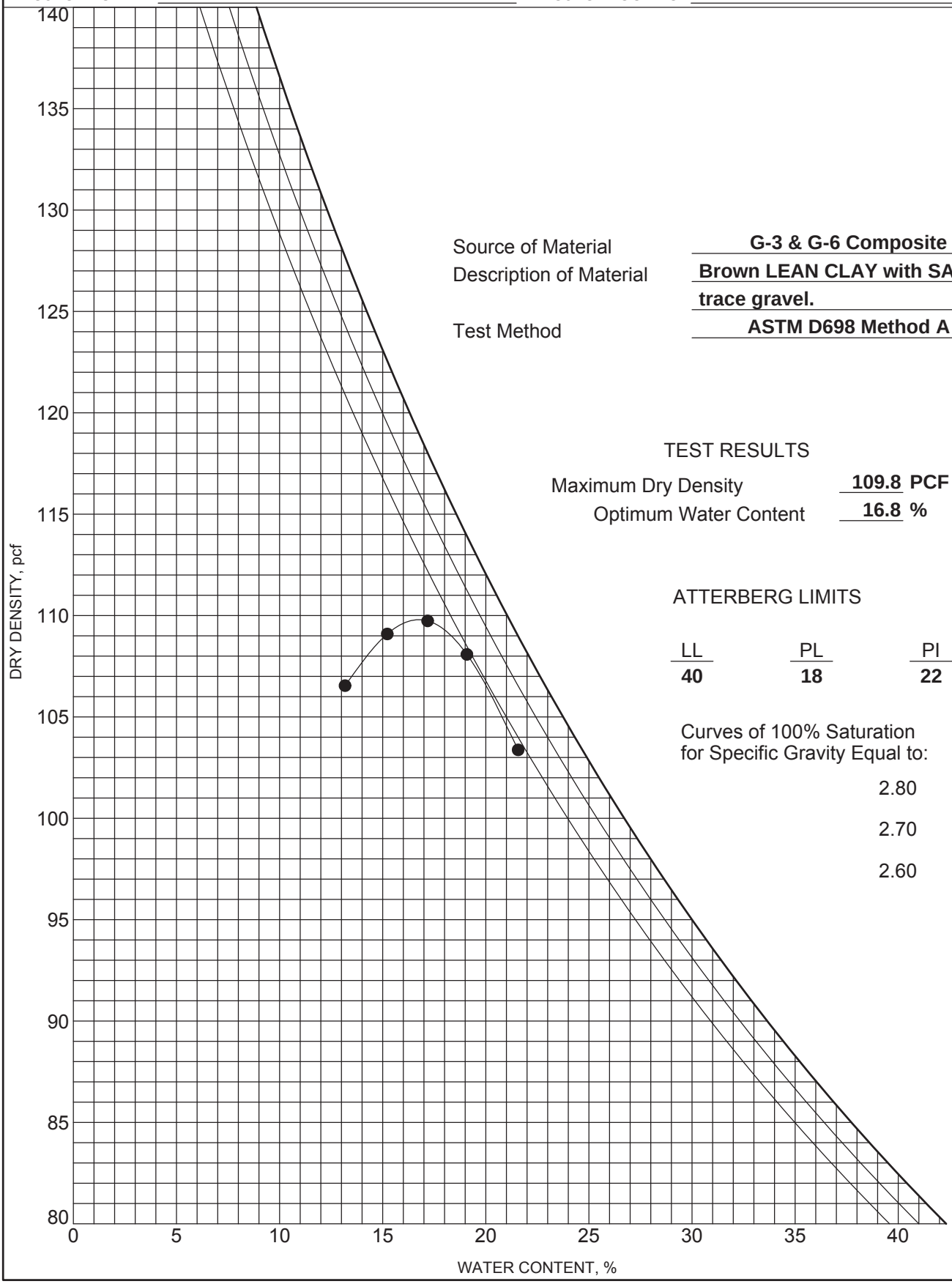
MOISTURE-DENSITY RELATIONSHIP

CLIENT NASA

PROJECT NAME Plumbrook Sta Main Gate Borrow Pit

PROJECT NUMBER

PROJECT LOCATION



Source of Material: **G-3 & G-6 Composite**

Description of Material: **Brown LEAN CLAY with SAND, trace gravel.**

Test Method: **ASTM D698 Method A**

TEST RESULTS

Maximum Dry Density **109.8** **PCF**

Optimum Water Content **16.8** **%**

ATTERBERG LIMITS

LL	PL	PI
40	**18**	**22**

Curves of 100% Saturation for Specific Gravity Equal to:

2.80

2.70

2.60

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Columbus, Ohio 43231
Telephone: (614) 714-0270
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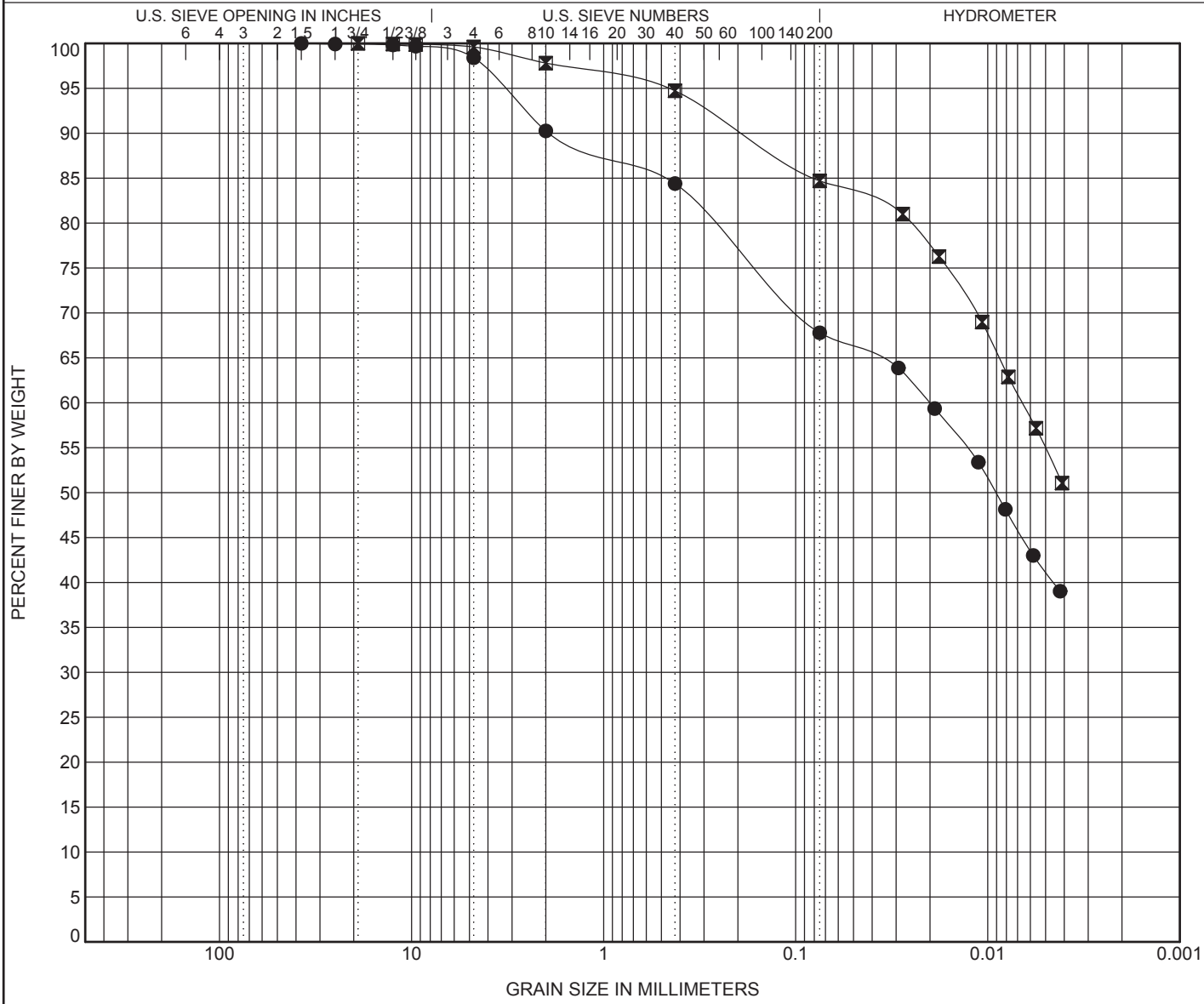
GRAIN SIZE DISTRIBUTION

