amec foster wheeler

Final Geotechnical Investigation and Foundation Recommendation Report
BIA Project N8066(3), N8065(1) and School Spur
Black Mesa Community School, AZ (Navajo Nation)
BIA Order No. A15PD00791
BIA Requisition No. 0040235503
Architect – Engineer IDIQ Contract No. A12PC00121

Submitted to:

Bureau of Indian Affairs, Navajo Regional Office
Gallup, New Mexico

Naida Causevic

Registered Professional Engineer (Civil)
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Expires 12/31/ 2016

Submitted by:

Amec Foster Wheeler
Environment & Infrastructure, Inc.
Phoenix, Arizona

June 15, 2016

Project No. 17-2015-4045

June 15, 2016
Project No. 17-2015-4045

Bureau of Indian Affairs, Navajo Regional Office
Division of Acquisition
PO Box 1060
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Attn: Christopher Becenti, PE

Re: Final Geotechnical Investigation and Foundation Recommendation Report
BIA Project N8066(3), N8065(1) and School Spur
Black Mesa Community School, AZ (Navajo Nation)
BIA Order No. A15PD00791
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Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler) has completed this Final Geotechnical Investigation and Foundation Recommendation Report in support of the proposed improvements of Bureau of Indian Affairs (BIA) Route N8066(3), BIA Route N8065(1) and School Spur near Black Mesa Community School, Arizona. This work was performed in general accordance with BIA Order No. A15PD00791 dated September 18, 2015. The sections of this report include a project description, discussions of the geotechnical profile encountered at the site, recommended foundation types for the bridge structures at Route N8066(3) and N8065(1), and other aspects of the project where geotechnical recommendations are appropriate.

We at Amec Foster Wheeler appreciate the opportunity to provide these services for you. If you have any questions regarding this report, please do not hesitate to contact us.

Respectfully submitted,

Amec Foster Wheeler
Environment & Infrastructure, Inc.

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TABLE OF CONTENTS

LIST OF APPENDICES

pg 207

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1.0 PROJECT INFORMATION AND PURPOSE

Included in this report are the results of our investigation in support of the planned improvements to the Bureau of Indian Affairs (BIA) Route N8066(3) drainage crossing at approximately Station 22+431, and BIA Route N8065(1) drainage crossing at approximately Station 0+327. The project consist of one new culvert structure or arch bridge structure along BIA Route N8066(3) and one new bridge structure along BIA Route N8065(1), both crossing the Oraibi Wash. The geological and geotechnical findings, along with the recommendations for the foundations, are presented in two separate Foundation Design Memoranda, which have been provided as Appendices A and B to this document. Each Foundation Design Memorandum presents a summary of the investigations performed at each drainage crossing, a summary of the geological and geotechnical conditions at the drainage crossing, the results of our engineering analyses, and discussions of foundation design considerations. Pavement design recommendations for the roadway improvements to the existing unpaved roads at BIA N8066(3), N8065(1) and School Spur are provided under separate cover in the Geotechnical Investigation and Pavement Design Report.

At the request of the BIA, our investigation consisted of a subsurface exploration and a laboratory testing program to classify and evaluate the subgrade soils at the two drainage crossing locations identified above. This report provides foundation recommendations and construction considerations for each of the structures.

This report does not address any environmental issues related to the site or the project. If you have any questions concerning environmental aspects of this project please contact us and we can discuss additional services with you.

This report has been prepared for the BIA, Navajo Regional Office for the purpose of providing the information described in the attached documents. This report has not been prepared for any other parties, and may not contain sufficient information for purposes of other parties. If any of the project information described in this report has changed, we should be notified so that we may amend our recommendations, as necessary.

APPENDIX A

FOUNDATION DESIGN MEMORANDUM 1
BIA ROUTE N8066(3) DRAINAGE CROSSING

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ATTACHMENTS

June 15, 2016
Project No. 17-2015-4045
Foundation Design Memorandum No. 1

Bureau of Indian Affairs, Navajo Regional Office
Division of Acquisition
PO Box 1060
301 West Hill, Room 346
Gallup, New Mexico 87301

Attn: Christopher Becenti, PE

Re: Foundation Design Memorandum – N8066(3) Drainage Crossing
BIA Project N8066(3), N8065(1) and School Spur
Black Mesa Community School, AZ (Navajo Nation)
BIA Order No. A15PD00791
BIA Requisition No. 0040235503
Architect – Engineer IDIQ Contract No. A12PC00121

1.0 INTRODUCTION

This memorandum provides recommendations for the design of box culvert or arch bridge structure foundations at the BIA Route N8066(3) drainage crossing, as part of the BIA N8066(3), N8065(1) and School Spur project. The foundation design was based on the geotechnical investigation segment performed at the BIA N8066(3) drainage crossing by Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler). The planned structure will cross the Oraibi Wash at approximately BIA Route N8066(3) Station 22+431. The box culvert structure will be supported on shallow foundations, and the arch bridge structure will be a one-span arch with abutments founded on deep foundations.

2.0 FIELD INVESTIGATION

2.1 Subsurface Exploration

The subsurface exploration for the BIA N8066(3) culvert structure segment was performed from January 27 to February 3, 2016, and February 18 to February 19, 2016. Field direction, sample collection and logging of borings were performed by Joseph Zaleski, EIT and Mark Keyes, PG of Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler). Logs of the completed borings are presented in Attachment A of this memorandum. Attachment A also includes a description of drilling and sampling procedures, and photographs of the rock core recovered from the borings. Amec Foster Wheeler advanced five borings for the proposed BIA N8066(3) drainage structure to depths ranging from 15 to 30 meters below existing site grades. Borings B-1 and B-2 correspond to the arch bridge structure option; borings B-4 and B-5 correspond to the box culvert structure; and boring B-3 applies to both structures. The total drill footage was approximately 126 meters, which was less than the targeted/proposed footage of 150 meters due to borings B-2, B-4 and B-5 encountering rock prior to reaching the 30-meter boring depth. Rock coring was performed at four of the five boring locations, once encountered, for 6 meters or to the required 30-meter depth, whichever was reached first. Locations of the

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borings are shown on Figure 4, Boring and Resistivity Location Map, and are presented in tabular format in Table 1.

The borings were completed by Southlands Engineering, LLC (Southlands) with a specialized ATV mounted CME-75 drill rig utilizing a 210-millimeter outside-diameter continuous-flight hollow-stem auger for the soil portion and a triple-core barrel and HQ sized wireline diamond-bit rock coring system for the rock coring portion. The HQ core system produces a 63.5-millimeter diameter core. Completed soil borings were backfilled with soil cuttings and cement grouted in the upper 6 meters.

Each boring location was established in the field using the laid out proposed alignments for the roadway segment and confirmed with a handheld GPS unit in NAD 83 – UTM Zone 12N coordinates. The locations of the borings are shown on the boring logs and are presented in Attachment A. Encountered soils were visually inspected, labeled and classified in the field, and logged in general accordance with ASTM D2488 and the Unified Soil Classification System. After completion of the laboratory tests on the samples retrieved, the field logs were reviewed and modified, where necessary, to produce the final boring logs presented in Attachment A.

2.2 Laboratory Testing

Laboratory tests were performed on representative bulk, split-spoon, ring, and Shelby tube samples obtained during our subsurface exploration to evaluate and characterize the site soils for engineering analysis and design. The following tests were performed in general accordance with applicable American Association of State Highway and Transportation Officials (AASHTO) test methods. In the absence of an AASHTO test method, American Society for Testing and Materials (ASTM) test methods were used.

- Sieve Analysis (Gradation and minus 75-micrometer wash) (AASHTO T11,T27)
- Plasticity Index (AASHTO T89, T90)
- Density Test (ASTM D2937)
- Moisture (AASHTO T265)
- Direct Shear Test of Soils (AASHTO T236)
- Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils (AASHTO T296)
- One-Dimensional Consolidation (AASHTO T216)
- Unconfined Compressive Strength of Rock (AASHTO T208)

A summary of the laboratory test results is presented in Table B-1 in Attachment B, along with the test worksheets.

3.0 GEOTECHNICAL PROFILE

3.1 Geologic Setting

Surficial geologic units exposed within the project site include Holocene-aged and/or Pleistocene-aged Quaternary alluvial and eolian deposits and Upper Cretaceous-aged sandstone and siltstone. The Holocene deposits are comprised of stream deposits and windblown silt and sand deposited on benches, small terraces and in broad valleys. These deposits have been reworked by water. The Upper Cretaceous-aged sandstones and siltstones of the Wepo Formation are part of the Mesaverde Group. The Wepo Formation is comprised of alternating siltstone and sandstone layers of continental and near-shore origin, and to some extent coal beds of up to 1.5 meters in thickness. The siltstone is generally olive-green in color and the sandstone is typically yellowish-gray. This unit varies from 40 meters to 225 meters in thickness. (Haynes and Hackman, 1978)[1]. The Wepo Formation sandstone with siltstone and mudstone interbeds was encountered at various depths in borings B-1 through B-5 at the N8066(3) culvert structure.

3.2 Geotechnical Profile

The native soils encountered during the investigation along the proposed BIA N8066(3) drainage structure crossing primarily consist of fine-grained soil mixtures, including sandy clays to clays, overlaying course-grained soil mixtures of silty sand to sand with silt or bedrock. The predominant soil types were combined into two groups based on their characteristics: clays and silts. The clays group consists of high-plasticity clays (CH), low-plasticity clays (CL) and clayey sands (SC). The silts group consists of silty sand (SM) to sand with silt (SP-SM).

In general, the site soils can be characterized into three layers: Layers A, B and C. These layers are described in detail in Sections 3.2.1 through 3.2.3. The profiles for the two drainage crossing structures differ slightly, specifically as it pertains to the bedrock in Layer C. A subsurface profile of the soil borings for the arch bridge structure and the box culvert structure alignment, at the BIA N8066(3) drainage crossing, is provided in Figures 7 and 8, respectively. An overview of the three layers is as follows:

- Layer A is primarily expressed at the Oraibi Wash banks and extends from the surface to a depth of about 16 meters below the ground surface (bgs), and predominantly consists of a mixture of fines (particles less than the 75-micrometer sieve), including sandy clay to clayey sand. At the wash bottom, Layer A extends to about 10 meters bgs within borings B-3 and B-5 and to about 4 meters bgs within boring B-4, and is overlain by a 1.5 to 3 meter silty sand to silty gravel layer.
- Layer B extends from a depth of about 16 meters to 22 meters bgs at the wash banks and from about 10 meters to 18 meters bgs at the wash bottom. Layer B was not encountered within boring B-4. The layer predominantly consists of lower fines content and increased sand content soils. The soils are predominantly classified as silty sand to sand with silt. Layer B is interfingered with zones of higher fines content soils, approximately 150 millimeters in thickness.
- Layer C extends below the B Layer to the full depth of the investigation, approximately 30 meters bgs from the wash banks, and 30 meters bgs from the wash bottom. Layer C consists of the Wepo Formation bedrock. The bedrock varies in depth along the box culvert alignment in the Oraibi Wash (borings B-4, B-3 and B-5), sloping downwards from the west to the east (Figure 7). The bedrock profile along the arch bridge structure alignment in line with the BIA N8066 roadway alignment (B-1, B-3 and B-2) was relatively uniform in depth (Figure 8).

[1] References are presented in Section 5.0 of this memorandum.

The direct shear test result, adjusted to show the residual shear strength, is plotted on Figure 5. An internal friction angle of 14 degrees and 36 kilopascals (kPa) cohesion is the lower bound for the data. The unconsolidated-undrained triaxial compression (UU) tests, performed on cohesive soils, are plotted on Figure 6. Analysis of the UU test results was completed as a function of soil type and depth. The various soil layers are discussed in greater detail in the following sections.

3.2.1 Layer A – Near Surface Clayey Soils

Layer A extends from the surface to a depth of about 16 meters bgs at the wash banks and consists primarily of clayey soils. At the wash bottom, Layer A extends to about 10 meters bgs within borings B-3 and B-5 and to about 4 meters bgs within boring B-4, and is overlain by a 1.5- to 3-meter thick silty sand to silty gravel layer. The soil types include low plasticity clay (CL), high plasticity clay (CH) and, to a lesser extent, zones of clayey sand (SC). Layer A soils are characterized as having a fines content typically greater than 50 percent with a maximum of 100 percent. The soils within Layer A primarily have medium to high plasticity and, to a lesser extent, zones of low plasticity. The zones of low plasticity are primarily localized to clayey sand zones. Layer A is predominantly moderately firm to very firm with some soft and hard zones. The measured uncorrected SPT blow counts varied from zero (i.e., weigh of hammer for a 300-millimeter interval) to 34 with an average of 13 and a median value of 9. The soils are predominantly uncemented.

The direct shear test result performed on Layer A, adjusted to show the residual shear strength, is plotted on Figure 5. Based on these results, an angle of internal friction of 14 degrees with a cohesion intercept of 36 kPa was determined. UU test results performed on Layer A soils show a range of undrained shear strength, from 320 to 720 kPa, as shown on Figure 6. Undrained shear strength values were also developed using correlations by Terzaghi and Peck, as presented in Kulhawy and Mayne (1990), and ranged from approximately 40 to 120 kPa.

3.2.2 Layer B – Silty Sand Soils

Layer B extends from a depth of about 16 meters to 22 meters bgs from the wash banks and about 10 meters to 18 meters bgs from the wash bottom and predominantly consists of lower fines content and increased sand content soils. Layer B was not encountered within boring B-4. The soil types consist primarily of silty sand (SM) and, to a lesser extent, zones of sand with silt (SP-SM). The fines content for Layer B is typically less than 50 percent. These soil types are primarily non plastic with occasional zones of medium to high plasticity. The zones of medium to high plasticity are localized to thin clay soil zones encountered at depth. These soils are predominantly soft to moderately firm with some firm zones. The measured uncorrected SPT blow counts varied from 2 to 25 with an average of 5 and a median value of 5. The soils are predominantly uncemented.

Due to the nature of these soils, adequate undisturbed samples could not be obtained to perform direct shear tests or UU tests. The average blow count value of 5 was considered very conservative for strength estimation of the material due to the likelihood of heaving sand during sampling given that Layer B was below the groundwater table. The correlations presented in FHWA Design and Construction of Driven Pile Foundations guidelines (2006) recommend a friction angle of 27 to 32 be used for loose soils. Amec Foster Wheeler selected the upper bound of 32 degrees for analysis, which is a typical friction angle value for this type of material.

3.2.3 Layer C – Wepo Formation Bedrock

Layer C extends from a depth of about 20 meters to the depth of the investigation (i.e. 30 meters bgs) at the wash banks and about 18 meters to the depth of the investigation (i.e. 30 meters bgs) at the wash bottom and consists primarily of the Wepo Formation bedrock. The bedrock was encountered at depth within borings B-1, B-2, B-3, and B-5, ranging from approximately 18 meters to 20 meters bgs. However, at boring B-4, the planed box culvert outlet, bedrock was encountered at approximately 4.5 meters bgs. Photographs of the core recovered from the borings are presented in Attachment A, Core Photographs. The Wepo Formation sandstone and siltstone, encountered at the site is a massive unit with few discontinuities. Almost all of the core breaks that occurred within the core samples can be attributed to machine breaks resulting from the drilling process. These breaks tend to break along laminations within the sandstone and siltstone. The definition of RQD includes rock soundness and all intervals of the rock were soft to very soft; therefore, the RQD values assigned to some core runs were low. Some of the low RQD values were the result of soft zones within the rock mass rather than the presence of discontinuities or joints.

The UCS of the sandstone and siltstone encountered during our investigation ranged from 1,427 to 28,524 kPa, with an average of 15,419 kPa and a lower quartile of 14,503kPa. The Geologic Strength Index (GSI) ranged from 37 to 45, and the intact rock modulus ranged from 146,667 to 1,345,456 kPa. The rock mass density is approximately 2,080 kilograms per cubic meter (kcm). Due to the soft to very soft nature of the sandstone and siltstone, a portion of the rock encountered, was advanced with auger. Split-spoon samples were taken at 5-foot intervals within those depths, and the blow count values ranged from 22 to refusal (i.e., 50 blows for less than a 150-mm interval).

Amec Foster Wheeler performed a sensitivity analyses on the sandstone/siltstone bulk rock modulus as a function of both a soft to very soft rock and a hard sand with fines. The bulk modulus, when analyzed as rock using the Yang correlation presented in AASHTO (2014), varied slightly compared to the modulus when analyzed as soil. The rock modulus when analyzed using the Hoek and Brown criterion as presented in AASHTO (2014) was very low and improbable. Comparing the calculated rock modulus using Yang to the published values in AASHTO (2014) for sandstone and siltstone, the calculated values were still conservative. The average soil modulus for a sand with fines, based on a correlation from Kulhawy and Mayne (1990), using a refusal blow count is 69.1 megapascal (MPa), and the average bulk rock modulus, based on Yang's correlation, using GSI and intact rock modulus, ranged from 9.9 to 88.1 MPa, with an average of 62.2 MPa. The rock bulk modulus varied with depth. Amec Foster Wheeler used the average bulk rock modulus based on Yang's correlations, for design.

3.3 Groundwater and Soil Moisture Conditions

Groundwater was encountered at the drainage crossing. Moisture content tests developed as part of the density tests (ASTM D2937) and UU test (AASHTO T296) were used to evaluate the on-site soil moisture characteristics. The site soils were generally described as being slightly moist with occasional moist zones above the groundwater table, and moist to wet below the groundwater table. The measured soil moisture contents varied from 13.5 to 25.2 percent (of dry weight), with an average value of approximately 19 percent.

The groundwater level was encountered near the ground surface of the Oraibi Wash. The groundwater level elevation dropped slightly within the wash banks of the drainage crossing.

Seasonal variations could cause fluctuations in groundwater depth and depth to groundwater could be shallower or deeper depending on the water flow in Oraibi Wash.

3.4 Site Seismicity

The project seismic criteria were determined in accordance with Section 3.10 of AASHTO (2014). The horizontal design acceleration is defined as having a 7 percent chance of exceedance during a 75-year recurrence interval. The probabilistic horizontal spectral acceleration values for the designated return period and corresponding peak horizontal ground acceleration (PGA) were obtained from the U.S. Geological Survey (USGS) seismic hazards program website (2014). The values obtained from the website are based on 2009 AASHTO Guide Specifications for Load and Resistance Factor Design (LRFD) Seismic Bridge Design and use 2002 USGS seismic hazard data. The values for the box culvert structure and the arch bridge structure are presented in Table 3.1.

Table 3.1: BIA N8066(3) - Seismic Design Parameters for Site Class B[1]

Period, seconds	Spectral Acceleration Value, g	Seismic Design Parameter
0.0	0.051	PGA[2]
0.2	0.111	S_s
1.0	0.032	S_1

Note:
[1] Results are based on a latitude of 36.34559 degrees and a longitude of -110.07058 degrees.
[2] PGA = peak ground acceleration

Based on the geotechnical investigation blow counts, a weighted average blow count of 12 was determined for the upper 30 meters using Method B or the N Method from Table C3.10.3.1-1 of AASHTO (2014). Site Class E was selected for the site as the weighted average blow count was between 9 and 15, with the exception of B-4. Site Class E is defined as a site underlain by soft clay. The modified seismic design parameters for Site Class E are presented in Table 3.2.

Table 3.2: BIA N8066(3) - Seismic Design Parameters for Site Class E[1]

Period, seconds	Spectral Acceleration Value, g	Seismic Design Parameter
0.0	0.129	A_S
0.2	0.277	S_{DS}
1.0	0.112	S_{D1}

Note:
[1] Results are based on a latitude of 36.34559 degrees and a longitude of -110.07058 degrees.

A horizontal response spectral acceleration coefficient (S_{D1}) of 0.112 was calculated using the long-period range of acceleration spectrum coefficient (F_v). The calculated S_{D1} is less than the threshold value of 0.15g for Seismic Zone 1, Table 3.10.6-1 (AASHTO 2014).

4.0 DISCUSSION AND RECOMMENDATIONS

The following sections provide information and recommendations for foundation types for the proposed culvert structure at the BIA Route N8066(3) Oraibi Wash crossing.

4.1 Foundation Type Recommendations

Amec Foster Wheeler understands that the BIA plans to construct a concrete box culvert structure at the BIA Route N8066(3) Oraibi Wash crossing, at approximately Station 22+431. The bottom of a box culvert structure behaves as a mat foundation supporting the box culvert and embankment fill, and therefore was designed as a mat foundation.

Based on the differential bedrock profile depth encountered at the bottom of the Oraibi Wash at the BIA Route N8066(3) crossing, and the potential for differential settlements between the inlet, midpoint and outlet of the box culvert structure, Amec Foster Wheeler recommends BIA consider an arch bridge structure supported on driven steel H-piles as an alternative to the box culvert. Based on discussions with the BIA, the proposed precast concrete arch structure would span the wash without a pier in the middle. If the arch structure layout changes, and a pier is needed in the middle of the wash, Amec Foster Wheeler recommends using H-piles to support the arch structure pier.

This memorandum presents recommendations for mat foundations for the box culvert in Section 4.2.1 and H-pile foundations for the arch structure are discussed in Section 4.2.2.

4.2 Foundation Design Recommendations

The recommended design criteria is based on AASHTO LRFD Bridge Design Specifications (AASHTO 2014).

Scour depths were considered in the design and are based on discussions and e-mail correspondence with Messrs. Corwyn Henry and Harold Riley at the BIA. Scour depths for the BIA Route N8066(3) crossing are reported in Table 4.1 for a 100-year storm event.

Table 4.1: Scour Depths for Oraibi Wash BIA N8066(3) Drainage Crossing

Scour Type	100-Year Scour Depth
Concrete Box Culvert with Wing Walls	1.5 meters
Piers	1.5 meters

The channel thalweg was identified as elevation 2028.3 meters. The scour depth values presented in Table 4.1 need to be confirmed by the designer once the final drainage report is available. If the recommendations in the final drainage report differ from what is presented above, Amec Foster Wheeler should be contacted to revise our recommendations.

Seasonal frost depth was considered in the design of the foundations. Amec Foster Wheeler calculated a frost depth for design of spread footings based on the Arizona Department of Transportation (ADOT) Freezing Index (1989). A frost depth of approximately 1 meter was calculated based on the drainage crossing location. A conservative frost depth of 1.5 meters was used in design. Any foundations placed should be founded a minimum of 1.5 meters below grade to mitigate impacts due to frost.

The following sections provide design recommendations for the strength limit state and the service limit state accounting for the 100-year scour depth.

4.2.1 Box Culvert Mat Foundation

4.2.1.1 Strength Limit State

The factored bearing resistance is calculated by multiplying the nominal bearing resistance by the appropriate resistance factor. The resistance factor used in the determination of the factored bearing resistance is a function of the design methodology, the soil type and the test method used to determine the strength of the soil. The resistance factor used was 0.45, as presented in Table 10.5.5.2.2-1 of AASHTO (2014) using the theoretical method and standard penetration test results. The nominal bearing resistance was calculated using a friction angle of 14 degrees and cohesion of 36 kPa to evaluate the equations in Section 10.6.3 of AASHTO (2014).The factored bearing resistance chart for various box culvert mat foundation widths is provided in the Mat Foundation Design Chart shown in Figure 4.1. Calculation inputs and outputs for the design chart are provided in Attachment C.

The factored bearing resistance chart in Figure 4.1 presents bearing resistances for various effective footing widths. The bearing resistance for the strength limit state is identified by the "Strength Limit State" curve. The effective width of eccentrically loaded footings should be determined using equation 10.6.1.3-1 of AASHTO (2014). Note that the footings should be sized to satisfy the limiting eccentricity requirements discussed in Section 4.4.2.

4.2.1.2 Service Limit State

The magnitude of foundation settlement is a function of the vertical net bearing resistance developed by the soil. The relationship between settlement and nominal net bearing resistance was calculated using the method presented by Schmertmann (1970) and Schmertmann, et al (1978). Estimates of soil elastic modulus were developed using correlations with SPT blow counts presented in Bowles (1982), AASHTO (2014: Article 10.4.6.3) and Kulhawy and Mayne (1990). The uncorrected SPT (N) values ranged from 3 to 36. The soil modulus values used in the design varied from approximately 412 to 29,664 kPa. As discussed in Section 3.2.3 of this memorandum, estimates of rock bulk modulus were developed using GSI and intact rock modulus values (AASHTO 2014: Article 10.4.6). The rock bulk modulus value used in the design was 62.2 MPa from approximately 19.5 to 25.5 meters bgs and 71.8 MPa below 25.5 meters bgs.

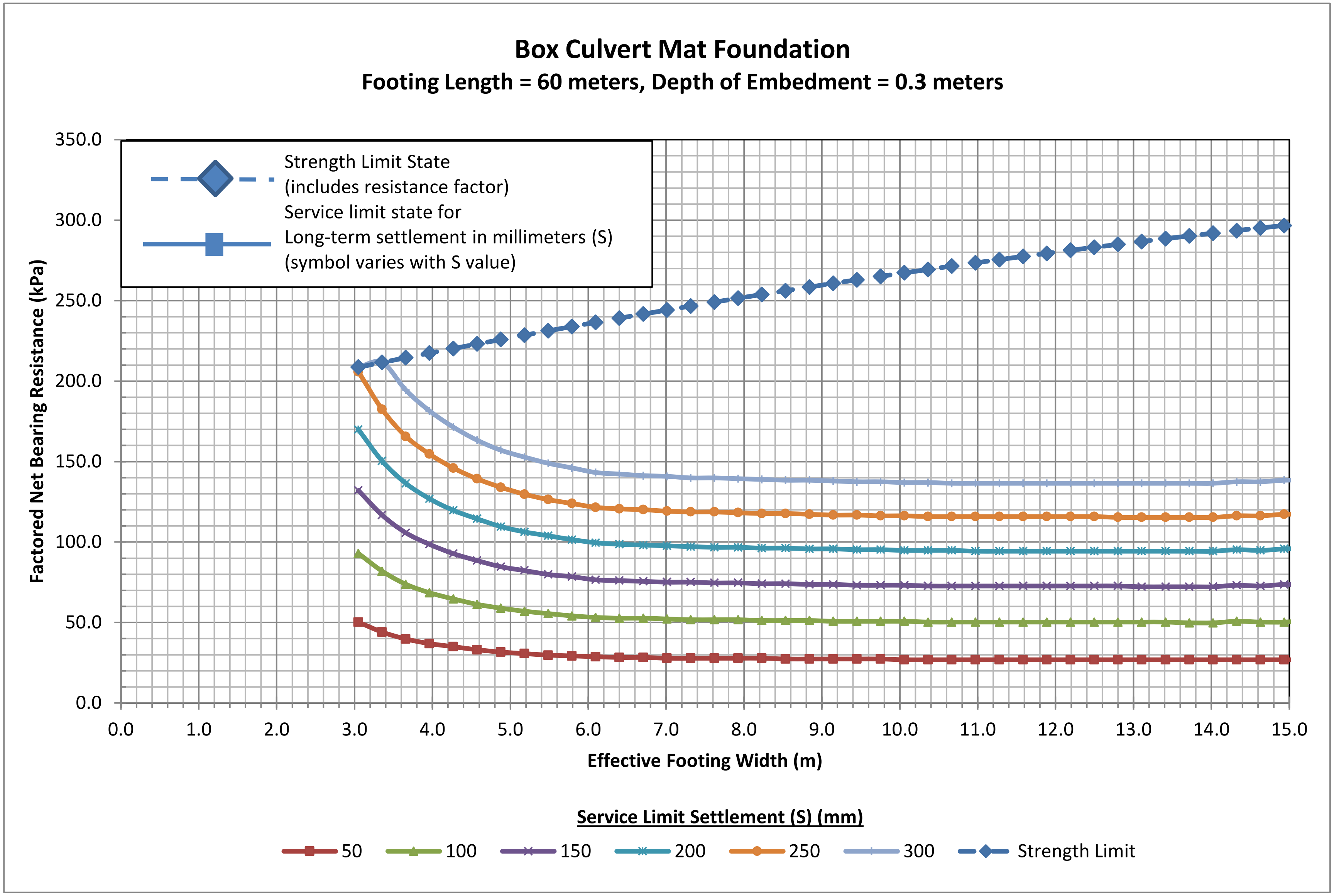

Figure 4.1: Mat Foundation Design Chart

The limited vertical net bearing resistance was determined for settlement values of 50, 100, 150, 200, 250, and 300 millimeters, and various box culvert mat foundation footing widths and is provided in the Mat Foundation Design Chart shown in Figure 4.1. The net bearing resistances for the various service limit states is identified by the “Long-term settlement in millimeters (S)” curves.

Due to the low soil modulus values overlaying the bedrock, settlements of up to 300 millimeters can be anticipated depending on the mat foundation loads. As mentioned in Section 3.2.3, the bedrock depth varies across the length of the planned box culvert alignment, and the shallowest rock depth is at the outlet of the planned box culvert. The bedrock drops off to the east or toward the inlet of the structure. The variable rock depth will lead to differential settlements of the embankment and should be considered when designing the drainage flow of the box culvert.

The liquid limit of the clays encountered at the wash bottom varied from medium to high plasticity. Based on the liquid limit, an estimated coefficient of consolidation and the drainage path length, primary consolidation (90 percent) of the clay could take two to three years to occur.

If the anticipated settlement determined from the Mat Foundation Design Chart shown in Figure 4.1, along with the potential differential settlement and duration, is not acceptable to the designer, Amec Foster Wheeler recommends that the BIA consider the arch structure supported on driven H-piles for the drainage crossing at BIA N8066(3). The arch structure foundations are addressed in Section 4.2.2 of this memorandum.

4.2.1.3 Modulus of Subgrade Reaction

Amec Foster Wheeler recommends mat foundations bearing on native soils be designed using a modulus of subgrade reaction (k) value of 18,000 kilo Newton per cubic meter.

4.2.1.4 General Design Criteria

The footings should be founded on a minimum of 150 millimeters of bedding material that is scarified and recompacted to at least 95 percent of maximum dry density (standard Proctor) as determined by the applicable AASHTO test methods. The bedding material should be in accordance with Federal Highway Administration (FHWA) FP-14 Standard Specifications for Construction of Roads and Bridges Section 704.02 (2014).

4.2.2 Driven H-Pile Foundations for Arch Bridge Structure

4.2.2.1 General

Recommendations are presented herein for driven H-piles bearing in predominantly fine-grained soils for support of the arch bridge structure. The recommended design criteria presented herein is based on the AASHTO LRFD procedures presented in Section 10.7 of AASHTO (2014) and FHWA Design and Construction of Driven Pile Foundations guidelines (2006).

Amec Foster Wheeler evaluated if negative skin friction loads, or downdrag, needed to be included for the piles at the bridge abutments. Based on a review of the available road profile design plans provided by the BIA on September 12, 2015, the bridge abutment foundations do not penetrate fill and will be founded in native soils. Since no fill is present, settlement of the soil around the pile is not anticipated to cause downdrag. Therefore, downdrag loads were not included. If the abutment locations, as drilled, or road profile alignment changes, Amec Foster Wheeler should be notified to review the revised drawings and modify our recommendations, as necessary.

Scour depths were considered in the design and are based on discussions and e-mail correspondence with Messrs. Corwyn Henry and Harold Riley at the BIA. Scour is not anticipated at the abutments for the BIA N8066(3) drainage crossing. However, if the location of the abutments, as drilled, changes, scour should be evaluated and scour protection of the abutments may be necessary.

Seasonal frost depth was considered in the design of the foundations. Amec Foster Wheeler calculated a frost depth for the design based on the Arizona Department of Transportation (ADOT) Freezing Index (1989). A frost depth of approximately 1 meter was calculated based on the bridge location. A conservative frost depth of 1.5 meters was used in the design. The upper 1.5 meters were not considered to contribute to the vertical resistance of the piles at the abutments.

The following sections provide design recommendations for the strength limit state. The service limit state could not be assessed due to limited information available on foundation loads and pile group configurations. The design charts for the strength limit state are presented in Figures 4.2 through 4.5.

Section 10.7.6 of AASHTO (2014) provides direction regarding minimum pile penetration. The minimum pile penetration needs to be determined to meet the following requirements:

1. Single and pile group settlement (service limit state)
2. Lateral loading and deflection (service limit state)
3. Uplift (strength limit state)
4. Downdrag (strength limit state)
5. Scour

Uplift, downdrag and scour were considered for the development of the strength limit design charts presented in Section 4.2.2.2 of the memorandum.

4.2.2.2 Strength Limit State

Resistance factors used in the determination of the vertical resistance for H-piles are a function of the design methodology. The H-pile capacities were calculated using the Nordlund/Thurman Method for side resistance and tip resistance in cohesionless soils (AASHTO 2014: Section 10.7.3.8.6f). The α-Method was used for side resistance calculations and the tip resistance method was used for tip resistance calculations in cohesive soils as presented in Section 10.7.3.8.6 (b and e) of AASHTO (2014). The corresponding nominal bearing resistance factor for the Nordlund/Thurman Method driven pile design, for side resistance and end bearing, is 0.45 and the nominal bearing resistance factor for the α-Method is 0.35, as presented in Table 10.5.5.2.3-1 of AASHTO (2014). The resistance factors used for the vertical resistance assume redundant foundations as defined in Section 10.5.5.2 of AASHTO (2014), see Section 4.2.2.5 of this memorandum for details. Calculation inputs and outputs for the vertical resistance design charts are provided in Attachment C.

The uplift resistance was determined based on AASHTO (2014) Section 10.7.3.10 for single piles. Uplift on single piles should be evaluated when tensile forces are present. The resistance factors for uplift are 0.35 for cohesionless soils using the Nordlund/Thurman Method and 0.25 for cohesive soils using the α-Method. Calculation inputs and outputs for the uplift resistance design charts are provided in Attachment C. Uplift resistance of a pile group will need to be verified per Section 10.7.3.11 of AASHTO (2014) once the pile configuration and embedment depth have been determined. The nominal uplift resistance should be taken as the lesser of the sum of the individual pile uplift resistance, or the uplift resistance of the pile group considered as a block.

The vertical resistance above elevation 2031.5 meters for the abutments, and 2026.5 meters for the pier, was neglected during the development of the design charts due to frost potential and/or scour within that zone.

The maximum factored pile strength, assuming the use of 345 MPa steel and a resistance factor of 0.50 (AASHTO Section 6.5.4.2), shall be less than 172.5 MPa.

The design chart for the arch structure abutments, presenting the nominal bearing resistance of various H-piles, is presented in the Arch Structure Foundation Design Chart - Abutments shown in Figure 4.2. The design chart for the arch pier, presenting the nominal bearing resistance of various H-piles, is presented in the Arch Structure Foundation Design Chart - Pier shown in Figure 4.3.

The nominal uplift resistance of various H-piles for the arch structure abutments, is presented in the foundation design chart shown in Figures 4.4. The design charts for the arch pier, presenting the nominal uplift resistance of various H-piles, is presented Figures 4.5.

4.2.2.3 Service Limit State

Service limit state for the bridge abutments was not assessed due to limiting information available on the foundation loads and configurations. The service limit state will need to be examined once more information is available. Service limit state settlement of driven piles is a function of the pile group size, pile embedment depth and corresponding soil strata, and the net foundation pressure applied.

Amec Foster Wheeler has provided a sample calculation for anticipated settlement of pile foundations, assuming foundation loading and number of piles. An estimated settlement of about 1 inch at the abutments was calculated for four HP12x53 H-piles, spaced at four diameters, and embedded at 40 feet below ground surface. The sample calculations are provided in Attachment D.

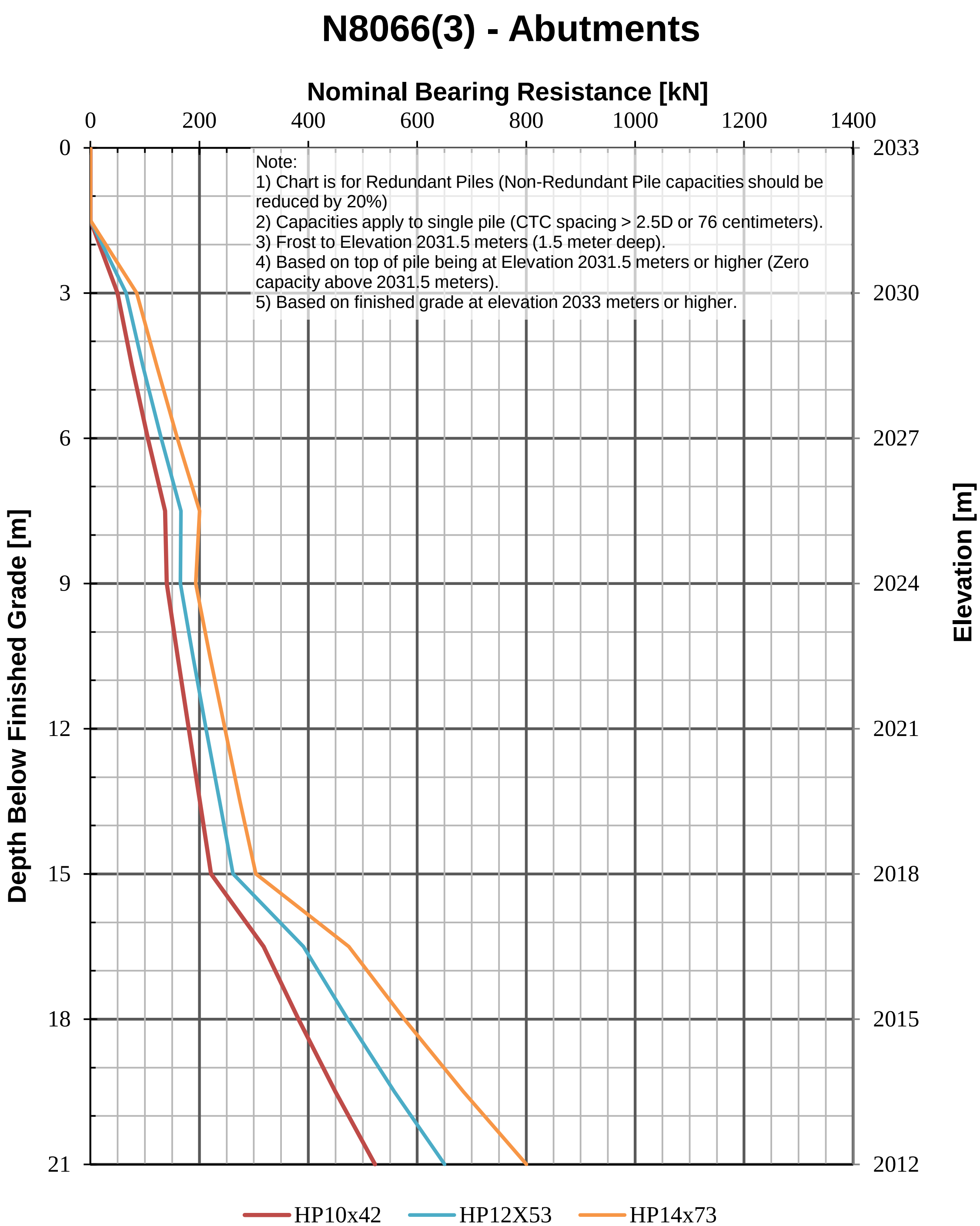

Figure 4.2: Arch Structure Foundation Design Chart for Bearing Resistance – Abutments

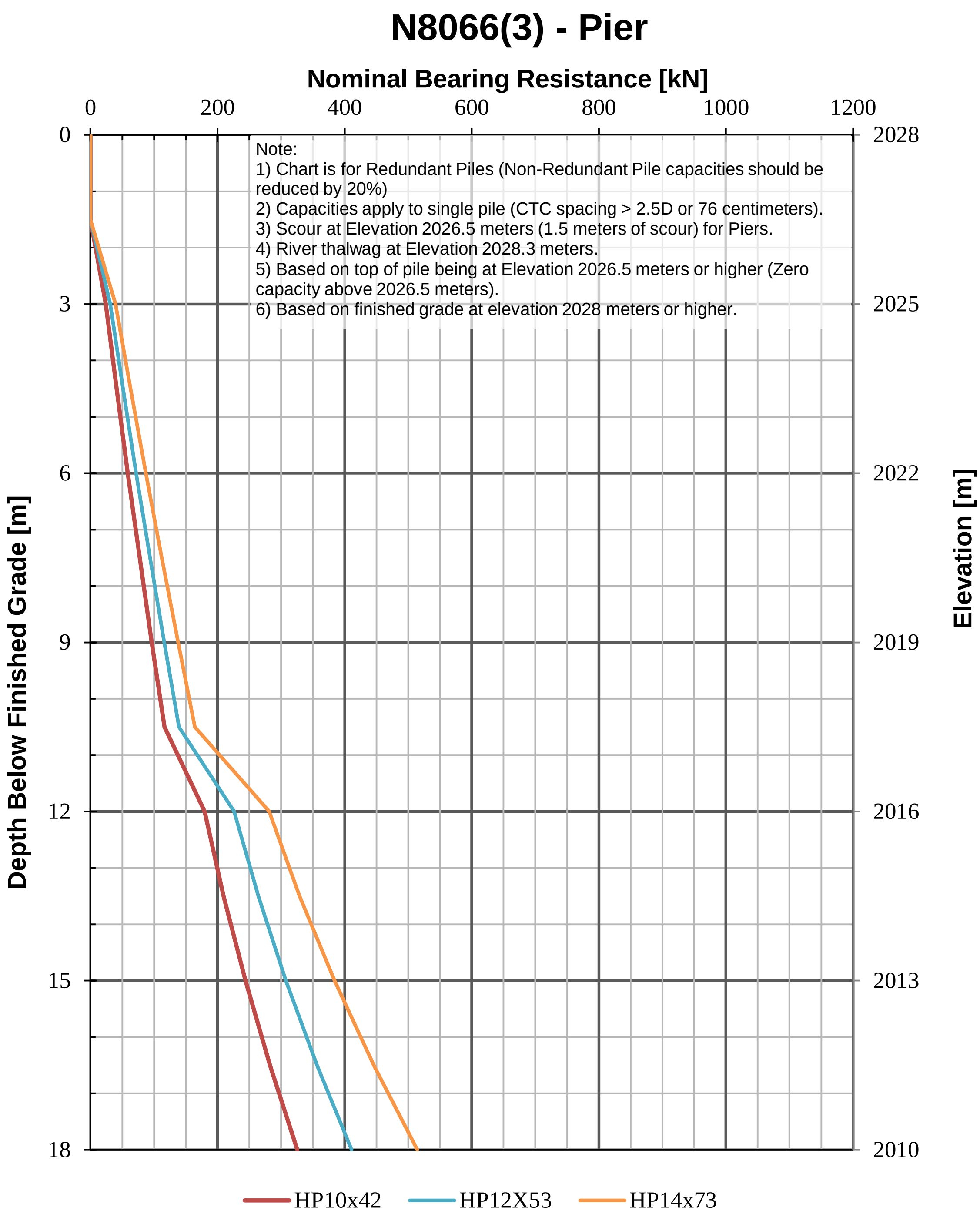

Figure 4.3: Arch Structure Foundation Design Chart for Bearing Resistance – Pier

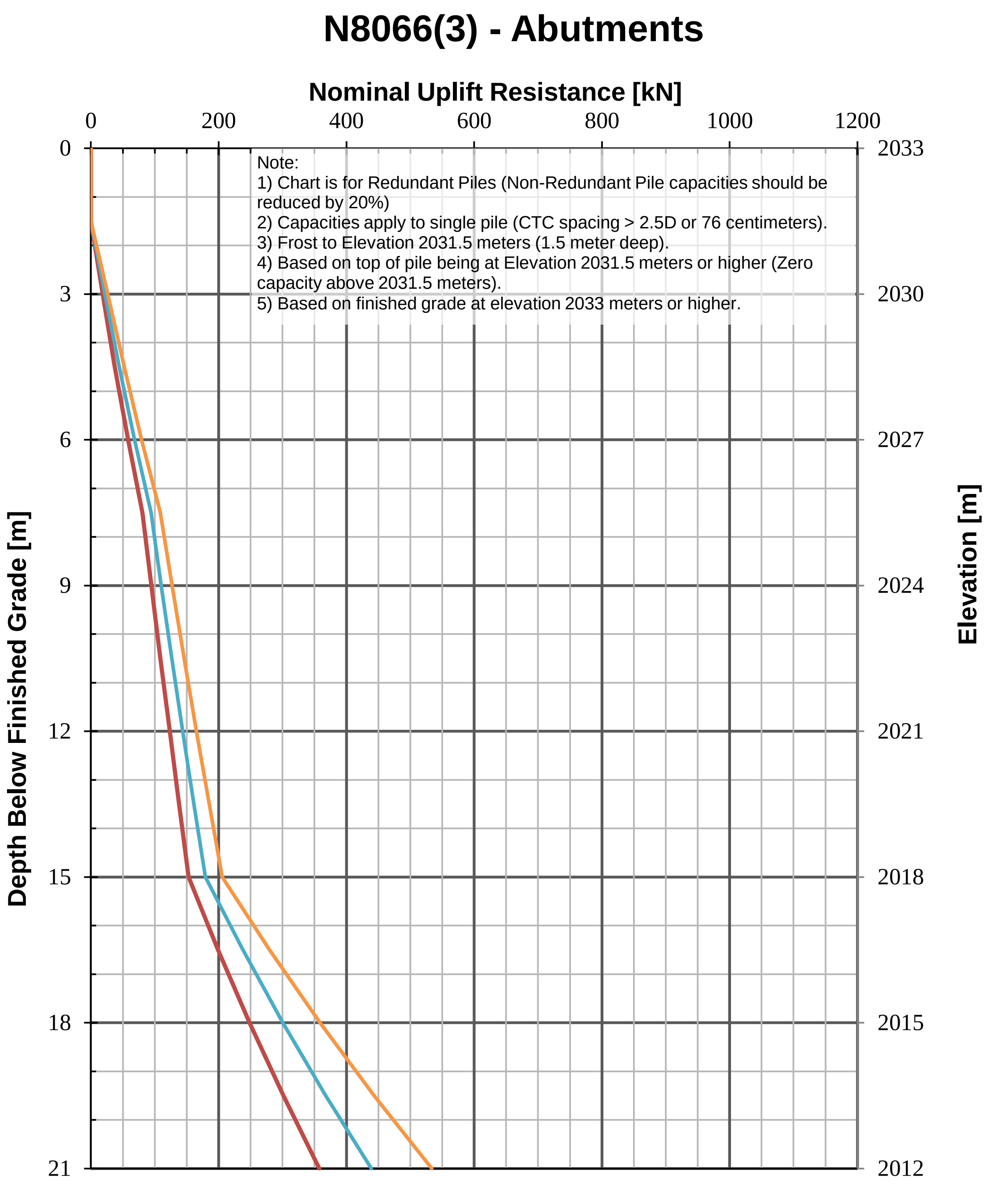

Figure 4.4: Arch Structure Foundation Design Chart for Uplift Resistance – Abutments

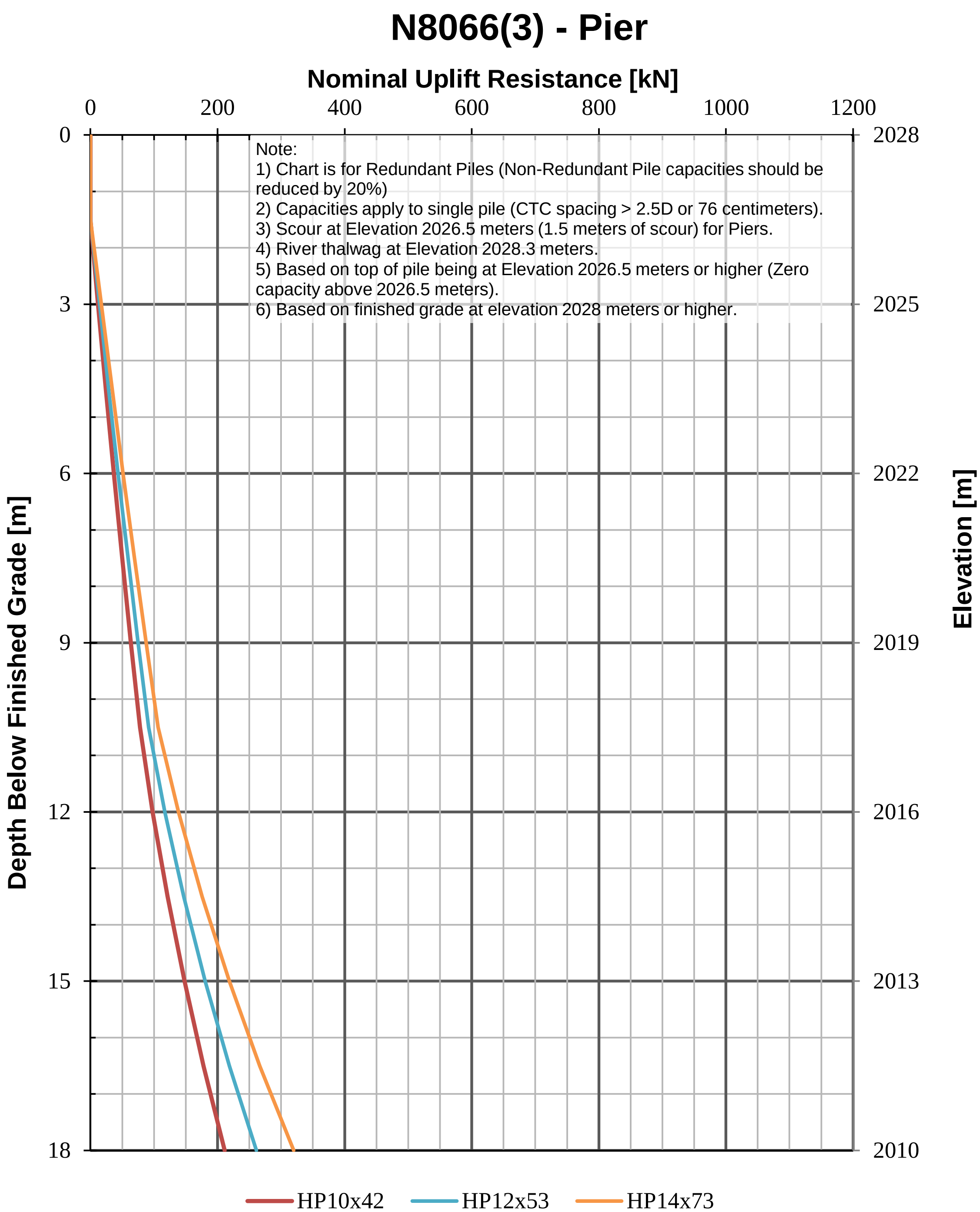

Figure 4.5: Arch Structure Foundation Design Chart for Uplift Resistance – Pier

4.2.2.4 Group Effects - Axial

Design criteria for reductions in axial resistance resulting from group effects are presented in Section 10.7.3.9 of the AASHTO (2014) manual. For pile groups in clay, if the cap is not in firm contact with the ground and if the soil at the surface is soft, the individual nominal resistance of each pile shall be multiplied by an efficiency factor η, taken as:

- η = 0.65 for a center-to-center spacing of 2.5 diameters,
- η = 1.0 for a center-to-center spacing of 6.0 diameters.

For intermediate spacings, the value of η should be determined by linear interpolation.

If the cap is in firm contact with the ground, the nominal resistance of each pile does not need to be reduced. Also, if the cap is not in firm contact with the ground and if the soil is stiff, the nominal resistance of each pile does not need to be reduced.

For pile groups in cohesionless soil, if the cap is or is not in contact with the ground, the efficiency factor, η, shall be 1.0 for a center-to-center pile spacing of 2.5 diameters or greater.

Based on the ground conditions encountered at the site, Amec Foster Wheeler recommend using an efficiency factor η for pile groups in clay where the soil at the surface is soft due to the seasonal moisture variation of the soils at the ground surface.

In addition, for pile groups in clay, the nominal bearing resistance should be the lesser of:

- The sum of the individual nominal resistances of each pile in the group, or
- The nominal resistance of an equivalent pier consisting of the piles and the block of soil within the area bounded by the piles.

For pile groups in cohesionless soil, the nominal bearing resistance should be the sum of the resistances of all the piles in the group.

4.2.2.5 Redundancy of Foundations

The resistance factors used for calculating the vertical capacity may need to be modified depending upon the number of piles used at each foundation element or the redundancy of the foundations. Section 10.5.5.2.3 of AASHTO (2014) states, “If the resistance factors provided in Table 10.5.5.2.3-1 are to be applied to small pile groups, the resistance factor values in the table [Table 10.5.5.2.3-1] should be reduced by 20 percent to reflect the reduced ability for overstressing of an individual foundation element to be carried by adjacent foundation elements. The minimum size of a pile group necessary to provide significant opportunity for load sharing ranges from 2 or 3 (Isenhower and Long, 1997) to 5 (Paikowsky, et al., 2004)”.

The BIA stated that a minimum of four piles will be used per foundation element, and thus the minimum group pile size requirement will be met. The strength limit state design charts, Figures 4.2 through 4.5, were prepared assuming redundancy in the foundations, and can be used without the 20 percent reduction.

4.2.2.6 Resistance to Lateral Load – Lateral Analysis

Lateral soil-structure interaction analyses of single piles are typically performed using the computer program LPILE (Ensoft 2012). This procedure estimates the lateral load-displacement behavior using a finite difference technique based on elastic beam column theory and soil reaction-displacement curves. Based on Reese and others (1984), the behavior of the soil surrounding the laterally loaded pile is described by lateral load-transfer functions referred to as p-y curves. The soil reaction (p) is related to the pile deflection (y) for various depths below the ground surface. In general, these curves are nonlinear and depend upon several parameters including depth, pile size and soil strength. Deflection, bending moment and shear profiles at specified intervals along the length of the pile can be computed.

An L-Pile analysis is recommended to evaluate the soil-structure interaction. Soil strength parameters for use in LPILE analyses are provided in Table 4.2.

Table 4.2: Soil Strength Parameters for LPILE Analyses – BIA N8066(3)

Elevation (meters)	Average Moist Unit Weight[1] (kg/m^3)	Friction Angle (degrees)	Undrained Shear Strength (kPa)	Soil Strain Ratio ε_{50}	Horizontal Subgrade Modulus K (kN/m^3)	Recommended Soil Type in LPILE
Abutments 1 & 2						
Above 2031.5	-----	-----	-----	-----	-----	-----
2031.5 – 2025.5	1,760	-----	120	0.005	-----	Stiff Clay without free water
2025.5 – 2018	1,920	-----	38	0.010	-----	Soft Clay
2018 – 2012	2,000	32	0	-----	13,570	Sand
Below 2012	2,080	35	0	-----	21,715	Sand
Pier						
Above 2026.5 (or scour depth)	-----	-----	-----	-----	-----	-----
2026.5 – 2019.5	1,920	-----	38	0.010	-----	Soft Clay
2019.5 – 2010.5	2,000	32	0	-----	13,570	Sand
Below 2010.5	2,080	35	0	-----	21,715	Sand

Notes:

[1] Soil buoyant unit weight should be used in LPILE below the groundwater elevation. Groundwater elevation was at approximately elevation 2024 meters for the abutments and 2028 meters for the pier, at the time of the geotechnical investigation. Buoyant unit weight is obtained by subtracting 1000 kilograms per cubic meter from the moist unit weight in the above table.

kg/m^3 kilogram per cubic meter, kPa = kilopascal, kN/m^3 kilonewton per cubic meter.

Where embankments, in front of piles, slope downward away from the abutment, the lateral soil resistance against piles should be reduced. It is conservatively recommended that lateral soil pressures (for loading normal to the column line) be neglected within the zone above the catch point (on the slope) of a horizontal line projected outward a distance of three pile diameters or

1.5 meters, whichever is greater (for example, a horizontal distance of 1.5 meters to the catch point on the slope for a 0.5-meter-diameter pile) from the front of the pile.

4.2.2.7 Group Effects – Lateral

The design of laterally loaded piles must account for the influence from adjacent piles in a group. Section 10.7.2.4 (AASHTO 2014) defines a group with respect to lateral loading as piles spaced less than five diameters center-to-center in the direction parallel and normal to the applied load. When the piles are in a group, the lateral resistance of the soil is reduced to account for the influence of adjacent piles by multiplying the values of p, of the p-y curves, by P-multiplier values (P_m). The values of P_m vary as a function of the center-to-center spacing of the piles within the group. The loading direction and spacing are shown in Figure 10.7.2.4-1 in AASHTO (2014). Recommendations for P_m values are also shown in Table 10.7.2.4-1 in AASHTO (2014).

The center-to-center pile spacing should not be less than 76 centimeters or 2.5 pile diameters. The distance from the side of any pile to the nearest edge of the pile cap should not be less than 23 centimeters.

4.2.2.8 Overall Stability

The overall stability of the abutments will need to be examined once more information is available on the foundation loading and pile configuration. To determine the slope stability of the slope, a friction angle of 14 degrees with a cohesion intercept of 36 kPa and a unit weight of 1920 kcm should be used for the clay soil (Layer A) strength. For the silty sand soil (Layer B) strength, a friction angle of 32 degrees, zero cohesion, and a unit weight of 2000 kcm. Layer A extends form the surface to a depth of about 16 meters bgs at the wash banks and layer B extends from a depth of about 16 meters to 22 meters bgs at the wash banks (Section 3.2 of this memorandum).

4.3 Construction Considerations

4.3.1 Temporary Excavations for Spread-Type Footings or Mat Foundations

Temporary excavations above the groundwater table should conform to Occupational Safety and Health Administration (OSHA) regulations. Within this system, the classification of the on-site soils is Type B. It is recommended that unsupported temporary cut slopes, less than 20 feet in height, in these soils be made no steeper than 1H:1V. Excavations below the groundwater table should conform to the site conditions during construction. The slopes may need to be flatter than a 1H:1V. The Contractor should analyze the stability to the slopes prior to construction. A temporary bracing system and dewatering of the trench may be necessary. A temporary excavation support systems should be designed by a geotechnical engineer. Due to soft ground conditions (low blow count values and groundwater), the contractor may need to use a working platform during construction.

Spoil piles should be located no closer than 2 meters from the crest of the slopes. Large particles, including large clods, should be kept away from the crest of the slopes. Moisture increases in the soils will weaken them and could cause slope failures. Some localized raveling could occur as the exposed soils dry. The excavations should be protected from stormwater runoff or other sources of moisture. Small berms may be necessary to protect the excavations from storm runoff. If the soils are subjected to moisture increases, the stability of the slopes should be reevaluated.

4.3.2 Excavations Adjacent to Spread-Type Footings or Mat Foundations

Excavations adjacent to spread footings or mat foundations should not be permitted within the area of influence of the footings. The influence area is defined as the footing width (B) with 1H:1V (horizontal to vertical) side slopes continuing to depth. If excavations in the native soils, extending into the area of influence, are performed prior to construction of the spread-type footings or mat foundations, the excavations should be backfilled with structural backfill. If excavations in the bedrock, extending into the area of influence, are performed prior to construction of the footings, the excavations should be backfilled with a controlled low-strength material (CLSM) (i.e., one-sack slurry).

4.3.3 Pile Load Testing

A test pile program at the site is strongly recommended for this project prior to construction. The purpose of the test pile program is to gather information regarding hammer/pile/soil interaction, develop driving criteria, verify the contractor’s equipment and installation procedures, determine the uplift resistance and verify the pile capacities estimated from the static analysis.

If possible, the test pile program should be performed during the design phase to confirm and verify the recommendations contained in this report, and properly evaluate the pile driving characteristics of the subsurface profile. A design stage test pile program would yield a more sophisticated design that would allow for a more cost efficient foundation design. Otherwise, consideration should be given to limit the number of piles ordered before the pile testing program is performed.

Adjustments, based upon the dynamic testing results, may need to be made to the pile capacities estimated from the static analysis in this report.

4.4 Box Culvert Design Considerations

4.4.1 Sliding

Sliding resistance can consist of two components: sliding resistance between soil and foundation and passive resistance of the soil. The resistance factor for sliding depends on the resistance component, the soil type and construction method. Resistance factors are shown in Table 4.4 and should be used in conjunction with Equation 10.6.3.4-1 (AASHTO 2014) to calculate the factored nominal sliding resistance.

Table 4.4: Resistance Factors for Sliding of Shallow Foundations at the Strength Limit State (After Table 10.5.5.2.2-1 of AASHTO 2014)

	Method/Soil/Condition	Resistance Factor
ϕ_τ	Precast concrete placed on sand	0.90
	Cast-in-place concrete on sand	0.80
	Cast-in-place concrete or precast concrete on clay	0.85
	Soil on soil	0.90
ϕ_{ep}	Passive earth pressure component of sliding resistance	0.50

The nominal sliding resistance between soil and foundation should be calculated using Equation 10.6.3.4-2 (AASHTO 2014). An internal friction angle of the soil (ϕ_f) of 14 degrees is recommended for determining the sliding resistance between the soil and the foundation.

The nominal passive resistance of soil can be included below a depth of 1.5 meters from the finished grade. The passive resistance against the edges of footings, stem walls and other vertical foundation elements, in contact with properly compacted structure backfill or native site soils, should be considered as being equal to the force exerted by a fluid pressure of 14.4 kPa, per foot of depth. For sloping ground conditions, the above passive value should be applied only to the portions of the footing that are a minimum horizontal distance of 3 meters from the edge of the slope.

4.4.2 Limiting Eccentricity

The maximum allowable eccentricity, e, of loading at the strength limit state for spread footings should be calculated. AASHTO Section 10.6.3.3 Eccentric Load Limitations does not account for a backslope inclination angle of soil retained behind a wall; hence, Amec Foster Wheeler recommends calculating the e in accordance with Arizona Department of Transportation's (ADOT) Geotechnical Design Policy SF-2 (ADOT 2010). The formulas are presented below:

- $e \leq B[(1/3) – (\beta/320)]$ for footings on soils
- $e \leq B[(3/7) – (\beta/500)]$ for footings on rock

Where:

B = This represents the footing dimension (width of length) for which eccentricity is being calculated.
β = The backslope inclination angle for the soil retained behind the wall in degrees with respect to horizontal. The maximum limit on β is 26.6 degrees.

The formula for soils should be used for footings on this project.

4.4.3 Overall Stability

The overall stability of the embankment will need to be examined once more information is available. The current source of borrow is unknown and therefore shear strength parameters cannot be provided. Prior to construction, the roadway designer will need to evaluate the soil shear strength characteristics and provided stability analysis results for the proposed embankment geometry.

4.5 Corrosion and Degradation Potential – Steel Pipes

Corrosion potential was not evaluated at the N8066(3) box culvert structure. However, if the arch bridge structure supported on H-piles is considered, the test results from the N8065(1) bridge structure can be used to assess the soil due to the similarity in soil properties. Three soil samples at the N8065(1) bridge borings BS-2, BS-4 and BS-5, located within the planned pile locations, were tested to evaluate the corrosion potential on steel H-piles. The corrosion potential for the site was characterized using laboratory pH and electrical resistivity testing, performed in accordance with Arizona Test Method 236.

The laboratory resistivity values ranged from 212 to 1,468 ohm-centimeters (ohm-cm), and the pH values ranged from 8.3 to 8.4. Section 10.7.5 of AASHTO (2014) states that pile corrosion and/or deterioration is likely under the following site conditions:

1. Resistivity less than 2,000 ohm-cm
2. pH less than 5.5
3. pH between 5.5 and 8.5 in soils with high organic content

The site soils meet the first condition, which warrants the use of pile coatings or other protective methods. Protective coatings should be abrasion resistant. Piles can also be protected by low permeability concrete encasement, or made of special steel alloys of increased corrosion resistance.

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TABLES

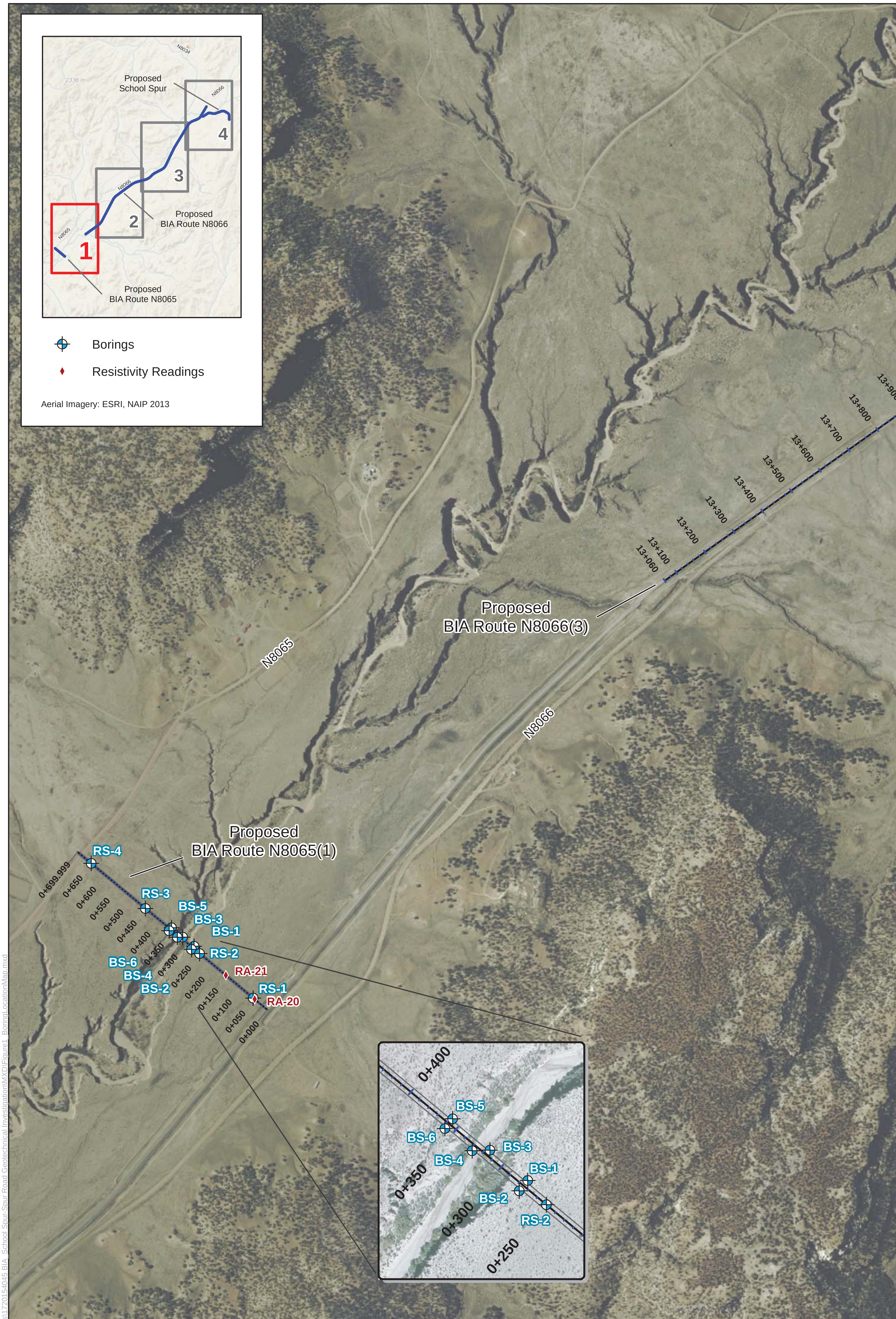
TABLE 1
Boring Locations - BIA N8066(3)

Boring Number	Station Reference	Location	Elevation (m)	Direction[1]	Offset (m)	Boring Type[2]	Structure	Targeted Boring Depth (m)	Actual Boring Depth (m)	
									Auger	Coring
B-1	Proposed BIA Route N8066 CL	22+480	2033.0	CL	-	ATV	Arch	30	29.7	0
B-2	Proposed BIA Route N8066 CL	22+418	2032.7	CL	-	ATV	Arch	30	21	6
B-3	Proposed BIA Route N8066 CL	22+435	2028.3	CL	-	ATV	Culvert/Arch	30	27.6	2.4
B-4	Proposed BIA Route N8066 CL	22+422	2028.3	L	8.4	ATV	Culvert	30	8.85	6
B-5	Proposed BIA Route N8066 CL	22+455	2030.0	R	13	ATV	Culvert	30	18	6.4

[1] CL - Centerline, R - Right, L - Left

[2] ATV - Specialized ATV Mounted Drill Rig with 210mm Hollow Stem Auger

FIGURES



0 150 300 600 Meters

Job No.:	1720154045
PM:	NC
Date:	4/14/2016
Scale:	1 cm = 100 meters

N

BIA Project N8066(3), N8065(1), and School Spur
Black Mesa Community School
Arizona

Boring and Resistivity Location Map

FIGURE
1

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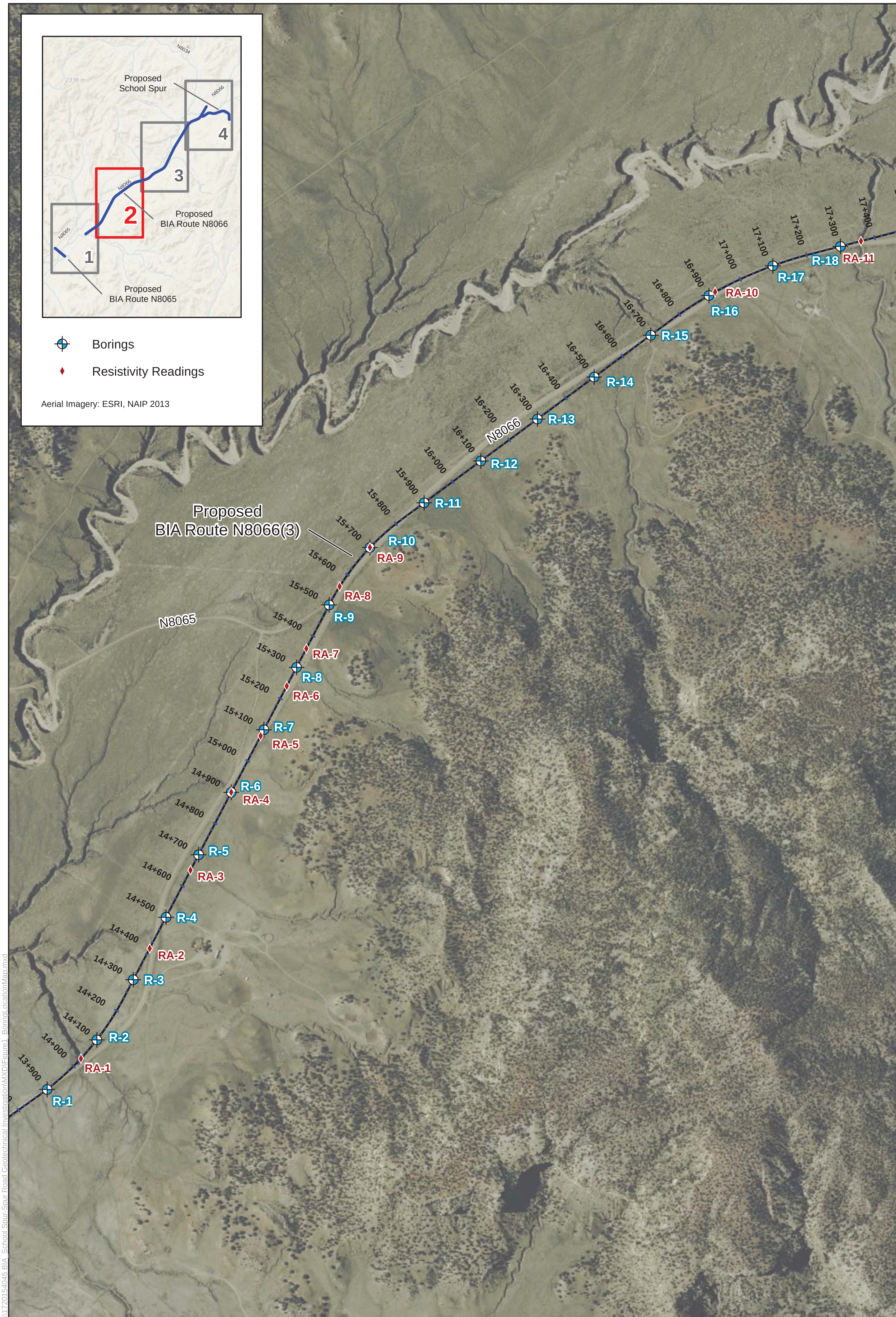