CLIENT NASA **PROJECT NAME** Plum Brook Station Main Gate Borrow Pit

PROJECT NUMBER **PROJECT LOCATION**



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Specimen Identification		Classification	LL	PL	PI	Cc	Cu
●	**G-2 & G-8**	**0.0**	**SANDY LEAN CLAY(CL)**	**35**	**14**	**21**		
⊠	**G-3 & G-6**	**0.0**	**LEAN CLAY with SAND(CL)**	**40**	**18**	**22**		

	Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**G-2 & G-8**	**0.0**	**37.5**	**0.02**			**1.6**	**30.6**	**26.6**	**41.2**
⊠	**G-3 & G-6**	**0.0**	**19**	**0.007**			**0.4**	**14.9**	**29.7**	**54.9**

CALIFORNIA BEARING RATIO (CBR)
AASHTO T 193--ASTM D 1883

Client: ***NASA*** **Analyst:** *CH*
Project: ***Plum Brook Station Main Gate*** **Test Date:** *1/7/2013*
Job No.:

Sample ID: ***G-2 & G-8 composite*** Sample Description: *10 blows*
Condition of sample: ***soaked*** Surcharge Mass: *10lb*

% Sand and Gravel = 32.2
% Silt = 26.6
% Clay = 41.2
Additional tests run on sample: NA

ASTM D698 Method A
Optimum moisture (%) = 15.2
Maximum dry unit weight (pcf) = 113.7

	Compaction Before	Compaction After	After Soaking top 1"	Average	
Mass of tare (g) =	18.49	18.37	62.78	25.53	#1
Mass of tare and wet soil (g) =	974.51	381.85	852.94	25.53	#2
Mass of tare and dry soil (g) =	852.34	337.58	691.17	25.53	#3
Moisture content (%) =	**14.65**	**13.87**	**25.74**	**25.53**	Average

Mass of mold (g) =	4188.60	4188.60
Height of sample (in) =	4.584	4.584
Diameter of mold (in) =	6.001	6.001
Mass of mold and wet soil (g) =	7771.40	8176.30
Dry unit weight (pcf) =	**91.84**	**93.35**
% Compaction =	80.8	

Swell Not recorded on retest
Initial swell reading (10^{-3} in) = 0.323
Final swell reading (10^{-3} in) = 0.4125
% Swell = 1.95

Ring Factor =
Piston Area (in^2) = 3

Penetration in	Dial Reading 10^{-4} in	Load lbs	Stress psi	CBR Value %
0.000		1.000	0.000	
0.025		5.000	1.667	
0.050		7.500	2.500	
0.075		9.500	3.167	
0.100		**11.000**	3.667	**0.4**
0.125		12.000	4.000	
0.150		13.000	4.333	
0.175		14.000	4.667	
0.200		**15.000**	5.000	**0.3**
0.300		17.000	5.667	0.3
0.400		18.000	6.000	0.3
0.500		19.000	6.333	0.2

DESIGNATED CBR = 0.3

Prepared by: EC Date: 1/7/13
Checked by: SE Date: 1/9/13

CALIFORNIA BEARING RATIO (CBR)
AASHTO T 193--ASTM D 1883

Client: ***NASA*** **Analyst:** *CH*
Project: ***Plum Brook Station Main Gate*** **Test Date:** *1/7/2013*
Job No.:

Sample ID: ***G-2 & G-8 composite*** Sample Description: *25 blows*
Condition of sample: ***soaked*** Surcharge Mass: *10lb*

% Sand and Gravel = 32.2
% Silt = 26.6
% Clay = 41.2
Additional tests run on sample: NA