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Date:	2/11/2016
Scale:	1 cm = 100 meters

N

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BIA Project N8066(3), N8065(1), and School Spur
Black Mesa Community School
Arizona

Boring and Resistivity Location Map

FIGURE
2

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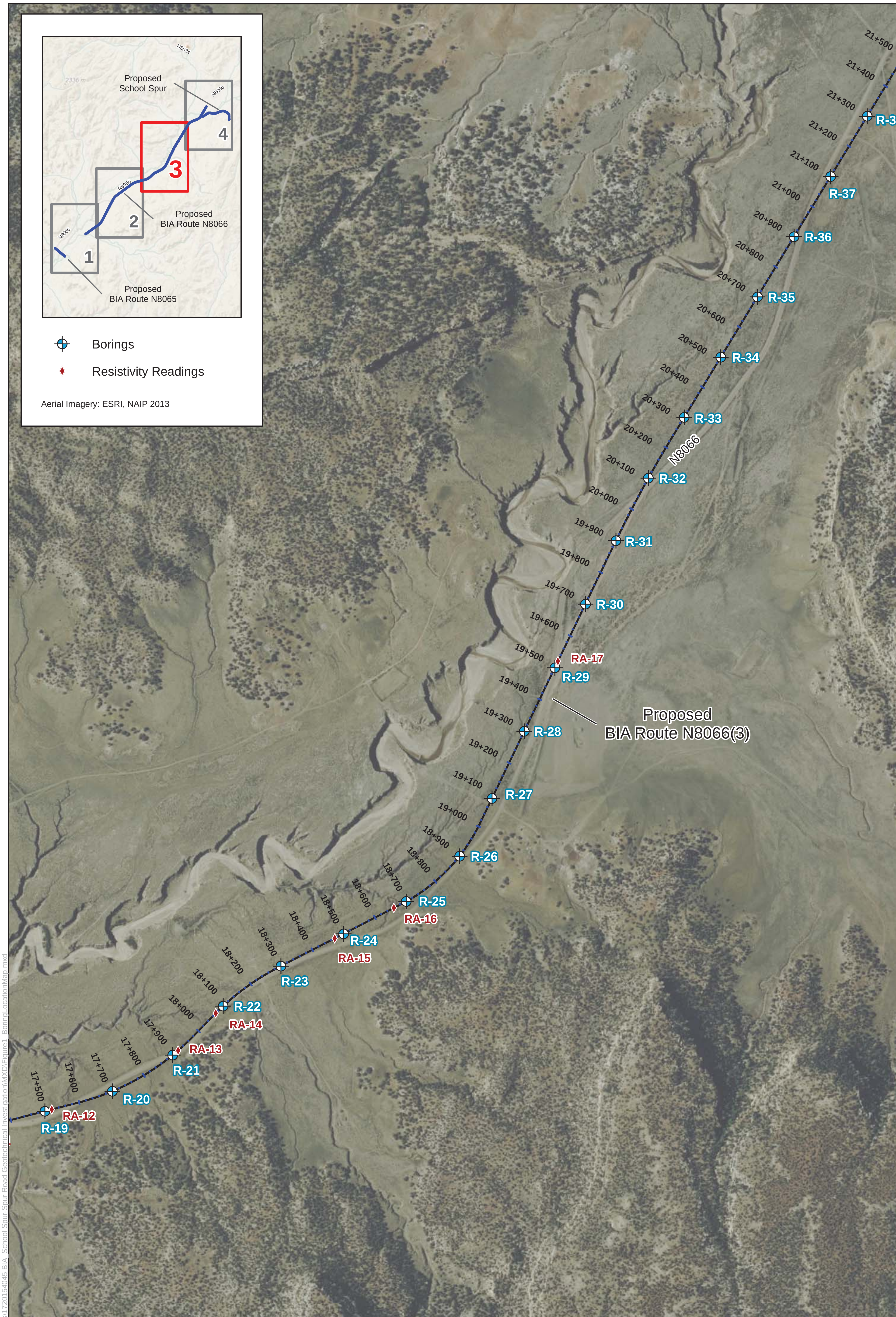

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BIA Project N8066(3), N8065(1), and School Spur
Black Mesa Community School
Arizona

Boring and Resistivity Location Map

FIGURE
3

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BIA Project N8066(3), N8065(1), and School Spur
Black Mesa Community School
Arizona

Boring and Resistivity Location Map

FIGURE 4

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Date:	4/14/2016
Scale:	1 cm = 100 meters

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FIGURE 5
Summary of Direct Shear Test Results

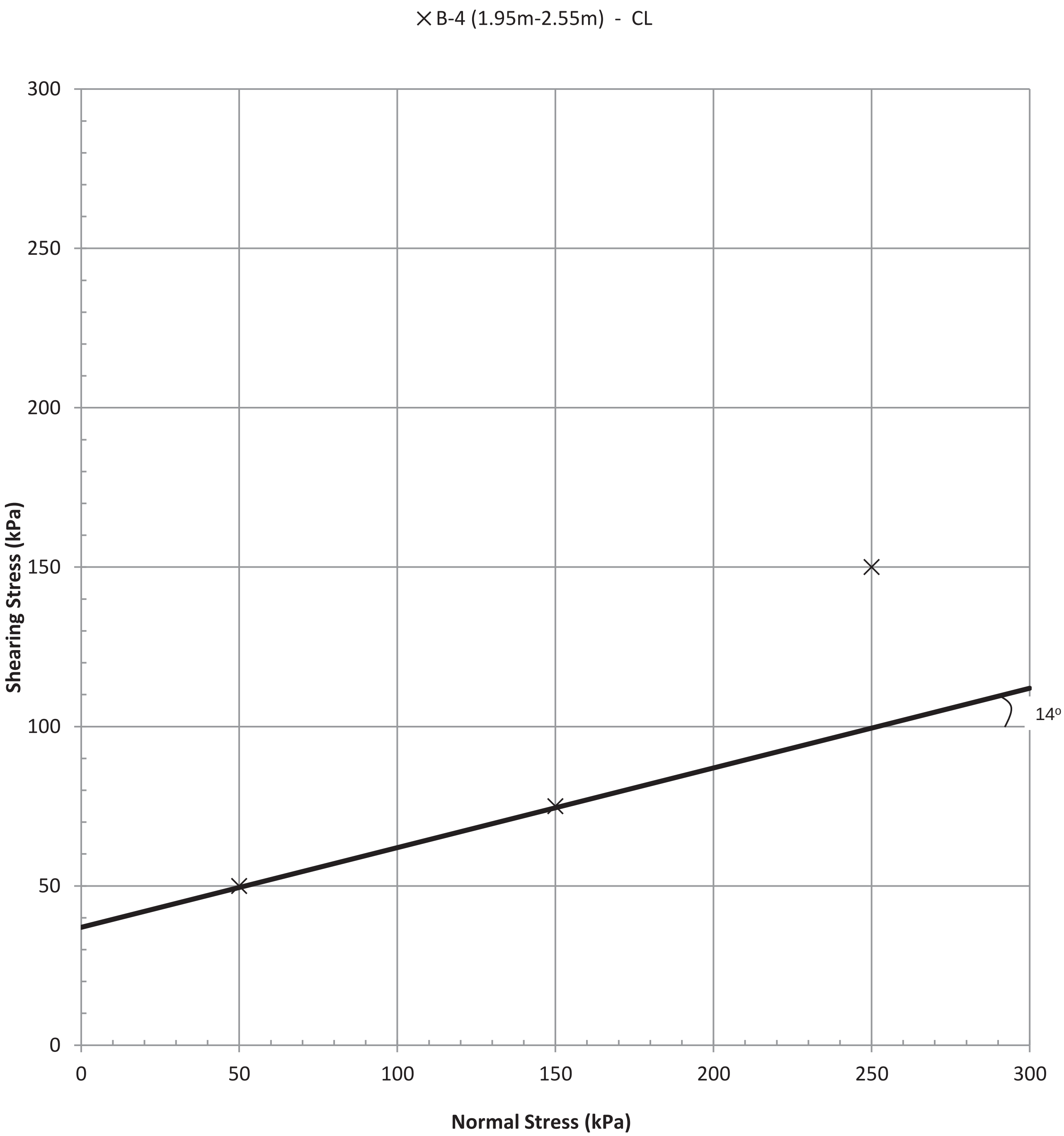


FIGURE 6
Summary of UU Test Results
CH Soils

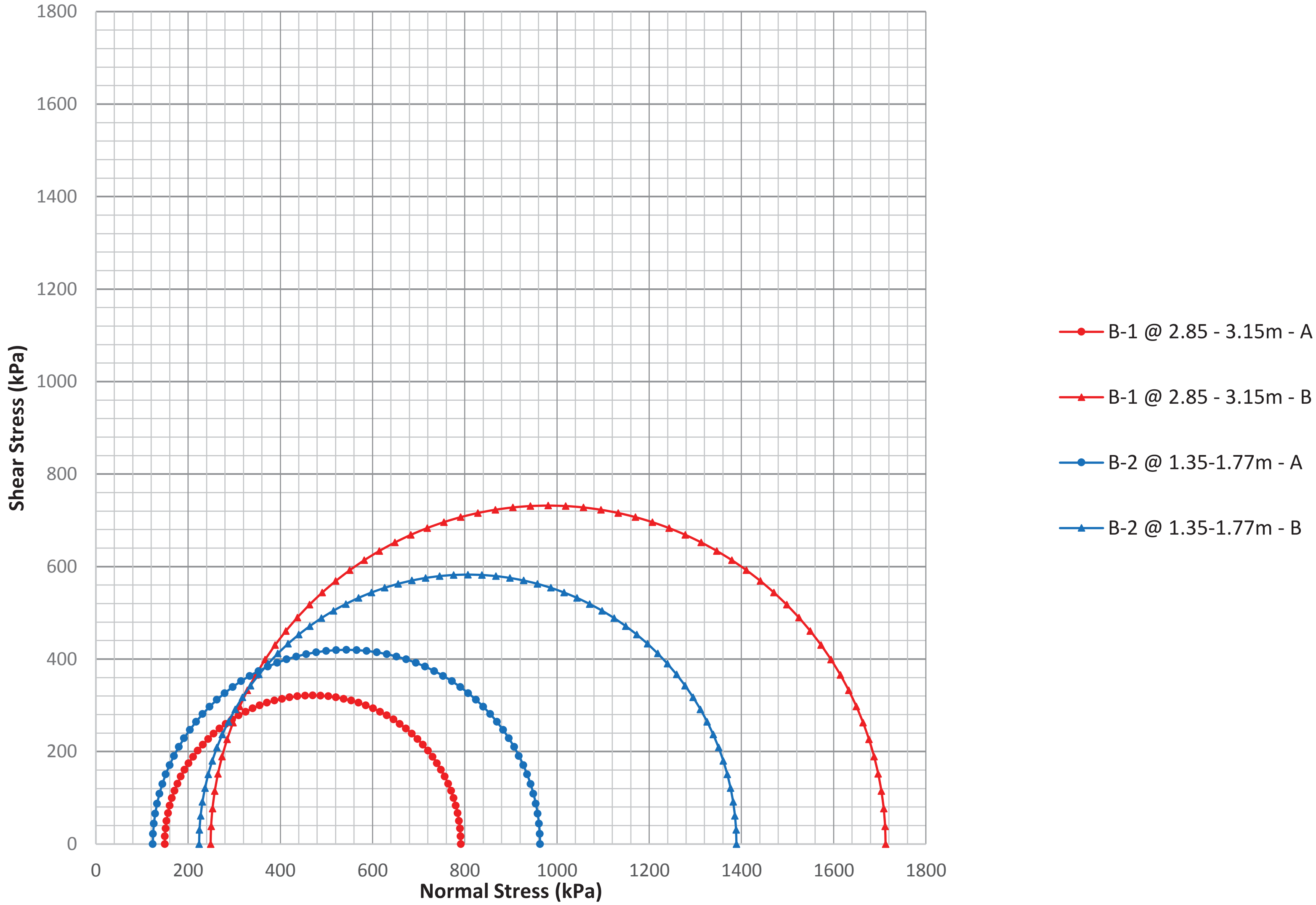


Figure 7
Subsurface Profile for N8066(3) Arch Bridge Structure

Legend

SP-SM	CH
SM	Sandstone
SC	Siltstone
CL	Groundwater Table Elevation

Boring ID	B-1		B-3		B-2	
Elevation (m[1])	2033.4		2028.3		2033	
	USCS[2]	N	USCS	N	USCS	N
2033	CH/CL	15			CH/CL	14
2031.5	CH/CL	31			CH/CL	34
2030	CH/CL	23			CH/CL	30
2028.5	CL	18	SM/SC	33	CH	21
2027	CL	17	CH	5	CH	15
2025.5	CH	30	CH	8	CH	9
2024	CH	30	CH	10	CL	8
2022.5	CH	6	CL	5	CL	6
2021	CH	13	CL	8	CL	5
2019.5	CH	10	SC	3	SC	0
2018	CH	8	SM	5	SC	4
2016.5	SM	6	SM	2	SM	2
2015	SM	6	SM/SP	5	SM	3
2013.5	SM	4	SM/SP	3	Sandstone	46
2012	SM	3	SM/SP	11	Sandstone	100
2010.5	Sandstone	45	CH	77	Siltstone/Mudstone	100
2009	Sandstone	100	Sandstone/Siltstone	100	Siltstone/Mudstone	100
2007.5	Sandstone	100	Sandstone/Siltstone	100	Siltstone/Mudstone	100
2006	Sandstone	100	Sandstone/Siltstone	100	Siltstone/Mudstone	100
2004.5	Sandstone	100	Sandstone/Siltstone	100		
2003	Sandstone	100	Sandstone/Siltstone	100		
2001.5			Sandstone/Siltstone	100		
2000			Sandstone/Siltstone	100		
1998.5			Sandstone/Siltstone	100		

[1]m = meters
[2]USCS = Unified Soil Classification System

Figure 8
Subsurface Profile for N8066(3) Box Culvert Structure

Legend

SP-SM	CH
SM	Sandstone
SC	Siltstone
CL	Groundwater Table Elevation

Boring ID	B-4		B-3		B-5	
Elevation (m[1])	2028.3		2028.3		2029	
	USCS[2]	N	USCS	N	USCS	N
2033						
2031.5						
2030					SM	3
2028.5	SM/SP	44	SM/SC	33	CH	5
2027	SM/GM	6	CH	5	CH	5
2025.5	CL	28	CH	8	CH	9
2024	Sandstone/Siltstone	100	CH	10	CH	8
2022.5	Sandstone/Siltstone	100	CL	5	CH	9
2021	Sandstone/Siltstone	100	CL	8	CH	4
2019.5	Sandstone/Siltstone	100	SC	3	CH	8
2018	Sandstone	100	SM	5	SM	4
2016.5	Sandstone	100	SM	2	SM	6
2015	Sandstone	100	SM/SP	5	SM	5
2013.5	Sandstone	100	SM/SP	3	SP-SM	25
2012			SM/SP	11	Sandstone/Siltstone	22
2010.5			CH	77	Sandstone/Siltstone	100
2009			Sandstone/Siltstone	100	Sandstone/Siltstone	100
2007.5			Sandstone/Siltstone	100	Sandstone/Siltstone	100
2006			Sandstone/Siltstone	100	Sandstone/Siltstone	100
2004.5			Sandstone/Siltstone	100		
2003			Sandstone/Siltstone	100		
2001.5			Sandstone/Siltstone	100		
2000			Sandstone/Siltstone	100		
1998.5			Sandstone/Siltstone	100		

[1]m = meters
[2]USCS = Unified Soil Classification System

ATTACHMENT A

FIELD INVESTIGATION

TEST DRILLING EQUIPMENT AND PROCEDURES

Description of Subsurface Exploration Methods

Auger Boring Drilling through overburden soils is performed with 6 5/8-inch O.D., 3 1/4-inch I.D. hollow stem auger or 4 1/2-inch solid stem continuous flight auger. Carbide insert teeth are normally used on bits so they can penetrate soft rock or very strongly cemented soils. A CME-75 truck-mounted drill rig is used to advance the auger. The drill rigs are powered with six-cylinder Cummins diesel engines capable of delivering about 11.4 kN-m torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 90 kN (20,000 pounds) downward force.

Generally, refusal to penetration of the auger is adopted as top of the SGC or "river-run" material or harder bedrock, which require other techniques for penetration. Grab samples or auger cuttings may be taken as necessary. Standard penetration tests or 2.42-inch diameter ring samples are taken in conjunction with the auger borings as needed, with the sampling interval and type being indicated on the boring logs.

Hammer Drill Drilling with the Hammer drill is accomplished with a Drill Systems AP-1000 drill rig advancing a double-walled drive casing with a link-belt 180 diesel pile driving hammer, having a rated energy of 8,100 foot-pounds per blow. Where noted on the boring log, the hammer is equipped with a supercharger which can boost the energy to approximately 12,000 foot-pounds per blow. The supercharger is used only in portions of the boring where blow counts are relatively high. Cuttings are removed with compressed air by a reverse circulation process, and are collected in a cyclone from which grab samples are obtained. The drive casing is either 9-inch O.D. by 6-inch I.D. or 6 5/8-inch O.D. by 4-inch I.D. and employs an expendable bit of slightly larger diameter than the O.D. of the casing. Hammer blows required to advance the drive casing are recorded in 1-foot increments, as noted on the boring logs. Standard penetration tests or 2.42-inch diameter ring samples taken are noted on the boring logs.

Core Boring Rock core samples are retrieved using a CME-75 drill rig, SAITECH GH 3 rig or Burley 2500, 4500 or 4000. The GH 3 is a portable hydraulic core drill. The GH 3 is powered by a Kohler two-cylinder 25-horsepower engine. The hydraulics motor which feeds a two-speed transmission and powers the BW spindle. This unit has a 3-foot stroke and is hand-fed with a 2,000 pound push-pull capability. The GH 3 has the capability of drilling with either B- or N-size core steel using standard or wireline systems. N-size core is the preferred size and it has a nominal O.D. of about 2 inches. The Burley 2500 and 4500 series are portable hydraulic core drills. The 4500 series is capable of a track-mounted or skid-type chassis. The Burley 2500 and 4500 series are powered by 44 and 75 HP power units, respectively, provide up to 2,000 foot-pounds (ft.-lbs.) of torque and in excess of 1,000 revolutions per minute (RPM) of spindle speed. Both rigs are capable of retrieving either N- or H-sized core using wireline systems. The N-size core has a nominal O.D. of about 2 inches and the H-size of about 2.4 inches. The Burley 4000 is a track-mounted core drill.

The CME-75 utilizes a wireline core drilling system that takes N-size cores. Using the NQ wireline system, core is recovered quickly by retrieving the core-laden inner tube through the drill string.

TEST DRILLING EQUIPMENT AND PROCEDURES (Cont.)

Sampling Procedures Dynamically driven tube samples are usually obtained at selected intervals in the borings by the ASTM D1586 test procedure. In many cases, 2-inch O.D., 1 3/8-inch I.D. samples are used to obtain the standard penetration resistance. “Undisturbed” samples of firmer soils are often obtained with 3-inch O.D. samples lined with 2.42-inch I.D. brass rings. The driving energy is generally recorded as the number of blows of a 140-pound, 30-inch free fall drop hammer required to advance the samples in 6-inch increments. However, in stratified soils, driving resistance is sometimes recorded in 2- or 3-inch increments so that soil changes and the presence of scattered gravel or cemented layers can be readily detected and the realistic penetration values obtained for consideration in design. These values are expressed in blows per 6 inches on the boring logs. "Undisturbed" sampling of softer soils is sometimes performed with thin walled Shelby tubes (ASTM D1587), pitcher samplers, Denison samplers or continuous CME samplers. Where samples of rock are required, they are obtained by NQ diamond core drilling (ASTM D2113). Tube samples are labeled and placed in watertight containers to maintain field moisture contents for testing. When necessary for testing, larger bulk samples are taken from auger cuttings. Also, representative samples are obtained from the cuttings from the hammer and Schramm drill rig.

Boring Records Drilling operations are directed by our field engineer or geologist who examines soil recovery and prepares the boring logs. Soils are visually classified in accordance with the Unified Soil Classification System (ASTM D2487), with appropriate group symbols being shown on the boring logs.

TERMINOLOGY USED TO DESCRIBE THE RELATIVE DENSITY, CONSISTENCY OR FIRMNESS OF SOILS

The terminology used on the boring logs to describe the relative density, consistency or firmness of soils relative to the standard penetration resistance is presented below. The standard penetration resistance (N) in blows per foot is obtained by the ASTM D1586 procedure using 2" O.D., 1 3/8" I.D. samplers.

1. **Relative Density.** Terms for description of relative density of cohesionless, uncemented sands and sand-gravel mixtures.

N	Relative Density
0-4	Very loose
5-10	Loose
11-30	Medium dense
31-50	Dense
50+	Very dense

2. **Relative Consistency.** Terms for description of clays which are saturated or near saturation.

N	Relative Consistency	Remarks
0-2	Very soft	Easily penetrated several inches with fist.
3-4	Soft	Easily penetrated several inches with thumb.
5-8	Medium stiff	Can be penetrated several inches with thumb with moderate effort.
9-15	Stiff	Readily indented with thumb, but penetrated only with great effort.
16-30	Very stiff	Readily indented with thumbnail.
30+	Hard	Indented only with difficulty by thumbnail.

3. **Relative Firmness.** Terms for description of partially saturated and/or cemented soils which commonly occur in the Southwest including clays, cemented granular materials, silts and silty and clayey granular soils.

N	Relative Firmness
0-4	Very soft
5-8	Soft
9-15	Moderately firm
16-30	Firm
31-50	Very firm
50+	Hard

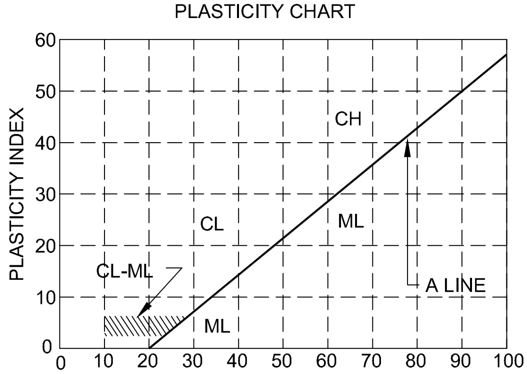
UNIFIED CLASSIFICATION SYSTEM FOR SOILS

Soils are visually classified by the United Soil Classification System on the boring logs presented in this report. Grain-size analysis and Atterberg Limits Tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see " The Unified Soil Classification System " ASTM Designation: D2487

MAJOR DIVISION				GRAPH SYMBOL	GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	**GRAVELS** (50% or less of coarse fraction passes No. 4 sieve)	**CLEAN GRAVELS** (Less than 5% passes No. 200 sieve)			GW	Well graded gravels, gravel-sized mixtures or sand-gravel-cobble mixture.
					GP	Poorly graded gravels, gravel-sized mixtures or sand-gravel-cobble mixture.
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		GM	Silty gravels, gravel-sand-silt mixture.
			Limits plot below "A" line & hatched zone on plasticity chart		GC	Clayey gravels, gravel-sand-clay mixture.
	SANDS (More than 50% of coarse fraction passes No. 4 sieve)	**CLEAN SANDS** (Less than 5% passes No. 200 sieve)			SW	Well graded sands, gravelly sands.
					SP	Poorly graded sands, gravelly sands.
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		SM	Silty sands, sand-silt mixtures.
			Limits plot below "A" line & hatched zone on plasticity chart		SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	**SILTS** LIMITS PLOT BELOW "A" LINE & HATCH ZONE ON PLASTICITY CHART	**SILTS OF LOW PLASTICITY** (Liquid limit less than 50)			ML	Inorganic silts, clayey silts with slight plasticity.
		SILTS OF HIGH PLASTICITY (Liquid limit more than 50)			MH	Inorganic silts of high plasticity, silty soils, elastic silts.
	CLAYS LIMITS PLOT BELOW "A" LINE & HATCH ZONE ON PLASTICITY CHART	**CLAYS OF LOW PLASTICITY** (Liquid limit less than 50)			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		CLAYS OF HIGH PLASTICITY (Liquid limit more than 50)			CH	Inorganic clays of high plasticity, fat clays, silty and sandy clays of high plasticity.

NOTE: Coarse-grained soils with between 5% to 12% passing the No. 200 sieve and fine-grained soils with limits plotting in the hatched zone on the plasticity chart to have dual symbol.

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Boulders	Above 300mm (12in.)
Cobbles	300mm to 75mm (12in. to 3in.)
Gravel	75mm (3in.) to No. 4 sieve
Coarse gravel	75mm to 19mm (3in to 3/4in.)
Fine gravel	19mm (3/4in.) to No. 4 sieve
Sand	No. 4 to No. 200
Coarse	No. 4 to No. 10
Medium	No. 10 to No. 40
Fine	No. 40 to No. 200
Fines (silt or clay)	Below No. 200 sieve

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 **DATE** 2-2-16 to 2-3-16

LOCATION (M) N. 4022737.0 E. 583433.7
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2033.4m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0	>4.5	S	5-6-9			CL	moist	**CLAY WITH SAND,** fine grained sand in zones, medium to high plasticity, dark brown
		A				to CH	at surface frozen from 0 to 0.3m	note: some short calcium carbonate filaments below 0.6m
		S	13-8-11				moderately firm to very firm	
1.5	>4.5	S	12-14-17				slightly moist below 0.3m	
3.0		T		1433.7	13.5			note: clayey sand zones up to 100mm thick below 2.7m
	2.50	S	10-12-11					
						CL	slightly moist	**CLAY,** trace silt, fine grained sand, low to medium plasticity, brown
4.5		S	5-7-11				firm	
6.0	2.40	S	7-7-10					note: decrease in fines at 6m
						CH	slightly moist	**CLAY,** trace fine grained sand, considerable calcium carbonate filaments, high plasticity, dark brown
7.5		U	39	1619.8	18.6		firm	note: 8.75 kg/cm^2 Torvane Shear Test

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	10.35	12:30	2-2-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-1

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 **DATE** 2-2-16 to 2-3-16

LOCATION (M) N. 4022737.0 E. 583433.7
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2033.4m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
						CH	slightly moist	**CLAY,** continued
		S	9-17-13				firm	note: some reddish-brown, iron-oxide staining
								note: decrease in sand below 8m
9.0	>4.5	S	9-13-17					note: 15.6 kg/cm^2 Torvane Shear Test
							moist at 10m	
								note: some clayey sand zones from 10m to 12m
10.5	2.10	S	1-3-3				very moist to wet at 10.35m	note: 4.5 kg/cm^2 Torvane Shear Test
							medium stiff	
12.0	3.30	S	2-5-8					note: 12 kg/cm^2 Torvane Shear Test
							very moist	
		U	15	1556.8	24.0		stiff to medium stiff below 12m	
							very moist to wet at 13m	
13.5	1.90	S	3-4-6				wet	note: 6 kg/cm^2 Torvane Shear Test
15.0	1-1.2	S	1-4-4					note: 2.5 kg/cm^2 Torvane Shear Test note: increase in sand at 15m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	10.35	12:30	2-2-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-1

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-2-16 to 2-3-16

LOCATION (M)	N. 4022737.0 E. 583433.7
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	2033.4m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CH	wet stiff to medium stiff	**CLAY,** continued
								SM		**SILTY SAND,** predominantly fine grained, subangular to subrounded, nonplastic to low plasticity, light brown
16.5				S	1-3-3				wet soft to very soft	note: increase in fines in zones up to 150mm thick
18.0				S	1-3-3					
										note: clay with sand zones, high plasticity, up to 125mm thick below 19.2m
19.5				S	2-2-2					note: rare coarse grained gravel at 19.5m
21.0				S	2-1-2			SC		note: decrease in fines at 21m note: rare coarse grained gravel at 21m
22.5				S	8-11-34					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	10.35	12:30	2-2-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-1

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-2-16 to 2-3-16

LOCATION (M)	N. 4022737.0 E. 583433.7
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	2033.4m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
										MESAVERDE GROUP - WEPO FORMATION SANDSTONE, fine grained texture, moderately weathered with some staining, medium bedded, soft to very soft, light yellowish-gray note: dark gray to black laminated, soft mudstone below 23.9m
24.0				S	14-50/ 125mm					
25.5				S	50/ 125mm					
27.0				S	50/ 125mm					note: bluish-gray, very soft to soft sandstone in zones below 26.7m comprised of predominant quartz grains
28.5				S	50/ 100mm					note: moderately hard sandstone in zones below 28.2m
				S	50/ 50mm					Auger refused at 29.7m Sampler refused at 29.9m
30.0										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	10.35	12:30	2-2-16
▼			

SAMPLE TYPE

A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-1

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-30-16 to 1-31-16

LOCATION (M) N. 4022681.2 E. 583401.8
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2033.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0		S / A	7-6-8			CL/CH	very moist to wet at surface slightly moist below 0.15m	**CLAY,** trace fine grained sand, medium to high plasticity, brown note: some calcium carbonate filaments below 0.6m
	3.2->4.5	S	12-15-19				moderately firm to very firm	note: 3.25 kg/cm^2 Torvane Shear Test
1.5		T		1446.5	15.7			
3.0	>4.5	S	14-16-14					note: considerable calcium carbonate filaments below 2.7m
4.5	>4.5	S	7-9-12					note: decrease in sand
						CH	slightly moist moderately firm	**CLAY,** high plasticity, brown
6.0		U	23	1610.0	16.1			
	>4.5	S	6-6-9					note: 12 kg/cm^2 Torvane Shear Test
								note: fine grained clayey sand zones up to 150mm thick below 7.2m
7.5	1.9-2.4	S	4-4-5					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	8.7	12:00	1-30-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-2

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-30-16 to 1-31-16

LOCATION (M) N. 4022681.2 E. 583401.8
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2033.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CH	moist moderately firm	**CLAY,** continued
								CL	wet below 9m medium stiff	**SANDY CLAY,** predominantly fine grained, subangular to subrounded sand, low to medium plasticity, dark brown
9.0				S	2-3-5					
10.5	0.5-0.6			S	1-3-3					note: high plasticity clay with sand zones up to 100mm thick below 10.2m
12.0	0.25-0.9			S	1-2-3					note: gradational clayey sand to sandy clay below 12m
								SC	very soft	**CLAYEY SAND,** predominantly fine grained, subangular to subrounded sand, low plasticity, light brown * note: WOH - weight of hammer
13.5				S	WOH *					
15.0				S	1-2-2					note: decrease in fines at 15m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	8.7	12:00	1-30-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-2

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-30-16 to 1-31-16

LOCATION (M) N. 4022681.2 E. 583401.8
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2033.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
			X					SC	wet very soft	**CLAYEY SAND,** continued note: clayey sand locally grading to sand with depth
16.5			X	S	1-1-1			SM	very soft	**SILTY SAND,** occasional fine grained, subangular to subrounded gravel, predominantly fine grained, subangular to subrounded sand, nonplastic, light brown
18.0			X	S	1-2-1					note: clayey sand with considerable gravel in zones below 17.7m
19.5			X	S	23-31-15					**MESAVERDE GROUP - WEPO FORMATION SANDSTONE,** siltstone & mudstone interbeds with some coal, fine grained texture, highly weathered at contact, soft, yellowish-brown to dark gray
21.0			X	S	25-50/138mm					
22.5										Auger refused at 21m Sampler refused at 21.1m Began HQ Coring at 21m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	8.7	12:00	1-30-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-2

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-30-16 to 1-31-16

RIG TYPE	CME-75
METHOD	HQ - Wireline Coring
OPERATOR	Southlands Engineering, LLC.
LOGGED BY	Mark Keyes
LOCATION (M)	NAD 1983 UTM Zone 12N (Meters)
STA/OFFSET	Sta. 22+418, on centerline
COORDS.	N. 4022681.2 E. 583401.8
ELEVATION	2033.0m ±
DATUM	NAVD88

Boring Operation and Drill Rate (min/meter)	Depth in Meter	Sample	Sample Type	Unconfined Compression or Point Load index Test (KPa)	% Core Recovery	% Drilling Fluid/Air Rec.	Rock Quality Designation (RQD)	Discontinuities Spacing (Wide - Close 1 2 3 4 5)	Discontinuities Orientation (Horiz - Vert H 45 V)	Condition	Bedding and/or Fabric	Weathering or USCS (Soils)	Rock Type & Remarks
													Began HQ Coring at 21m
1/30 HQ 6.0	21.0		HQ		100	50-70	35	NONE	NONE	N/A	MB to TkB Fgn	SlW	**MESAVERDE GROUP - WEPO FORMATION** **SILTSTONE & MUDSTONE,** occasional irregularly-shaped, high-angle, partially-open fracture, moderately soft to very soft zones up to 0.5m thick, gray to black
													note: losing partial drilling mud circulation
						100							note: predominantly soft to very soft, mudstone below 21.6m
1/31 8.0	22.5		HQ		85	50	5					MdW	
						30-40							
6.6	24.0		HQ		100		90				MB with Lam in zones	SlW	
										Smth Slcks curved			note: slickensides at 24.9m & 25.8m along fracture surface
4.0	25.5		HQ		100		95						
										N/A	Thn to MB with Lam zones		note: predominantly moderately hard to hard sandstone below 26.1m
	27.0												Stopped HQ Coring at 27m

GROUNDWATER

DEPTH (m)	HOUR	DATE
8.7	12:00	1-30-16

BORING OPERATION
B - BDBGM 51mm O.D. Wireline Rock Coring
BWC - B-size casing
HQ - 96mm O.D. Wireline Rock Coring
NQ - 71mm O.D. Wireline Rock Coring
S - 51mm O.D./35mm I.D. Tube Sample
D - Disturbed Bulk Sample

LOG OF TEST BORING NO. B-2

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-27-16 to 1-28-16

amec foster wheeler

LOCATION (M)	N. 4022698.1 E. 583411.2
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	2028.3m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S A	24-24-9			SC/SM	frozen ground from 0 to 0.3m wet below 0.75m wet very soft	**CLAYEY SAND TO SILTY SAND,** predominantly fine grained, subangular to subrounded, low to medium plasticity, brown note: 75mm to 100mm of snow on wash bottom note: increase in clay with depth note: some sand-sized coal particles at 0.75m * note: WOH - weight of hammer
				S	1-1-WOH *					
								CH		
1.5	1.00			S	1-3-2				very moist to wet medium stiff to stiff	**CLAY WITH SAND,** some brown iron-oxide staining, high plasticity, reddish-brown to brown note: 5 kg/cm^2 Torvane Shear Test note: clayey sand zones 50mm to 75mm thick below 2.7m note: 3.8 kg/cm^2 Torvane Shear Test
3.0	1.50			S	3-3-5					
4.5				S	4-4-6					
								CL	wet medium stiff	**SANDY CLAY,** predominantly fine grained sand, medium plasticity, reddish-brown to brown note: alternating fine grained clayey sand zones & highly plastic clay zones 150mm thick below 5.4m note: predominantly clay with sand from 6.3m to 7.5m
6.0				S	2-2-3					
7.5	0.5-0.6			S	3-4-4					note: 0.6 kg/cm^2 Torvane Shear Test

GROUNDWATER

	DEPTH (m)	HOUR	DATE
∇	0.75	13:45	1-27-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 DATE 1-27-16 to 1-28-16

LOCATION (M) N. 4022698.1 E. 583411.2
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2028.3m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CL	wet medium stiff	**SANDY CLAY,** continued
								SC	wet very soft	**CLAYEY SAND,** predominantly fine grained, subangular to subrounded, medium plasticity, dark brown
9.0	0.10			S	1-1-2					
								SM	wet soft to very soft	**SILTY SAND,** predominantly fine grained, subangular to subrounded, nonplastic, light brown
10.5	0.10			S	1-2-3					
12.0				S	1-1-1					
13.5				S	1-2-3					
								SM/SP	wet	**SILTY SAND TO SAND,** predominantly fine grained, subangular to subrounded sand, nonplastic, light brown note: heaving sand at 13.5m, added water to auger
15.0				S	1-2-1					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
∇	0.75	13:45	1-27-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-27-16 to 1-28-16

LOCATION (M) N. 4022698.1 E. 583411.2
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2028.3m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM/SP	wet very loose to medium dense	**SILTY SAND TO SAND,** continued
16.5	0.10			S	3-4-7					note: trace gravel at 16.5m
18.0	>4.5			S	11-29-48					note: dark gray, high plasticity clay zone with coal fragments at 18m
								CH	wet hard	**CLAY,** high plasticity, dark gray to black
	15.50			U	100/75mm					
										MESAVERDE GROUP - WEPO FORMATION SANDSTONE & SILTSTONE INTERBEDS, soft to very soft, fine grained texture, thinly bedded to laminated, dark gray
19.5				S	45-50/100mm					
21.0				S	50/100mm					
										note: medium bedded zones up to 125mm thick below 21.6m
22.5				S	50/125mm					

GROUNDWATER

DEPTH (m)	HOUR	DATE
0.75	13:45	1-27-16

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 DATE 1-27-16 to 1-28-16

LOCATION (M) N. 4022698.1 E. 583411.2
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2028.3m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
										MESAVERDE GROUP - WEPO FORMATION SANDSTONE & SILTSTONE INTERBEDS, fine grained sandstone texture (predominantly sandstone from 22.5m to 24m), medium bedded, soft, gray to light gray
										note: occasional thin coal zone up to 12.5mm thick below 23.7m
24.0			X	S	50/ 100mm					note: predominantly subangular quartz grains within sandstone zones
25.5			X	S	50/ 100mm					
27.0			X	S	50/ 75mm					note: soft, dark gray siltstone laminae to thin laminae in zones below 26.7m
										Auger refused at 27.6m Begin HQ Coring at 27.6m
28.5										
30.0										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	0.75	13:45	1-27-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-27-16 to 1-28-16

RIG TYPE	CME-75
METHOD	HQ - Wireline Coring
OPERATOR	Southlands Engineering, LLC.
LOGGED BY	Mark Keyes
LOCATION (M)	NAD 1983 UTM Zone 12N (Meters)
STA/OFFSET	Sta. 22+435, on centerline
COORDS.	N. 4022698.1 E. 583411.2
ELEVATION	2028.3m ±
DATUM	NAVD88

Boring Operation and Drill Rate (min/meter)	Depth in Meter	Sample	Sample Type	Unconfined Compression of Point Load index Test (KPa)	% Core Recovery	% Drilling Fluid/Air Rec.	Rock Quality Designation (RQD)	DISCONTINUITIES Spacing Wide - Close 1 2 3 4 5	DISCONTINUITIES Orientation Horiz - Vert H 45 V	Condition	Bedding and/ or Fabric	Weathering or USCS (Soils)	Rock Type & Remarks
	27.0												Began HQ Coring at 27.6m
1/28 HQ 9.0			HQ		100	100	25	NONE	NONE	N/A	ThB to Lam some ThL	SIW	**WEPO FORMATION** **SANDSTONE & SILTSTONE INTERBEDS,** soft to moderately soft, dark gray & gray zones note: horizontal to subhorizontal, wavy bedding
4.0	28.5		HQ		85		45				MB to ThB		note: low RQD values due to machine breaks along bedding planes note: moderately hard sandstone zones up to 300mm thick below 28.8m note: sample from 29.6m to 29.9m
	30.0												Stopped HQ Coring at 30m
	31.5												
	33.0												

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	0.75	13:45	1-27-16
▼			
▽			

BORING OPERATION
B - BDBGM 51mm O.D. Wireline Rock Coring
BWC - B-size casing
HQ - 96mm O.D. Wireline Rock Coring
NQ - 71mm O.D. Wireline Rock Coring
S - 51mm O.D./35mm I.D. Tube Sample
D - Disturbed Bulk Sample

LOG OF TEST BORING NO. B-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1/29/16

LOCATION (M) N. 4022699.2 E. 583380.3
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2028.3m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S A	19-29-15			SM/SP	frozen ground from 0 to 0.3m very moist to wet very loose	**SILTY SAND TO SAND,** trace fine grained gravel, fine grained, subangular to subrounded sand, nonplastic, brown
				S	2-1-2					
▽								SM/GM	wet below 0.9m loose	**SILTY SAND TO SILTY GRAVEL,** predominantly medium to coarse grained, subangular sand, predominantly coarse grained, angular gravel, nonplastic, brown note: high plasticity clay zones up to 75mm thick
1.5				S	1-3-3					
	0.75			T		1810.6	14.0	CL	wet very stiff hard below 4m	**CLAY WITH SAND & GRAVEL,** trace fine grained, subangular to angular gravel, predominantly fine grained, subangular sand, medium to high plasticity, black & brown zones note: 3.1 kg/cm^2 Torvane Shear Test note: considerable black organic material at 3m note: high plasticity clay zones up to 150mm thick
3.0				S	2-12-16					
4.5				S	50/125mm					**MESAVERDE GROUP - WEPO FORMATION SILTSTONE TO SANDSTONE INTERBEDS,** fine grained texture, slightly weathered to moderately weathered, soft, light brown & gray zones
6.0				S	50-50/75mm					note: predominantly sandstone below 6m
7.5				S	50-50/75mm					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	0.9	12:15	1-29-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-4

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1/29/16

LOCATION (M) N. 4022699.2 E. 583380.3
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2028.3m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
										MESAVERDE GROUP - WEPO FORMATION SILTSTONE TO SANDSTONE INTERBEDS, continued
				S	50/ 100mm					
9.0										Stopped Auger at 8.85m Sampler refused at 8.95m Began HQ Coring at 8.85m
10.5										
12.0										
13.5										
15.0										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
∇	0.9	12:15	1-29-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-4

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-29-6

amec foster wheeler

RIG TYPE	CME-75
METHOD	HQ - Wireline Coring
OPERATOR	Southlands Engineering, LLC.
LOGGED BY	Mark Keyes
LOCATION (M)	NAD 1983 UTM Zone 12N (Meters)
STA/OFFSET	Sta. 22+422, 8.4m L
COORDS.	N. 4022699.2 E. 583380.3
ELEVATION	2028.3m ±
DATUM	NAVD88

Boring Operation and Drill Rate (min/meter)	Depth in Meter	Sample	Sample Type	Unconfined Compression of Point Load index Test (KPa)	% Core Recovery	% Drilling Fluid/Air Rec.	Rock Quality Designation (RQD)	Discontinuities Spacing (Wide - Close 1 2 3 4 5)	Discontinuities Orientation (Horiz - Vert H 45 V)	Condition	Bedding and/ or Fabric	Weathering or USCS (Soils)	Rock Type & Remarks
HSA													Began HQ Coring at 8.85m
1/29 HQ 1.0	9.0		HQ		85	100	40	NONE	NONE	N/A	Fgn MB to TkB with occ Lam	SlW	**MESAVERDE GROUP - WEPO FORMATION SANDSTONE,** predominantly fine grained with thin coarse grained zones, moderately hard, light gray with reddish-brown streaks & black laminea note: thin, highly oxidized zones up to 75mm thick note: wavy, low-angle to subhorizontal bedding
2.5	10.5		HQ		75		10					MdW zones	
												SlW	
6.8	12.0		HQ		75		50				ThB to MB		note: some thin, soft clay-rich mudstone zones up to 150mm thick from 12m to 13.5m
3.2	13.5		HQ		80		70				Lam to ThB		note: predominantly dark gray & black, organic-rich, moderately soft siltstone below 13.2m
												MdW	
	15.0												Stopped HQ Coring at 14.85m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	0.9	12:15	1-29-16
▼			
▼			

BORING OPERATION
B - BDBGM 51mm O.D. Wireline Rock Coring
BWC - B-size casing
HQ - 96mm O.D. Wireline Rock Coring
NQ - 71mm O.D. Wireline Rock Coring
S - 51mm O.D./35mm I.D. Tube Sample
D - Disturbed Bulk Sample

LOG OF TEST BORING NO. B-4

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 **DATE** 2-18-16 to 2-19-16

LOCATION (M) N. 4022711.0 E. 583434.1
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2029.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S	1-1-2			SM	slightly moist very soft to soft	**FILL** **SILTY SAND,** predominantly fine to medium grained, subrounded sand, nonplastic, brown note: possible sandstone zones about 75mm thick, yellow in color at 1m
				A						
				S	2-2-4					
				S	3-3-2			CH	moist soft to moderately firm	**NATIVE** **CLAY WITH SAND,** predominantly fine grained, subrounded sand, high plasticity, dark brown note: trace silt below 2.4m
1.5										
3.0				S	2-2-3					
										note: 12.5 kg/cm^2 Torvane Shear Test
4.5	3.25			U	18	1552.2	25.2			note: increase in clay at 4.5m
				S	3-4-5					
6.0				S	3-3-5					
										note: up to 150mm thick sandy clay zones throughout, medium plasticity & dark brown below 6.9m
7.5	1.50			U	11	1619.5	24.2			note: 8 kg/cm^2 Torvane Shear Test

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	9.3	10:40	2-18-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-5

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-18-16 to 2-19-16

LOCATION (M) N. 4022711.0 E. 583434.1
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 2029.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CH	moist soft to moderately firm	**CLAY WITH SAND,** continued note: up to 150mm thick clayey sand zones throughout, low plasticity & brown below 7.8m
				S	4-5-5					
9.0				S	1-1-3				wet below 9.3m medium stiff	note: up to 75mm thick silty sand zones throughout, nonplastic & brown below 9.9m
▽										
10.5				S	2-3-5					
								SM	wet very soft to soft	**SILTY SAND,** predominantly fine grained, subrounded sand, nonplastic, brown note: up to 75mm thick sandy clay zones with depth, low to medium plasticity, brown
12.0				S	1-2-2					
13.5				S	2-3-3					
15.0				S	2-2-3					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	9.3	10:40	2-18-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-5

PROJECT: BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 DATE 2-18-16 to 2-19-16

LOCATION (M): N. 4022711.0 E. 583434.1
PROJECTION: NAD 1983 UTM Zone 12N (Meters)
RIG TYPE: CME-75
BORING TYPE: 210mm Hollow Stem Auger
SURFACE EL. (M): 2029.0m ±
DATUM: NAVD88

amec foster wheeler

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM	wet firm	**SILTY SAND,** continued note: up to 75mm thick clay with sand zones below 15m, medium to high plasticity, dark brown
16.5				S	3-15-10					
								SP-SM	wet medium dense	**SAND WITH SILT,** predominantly medium grained, subrounded sand, weakly cemented, nonplastic, yellow note: possible sandstone
				S	2-4-18					
18.0										Auger refused at 18m Stopped Sampler at 18.3m Began HQ Coring at 18m
19.5										
21.0										
22.5										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	9.3	10:40	2-18-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. B-5

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-18-16 to 2-19-16

RIG TYPE	CME-75
METHOD	HQ - Wireline Coring
OPERATOR	Southlands Engineering, LLC.
LOGGED BY	Joe Zaleski
LOCATION (M)	NAD 1983 UTM Zone 12N (Meters)
STA/OFFSET	Sta. 22+455, 13m R
COORDS.	N. 4022711.0 E. 583434.1
ELEVATION	2029.0m ±
DATUM	NAVD88

Boring Operation and Drill Rate (min/meter)	Depth in Meter	Sample	Sample Type	Unconfined Compression or Point Load index Test (KPa)	% Core Recovery	% Drilling Fluid/Air Rec.	Rock Quality Designation (RQD)	Discontinuities Spacing (Wide - Close 1 2 3 4 5)	Discontinuities Orientation (Horiz - Vert H 45 V)	Condition	Bedding and/ or Fabric	Weathering or USCS (Soils)	Rock Type & Remarks
													Began HQ Coring at 18m
2/18 HQ 8.0	18.0		HQ		100	100	35	NONE	NONE	N/A	Fgn MB to TkB with zones of Lam	HiW / MdW	**MESAVERDE GROUP - WEPO FORMATION SILTSTONE & MUDSTONE Interbeds,** soft to moderately soft, dark gray to grayish-green note: very soft from 18m to 18.3m note: horizontal to subhorizontal bedding note: moderately hard siltstone zone from 19.4m to 19.7m
7.0	19.5		HQ		90		30					SlW to MdW / SlW	note: iron-oxide staining from 19.4m to 19.7m (wavy, near vertical fracture) note: dark gray to gray mudstone below 19.7m note: occasional slickensides from 19.7m to 20m note: moderately hard siltstone from 20.9m to 21.3m
8.0	21.0		HQ		100		40					MdW to HiW / SlW	note: mechanical breaks throughout recovery (breaking along bedding planes) note: moderately hard to moderately soft below 22m
3.0	22.5		HQ		100		80				Fgn TkB with Lam zones	SlW	**MESAVERDE GROUP - WEPO FORMATION SANDSTONE,** moderately hard to hard, gray with occasional black mudstone laminae
	24.0												Stopped HQ Coring at 24.4m Backfilled with cuttings & grouted upper 6m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	9.3	10:40	2-18-16
▼			
▼			

BORING OPERATION
B - BDBGM 51mm O.D. Wireline Rock Coring
BWC - B-size casing
HQ - 96mm O.D. Wireline Rock Coring
NQ - 71mm O.D. Wireline Rock Coring
S - 51mm O.D./35mm I.D. Tube Sample
D - Disturbed Bulk Sample

LOG OF TEST BORING NO. B-5

CORE PHOTOGRAPHS

Boring B-2	
Core Box 1	Interval 70.0’ to 79.0’ (21 m to 23.7 m)
Core Box 2	Interval 79.0’ to 88.8’ (23.7 m to 26.6 m)
Core Box 3	Interval 88.8’ to 90.0’ (26.6 m to 27.0 m)

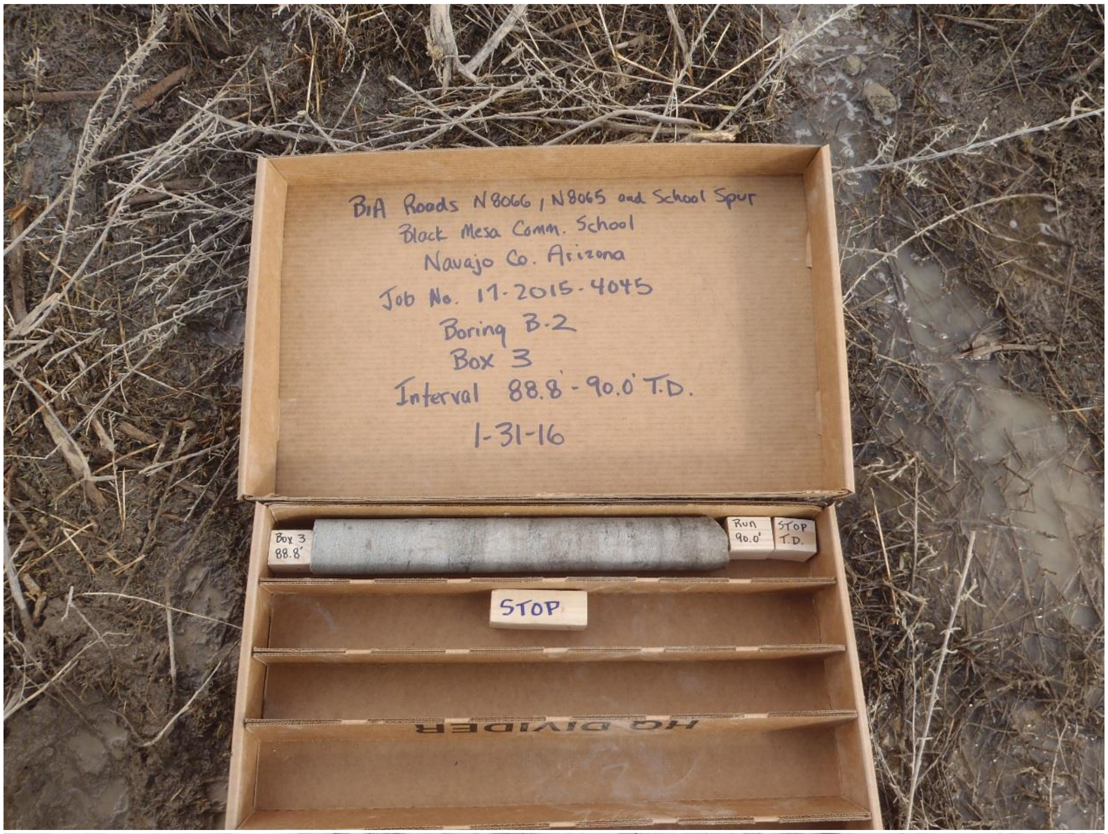
Boring B-3	
Core Box 1	Interval 92.0’ to 100.0’ (27.6 m to 30.0 m)

Boring B-4	
Core Box 1	Interval 29.5’ to 40.1’ (8.9 m to 12.03 m)
Core Box 2	Interval 40.1’ to 49.5’ (12.03 m to 14.85 m)

Boring B-5	
Core Box 1	Interval 60.0’ to 68.6’ (18 m to 20.6 m)
Core Box 2	Interval 68.6’ to 75.0’ (20.6 m to 22.5 m)
Core Box 3	Interval 75.0’ to 80.0’ (22.5 m to 24.0 m)


BIA Roads N8066, N8065 and School
Spur, Black Mesa Comm. School
Navajo Co. Arizona
Job No. 17-2015-4045
Boring B-2
Box No. 1
Interval 70.0-79.0'
1-31-16
Start Boring B-3
Box 1 70.0'
Run 75.0'
Box 1 79.0'


BIA Roads N8066, N8065 and School Spur
Black Mesa Comm. School
Navajo Co. Arizona
Job No. 17-2015-4045
Boring B-2
Box 2
Interval 79.0'- 88.8'
1-31-16
Box 2 79.0'
Run 80.0'
85.0'
Box 2 88.8'


BIA Roads N8066, N8065 and School Spur
Black Mesa Comm. School
Navajo Co. Arizona
Job No. 17-2015-4045
Boring B-2
Box 3
Interval 88.8'-90.0' T.D.
1-31-16
Box 3 88.8'
Run 90.0'
STOP T.D.
STOP

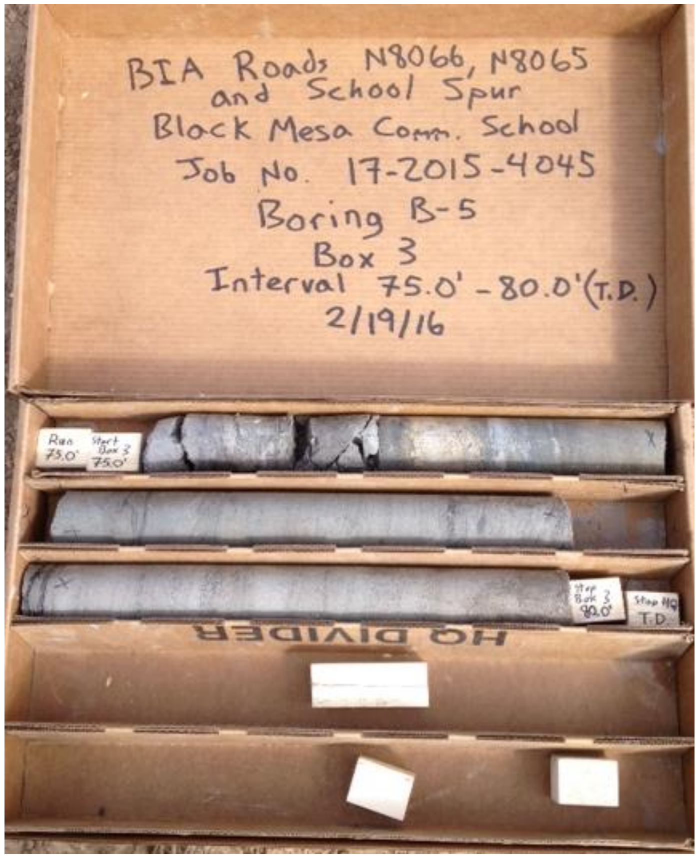

Job No. 17 2015 4045
BIA Roads N 8066, N 8065
and School Spur
Black Mesa Comm. School
Navajo Co. Az.
Boring B-3 / Box 1 of 1
Interval 92.0'-100.0' T.D.
1-28-16
Boring B-3
Start 92.0'
Run 95.0'
Run 100.0'
T.D. STOP


BIA Roads N8066, N 8065 and School
Spur, Black Mesa Comm. School
Navajo Co. Az.
Job No. 17-2015-4045
Boring B-4 (Sta 22+422, 27.5L)
Box 1 of 2
Interval 29.5-40.1'
1-29-16
Boring B-4
Start 29.5'
Run 34.5'
Run 39.5'
Box 1 40.1'


BIA Roads N8066, N8065 and School
Spur, Black Mesa Comm. School
Navajo Co. Az.
Job No. 17-2015-4045
Boring B-4
Box 2 of 2
Interval 40.1'-49.5' T.D.
1-29-16
Box 2 B-4 40.1'
Run 44.5'
STOP
T.D. 49.5'


BIA Roads N8066, N8065,
& School Spur
Black Mesa Comm. School
Navajo Co. Arizona
Job No. 17-2015-4045
Boring B-5
Box 1
Interval 60.0' - 68.6'
2/18/16


BIA Roads N8066, N8065,
& School Spur
Black Mesa Comm. School
Navajo County Arizona
Job No. 17-2015-4045
Boring B-5
Box 2
Interval 68.6' - 75.0'
2/18/16 - 2/19/16
Run 70.0
End Box 2 75.0


BIA Roads N8066, N8065
and School Spur
Black Mesa Comm. School
Job No. 17-2015-4045
Boring B-5
Box 3
Interval 75.0' - 80.0'(T.D.)
2/19/16
Run
75.0'
Start
Box 3
75.0'
Stop
Box 3
80.0'
T.D.
HQ DIVIDER

ATTACHMENT B

LABORATORY TEST RESULTS

LABORATORY TESTING PROCEDURES

Consolidation Tests Soiltest or Clockhouse apparatus of the "floating-ring" type are employed for the one-dimensional consolidation tests. They are designed to receive 1-inch high 2.5-inch O.D. brass liner rings with soil specimens as secured in the field. Procedures for the tests generally are those outlined in ASTM D2435. Loads are applied in several increments to the upper surface of the test specimen and the resulting deformations are recorded at selected time intervals for each increment. For soils which are essentially saturated, each increment of load is maintained until the deformation versus log of time curve indicates completion of primary consolidation. For partially saturated soils, each increment of load is maintained until the rate of deformation is equal or less than 1/10,000 inch per hour. Applied loads are such that each new increment is equal to the total previously applied loading. Porous stones are placed in contact with the top and bottom of the specimens to permit free addition or expulsion of water. For partially saturated soils, the tests are normally performed at in situ moisture conditions until consolidation is complete under stresses approximately equal to those which will be imposed by the combined overburden and foundation loads. The samples are then submerged to show the effect of moisture increase and the tests continued under higher loadings. Generally, the tests are continued to about twice the anticipated curve due to overburden and structural loads with a rebound curve then being established by releasing loads.

Expansion Tests The same type of consolidometer apparatus described above is used in expansion testing. Undisturbed samples contained in brass liner rings are placed in the consolidometers, subjected to appropriate surcharge loads and submerged. The loads are maintained until the expansion versus log of time curve indicates the completion of "primary swell".

Direct Shear Tests Direct shear tests are run using a Clockhouse or Soiltest apparatus of the strain-control of approximately 0.05 inch per minute. The machine is designed to receive one of the 1-inch high 2.42-inch diameter specimens obtained by tube sampling. Generally, each sample is sheared under a normal load equivalent to the effective overburden pressure at the point of sampling. In some instances, samples are sheared at several normal loads to obtain the cohesion and angle of internal friction. When necessary, samples are saturated and/or consolidated before shearing in order to approximate the anticipated controlling field loading conditions.

TABLE B-1
SUMMARY OF LABORATORY TEST RESULTS

Station Reference	Station	Offset	Direction	Boring Number	Depth (meter)		USCS/Group Symbol	Liquid Limit	Plasticity Index	Percent Fines (minus 75µm)	Moisture Content (%)	In Place Dry Density (kg/cu.m)[1]	Direct Shear Test of Soils Under Consolidated Drained Conditions (AASHTO T-236)	One Dimensional Consolidation Test (AASHTO T216)	Unconfined Compressive Strength of Rock Core Samples (kPa)[2] (AASTHO T208)	Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils (AASHTO T296)
		meter			Begin	End										
Proposed BIA Route N8066 CL	22+480	-	CL	B-1	2.85	3.15	CH	50	27	91	13.5	1433.0				X
Proposed BIA Route N8066 CL	22+480	-	CL	B-1	4.35	4.80	CL	38	17	91						
Proposed BIA Route N8066 CL	22+480	-	CL	B-1	7.35	7.65					18.6	1619.8				
Proposed BIA Route N8066 CL	22+480	-	CL	B-1	12.45	12.75	CH	62	39	100	24	1556.8		X		
Proposed BIA Route N8066 CL	22+480	-	CL	B-1	17.85	18.30	SM	NV	NP	49						
Proposed BIA Route N8066 CL	22+418	-	CL	B-2	1.35	1.77	CH	54	32	94	15.7	1445.8				X
Proposed BIA Route N8066 CL	22+418	-	CL	B-2	5.85	6.15	CH	60	36	100				X		
Proposed BIA Route N8066 CL	22+418	-	CL	B-2	8.85	9.30	CL	26	10	65						
Proposed BIA Route N8066 CL	22+418	-	CL	B-2	16.35	16.80	SM	NV	NP	28						
Proposed BIA Route N8066 CL	22+418	-	CL	B-2	21.72	21.93									18,821	
Proposed BIA Route N8066 CL	22+418	-	CL	B-2	24.00	24.15									17,145	
Proposed BIA Route N8066 CL	22+418	-	CL	B-2	25.35	25.50									1,427	
Proposed BIA Route N8066 CL	22+418	-	CL	B-2	26.70	27.00									14,976	
Proposed BIA Route N8066 CL	22+435	-	CL	B-3	0.00	0.45	SC	25	9	39						
Proposed BIA Route N8066 CL	22+435	-	CL	B-3	0.00	1.35	CL	36	19	72						
Proposed BIA Route N8066 CL	22+435	-	CL	B-3	5.85	6.30	CL	26	11	54						
Proposed BIA Route N8066 CL	22+435	-	CL	B-3	11.85	12.30	SM	NV	NP	41						
Proposed BIA Route N8066 CL	22+435	-	CL	B-3	29.10	29.40									17,139	
Proposed BIA Route N8066 CL	22+422	8.4	L	B-4	1.95	2.55	CL	43	24	77	14	1810.6	X	X		
Proposed BIA Route N8066 CL	22+422	8.4	L	B-4	9.00	9.15									7,962	
Proposed BIA Route N8066 CL	22+422	8.4	L	B-4	13.80	13.92									14,352	
Proposed BIA Route N8066 CL	22+422	8.4	L	B-4	14.43	14.70									28,524	
Proposed BIA Route N8066 CL	22+455	13	R	B-5	4.35	4.65	CH	71	46	98	25.2	1552.2		X		
Proposed BIA Route N8066 CL	22+455	13	R	B-5	7.35	7.65					24.2	1619.5				
Proposed BIA Route N8066 CL	22+455	13	R	B-5	13.35	13.80	SM	NV	NP	46						
Proposed BIA Route N8066 CL	22+455	13	R	B-5	22.14	22.44									16,890	
Proposed BIA Route N8066 CL	22+455	13	R	B-5	22.95	23.40									16,951	
							MEAN	**---**	**---**	**70**	**19**	**1577**	**---**	**---**	**15419**	**---**
							STDEV	**---**	**---**	**25**	**5.1**	**127.3**	**---**	**---**	**7043**	**---**
							MAXIMUM	**71**	**46**	**100**	**25.2**	**1810.6**	**---**	**---**	**28524**	**---**
							MINIMUM	**NV**	**NP**	**28**	**13.5**	**1433.0**	**---**	**---**	**1427**	**---**
							COUNT	**15**	**15**	**15**	**7**	**7**	**1**	**4**	**10**	**2**

[1](kg/cu.m) = kilograms per cubic meter
[2](kPa) = kilopascal
X = see attached test data sheet

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PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 3
DATE ASSIGNED: 2/25/16

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (AASHTO T27/T11/T89/T90)

PERCENT PASSING BY WEIGHT

				Silt or Clay	SAND								GRAVEL									COBBLES	
					Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	USCS	LL	PI	75um	150um	300um	425um	600um	1.18um	2.00mm	2.36mm	4.75mm	6.3mm	9.5mm	12.5mm	19mm	25mm	31.2mm	37.5mm	50mm	75mm	152mm	Lab #
B-3 (0.00-1.35m)	CL	36	19	72	82	97	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1010-01
BS-3 (0.00-1.35m)	CL-ML	25	6	56	78	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1010-23

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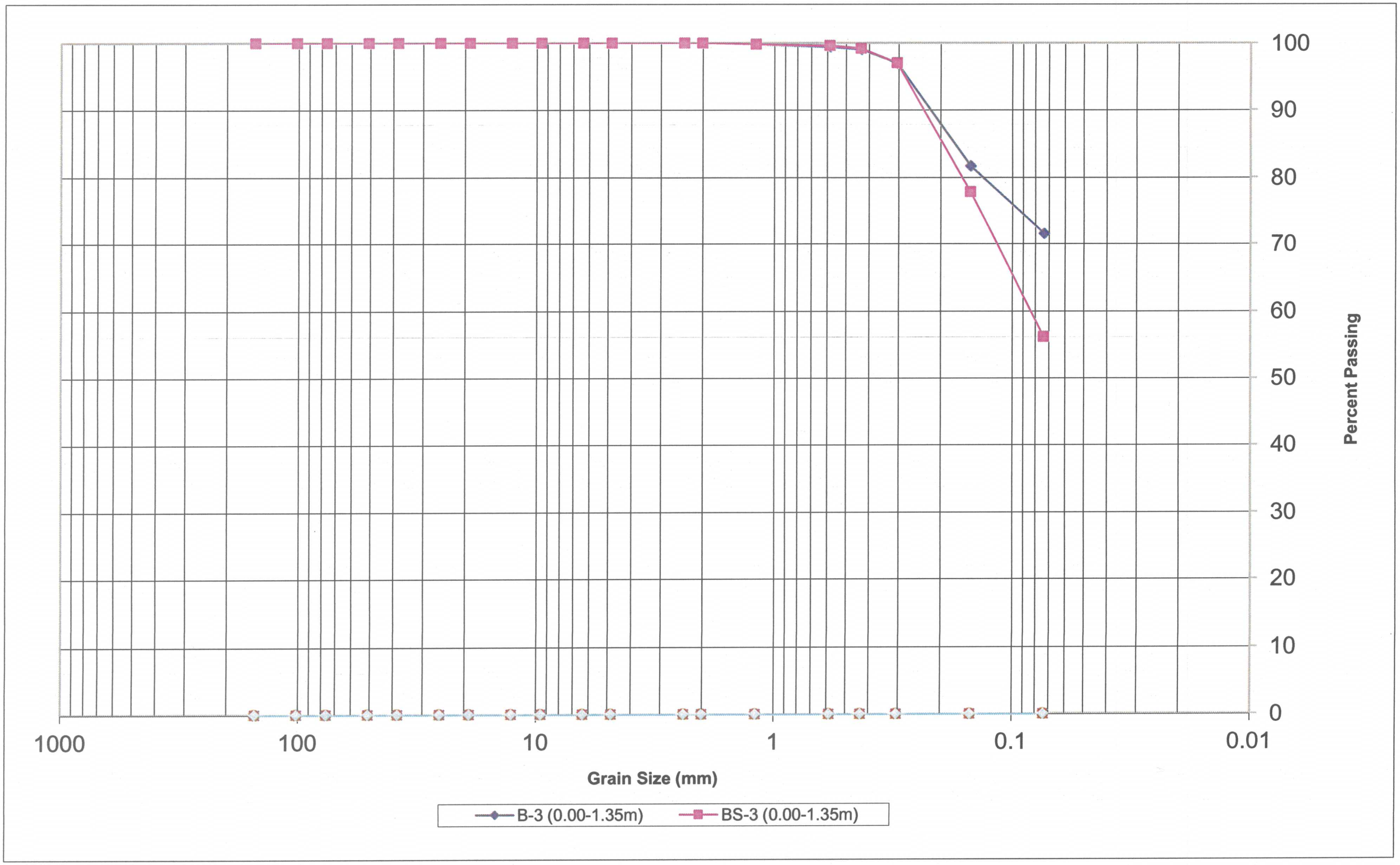
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 3
DATE ASSIGNED: 2/25/16

MECHANICAL SIEVE ANALYSIS



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PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (AASHTO T27/T11/T89/T90)

PERCENT PASSING BY WEIGHT

				Silt or Clay	SAND								GRAVEL									COBBLES	
					Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	USCS	LL	PI	75um	150um	300um	425um	600um	1.18um	2.00mm	2.36mm	4.75mm	6.3mm	9.5mm	12.5mm	19mm	25mm	31.2mm	37.5mm	50mm	75mm	152mm	Lab #
BS-06 (1.95-2.40m)	SM	NV	NP	48	77	96	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-134
BS-06 (7.95-8.40m)	CL	35	16	92	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-139
BS-06 (19.35-19.80m)	ML	NV	NP	59	89	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-148
B-1 (2.85-3.15m)	CH	50	27	91	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-161
B-1 (4.35-4.80m)	CL	38	17	91	96	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-163
B-1 (12.45-12.75m)	CH	62	39	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-170
B-1 (17.85-18.30m)	SM	NV	NP	49	69	90	96	97	99	99	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-174