ASTM D698 Method A
Optimum moisture (%) = 15.2
Maximum dry unit weight (pcf) = 113.7

	Compaction Before	Compaction After	After Soaking top 1"	Average	
Mass of tare (g) =	18.12	18.38	247.15	20.41	#1
Mass of tare and wet soil (g) =	935.37	244.70	1024.24	20.41	#2
Mass of tare and dry soil (g) =	819.41	217.59	869.37	20.41	#3
Moisture content (%) =	**14.47**	**13.61**	**24.89**	**20.41**	Average

Mass of mold (g) =	4201.50	4201.50
Height of sample (in) =	4.590	4.590
Diameter of mold (in) =	5.996	5.996
Mass of mold and wet soil (g) =	8230.00	8494.20
Dry unit weight (pcf) =	**103.46**	**104.81**
% Compaction =	91.0	

Swell
Initial swell reading (10^{-3} in) = 0.069
Final swell reading (10^{-3} in) = 0.2125
% Swell = 3.13

Ring Factor =
Piston Area (in^2) = 3

Penetration in	Dial Reading 10^{-4} in	Load lbs	Stress psi	CBR Value %
0.000		2.000	0.000	
0.025		14.000	4.000	
0.050		19.000	5.667	
0.075		24.000	7.333	
0.100		**29.000**	9.000	**0.9**
0.125		33.000	10.333	
0.150		35.500	11.167	
0.175		38.000	12.000	
0.200		**41.000**	13.000	**0.9**
0.300		51.000	16.333	0.9
0.400		62.000	20.000	0.9
0.500		70.000	22.667	0.9

DESIGNATED CBR = 0.9

Prepared by: EC Date: 1/7/13
Checked by: SE Date: 1/9/13

CALIFORNIA BEARING RATIO (CBR)
AASHTO T 193--ASTM D 1883

Client: ***NASA*** **Analyst:** *CH*
Project: ***Plum Brook Station Main Gate*** **Test Date:** *1/7/2013*
Job No.:

Sample ID: ***G-2 & G-8 composite*** Sample Description: *56 blows*
Condition of sample: ***soaked*** Surcharge Mass: *10 lb*

% Sand and Gravel = 32.2
% Silt = 26.6
% Clay = 41.2
Additional tests run on sample: NA

ASTM D698 Method A
Optimum moisture (%) = 15.2
Maximum dry unit weight (pcf) = 113.7

	Compaction Before	Compaction After	After Soaking top 1"	Average	
Mass of tare (g) =	17.94	18.49	161.78	16.29	#1
Mass of tare and wet soil (g) =	719.88	304.62	859.76	16.29	#2
Mass of tare and dry soil (g) =	629.53	268.87	741.59	16.29	#3
Moisture content (%) =	**14.77**	**14.28**	**20.38**	**16.29**	Average

Mass of mold (g) =	4197.10	4197.10
Height of sample (in) =	4.589	4.589
Diameter of mold (in) =	6.001	6.001
Mass of mold and wet soil (g) =	8593.80	8686.50
Dry unit weight (pcf) =	**112.45**	**113.32**
% Compaction =	98.9	

Swell
Initial swell reading (10^{-3} in) = 0.091
Final swell reading (10^{-3} in) = 0.167
% Swell = 1.66

Ring Factor =
Piston Area (in^2) = 3

Penetration in	Dial Reading 10^{-4} in	Load lbs	Stress psi	CBR Value %
0.000		0.000	0.000	
0.025		45.000	15.000	
0.050		73.000	24.333	
0.075		98.000	32.667	
0.100		**120.000**	**40.000**	**4.0**
0.125		138.000	46.000	
0.150		160.000	53.333	
0.175		183.000	61.000	
0.200		**195.000**	**65.000**	**4.3**
0.300		260.000	86.667	4.6
0.400		316.000	105.333	4.6
0.500		365.000	121.667	4.7

DESIGNATED CBR = 4.3

Prepared by: EC Date: 1/7/13
Checked by: SE Date: 1/9/13