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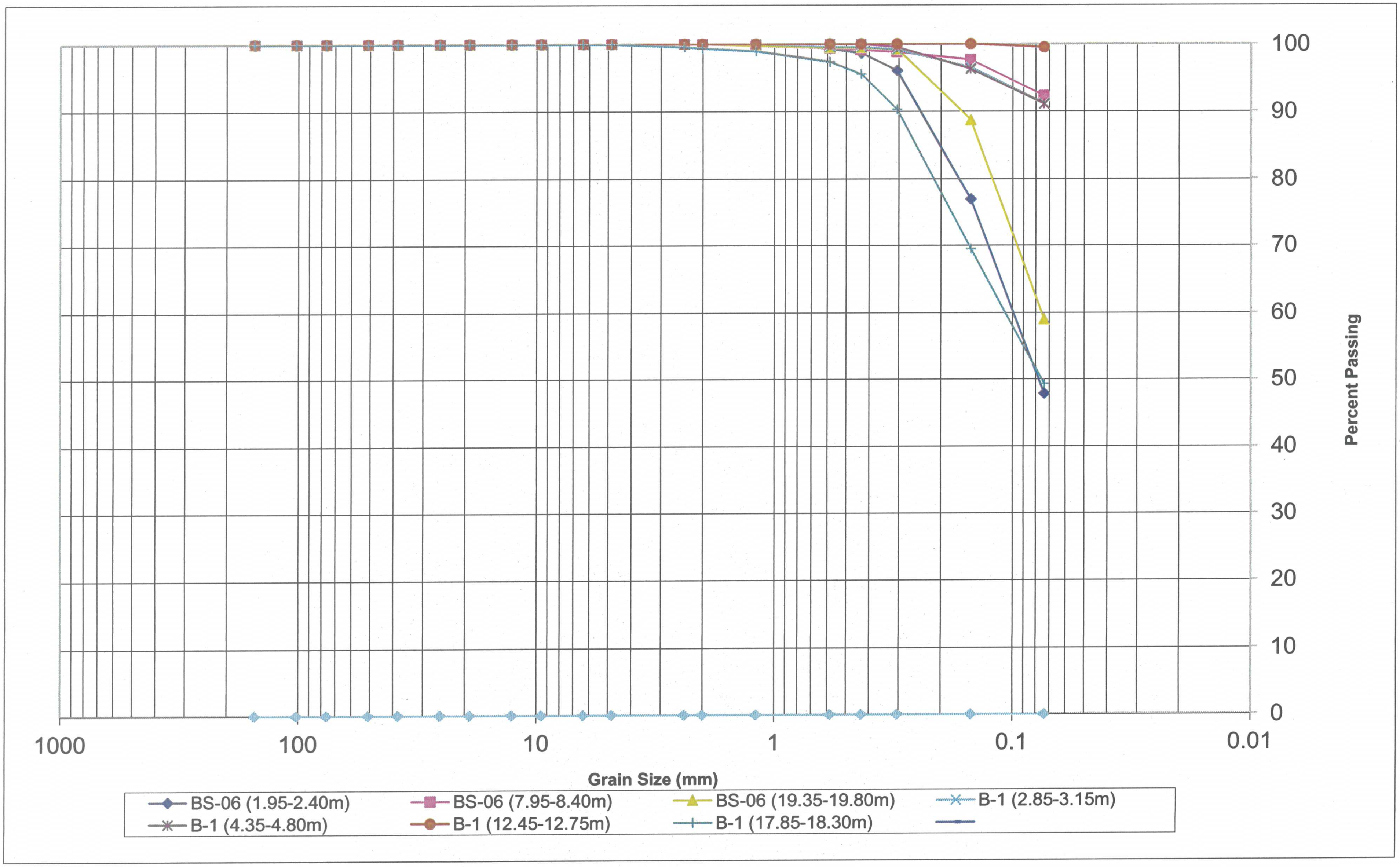
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS



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PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (AASHTO T27/T11/T89/T90)

PERCENT PASSING BY WEIGHT

				Silt or Clay	SAND								GRAVEL									COBBLES	
					Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	USCS	LL	PI	75um	150um	300um	425um	600um	1.18um	2.00mm	2.36mm	4.75mm	6.3mm	9.5mm	12.5mm	19mm	25mm	31.2mm	37.5mm	50mm	75mm	152mm	Lab #
B-2 (1.35-1.77m)	CH	54	32	94	97	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-186
B-2 (5.85-6.15m)	CH	60	36	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-189
B-2 (8.85-9.30m)	CL	26	10	65	79	91	93	95	97	98	98	99	100	100	100	100	100	100	100	100	100	100	16-1044-192
B-2 (16.35-16.80m)	SM	NV	NP	28	50	75	81	84	89	91	92	96	97	100	100	100	100	100	100	100	100	100	16-1044-197
B-3 (0.00-0.45m)	SC	25	9	39	51	88	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-206
B-3 (5.85-6.30m)	CL	26	11	54	67	83	89	92	96	98	98	100	100	100	100	100	100	100	100	100	100	100	16-1044-211
B-3 (11.85-12.30m)	SM	NV	NP	41	60	82	88	91	95	96	96	98	99	100	100	100	100	100	100	100	100	100	16-1044-215
B-4 (1.95-2.55m)	CL	43	24	77	83	85	86	86	87	87	88	89	90	98	98	100	100	100	100	100	100	100	16-1044-233
B-5 (4.35-4.65m)	CH	71	46	98	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-248
B-5 (13.35-13.80m)	SM	NV	NP	46	68	90	95	96	98	98	98	99	99	100	100	100	100	100	100	100	100	100	16-1044-256

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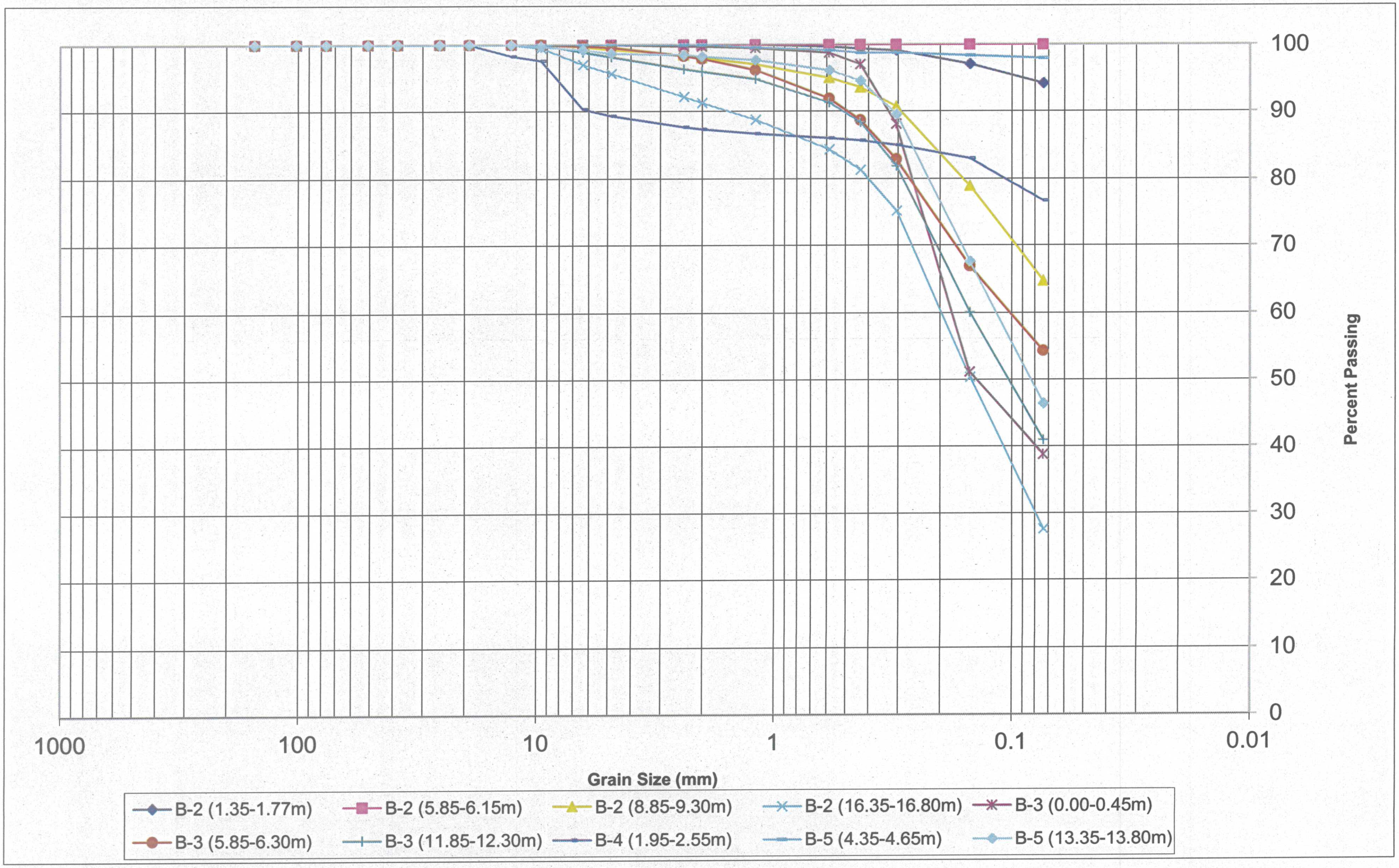
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS



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PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BORING

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: SEE BELOW
DATE SAMPLED: 3/7/16

DENSITY OF SOIL IN PLACE BY THE DRIVE-CYLINDER METHOD(ASTM D2937)

LAB #	BORING	MOISTURE WET WT. (g)	MOISTURE DRY WT. (g)	MOISTURE CONTENT	NUMBER OF RINGS	WET WGT. + RINGS (g)	WEIGHT OF RINGS (g)	DRY DENSITY (kg/m³)
16-1044-24	BS-01 (27.45-27.75m)	878.7	700.1	25.5%	6	1,154.6	273.5	1551.8
16-1044-41	BS-02 (14.85-15.15m)	882.6	773.5	14.1%	6	1,140.7	256.5	1713.0
16-1044-51	BS-02 (28.35-28.65m)	887.9	691.6	28.4%	6	1,153.6	263.2	1533.1
16-1044-65	BS-3 (13.35-13.65m)	364.3	289.6	25.8%	4	776.7	184.1	1562.0
16-1044-87	BS-4 (10.35-10.65m)	310.3	236.2	31.4%	5	956.7	225.5	1476.4
16-1044-91	BS-4 (14.85-15.15m)	289.0	243.7	18.6%	6	1,198.5	271.7	1727.6
16-1044-99	BS-4 (25.35-25.65m)	867.0	659.1	31.5%	6	1,137.7	266.7	1463.7
16-1044-113	BS-05 (7.95-8.25m)	337.2	311.6	8.2%	6	983.6	265.8	1466.3
16-1044-116	BS-05 (11.85-12.15m)	878.3	742.5	18.3%	6	1,146.4	266.9	1643.6
16-1044-143	BS-06 (13.35-13.65m)	724.3	610.0	18.7%	5	946.4	221.0	1620.6
16-1044-165	B-1 (7.35-7.65m)	866.1	730.4	18.6%	6	1,132.2	263.3	1619.8
16-1044-170	B-1 (12.45-12.75m)	285.8	230.4	24.0%	4	755.0	172.6	1556.8
16-1044-248	B-5 (4.35-4.65m)	279.7	223.4	25.2%	4	760.0	173.9	1552.2
16-1044-251	B-5 (7.35-7.65m)	908.8	731.8	24.2%	6	1,170.2	260.4	1619.5

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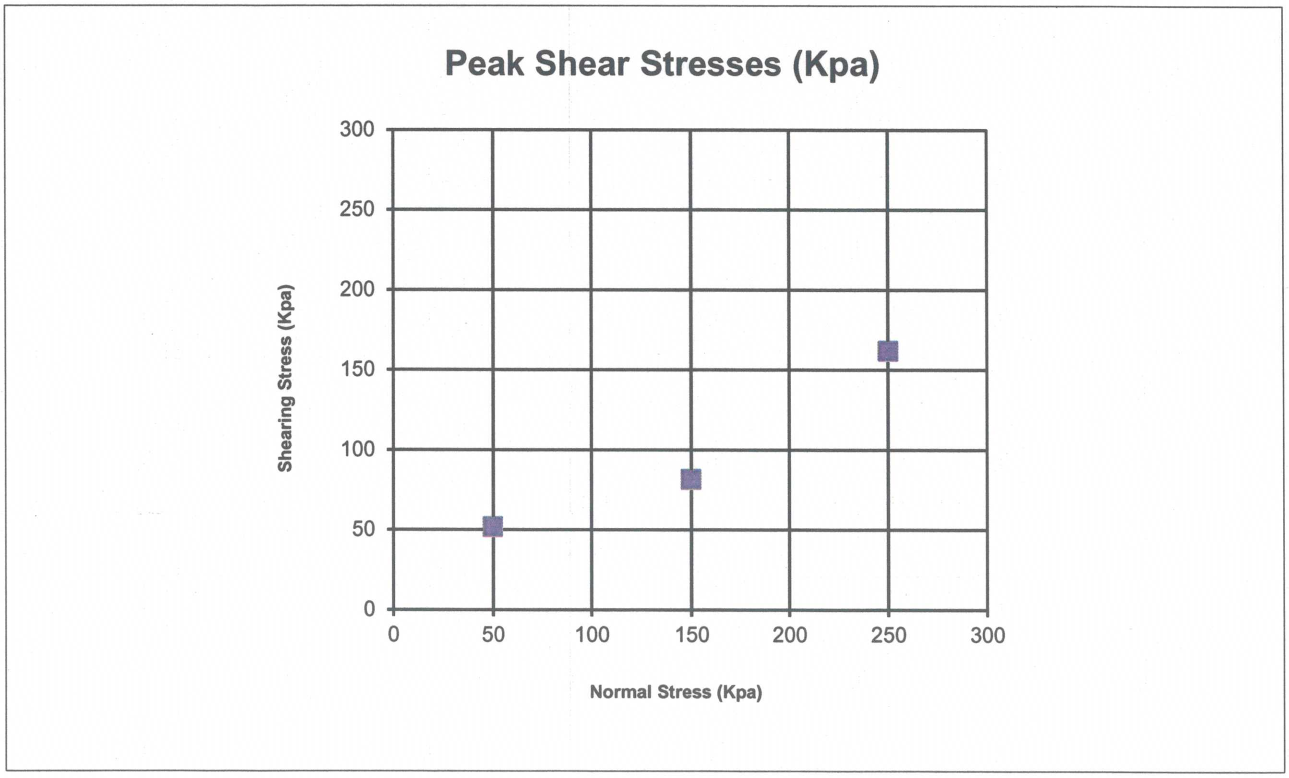
PROJECT:	BIA N8066(3), 8065(1), & School Spur	**JOB NO:**	17-2015-4045
LOCATION:	Black Mesa Community School, AZ	**WORK ORDER NO:**	4
MATERIAL:	Native Soil	**LAB NO:**	16-1044-233
SAMPLE SOURCE:	B-4 (1.95-2.55m)	**DATE ASSIGNED:**	3/7/2016
SAMPLE PREPARATION:	Insitu		
	50kPa, 150kPa, 250kPa Strain rate = 0.002 in/min		

DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS(AASHTO T-236)

Initial thickness of specimen (mm):	25.4	25.4	25.4
Initial diameter of specimen (mm):	61.5	61.5	61.5
Shearing device used:	Humboldt Automated Shear Test System by Trautwein Soil Testing Equipment		
Rate of deformation (mm/min):	0.0508	0.0508	0.0508
Direct shear point (Kpa):	50.0	150.0	250.0
Dry mass of specimen (g):	135.9	136.6	136.9
Initial Moisture Content:	13.9%	14.0%	14.2%
Initial Wet Density (Kg per cu.m):	2054.2	2065.7	2075.1
Initial Dry Density (Kg per cu.m):	1802.8	1812.5	1816.4
Final Moisture Content:	18.7%	17.0%	11.5%
Final Wet Density (Kg per cu.m):	2163.6	2170.2	2112.4
Final Dry Density (Kg per cu.m):	1822.9	1855.2	1893.8
Normal Stress (kpa):	50	150	250
Maximum Shearing Stress (Kpa):	51.57	81.23	161.46
Vertical Deformation @ Max Shear (mm):	-0.330	-0.258	-0.592
Horizontal Deformation @ Max Shear (mm):	12.450	3.326	11.320



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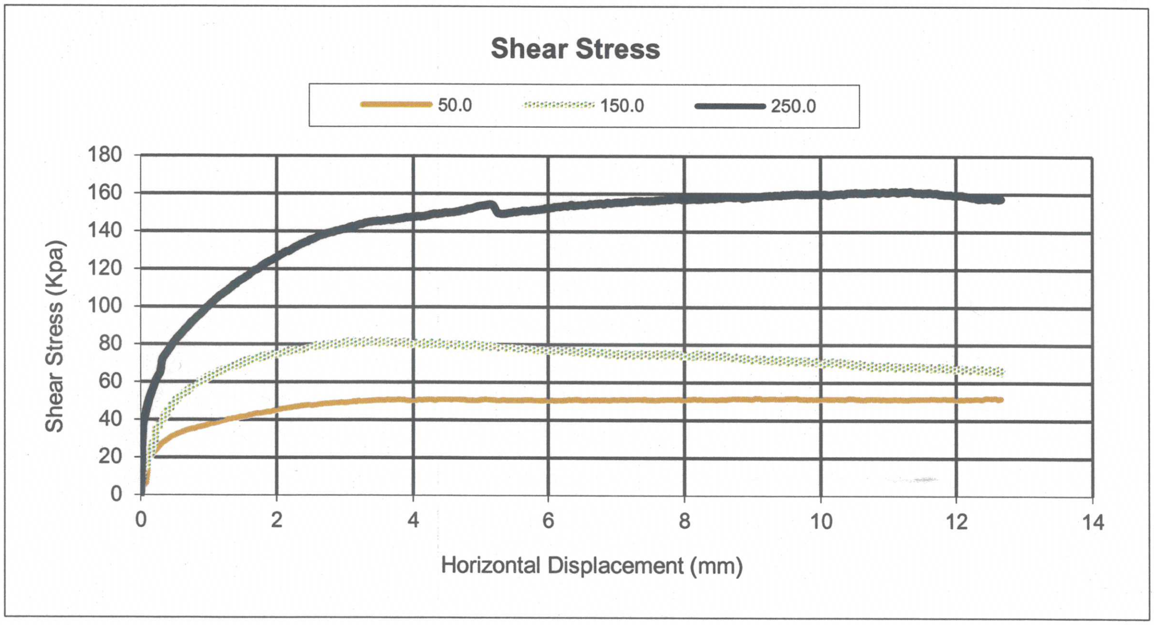
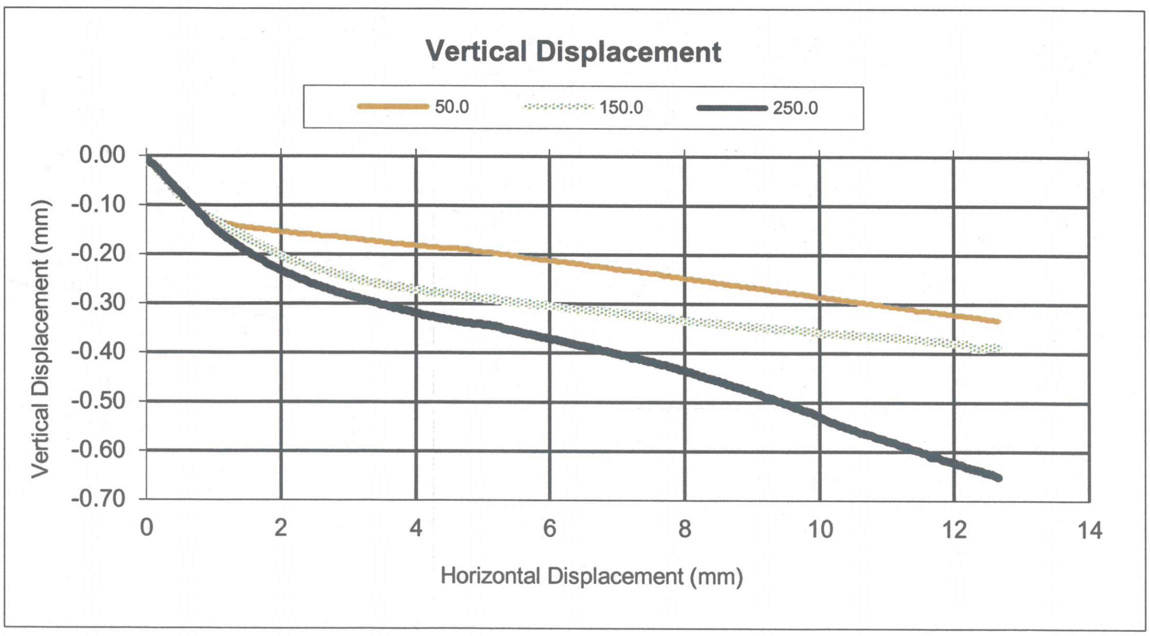
PROJECT:	BIA N8066(3), 8065(1), & School Spur	**JOB NO:**	17-2015-4045
LOCATION:	Black Mesa Community School, AZ	**WORK ORDER NO:**	4
MATERIAL:	Native Soil	**LAB NO:**	16-1044-233
SAMPLE SOURCE:	B-4 (1.95-2.55m)	**DATE ASSIGNED:**	3/7/2016
SAMPLE PREPARATION:	Insitu		
	50kPa, 150kPa, 250kPa Strain rate = 0.002 in/min		

NORMAL LOADS (Kpa): 50.0 150.0 250.0

DIRECT SHEAR TEST OF SOILS UNDER CONSOLIDATED DRAINED CONDITIONS(AASHTO T-236)





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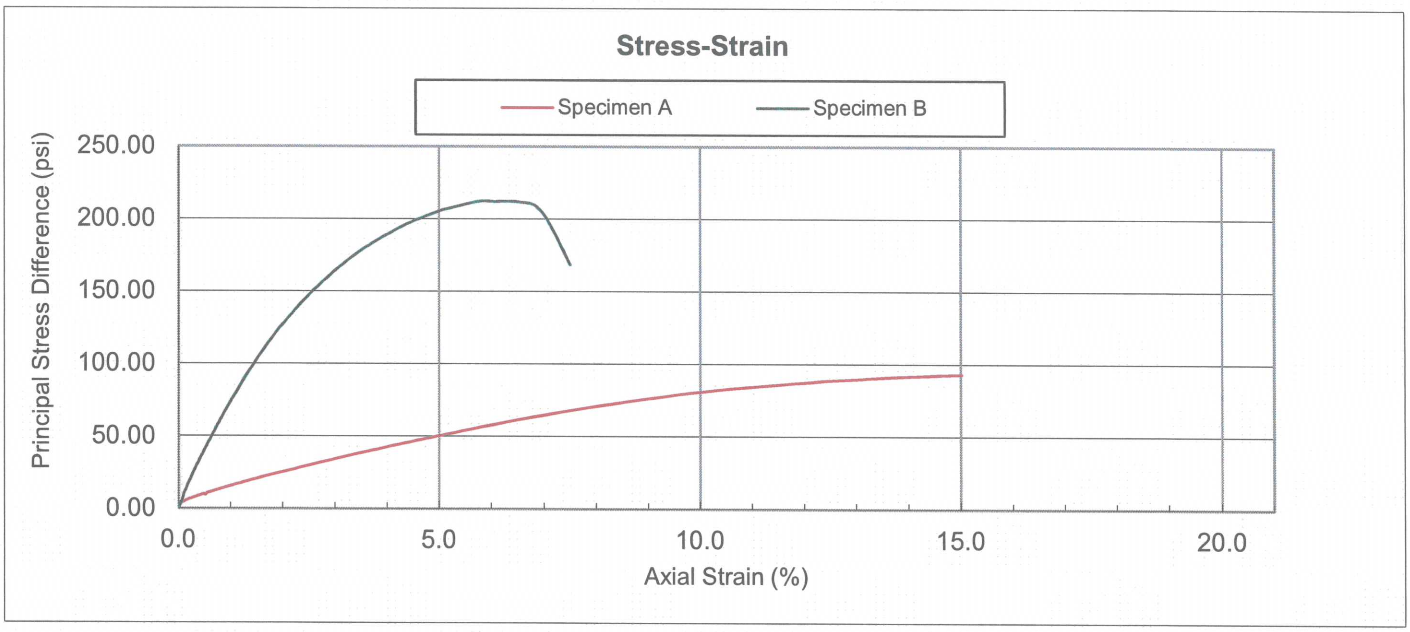
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: B-1 (2.85-3.15m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-161
DATE SAMPLED: 3/7/2016

UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ON COHESIVE SOILS (AASHTO T296)

	Specimen		
Initial Specimen Data	**A**	**B**	**C**
Water Content (%):	14.0%	13.6%	12.9%
Height (cm):	16.59	15.83	
Diameter (cm):	7.31	7.31	
Dry Density (kg/cu.m):	1347.9	1518.1	
Dry Density (pcf):	84.1	94.8	
Void Ratio:	0.97	0.74	
Saturation %:	38%	48%	
Saturation Method:	N/A	N/A	

	Specimen		
Test Data	**A**	**B**	**C**
B Value:	N/A	N/A	
Total Back Pressure (psi):	0.0	0.0	
Eff. Consolidation Stress (psi):	21.8	36.3	
Strain Rate (%/min):	0.65	0.65	
Axial Strain at Failure (%):	15.0	5.8	
Total Major Principal Stress, σ_1 (psi):	115	248	
Total Minor Principal Stress, σ_3 (psi):	22	36	
Deviator Stress, $\sigma_1 - \sigma_3$ (psi):	93	212	



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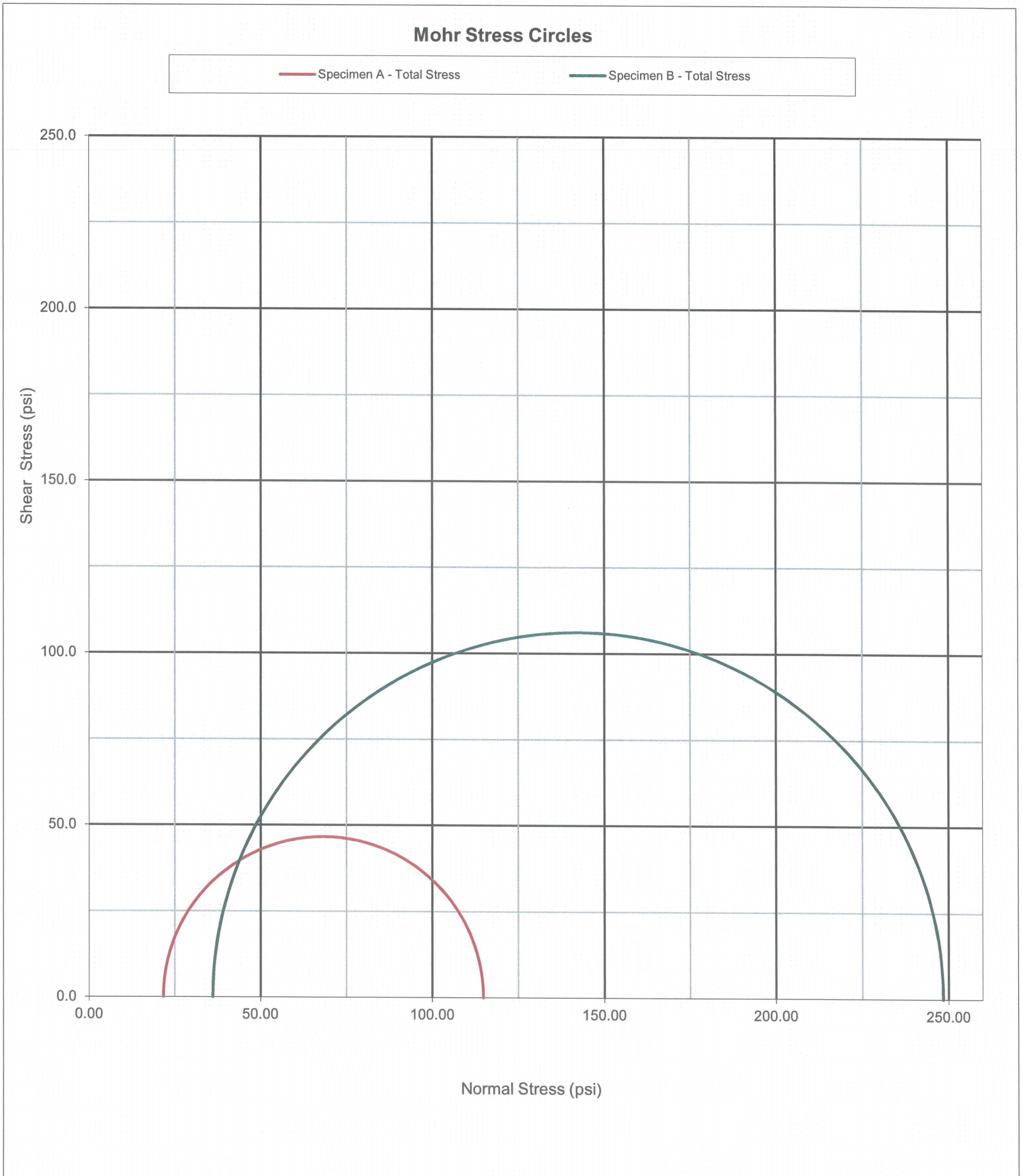
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: B-1 (2.85-3.15m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-161
DATE SAMPLED: 3/7/2016



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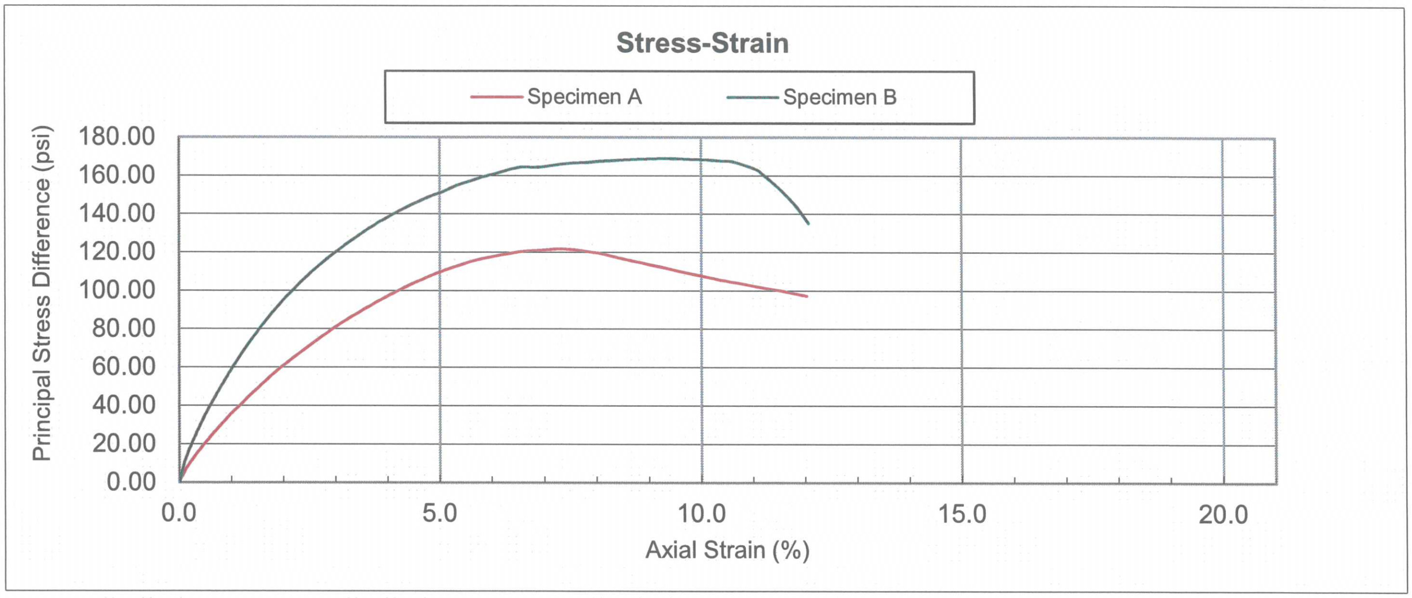
PROJECT:	BIA N8066(3), 8065(1), & School Spur	**JOB NO:**	17-2015-4045
LOCATION:	Black Mesa Community School, AZ	**WORK ORDER NO:**	4
MATERIAL TYPE:	Native Soil	**LAB NO:**	16-1044-186
SAMPLE SOURCE:	B-2 (1.35-1.77m)	**DATE SAMPLED:**	3/7/2016
SAMPLE PREPARATION:	Insitu		

UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ON COHESIVE SOILS (AASHTO T296)

Initial Specimen Data	**A**	**Specimen B**	**C**
Water Content (%):	16.1%	15.2%	
Height (cm):	16.38	16.12	
Diameter (cm):	7.31	7.31	
Dry Density (kg/cu.m):	1445.1	1446.4	
Dry Density (pcf):	90.2	90.3	
Void Ratio:	0.83	0.83	
Saturation %:	51%	48%	
Saturation Method:	N/A	N/A	

Test Data	**A**	**Specimen B**	**C**
B Value:	N/A	N/A	
Total Back Pressure (psi):	0.0	0.0	
Eff. Consolidation Stress (psi):	18.1	32.6	
Strain Rate (%/min):	0.65	0.65	
Axial Strain at Failure (%):	7.3	9.3	
Total Major Principal Stress, σ_1 (psi):	140	201	
Total Minor Principal Stress, σ_3 (psi):	18	32	
Deviator Stress, $\sigma_1 - \sigma_3$ (psi):	122	169	



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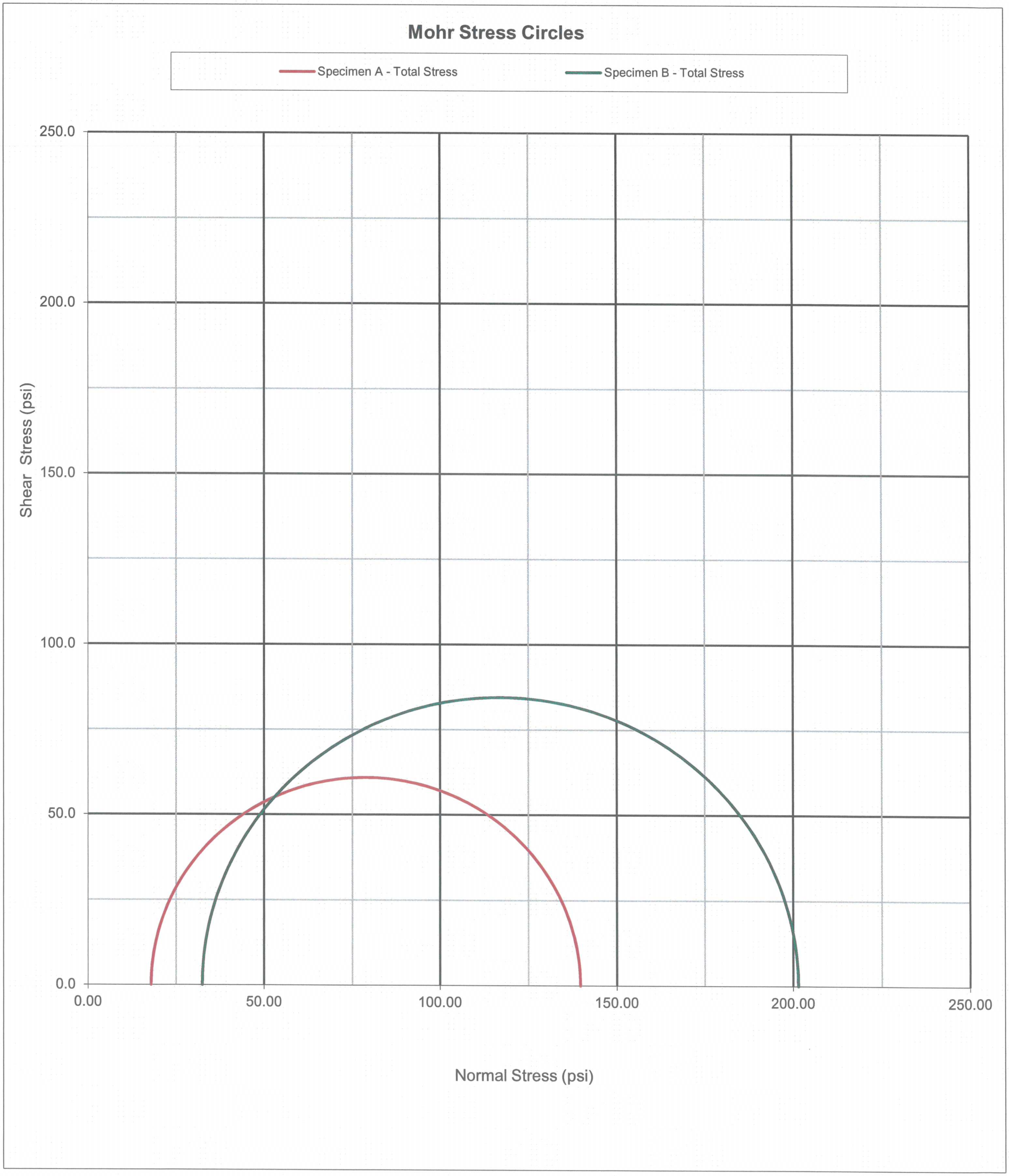
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: B-2 (1.35-1.77m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-186
DATE SAMPLED: 3/7/2016



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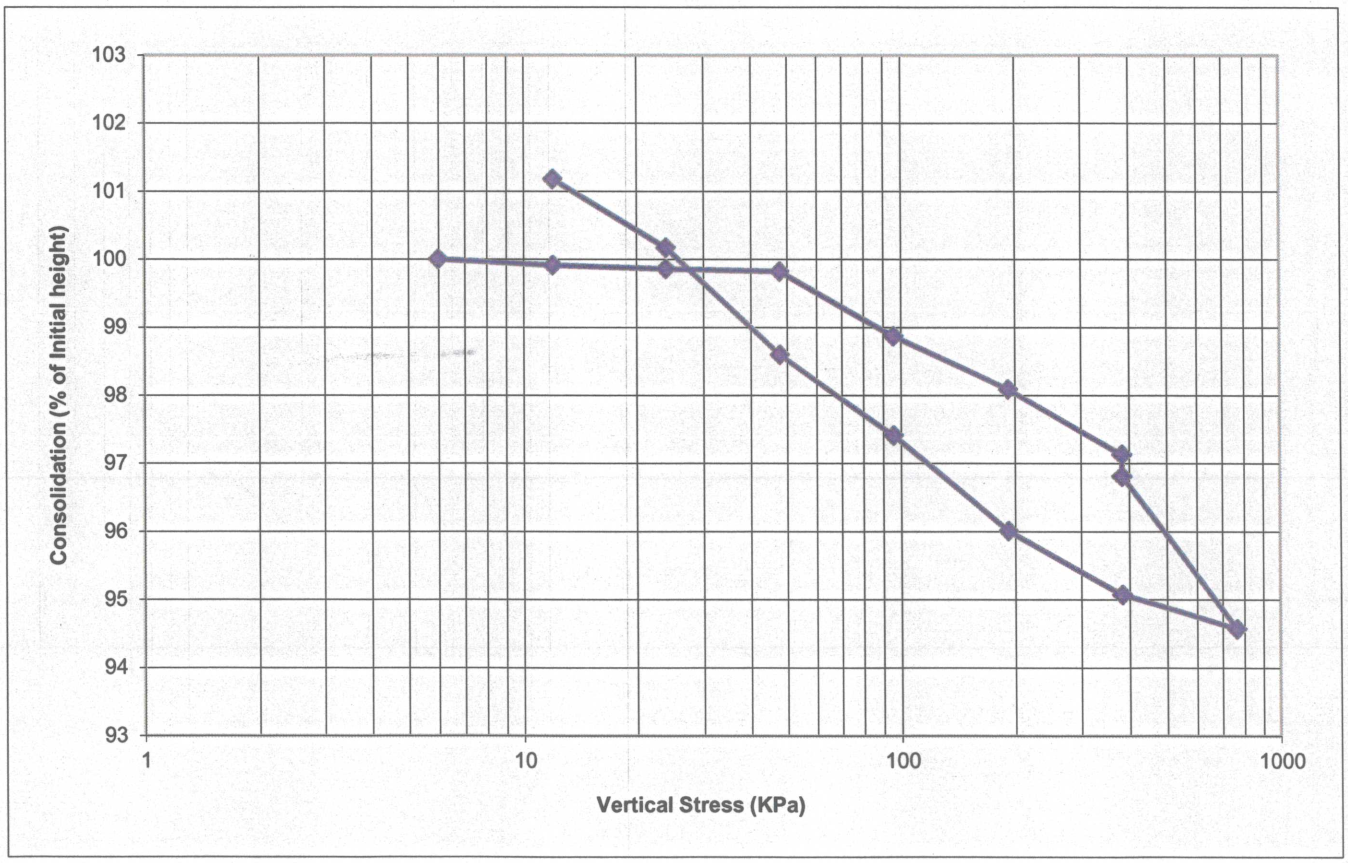
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: B-2 (5.85-6.15m)
SAMPLE PREP: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-189
DATE SAMPLED: 3/7/16

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (AASHTO T216)

INITIAL VOLUME (cu.cm): 75.45
INITIAL MOISTURE CONTENT: 16.1%
INITIAL DRY DENSITY (kg per cu.m): 1610.0
INITIAL DEGREE OF SATURATION: 66%
INITIAL VOID RATIO: 0.65
ESTIMATED SPECIFIC GRAVITY: 2.650

FINAL VOLUME (cu.cm): 71.36
FINAL MOISTURE CONTENT: 21.0%
FINAL DRY DENSITY (kg per cu.m): 1694.2
FINAL DEGREE OF SATURATION: 99%
FINAL VOID RATIO: 0.56
SATURATED AT: 383.14 KPa



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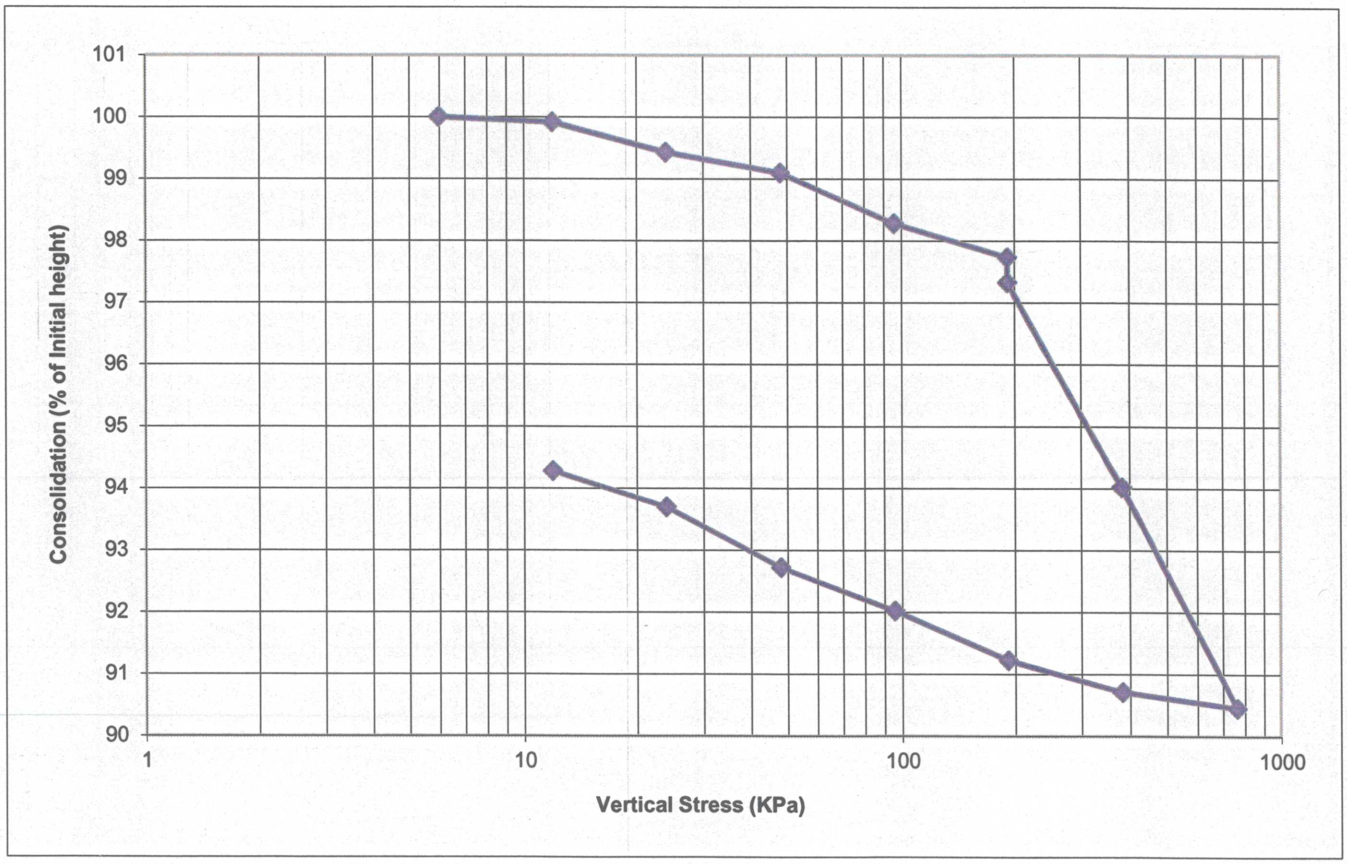
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: B-4 (1.95-2.55m)
SAMPLE PREP: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-233
DATE SAMPLED: 3/7/16

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (AASHTO T216)

INITIAL VOLUME (cu.cm): 75.45
INITIAL MOISTURE CONTENT: 19.9%
INITIAL DRY DENSITY (kg per cu.m): 1511.3
INITIAL DEGREE OF SATURATION: 70%
INITIAL VOID RATIO: 0.76
ESTIMATED SPECIFIC GRAVITY: 2.650

FINAL VOLUME (cu.cm): 68.25
FINAL MOISTURE CONTENT: 22.3%
FINAL DRY DENSITY (kg per cu.m): 1662.9
FINAL DEGREE OF SATURATION: 100%
FINAL VOID RATIO: 0.59
SATURATED AT: 191.57 KPa



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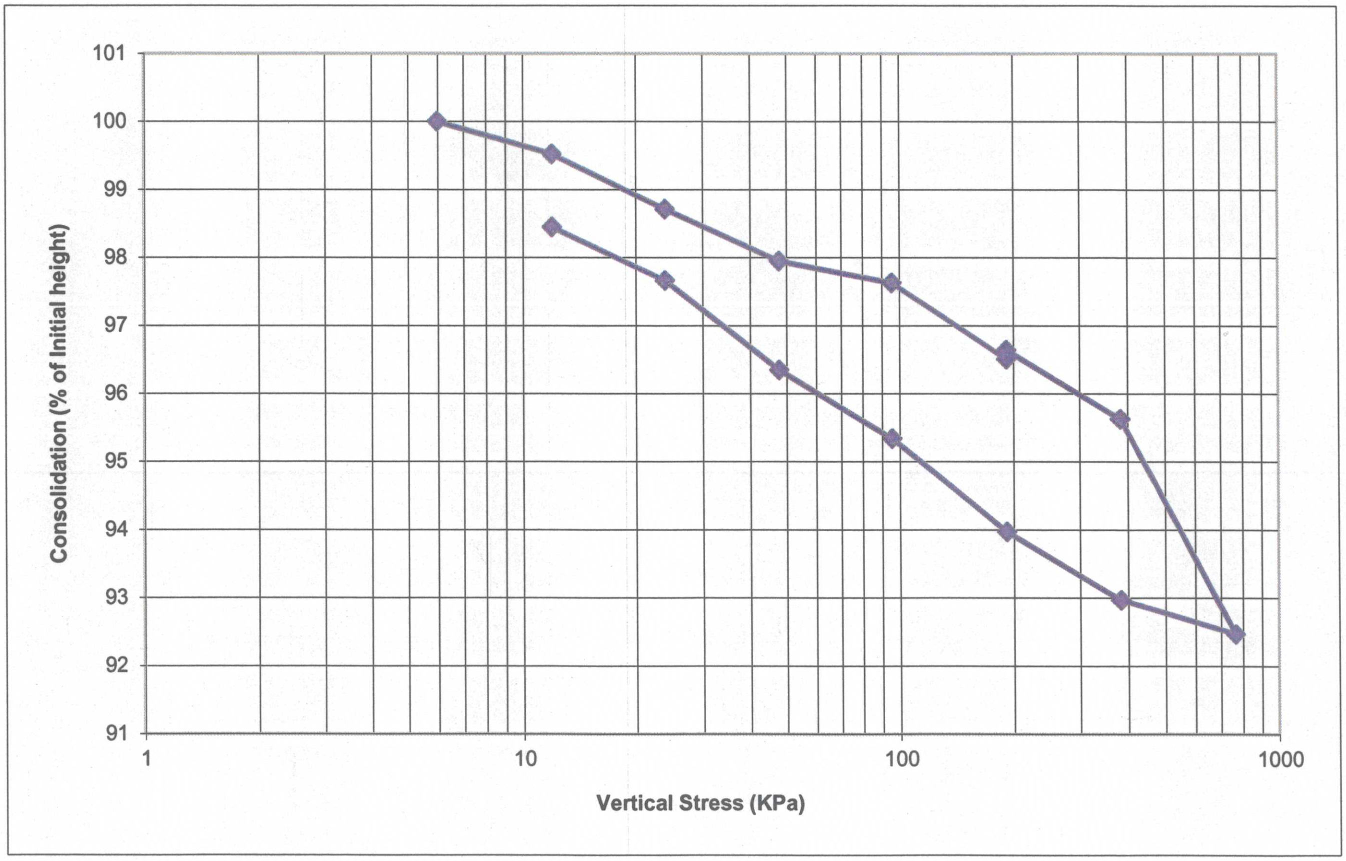
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: B-5 (4.35-4.65m)
SAMPLE PREP: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-248
DATE SAMPLED: 3/7/16

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (AASHTO T216)

INITIAL VOLUME (cu.cm): 75.45
INITIAL MOISTURE CONTENT: 21.9%
INITIAL DRY DENSITY (kg per cu.m): 1530.8
INITIAL DEGREE OF SATURATION: 79%
INITIAL VOID RATIO: 0.74
ESTIMATED SPECIFIC GRAVITY: 2.650

FINAL VOLUME (cu.cm): 69.77
FINAL MOISTURE CONTENT: 22.8%
FINAL DRY DENSITY (kg per cu.m): 1647.5
FINAL DEGREE OF SATURATION: 99%
FINAL VOID RATIO: 0.61
SATURATED AT: 191.57 KPa



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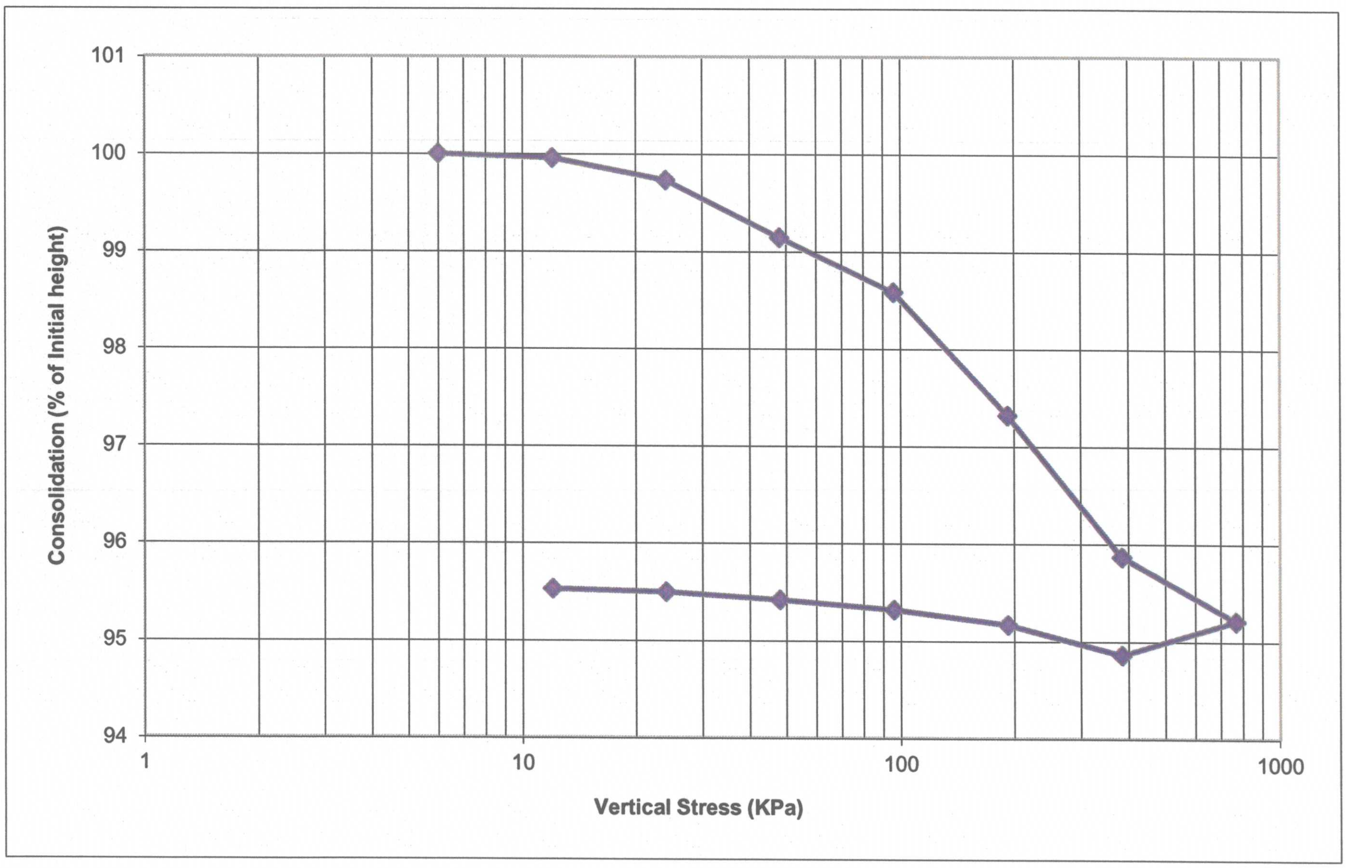
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: B-1 (12.45-12.75m)
SAMPLE PREP: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-170
DATE SAMPLED: 3/7/16

ONE-DIMENSIONAL CONSOLIDATION PROPERTIES OF SOILS (AASHTO T216)

INITIAL VOLUME (cu.cm): 75.45
INITIAL MOISTURE CONTENT: 24.8%
INITIAL DRY DENSITY (kg per cu.m): 1545.0
INITIAL DEGREE OF SATURATION: 92%
INITIAL VOID RATIO: 0.72
ESTIMATED SPECIFIC GRAVITY: 2.650

FINAL VOLUME (cu.cm): 71.57
FINAL MOISTURE CONTENT: 23.3%
FINAL DRY DENSITY (kg per cu.m): 1620.9
FINAL DEGREE OF SATURATION: 97%
FINAL VOID RATIO: 0.63
SATURATED AT: Not Inundated



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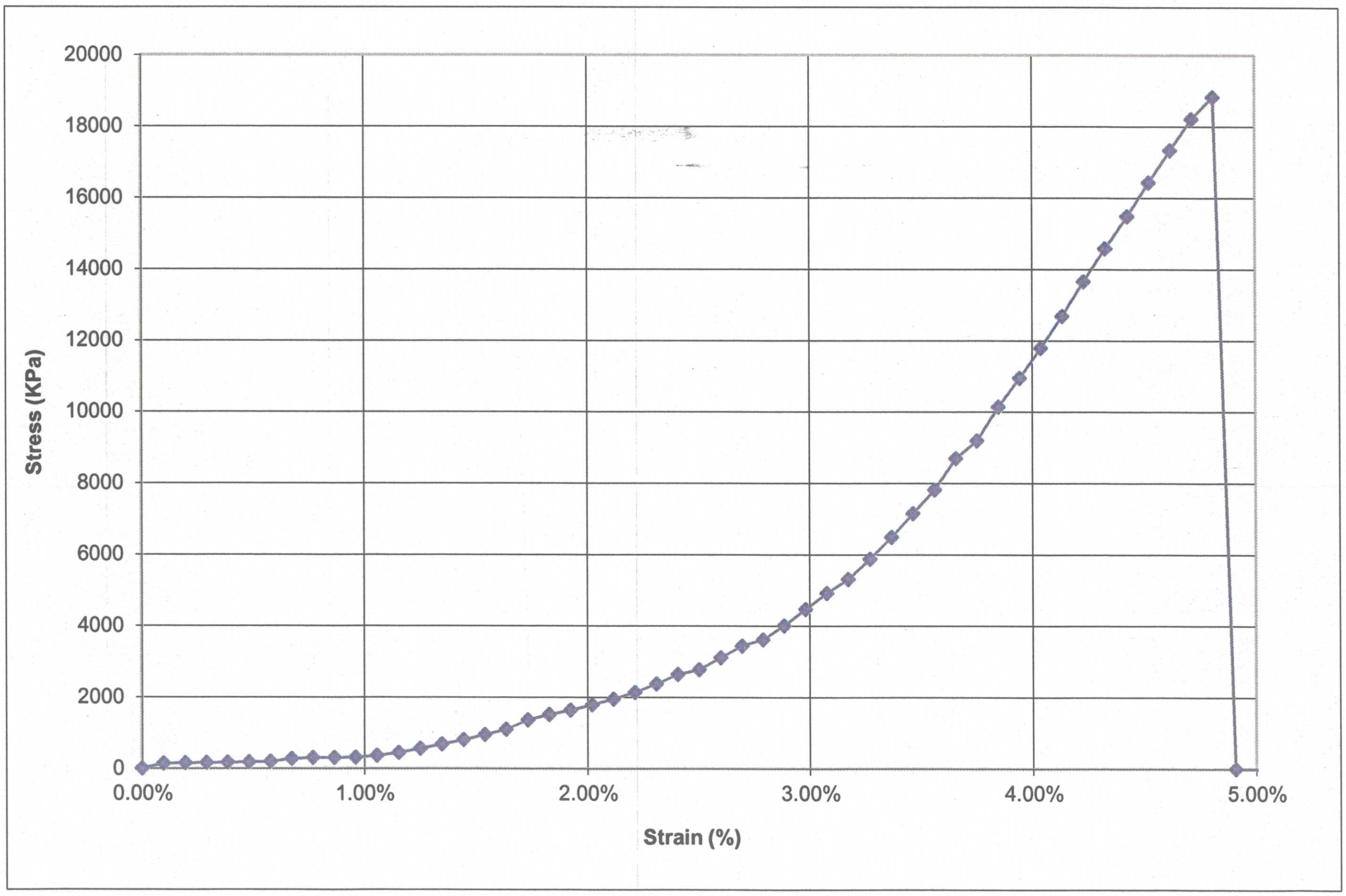
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Rock Core
SAMPLE SOURCE: B-2 (21.72-21.93m)
SAMPLE PREP: INSITU

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-201
DATE SAMPLED: 03/07/16

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	6.09
HEIGHT (cm):	13.20
STRAIN RATE(cm/min):	0.05
DRY DENSITY (kg/cu.m):	1,805.4

MAXIMUM STRESS (kPa):	18,821
AT STRAIN:	4.81%



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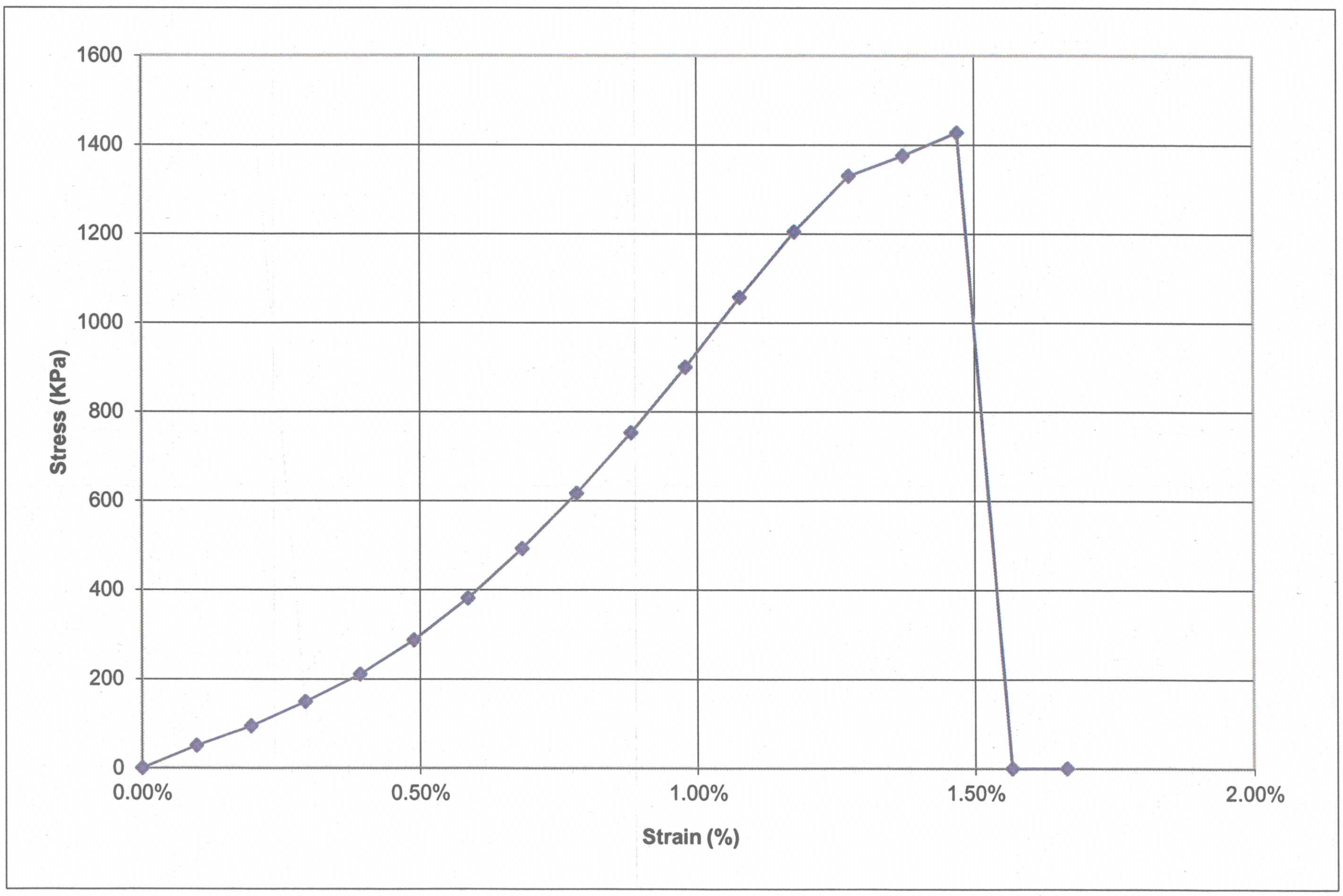
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Rock Core
SAMPLE SOURCE: B-2 (25.35-25.50m)
SAMPLE PREP: INSITU

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-202
DATE SAMPLED: 03/07/16

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	6.01	MAXIMUM STRESS (kPa):	1,427
HEIGHT (cm):	12.96	AT STRAIN:	1.47%
STRAIN RATE(cm/min):	0.05		
DRY DENSITY (kg/cu.m):	1,725.7		



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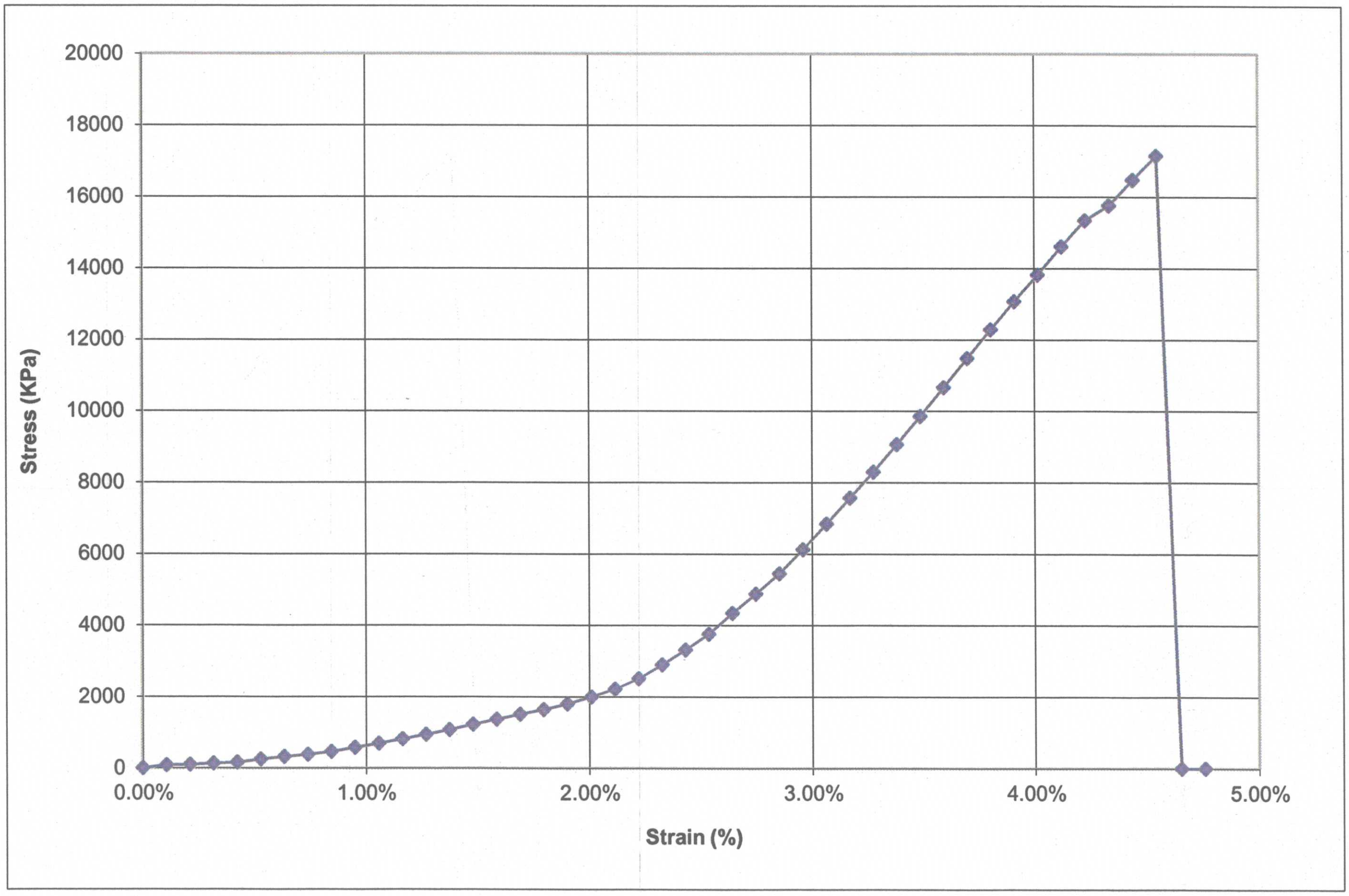
PROJECT:	BIA N8066(3), 8065(1), & School Spur	**JOB NO:**	17-2015-4045
LOCATION:	Black Mesa Community School, AZ	**WORK ORDER NO:**	4
MATERIAL:	Rock Core	**LAB NO:**	16-1044-203
SAMPLE SOURCE:	B-2 (24.00-24.15m)	**DATE SAMPLED:**	03/07/16
SAMPLE PREP:	INSITU		

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	5.81	MAXIMUM STRESS (kPa):	17,145
HEIGHT (cm):	12.01	AT STRAIN:	4.55%
STRAIN RATE(cm/min):	0.05		
DRY DENSITY (kg/cu.m):	2,227.0		



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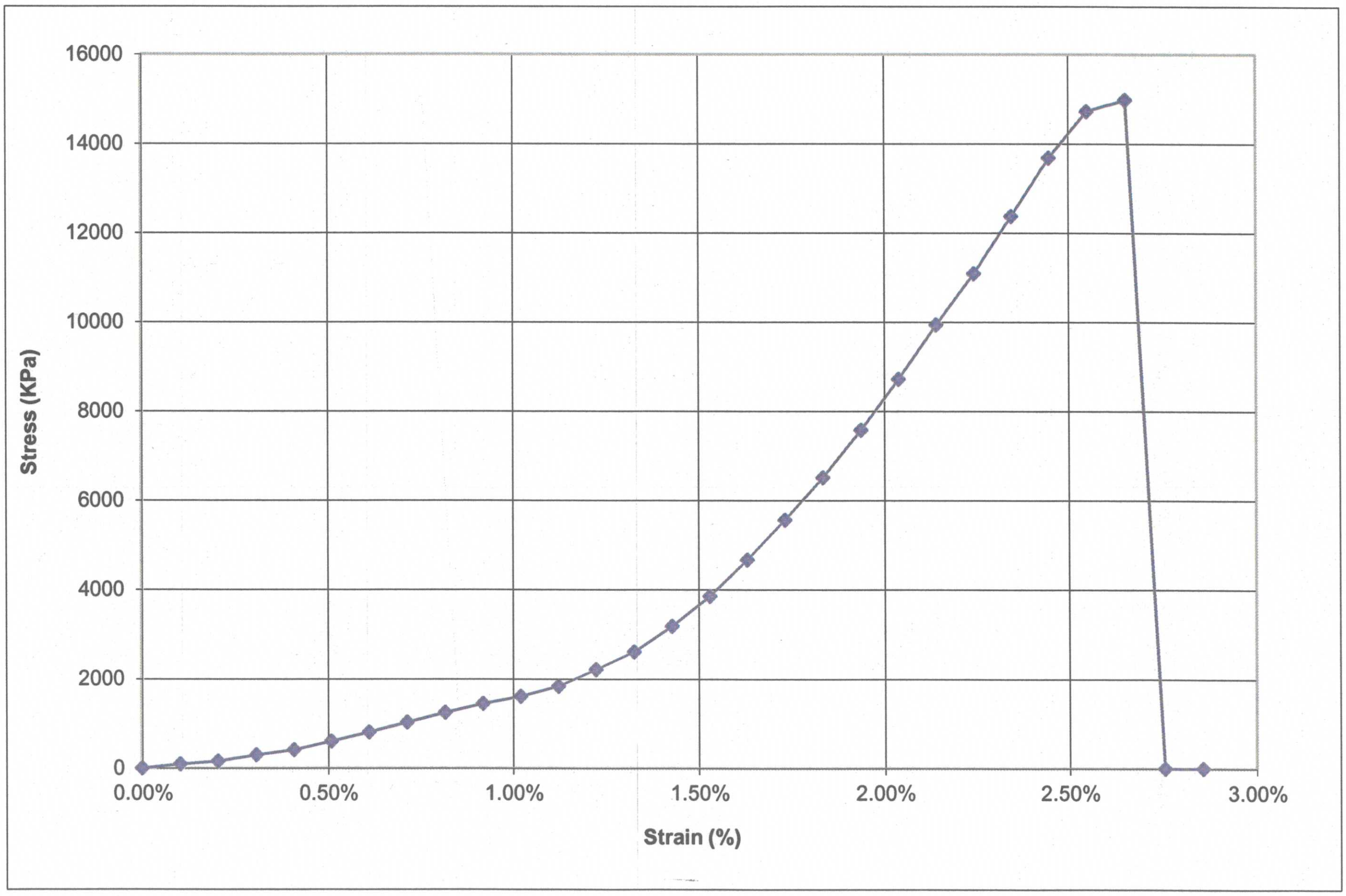
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Rock Core
SAMPLE SOURCE: B-2 (26.70-27.00m)
SAMPLE PREP: INSITU

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-204
DATE SAMPLED: 03/07/16

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	6.09
HEIGHT (cm):	12.45
STRAIN RATE(cm/min):	0.05
DRY DENSITY (kg/cu.m):	1,854.2

MAXIMUM STRESS (kPa):	14,976
AT STRAIN:	2.65%



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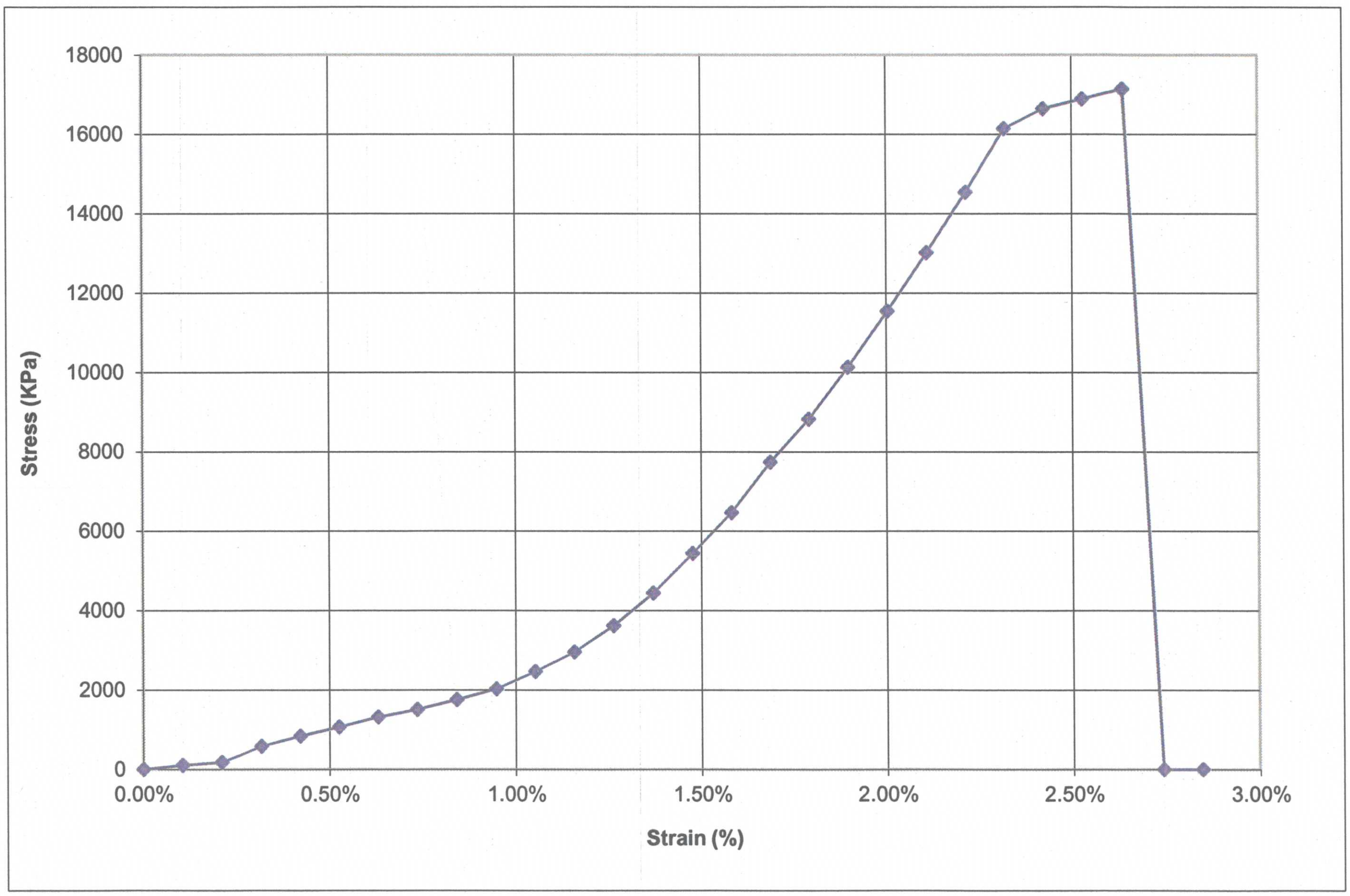
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Rock Core
SAMPLE SOURCE: B-3 (29.10-29.40m)
SAMPLE PREP: INSITU

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-227
DATE SAMPLED: 03/07/16

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	5.82	MAXIMUM STRESS (kPa):	17,139
HEIGHT (cm):	12.04	AT STRAIN:	2.64%
STRAIN RATE(cm/min):	0.05		
DRY DENSITY (kg/cu.m):	2,022.1		



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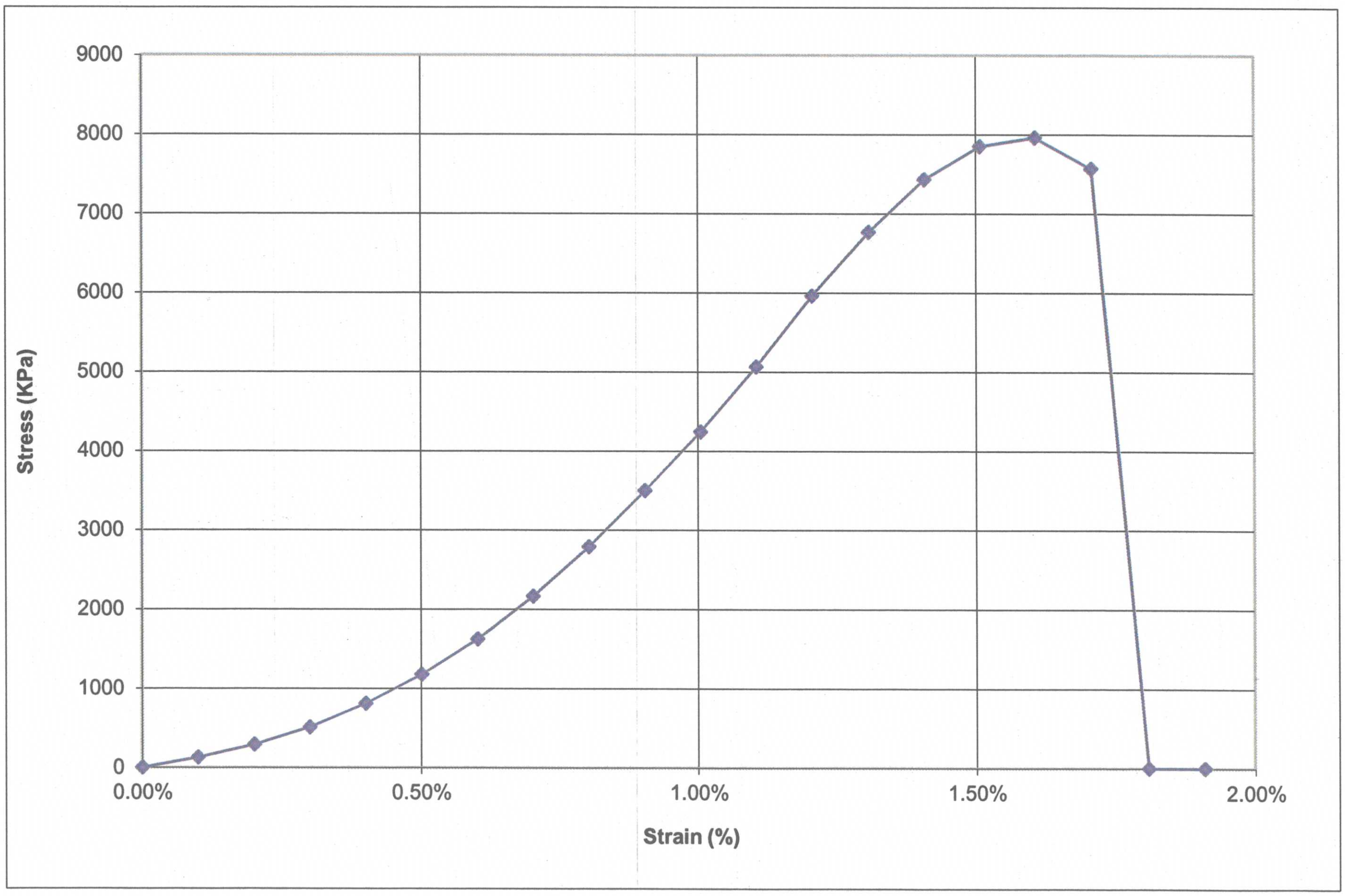
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Rock Core
SAMPLE SOURCE: B-4 (9.00-9.15m)
SAMPLE PREP: INSITU

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-239
DATE SAMPLED: 03/07/16

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	5.84
HEIGHT (cm):	12.63
STRAIN RATE(cm/min):	0.05
DRY DENSITY (kg/cu.m):	2,143.9

MAXIMUM STRESS (kPa):	7,962
AT STRAIN:	1.61%



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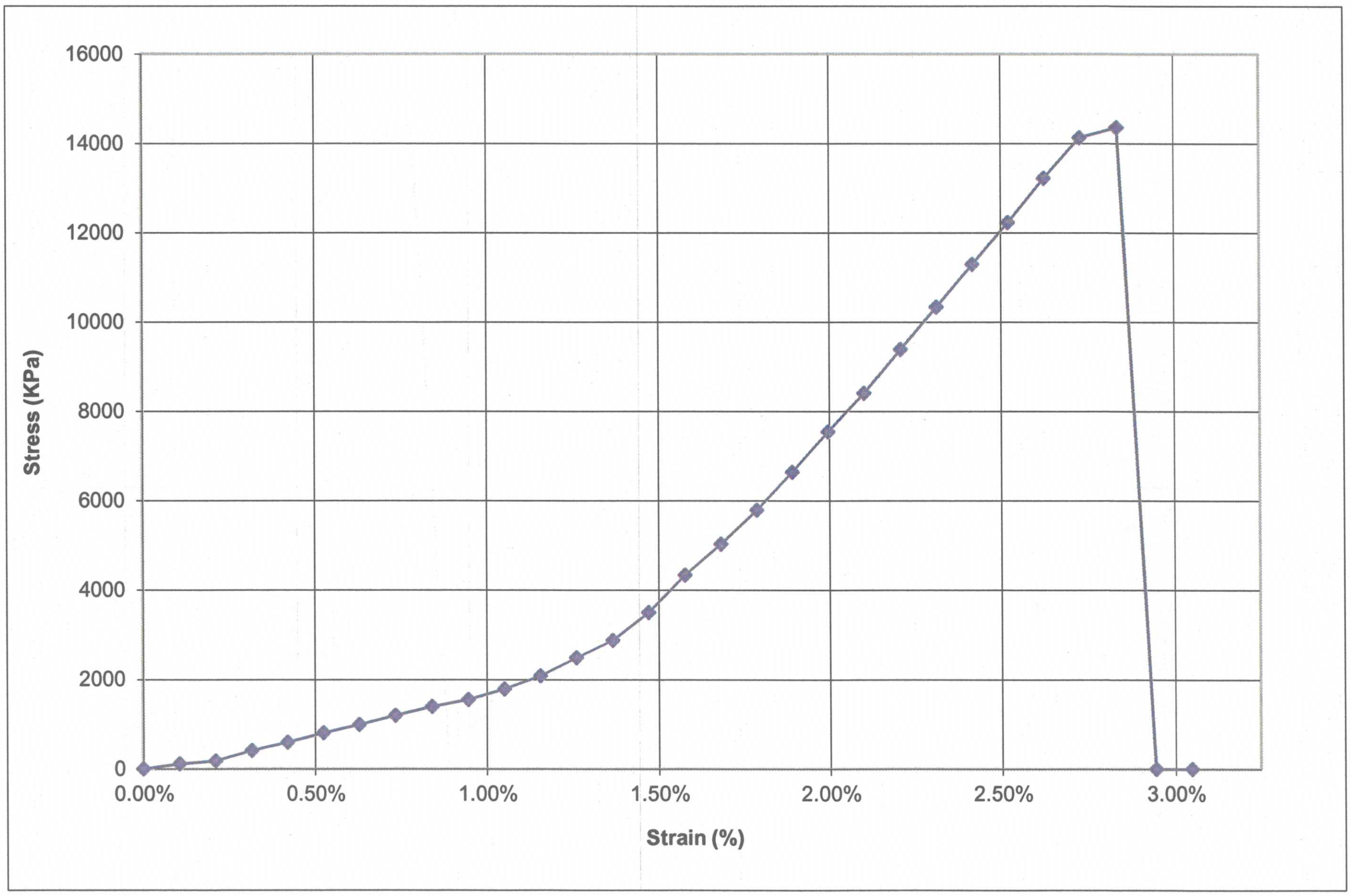
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Rock Core
SAMPLE SOURCE: B-4 (13.80-13.92m)
SAMPLE PREP: INSITU

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-241
DATE SAMPLED: 03/07/16

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	5.99
HEIGHT (cm):	12.08
STRAIN RATE(cm/min):	0.05
DRY DENSITY (kg/cu.m):	2,249.4

MAXIMUM STRESS (kPa):	14,352
AT STRAIN:	2.84%



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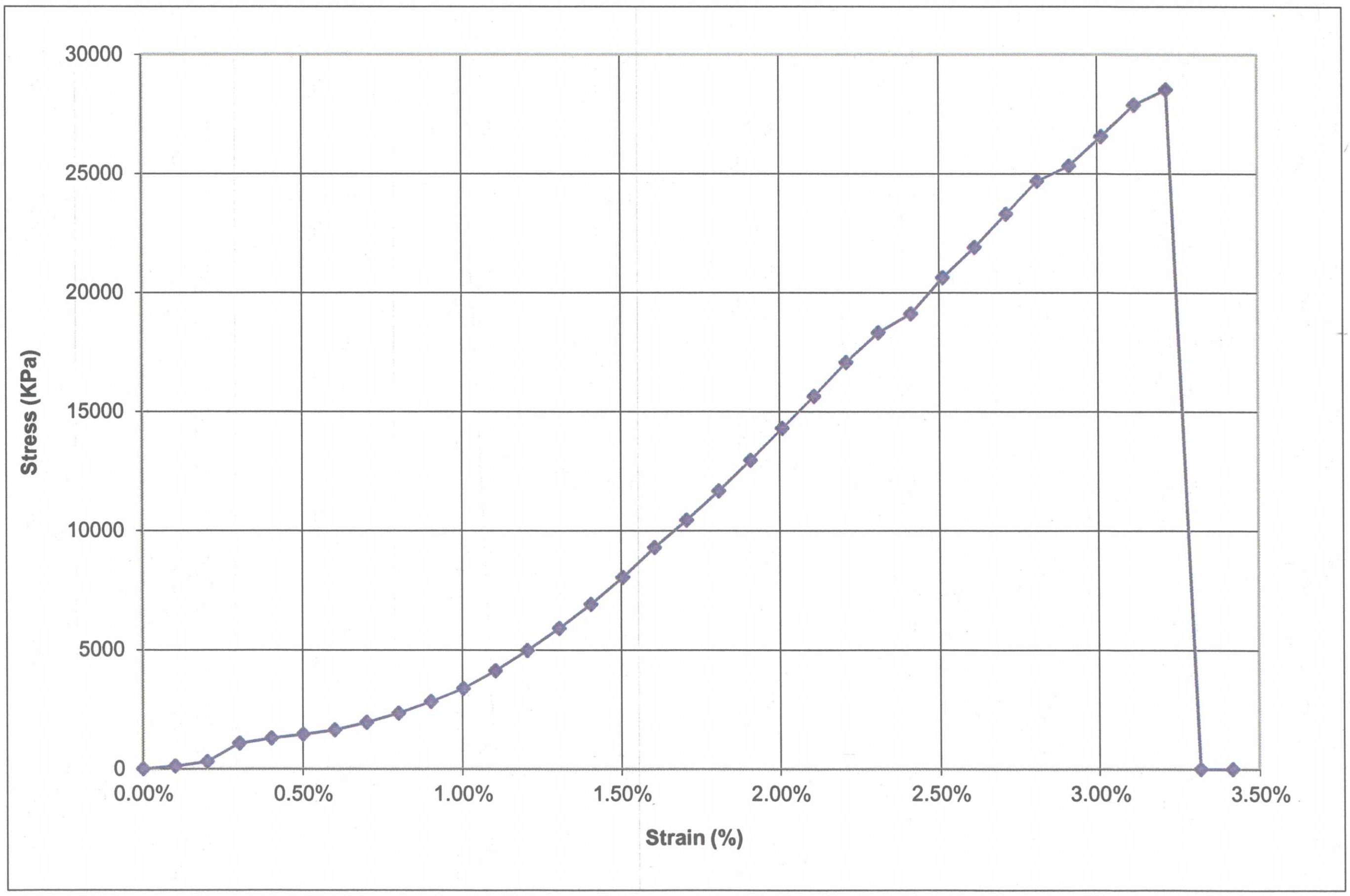
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Rock Core
SAMPLE SOURCE: B-4 (14.43-14.70m)
SAMPLE PREP: INSITU

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-242
DATE SAMPLED: 03/07/16

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	5.99
HEIGHT (cm):	12.64
STRAIN RATE(cm/min):	0.05
DRY DENSITY (kg/cu.m):	2,288.6

MAXIMUM STRESS (kPa):	28,524
AT STRAIN:	3.21%



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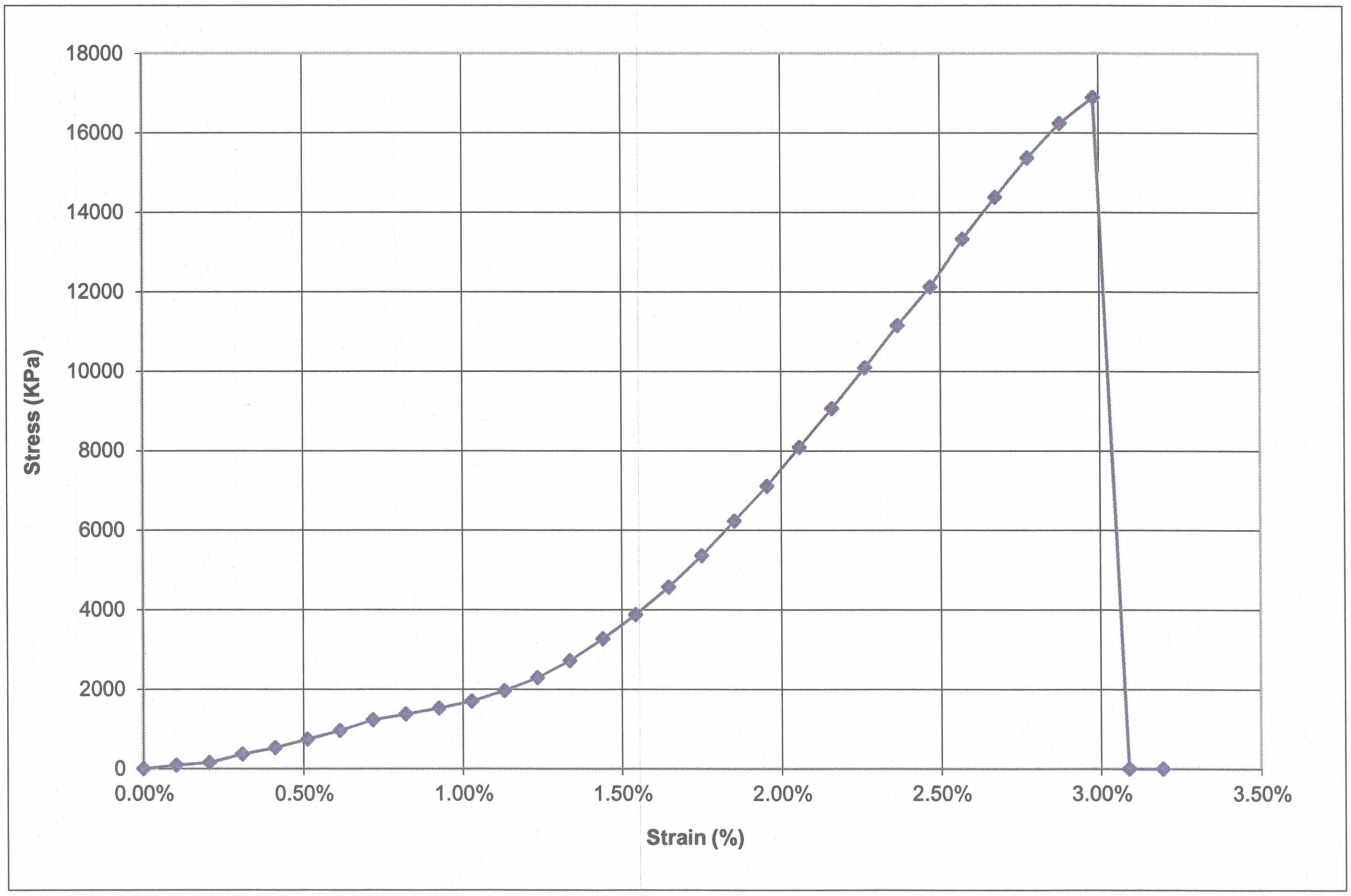
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Rock Core
SAMPLE SOURCE: B-5 (22.14-22.44m)
SAMPLE PREP: INSITU

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-262
DATE SAMPLED: 03/07/16

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	6.02
HEIGHT (cm):	12.34
STRAIN RATE(cm/min):	0.05
DRY DENSITY (kg/cu.m):	2,298.6

MAXIMUM STRESS (kPa):	16,890
AT STRAIN:	2.98%



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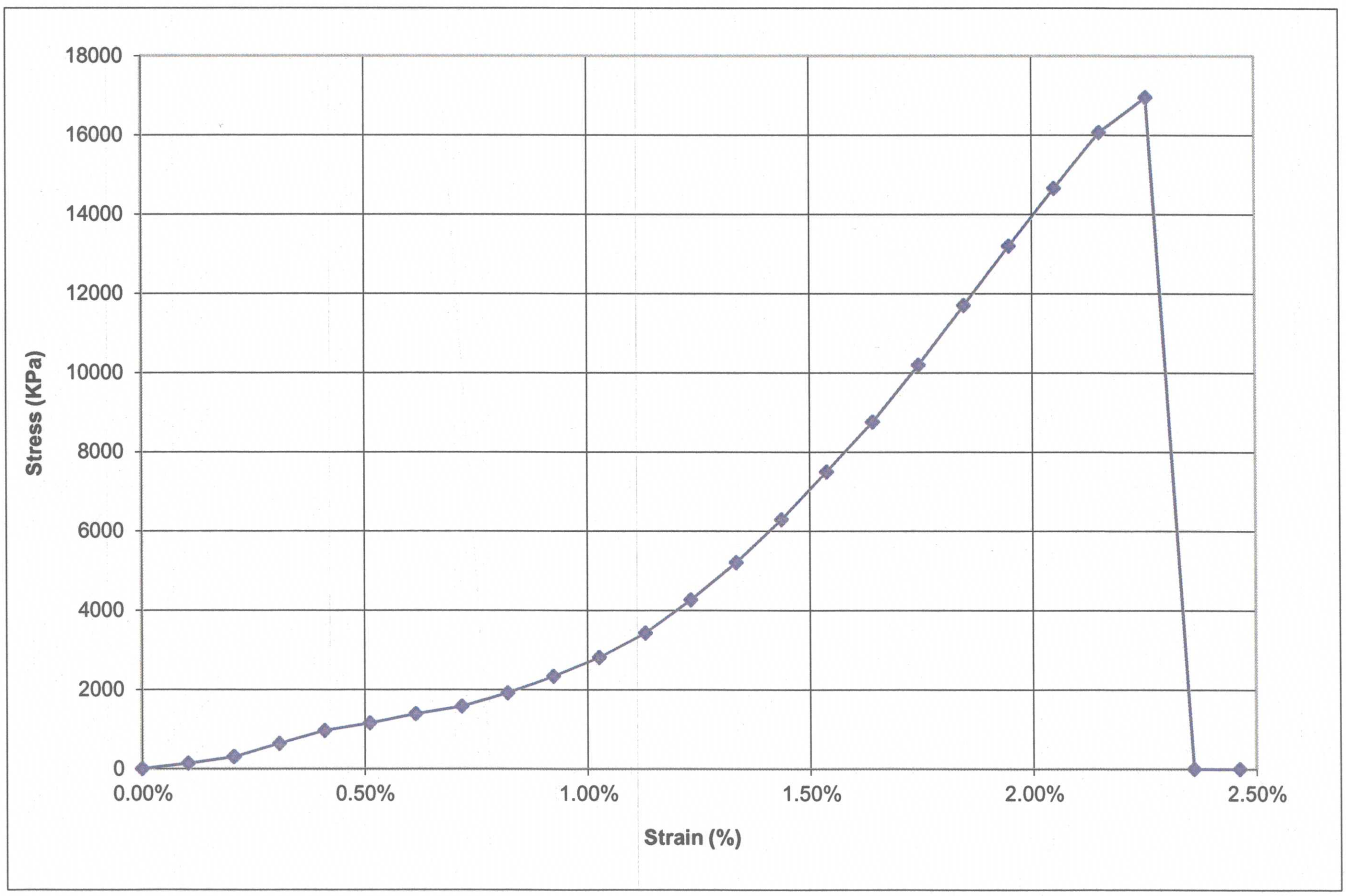
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Rock Core
SAMPLE SOURCE: B-5 (22.95-23.40m)
SAMPLE PREP: INSITU

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-263
DATE SAMPLED: 03/07/16

UNCONFINED COMPRESSIVE STRENGTH OF ROCK CORE SPECIMENS
(AASHTO T208)

DIAMETER (cm):	6.05	MAXIMUM STRESS (kPa):	16,951
HEIGHT (cm):	12.38	AT STRAIN:	2.26%
STRAIN RATE(cm/min):	0.05		
DRY DENSITY (kg/cu.m):	1,923.4		



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ATTACHMENT C

DESIGN CALCULATIONS

BOX CULVERT MAT FOUNDATION

Factored Bearing Resistance	$q_R = \phi_b q_n =$	**6.23**	ksf
Resistance Factor (see Table 10.5.5.2.2-1)	$\phi_b =$	0.45	
Nominal Bearing Resistance	$q_n = cN_{cm} + \gamma D_f N_{qm} C_{wq} + 0.5\gamma B N_{\gamma m} C_{w\gamma} =$	13.84	ksf
Modified Bearing Capacity Factors	$N_{cm} = N_c s_c i_c$ $\quad N_{qm} = N_q s_q d_q i_q$ $\quad N_{\gamma m} = N_\gamma s_\gamma i_\gamma$		

Limits: 10 50

Soil Properties

c	Soil Cohesion	0.75	ksf
ϕ_f	Soil Friction Angle	14	degrees
γ	Soil Unit Weight	0.13	kcf
n	$n = [(2 + L/B)/(1 + L/B)]\cos^2\theta + [(2 + B/L)/(1 + B/L)]\sin^2\theta$	1.55	dim

Loading Properties

H	Unfactored Horizontal Load	1	kips
V	Unfactored Vertical Load	200	kips
θ	Projected Direction of Load (see Figure C10.6.3.1a-1)	10	degrees

Fondation Properties

B	Foundation Least Dimension	50.0	feet
L	Foundation Greater Dimension	40.0	feet
D_f	Depth to Base of Foundation	1.0	feet
D_w	Depth to Groundwater	120.0	feet
D_f/B	Used for Depth Factor (see Table 10.6.3.1.2a-4)	0.02	dim

Depth and Correction Factors

d_q	Depth Factor (see Table 10.6.3.1.2a-4)	1.00	dim
C_{wq}	Correction Factor for groundwater	1.00	dim
$C_{w\gamma}$	Correction Factor for groundwater	1.00	dim

Bearing Capacity Factors

$N_c = (N_q - 1)\cot\phi_f$	10.4
$N_q = e^{\pi\tan\phi}\tan^2(45 + \phi/2)$	3.6
$N_\gamma = 2(N_q - 1)\tan\phi_f$	1.3

Footing Shape Factors

If $\phi_f = 0$	If $\phi_f > 0$	
$s_c = 1 + (B/5L)$	$s_c = 1 + (B/L)(N_q/N_c)$	1.43
$s_q = 1.0$	$s_q = 1 + (B/L)(\tan\phi_f)$	1.31
$s_\gamma = 1.0$	$s_\gamma = 1 - 0.4(B/L)$	0.50

Inclination Factors

If $\phi_f = 0$	If $\phi_f > 0$	
$i_c = 1 - (nH/cBLN_c)$	$i_c = i_q - [(1 - i_q)/(N_q - 1)]$	1.00
	$i_q = [1 - H/(V + cBL\cot\phi_f)]^n$	1.00
	$i_\gamma = [1 - H/(V + cBL\cot\phi_f)]^{(n+1)}$	1.00

Reference: American Association of State Highway and Transportation Officials (AASHTO), 2010 LRFD Bridge Design Specifications, Fifth Edition, Washington DC

Notes: N_γ is an approximation based on Vesic 1975. Values are conservative for friction angles between 15 and 45 degrees by less than 10%, and less than 5% for friction angles between 20 and 40 degrees. Additonal capacity may be obtained by using values for N_γ provided in Table 10.6.3.2a-1.

Depth Factors		
ϕ_f	14	degrees
D_f/B	0.02	(dim)
ϕ_f	D_f/B	d_q
32	1	1.20
	2	1.30
	4	1.35
	8	1.40
37	1	1.20
	2	1.25
	4	1.30
	8	1.35
42	1	1.15
	2	1.20
	4	1.25
	8	1.30

Table 10.6.3.1.2a-4 (AASHTO, 2010)

Method/soil/Conditon			Resistance Factor
Bearing Resistance	ϕ_b	Theoretical Method (Munfakh et al., 2001), in clay	0.50
		Theoretical Method (Munfakh et al., 2001), in sand, using CPT	0.50
		Theoretical Method (Munfakh et al., 2001), in sand, using SPT	0.45
		Semi-empirical methods (Meyerhof, 1957), all soils	0.45
		Footings on rock	0.45
		Plate Load Test	0.55

Upper Limits	Width
4359	10
4421	11
4482	12
4542	13
4601	14
4660	15
4717	16
4774	17
4831	18
4886	19
4941	20
4995	21
5048	22
5100	23
5152	24
5203	25
5253	26
5302	27
5351	28
5398	29
5446	30
5492	31
5537	32
5582	33
5626	34
5670	35
5712	36
5754	37
5795	38
5835	39
5875	40
5913	41
5951	42
5989	43
6025	44
6061	45
6096	46
6130	47
6164	48
6196	49
6228	50

Project Name:	Box Culvert
Project #:	17-2015-4045
Date:	4/13/2016
User:	NC

Input

Hammer Type	3	(Safety(1) or Donut(2), or Automatic(3))
Borehole Diameter	7	[in]
Sampling Method	1	(Standard sampler(1) or Sampler without liner(2))

Correction Values

C_{ER}	1.3	Correction for energy ratio
C_B	1.05	Correction for borehole diameter
C_S	1	Correction for sampling method
C_R	Function of Depth	Correction for rod length
C_N	Function of Depth	Correction for overburden = $2/(1+\sigma_{vo}/p_a)$

N_{60} N corrected for field procedures = $C_{ER}*C_B*C_S*C_R*N$

$(N_1)_{60}$ N_{60} corrected for overburden = C_N*N_{60}

N_1 N corrected for overburden =C_N*N

Elastic modulus is a function of Soil Type

Soil Type

1	sand with fines, silts, sandy silts, slightly cohesive mixtures
2	clean NC sands, clean fine to medium sands and slightly silty sands
3	clean OC sands, coarse sands and sands with little gravel
4	sandy gravels and gravels
5	submerged sand
6	clay
7	cemented fine-grained soils

Avg. Effec. Unit Weight (γ') 130 [pcf]

Atmospheric Pressure (p_a) 2116 [pcf]

Which Column: 1 / Avg Em Values

Depth [ft]	C_R	N	N_{60}	N_{55}	C_N	N_1	$(N_1)_{60}$	Soil Type	1 Kulhawy & Mayne 1990 E_{N60} [ksf]	2 AASHTO 1996 $E_{(N1)}$ [ksf]	3 Bowles 1996 E_{N55} [ksf]	4 Hansen & Beckwith E_N [ksf]	Design Values
0	0.75	5	5	6	2.0	10	10	6	113	No Corr.	No Corr.	No Corr.	112,842
5	0.75	6	6	6	1.5	9	9	6	123	No Corr.	No Corr.	No Corr.	123,255
10	0.85	9	11	12	1.2	11	13	6	166	No Corr.	No Corr.	No Corr.	166,415
15	0.95	6	7	8	1.0	6	8	6	123	No Corr.	No Corr.	No Corr.	123,255
20	0.95	8	11	12	0.9	7	10	6	155	No Corr.	No Corr.	No Corr.	154,815
25	1	3	4	5	0.8	3	3	6	86	No Corr.	No Corr.	No Corr.	85,966
30	1	6	8	9	0.7	4	6	5	100	No Corr.	123	No Corr.	99,648
35	1	3	3	4	0.6	2	2	5	43	No Corr.	98	No Corr.	43,325
40	1	5	7	8	0.6	3.0	4	5	91	No Corr.	119	No Corr.	90,983
45	1	4	5	5	0.5	1.9	3	5	61	No Corr.	106	No Corr.	60,655
50	1	15	20	22	0.5	7.1	10	5	251	No Corr.	191	No Corr.	251,286
55	1	36	49	53	0.5	16.3	22	5	620	No Corr.	356	No Corr.	619,549
60	1	100	137	149	0.4	42.7	58	Rock	0	0	0	FALSE	1,300,000
65	1	100	137	149	0.4	40.1	55	Rock	0	0	0	FALSE	1,300,000
70	1	100	137	149	0.4	37.7	52	Rock	0	0	0	FALSE	1,300,000
75	1	100	137	149	0.4	35.7	49	Rock	0	0	0	FALSE	1,300,000
80	1	100	137	149	0.3	33.8	46	Rock	0	0	0	FALSE	1,300,000
85	1	100	137	149	0.3	32.1	44	Rock	0	0	0	FALSE	1,500,000
90	1	100	137	149	0.3	30.6	42	Rock	0	0	0	FALSE	1,500,000
95	1	100	137	149	0.3	29.3	40	Rock	0	0	0	FALSE	1,500,000
100	1	100	137	149	0.3	28.0	38	Rock	0	0	0	FALSE	1,500,000
105	1	100	137	149	0.3	26.8	37	Rock	0	0	0	FALSE	1,500,000
110	1	100	137	149	0.3	25.8	35	Rock	0	0	0	FALSE	1,500,000
115	1	100	137	149	0.2	24.8	34	Rock	0	0	0	FALSE	1,500,000
120	1	100	137	149	0.2	23.9	33	Rock	0	0	0	FALSE	1,500,000
125	1	100	137	149	0.2	23.0	31	Rock	0	0	0	FALSE	1,500,000

Kulhawy and Mayne (1990) Manual on Estimating Soil Properties for Foundation Design
AASHTO (1996) Standard Specifications for Highway Bridges - 16th edition
Bowles (1996) Foundation Analysis and Design - 5th edition
Hansen and Beckwith

Note: Check formulas to ensure that correct cells are used in the calculations

Depth	Depth	B-1	B-2	B-3	B-4	B-5	AVG	(AVG+MIN)/2	Lower Quartile (for comparison)
	~~0~~			~~33~~		~~3~~	~~18~~	~~11~~	10.5
Scour	~~2.5~~			~~1~~		~~6~~	~~4~~	~~2~~	2.25
0	5			5		5	5	5	5
5	10			8		5	7	6	5.75
10	15			10		9	10	9	9.25
15	20			5		8	7	6	5.75
20	25			8		9	9	8	8.25
25	30			3		4	4	3	3.25
30	35			5		8	7	6	5.75
35	40			2		4	3	3	2.5
40	45			5		6	6	5	5.25
45	50			3		5	4	4	3.5
50	55			11		25	18	15	14.5
55	60			77		22	50	36	35.75
60	65			100		100	100	100	100
65	70			100		100	100	100	100
70	75			100		100	100	100	100
75	80			100		100	100	100	100
80	85			100		100	100	100	100
85	90			100		100	100	100	100
90	95			100		100	100	100	100
95	100			100		100	100	100	100
100	105			100		100	100	100	100
105	110			100		100	100	100	100
110	115			100		100	100	100	100
115	120			100		100	100	100	100
120	125			100		100	100	100	100
125	130			100		100	100	100	100

Note: Check formulas to ensure that correct cells are used in the calculations

Depth	B-1	B-2	B-3	B-4	B-5	AVG	(AVG+MIN)/2	Lower Quartile
				Ei (ksi)				
30						#DIV/0!	#DIV/0!	#NUM!
35				112.07		112	112	112.07
40						#DIV/0!	#DIV/0!	#NUM!
45				123.94		124	124	123.94
50				173.47		173	173	173.47
55						#DIV/0!	#DIV/0!	#NUM!
60						#DIV/0!	#DIV/0!	#NUM!
65						#DIV/0!	#DIV/0!	#NUM!
70						#DIV/0!	#DIV/0!	#NUM!
75		125.7			147.68	137	131	131.195
80		103.94			195.14	150	127	126.74
85		21.27				21	21	21.27
90		162.44				162	162	162.44
95						#DIV/0!	#DIV/0!	#NUM!
100			189.87			190	190	189.87

Depth	B-1	B-2	B-3	B-4	B-5	AVG	(AVG+MIN)/2	Lower Quartile
Em - Low GSI (ksi)								
30						#DIV/0!	#DIV/0!	#NUM!
35				6.17		6	6	6.16608725
40						#DIV/0!	#DIV/0!	#NUM!
45				6.82		7	7	6.81894905
50				9.54		10	10	9.54381878
55						#DIV/0!	#DIV/0!	#NUM!
60						#DIV/0!	#DIV/0!	#NUM!
65						#DIV/0!	#DIV/0!	#NUM!
70						#DIV/0!	#DIV/0!	#NUM!
75		6.92			8.12	8	7	7.21814225
80		5.72			10.74	8	7	6.97311759
85		1.17				1	1	1.1703491
90		8.94				9	9	8.93719099
95						#DIV/0!	#DIV/0!	#NUM!
100			10.45			10	10	10.4460761

Depth	B-1	B-2	B-3	B-4	B-5	AVG	(AVG+MIN)/2	Lower Quartile
Em - High GSI (ksi)								
30						#DIV/0!	#DIV/0!	#NUM!
35				8.91		9	9	8.91493601
40						#DIV/0!	#DIV/0!	#NUM!
45				9.86		10	10	9.85884435
50				13.80		14	14	13.7984641
55						#DIV/0!	#DIV/0!	#NUM!
60						#DIV/0!	#DIV/0!	#NUM!
65						#DIV/0!	#DIV/0!	#NUM!
70						#DIV/0!	#DIV/0!	#NUM!
75		10.00			11.75	11	10	10.4359983
80		8.27			15.52	12	10	10.0817414
85		1.69				2	2	1.69209207
90		12.92				13	13	12.921401
95						#DIV/0!	#DIV/0!	#NUM!
100			15.10			15	15	15.1029488

Summary - Average with depth

Depth	Ei	Em (Low GSI)	Em (High GSI)	Em (Avg)	Soil Type: 1	Em Analysis
			Units: ksf			
30					1444	1000
35	16,138	888	1284	1086	1444	1000
40					1444	1200
45	17,847	982	1420	1201	1444	1200
50	24,980	1374	1987	1681	1444	1300
55					1444	1300
60					1444	1300
65					1444	1300
70					1444	1300
75	19,683	1083	1566	1324	1444	1300
80	21,534	1185	1713	1449	1444	1300
85	3,063	169	244	206	1444	1300
90	23,391	1287	1861	1574	1444	1500
95					1444	1500
100	27,341	1504	2175	1840	1444	1500
Average	19,247	1,059	1,531	1,295		
min	3,063	169	244	206		
max	27,341	1,504	2,175	1,840		
Lower Q	17,420	958	1,386	1,172		

Schmertmann's Modified Method (1978)

Project ID: Box Culvert
Project # 17-2015-4045
User NC

Starting Footing Width: 10
Ending Footing Width: 50
Settlements separated by semicolon: 2.0;4.0;6.0;8.0;10;12

Footing Dimensions
Width (B) [ft] 50
200
Depth to Base of Footing (D) [ft] 1

Depth to groundwater (ft) 0
Time Since Application of Load [yrs] 5
Average Soil Unit Weight (g) [pcf] 130

Net Bearing Pressure
q' [psf] 2880

Depth of Peak Strain
D_{ps} 33.3

$$D_{ps} = B/2 (L/B = 1)$$
$$D_{ps} = B (L/B > 10)$$
$$\text{Intermediate for } 1 < L/B \le 10$$

Initial Vertical Stress at Depth of Peak Strain Influence Factor
σ϶ϖπ [πσφ] 2321

$$\sigma'_{vp}(\text{at } z = D + D_{ps}) = \sum \gamma h - u$$

Depth of Influence
D_i 133.3

$$D_i = 2B (L/B = 1)$$
$$D_i = 4B (L/B > 10)$$
$$\text{Intermediate for } 1 < L/B \le 10$$

Effective Stress at Depth D Below the Ground Surface
σ϶Δ [πσφ] 68

$$\sigma'_D = \gamma D - u$$

Peak Strain Influence Factor
Izp 0.611

$$I_{zp} = 0.5 + 0.1\sqrt{\frac{q'}{\sigma'_{vp}}}$$

Strain Influence Factor at Surface
I_{zs} 0.13

$$I_{zs} = 0.1 (L/B = 1)$$
$$I_{zs} = 0.2 (L/B > 10)$$
$$\text{Intermediate for } 1 < L/B \le 10$$

Depth Factor
C1 0.99

$$C_1 = 1 - 0.5\left(\frac{\sigma'_D}{q'}\right)$$

Shape Factor
C_3 1.00

$$C_3 = 1.0$$

Secondary Creep Factor
C2 1.34

$$C_2 = 1 + 0.2\log\left(\frac{t}{0.1}\right)$$

Layer No.	Depth Below Ground Surface: Start [ft]	Depth Below Ground Surface: End [ft]	Depth of Midlayer below footing [ft]	Thickness of Layer Δz_i [ft]	Soil Modulus E_i [psf]	Strain Influence Factor I_{zi}	Settlement of Layer i ρ_i [in]
1	1	5	2	4	123,255	0.16	0.24
2	5	10	6.5	5	166,415	0.23	0.31
3	10	15	11.5	5	123,255	0.30	0.55
4	15	20	16.5	5	154,815	0.37	0.55
5	20	25	21.5	5	85,966	0.44	1.18
6	25	30	26.5	5	99,648	0.51	1.18
7	30	35	31.5	5	43,325	0.59	3.09
8	35	40	36.5	5	90,983	0.59	1.49
9	40	45	41.5	5	60,655	0.56	2.12
10	45	50	46.5	5	251,286	0.53	0.48
11	50	55	51.5	5	619,549	0.50	0.18
12	55	60	56.5	5	1,300,000	0.47	0.08
13	60	65	61.5	5	1,300,000	0.44	0.08
14	65	70	66.5	5	1,300,000	0.41	0.07
15	70	75	71.5	5	1,300,000	0.38	0.07
16	75	80	76.5	5	1,300,000	0.35	0.06
17	80	85	81.5	5	1,500,000	0.32	0.05
18	85	90	86.5	5	1,500,000	0.29	0.04
19	90	95	91.5	5	1,500,000	0.26	0.04
20	95	100	96.5	5	1,500,000	0.23	0.03
21	100	105	101.5	5	1,500,000	0.19	0.03
22	105	110	106.5	5	1,500,000	0.16	0.03
23	110	115	111.5	5	1,500,000	0.13	0.02
						Total Settlement [in]	11.97

$$\rho_i = C_1 C_2 C_3 q' \left(\frac{I_{zi}\Delta z_i}{E_i}\right)$$

$$\rho_{TOTAL} = \sum \rho_i$$

Settlement (inches)		2.00	4.00	6.00	8.00	10.00	12.00
Net Bearing Pressure							
Footing width	10	1050	1940	2760	3550	4300	4359
	11	920	1710	2440	3140	3810	4421
	12	830	1540	2210	2850	3460	4060
	13	770	1430	2060	2650	3230	3790
	14	730	1350	1940	2500	3050	3580
	15	690	1280	1850	2390	2910	3410
	16	660	1230	1770	2290	2800	3280
	17	640	1190	1720	2220	2710	3190
	18	620	1160	1670	2170	2640	3110
	19	610	1130	1640	2120	2590	3050
	20	600	1110	1600	2080	2540	2990
	21	590	1100	1590	2060	2520	2970
	22	590	1100	1580	2050	2510	2950
	23	580	1090	1570	2040	2490	2940
	24	580	1080	1570	2030	2480	2920
	25	580	1080	1560	2020	2480	2920
	26	580	1080	1560	2020	2470	2910
	27	580	1070	1550	2010	2460	2900
	28	570	1070	1550	2010	2460	2890
	29	570	1070	1540	2000	2450	2890
	30	570	1060	1540	2000	2440	2880
	31	570	1060	1530	1990	2440	2870
	32	570	1060	1530	1990	2430	2870
	33	560	1060	1530	1980	2430	2860
	34	560	1050	1520	1980	2420	2860
	35	560	1050	1520	1980	2420	2850
	36	560	1050	1520	1970	2420	2850
	37	560	1050	1520	1970	2420	2850
	38	560	1050	1520	1970	2420	2850
	39	560	1050	1520	1970	2420	2850
	40	560	1050	1520	1970	2420	2850
	41	560	1050	1520	1970	2420	2850
	42	560	1050	1520	1970	2410	2850
	43	560	1050	1510	1970	2410	2850
	44	560	1050	1510	1970	2410	2850
	45	560	1040	1510	1970	2410	2850
	46	560	1040	1510	1970	2410	2850
	47	560	1060	1530	1990	2430	2870
	48	560	1050	1520	1980	2430	2870
	49	560	1050	1540	2000	2450	2890
	50	560	1070	1530	2000	2450	2890
		560	1070	1530	2000	2450	2890
		560	1070	1530	2000	2450	2890
		560	1070	1530	2000	2450	2890

NOMINAL BEARING CAPACITY

DRIVEN H-PILES

ABUTMENTS

Site Inputs

Project No.: 17-2015-4045
Project: BIA Route N8066
Structure: Abutment, Pile Foundation, No Scour
Corresponding Boring: B-1/B-2
Depth to Groundwater Table [ft]: 25
Ground Elevation [ft]: 6670
Depth of Scour [ft]: 0 Not used in calcs
Resistance Factor [clay]: 0.35
Resistance Factor [sand]: 0.45
Atmospheric Pressure (p_a) [pcf]: 2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	110	--	2500	25
2	Cohesive	0.35	120	--	800	50
3	Cohesionless	0.45	125	32	--	70
4	Cohesionless	0.45	130	35	--	100
5		0.45				
6		0.45				
7		0.45				
8		0.45				

H-Pile Inputs		
Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.00	N/A	0.10	0.70	0.086	0.70	0.94
26	0.00	N/A	0.10	0.73	0.086	0.73	0.93
27	0.00	N/A	0.10	0.76	0.086	0.76	0.92
28	0.00	N/A	0.10	0.79	0.086	0.79	0.91
29	0.00	N/A	0.10	0.82	0.086	0.82	0.90
30	0.00	N/A	0.10	0.85	0.086	0.85	0.89
31	0.00	N/A	0.10	0.91	0.086	0.91	0.88
32	0.00	N/A	0.10	0.97	0.086	0.97	0.88
33	0.00	N/A	0.10	1.03	0.086	1.03	0.87
34	0.00	N/A	0.10	1.09	0.086	1.09	0.87
35	0.00	N/A	0.10	1.15	0.086	1.15	0.86
36	0.00	N/A	0.10	1.26	0.086	1.26	0.86
37	0.00	N/A	0.10	1.37	0.086	1.37	0.85
38	0.00	N/A	0.10	1.48	0.086	1.48	0.84
39	0.00	N/A	0.10	1.59	0.086	1.59	0.83
40	0.00	N/A	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**B-1**	**B-2**	**Average**
6670	0	15	14	15
6665	5	31	34	33
6660	10	23	30	27
6655	15	18	21	20
6650	20	17	15	16
6645	25	30	9	20
6640	30	30	8	19
6635	35	6	6	6
6630	40	13	5	9
6625	45	10	0	5
6620	50	8	4	6
6615	55	6	2	4
6610	60	6	3	5
6605	65	4	46	25
6600	70	3	100	52
6595	75	45	100	73
6590	80	100	100	100
6585	85	100	100	100
6580	90	100	100	100
6575	95	100		100
6570	100	100		100

			Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045		25	1	2750	2750
Project:	BIA Route N8066		50	2	5750	4190
Structure:	Abutment, Pile Foundation, No Scour		70	3	8250	5442
Corresponding Boring:	B-1/B-2		100	4	12150	7470
Groundwater Table [ft]:	25		0	5	12150	12150
Depth of Scour [ft]:	0		0	6	12150	12150
γ_w [pcf]:	62.4		0	7	12150	12150
			0	8	12150	12150

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	15	21
1	5	7.5	10	110	--	825	1100	1100	825	Cohesive	33	39
1	10	12.5	15	110	--	1375	1650	1650	1375	Cohesive	27	28
1	15	17.5	20	110	--	1925	2200	2200	1925	Cohesive	20	19
1	20	22.5	25	110	--	2475	2750	2750	2475	Cohesive	16	14
2	25	27.5	30	120	62.4	3050	3350	3038	2894	Cohesive	20	17
2	30	32.5	35	120	62.4	3650	3950	3326	3182	Cohesive	19	16
2	35	37.5	40	120	62.4	4250	4550	3614	3470	Cohesive	6	5
2	40	42.5	45	120	62.4	4850	5150	3902	3758	Cohesive	9	7
2	45	47.5	50	120	62.4	5450	5750	4190	4046	Cohesive	5	4
3	50	52.5	55	125	62.4	6062.5	6375	4503	4346.5	Cohesionless	6	4
3	55	57.5	60	125	62.4	6687.5	7000	4816	4659.5	Cohesionless	4	3
3	60	62.5	65	125	62.4	7312.5	7625	5129	4972.5	Cohesionless	5	3
3	65	67.5	70	125	62.4	7937.5	8250	5442	5285.5	Cohesionless	25	17
4	70	72.5	75	130	62.4	8575	8900	5780	5611	Cohesionless	52	33
4	75	77.5	80	130	62.4	9225	9550	6118	5949	Cohesionless	73	46
4	80	82.5	85	130	62.4	9875	10200	6456	6287	Cohesionless	100	61
4	85	87.5	90	130	62.4	10525	10850	6794	6625	Cohesionless	100	59
4	90	92.5	95	130	62.4	11175	11500	7132	6963	Cohesionless	100	58
4	95	97.5	100	130	62.4	11825	12150	7470	7301	Cohesionless	100	56
8	100	100.0	--	--	--	--	--	--	--	--	100	--

	Skin Friction Calculations by Layer									
Layer	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.30
1	--	--	--	--	--	--	2500	0.44	1.00	3.30
1	--	--	--	--	--	--	2500	0.46	1.03	3.40
1	--	--	--	--	--	--	2500	0.51	1.14	3.75
1	--	--	--	--	--	--	2500	0.56	1.24	4.09
2	--	--	--	--	--	--	800	0.98	0.75	2.47
2	--	--	--	--	--	--	800	0.99	0.78	2.57
2	--	--	--	--	--	--	800	1.00	0.80	2.64
2	--	--	--	--	--	--	800	1.00	0.80	2.64
2	--	--	--	--	--	--	800	1.00	0.80	2.64
3	32	0.74	23.68	0.97	0.88	6.01	--	--	--	--
3	32	0.74	23.68	0.97	0.88	6.44	--	--	--	--
3	32	0.74	23.68	0.97	0.88	6.88	--	--	--	--
3	32	0.74	23.68	0.97	0.88	7.31	--	--	--	--
4	35	0.74	25.9	1.15	0.86	9.87	--	--	--	--
4	35	0.74	25.9	1.15	0.86	10.47	--	--	--	--
4	35	0.74	25.9	1.15	0.86	11.06	--	--	--	--
4	35	0.74	25.9	1.15	0.86	11.66	--	--	--	--
4	35	0.74	25.9	1.15	0.86	12.25	--	--	--	--
4	35	0.74	25.9	1.15	0.86	12.85	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations by Layer							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
3	32	0.54	40	3200	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6670	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6665	0.35	0.00	0.00	0.00	0.00	0.00
1	10	6660	0.35	3.30	5.77	22.50	5.34	11.11
1	15	6655	0.35	3.40	11.73	22.50	5.34	17.07
1	20	6650	0.35	3.75	18.28	22.50	5.34	23.63
1	25	6645	0.35	4.09	25.43	22.50	5.34	30.77
2	30	6640	0.35	2.47	29.75	7.20	1.71	31.46
2	35	6635	0.35	2.57	34.24	7.20	1.71	35.95
2	40	6630	0.35	2.64	38.85	7.20	1.71	40.56
2	45	6625	0.35	2.64	43.47	7.20	1.71	45.18
2	50	6620	0.35	2.64	48.08	7.20	1.71	49.79
3	55	6615	0.45	6.01	61.61	33.00	10.08	71.68
3	60	6610	0.45	6.44	76.10	33.00	10.08	86.18
3	65	6605	0.45	6.88	91.57	33.00	10.08	101.65
3	70	6600	0.45	7.31	108.01	33.00	10.08	118.09
4	75	6595	0.45	9.87	130.23	108.00	32.98	163.22
4	80	6590	0.45	10.47	153.79	108.00	32.98	186.77
4	85	6585	0.45	11.06	178.69	108.00	32.98	211.67
4	90	6580	0.45	11.66	204.92	108.00	32.98	237.90
4	95	6575	0.45	12.25	232.49	108.00	32.98	265.47
4	100	6570	0.45	12.85	261.40	108.00	32.98	294.38
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Abutment, Pile Foundation, No Scour
Corresponding Boring:	B-1/B-2
Depth to Groundwater Table [ft]:	25
Ground Elevation [ft]:	6670
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	110	--	2500	25
2	Cohesive	0.35	120	--	800	50
3	Cohesionless	0.45	125	32	--	70
4	Cohesionless	0.45	130	35	--	100
5		0.45				
6		0.45				
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**B-1**	**B-2**	**Average**
6670	0	15	14	15
6665	5	31	34	33
6660	10	23	30	27
6655	15	18	21	20
6650	20	17	15	16
6645	25	30	9	20
6640	30	30	8	19
6635	35	6	6	6
6630	40	13	5	9
6625	45	10	0	5
6620	50	8	4	6
6615	55	6	2	4
6610	60	6	3	5
6605	65	4	46	25
6600	70	3	100	52
6595	75	45	100	73
6590	80	100	100	100
6585	85	100	100	100
6580	90	100	100	100
6575	95	100		100
6570	100	100		100

Calculation

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	25	1	2750	2750
Project:	BIA Route N8066	50	2	5750	4190
Structure:	Abutment, Pile Foundation, No Scour	70	3	8250	5442
Corresponding Boring:	B-1/B-2	100	4	12150	7470
Groundwater Table [ft]:	25	0	5	12150	12150
Depth of Scour [ft]:	0	0	6	12150	12150
γ_w [pcf]:	62.4	0	7	12150	12150
		0	8	12150	12150

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	15	21
1	5	7.5	10	110	--	825	1100	1100	825	Cohesive	33	39
1	10	12.5	15	110	--	1375	1650	1650	1375	Cohesive	27	28
1	15	17.5	20	110	--	1925	2200	2200	1925	Cohesive	20	19
1	20	22.5	25	110	--	2475	2750	2750	2475	Cohesive	16	14
2	25	27.5	30	120	62.4	3050	3350	3038	2894	Cohesive	20	17
2	30	32.5	35	120	62.4	3650	3950	3326	3182	Cohesive	19	16
2	35	37.5	40	120	62.4	4250	4550	3614	3470	Cohesive	6	5
2	40	42.5	45	120	62.4	4850	5150	3902	3758	Cohesive	9	7
2	45	47.5	50	120	62.4	5450	5750	4190	4046	Cohesive	5	4
3	50	52.5	55	125	62.4	6062.5	6375	4503	4346.5	Cohesionless	6	4
3	55	57.5	60	125	62.4	6687.5	7000	4816	4659.5	Cohesionless	4	3
3	60	62.5	65	125	62.4	7312.5	7625	5129	4972.5	Cohesionless	5	3
3	65	67.5	70	125	62.4	7937.5	8250	5442	5285.5	Cohesionless	25	17
4	70	72.5	75	130	62.4	8575	8900	5780	5611	Cohesionless	52	33
4	75	77.5	80	130	62.4	9225	9550	6118	5949	Cohesionless	73	46
4	80	82.5	85	130	62.4	9875	10200	6456	6287	Cohesionless	100	61
4	85	87.5	90	130	62.4	10525	10850	6794	6625	Cohesionless	100	59
4	90	92.5	95	130	62.4	11175	11500	7132	6963	Cohesionless	100	58
4	95	97.5	100	130	62.4	11825	12150	7470	7301	Cohesionless	100	56
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.48	1.09	4.31
1	--	--	--	--	--	--	2500	0.53	1.17	4.66
2	--	--	--	--	--	--	800	0.98	0.73	2.88
2	--	--	--	--	--	--	800	0.98	0.75	2.98
2	--	--	--	--	--	--	800	0.99	0.78	3.08
2	--	--	--	--	--	--	800	1.00	0.80	3.18
2	--	--	--	--	--	--	800	1.00	0.80	3.18
3	32	0.76	24.32	0.98	0.90	7.53	--	--	--	--
3	32	0.76	24.32	0.98	0.90	8.07	--	--	--	--
3	32	0.76	24.32	0.98	0.90	8.62	--	--	--	--
3	32	0.76	24.32	0.98	0.90	9.16	--	--	--	--
4	35	0.76	26.6	1.17	0.88	12.41	--	--	--	--
4	35	0.76	26.6	1.17	0.88	13.15	--	--	--	--
4	35	0.76	26.6	1.17	0.88	13.90	--	--	--	--
4	35	0.76	26.6	1.17	0.88	14.65	--	--	--	--
4	35	0.76	26.6	1.17	0.88	15.39	--	--	--	--
4	35	0.76	26.6	1.17	0.88	16.14	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
3	32	0.54	40	3200	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6670	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6665	0.35	0.00	0.00	0.00	0.00	0.00
1	10	6660	0.35	3.97	6.95	22.50	7.76	14.71
1	15	6655	0.35	3.97	13.90	22.50	7.76	21.66
1	20	6650	0.35	4.31	21.45	22.50	7.76	29.21
1	25	6645	0.35	4.66	29.60	22.50	7.76	37.36
2	30	6640	0.35	2.88	34.64	7.20	2.48	37.12
2	35	6635	0.35	2.98	39.85	7.20	2.48	42.34
2	40	6630	0.35	3.08	45.24	7.20	2.48	47.72
2	45	6625	0.35	3.18	50.80	7.20	2.48	53.28
2	50	6620	0.35	3.18	56.36	7.20	2.48	58.84
3	55	6615	0.45	7.53	73.30	33.00	14.63	87.94
3	60	6610	0.45	8.07	91.47	33.00	14.63	106.10
3	65	6605	0.45	8.62	110.86	33.00	14.63	125.49
3	70	6600	0.45	9.16	131.47	33.00	14.63	146.10
4	75	6595	0.45	12.41	159.38	108.00	47.89	207.27
4	80	6590	0.45	13.15	188.97	108.00	47.89	236.86
4	85	6585	0.45	13.90	220.25	108.00	47.89	268.13
4	90	6580	0.45	14.65	253.20	108.00	47.89	301.09
4	95	6575	0.45	15.39	287.84	108.00	47.89	335.73
4	100	6570	0.45	16.14	324.16	108.00	47.89	372.05
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Abutment, Pile Foundation, No Scour
Corresponding Boring:	B-1/B-2
Depth to Groundwater Table [ft]:	25
Ground Elevation [ft]:	6670
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	110	--	2500	25
2	Cohesive	0.35	120	--	800	50
3	Cohesionless	0.45	125	32	--	70
4	Cohesionless	0.45	130	35	--	100
5		0.45				
6		0.45				
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP14x73	Select from drop down menu
Depth [in]:	13.61	
Width [in]:	14.585	
Thickness [in]:	0.505	
End Area [sf]:	0.149	(unplugged)
End Area [sf]:	1.378	(plugged)
Volume[cf/ft]:	0.149	
Steel Perimeter (C_d) [ft]:	2.599	
Soil Perimeter (C_d) [ft]:	2.1000	
δ/ϕ:	0.78	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	535	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**B-1**	**B-2**	**Average**
6670	0	15	14	15
6665	5	31	34	33
6660	10	23	30	27
6655	15	18	21	20
6650	20	17	15	16
6645	25	30	9	20
6640	30	30	8	19
6635	35	6	6	6
6630	40	13	5	9
6625	45	10	0	5
6620	50	8	4	6
6615	55	6	2	4
6610	60	6	3	5
6605	65	4	46	25
6600	70	3	100	52
6595	75	45	100	73
6590	80	100	100	100
6585	85	100	100	100
6580	90	100	100	100
6575	95	100		100
6570	100	100		100

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	25	1	2750	2750
Project:	BIA Route N8066	50	2	5750	4190
Structure:	Abutment, Pile Foundation, No Scour	70	3	8250	5442
Corresponding Boring:	B-1/B-2	100	4	12150	7470
Groundwater Table [ft]:	25	0	5	12150	12150
Depth of Scour [ft]:	0	0	6	12150	12150
γ_w [pcf]:	62.4	0	7	12150	12150
		0	8	12150	12150

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	15	21
1	5	7.5	10	110	--	825	1100	1100	825	Cohesive	33	39
1	10	12.5	15	110	--	1375	1650	1650	1375	Cohesive	27	28
1	15	17.5	20	110	--	1925	2200	2200	1925	Cohesive	20	19
1	20	22.5	25	110	--	2475	2750	2750	2475	Cohesive	16	14
2	25	27.5	30	120	62.4	3050	3350	3038	2894	Cohesive	20	17
2	30	32.5	35	120	62.4	3650	3950	3326	3182	Cohesive	19	16
2	35	37.5	40	120	62.4	4250	4550	3614	3470	Cohesive	6	5
2	40	42.5	45	120	62.4	4850	5150	3902	3758	Cohesive	9	7
2	45	47.5	50	120	62.4	5450	5750	4190	4046	Cohesive	5	4
3	50	52.5	55	125	62.4	6062.5	6375	4503	4346.5	Cohesionless	6	4
3	55	57.5	60	125	62.4	6687.5	7000	4816	4659.5	Cohesionless	4	3
3	60	62.5	65	125	62.4	7312.5	7625	5129	4972.5	Cohesionless	5	3
3	65	67.5	70	125	62.4	7937.5	8250	5442	5285.5	Cohesionless	25	17
4	70	72.5	75	130	62.4	8575	8900	5780	5611	Cohesionless	52	33
4	75	77.5	80	130	62.4	9225	9550	6118	5949	Cohesionless	73	46
4	80	82.5	85	130	62.4	9875	10200	6456	6287	Cohesionless	100	61
4	85	87.5	90	130	62.4	10525	10850	6794	6625	Cohesionless	100	59
4	90	92.5	95	130	62.4	11175	11500	7132	6963	Cohesionless	100	58
4	95	97.5	100	130	62.4	11825	12150	7470	7301	Cohesionless	100	56
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer: Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.46	1.04	4.89
1	--	--	--	--	--	--	2500	0.50	1.11	5.22
2	--	--	--	--	--	--	800	0.97	0.70	3.30
2	--	--	--	--	--	--	800	0.97	0.72	3.40
2	--	--	--	--	--	--	800	0.98	0.74	3.50
2	--	--	--	--	--	--	800	0.99	0.76	3.59
2	--	--	--	--	--	--	800	1.00	0.79	3.69
3	32	0.78	24.96	1.04	0.91	9.58	--	--	--	--
3	32	0.78	24.96	1.04	0.91	10.27	--	--	--	--
3	32	0.78	24.96	1.04	0.91	10.96	--	--	--	--
3	32	0.78	24.96	1.04	0.91	11.65	--	--	--	--
4	35	0.78	27.3	1.25	0.90	16.01	--	--	--	--
4	35	0.78	27.3	1.25	0.90	16.97	--	--	--	--
4	35	0.78	27.3	1.25	0.90	17.94	--	--	--	--
4	35	0.78	27.3	1.25	0.90	18.90	--	--	--	--
4	35	0.78	27.3	1.25	0.90	19.87	--	--	--	--
4	35	0.78	27.3	1.25	0.90	20.83	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
3	32	0.54	40	3200	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6670	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6665	0.35	0.00	0.00	0.00	0.00	0.00
1	10	6660	0.35	4.70	8.22	22.50	10.86	19.08
1	15	6655	0.35	4.70	16.45	22.50	10.86	27.30
1	20	6650	0.35	4.89	25.00	22.50	10.86	35.86
1	25	6645	0.35	5.22	34.15	22.50	10.86	45.00
2	30	6640	0.35	3.30	39.93	7.20	3.47	43.40
2	35	6635	0.35	3.40	45.88	7.20	3.47	49.35
2	40	6630	0.35	3.50	52.00	7.20	3.47	55.47
2	45	6625	0.35	3.59	58.28	7.20	3.47	61.76
2	50	6620	0.35	3.69	64.74	7.20	3.47	68.21
3	55	6615	0.45	9.58	86.30	33.00	20.47	106.77
3	60	6610	0.45	10.27	109.41	33.00	20.47	129.88
3	65	6605	0.45	10.96	134.07	33.00	20.47	154.54
3	70	6600	0.45	11.65	160.29	33.00	20.47	180.76
4	75	6595	0.45	16.01	196.31	108.00	66.99	263.31
4	80	6590	0.45	16.97	234.50	108.00	66.99	301.50
4	85	6585	0.45	17.94	274.87	108.00	66.99	341.86
4	90	6580	0.45	18.90	317.40	108.00	66.99	384.39
4	95	6575	0.45	19.87	362.10	108.00	66.99	429.09
4	100	6570	0.45	20.83	408.97	108.00	66.99	475.97
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

PIERS

Site Inputs

Project No.: 17-2015-4045
Project: BIA Route N8066
Structure: Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring: B-3
Depth to Groundwater Table [ft]: 5
Ground Elevation [ft]: 6654.5
Depth of Scour [ft]: 5 Not used in calcs
Resistance Factor [clay]: 0.35
Resistance Factor [sand]: 0.45
Atmospheric Pressure (p_a) [pcf]: 2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesionless	0.45	0	30	--	5
2	Cohesive	0.35	120	--	800	35
3	Cohesionless	0.45	125	32	--	60
4	Cohesionless	0.45	130	35	--	100
5		0.45				
6		0.45				
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.00	N/A	0.10	0.70	0.086	0.70	0.94
26	0.00	N/A	0.10	0.73	0.086	0.73	0.93
27	0.00	N/A	0.10	0.76	0.086	0.76	0.92
28	0.00	N/A	0.10	0.79	0.086	0.79	0.91
29	0.00	N/A	0.10	0.82	0.086	0.82	0.90
30	0.00	N/A	0.10	0.85	0.086	0.85	0.89
31	0.00	N/A	0.10	0.91	0.086	0.91	0.88
32	0.00	N/A	0.10	0.97	0.086	0.97	0.88
33	0.00	N/A	0.10	1.03	0.086	1.03	0.87
34	0.00	N/A	0.10	1.09	0.086	1.09	0.87
35	0.00	N/A	0.10	1.15	0.086	1.15	0.86
36	0.00	N/A	0.10	1.26	0.086	1.26	0.86
37	0.00	N/A	0.10	1.37	0.086	1.37	0.85
38	0.00	N/A	0.10	1.48	0.086	1.48	0.84
39	0.00	N/A	0.10	1.59	0.086	1.59	0.83
40	0.00	N/A	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs			
Elevation	Depth	**B-3**	**Average**
6654.5	0	33	33
6649.5	5	5	5
6644.5	10	8	8
6639.5	15	10	10
6634.5	20	5	5
6629.5	25	8	8
6624.5	30	3	3
6619.5	35	5	5
6614.5	40	2	2
6609.5	45	5	5
6604.5	50	3	3
6599.5	55	11	11
6594.5	60	77	77
6589.5	65	100	100
6584.5	70	100	100
6579.5	75	100	100
6574.5	80	100	100
6569.5	85	100	100
6564.5	90	100	100
6559.5	95	100	100
6554.5	100	100	100

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring:	B-3
Groundwater Table [ft]:	5
Depth of Scour [ft]:	5
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1		
35	2	3600	1728
60	3	6725	3293
100	4	11925	5997
0	5	11925	11925
0	6	11925	11925
0	7	11925	11925
0	8	11925	11925

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	0	0	0	0	0	Cohesionless	33	0
2	5	7.5	10	120	62.4	300	600	288	144	Cohesive	5	8
2	10	12.5	15	120	62.4	900	1200	576	432	Cohesive	8	11
2	15	17.5	20	120	62.4	1500	1800	864	720	Cohesive	10	13
2	20	22.5	25	120	62.4	2100	2400	1152	1008	Cohesive	5	6
2	25	27.5	30	120	62.4	2700	3000	1440	1296	Cohesive	8	9
2	30	32.5	35	120	62.4	3300	3600	1728	1584	Cohesive	3	3
3	35	37.5	40	125	62.4	3912.5	4225	2041	1884.5	Cohesionless	5	5
3	40	42.5	45	125	62.4	4537.5	4850	2354	2197.5	Cohesionless	2	2
3	45	47.5	50	125	62.4	5162.5	5475	2667	2510.5	Cohesionless	5	5
3	50	52.5	55	125	62.4	5787.5	6100	2980	2823.5	Cohesionless	3	3
3	55	57.5	60	125	62.4	6412.5	6725	3293	3136.5	Cohesionless	11	9
4	60	62.5	65	130	62.4	7050	7375	3631	3462	Cohesionless	77	62
4	65	67.5	70	130	62.4	7700	8025	3969	3800	Cohesionless	100	77
4	70	72.5	75	130	62.4	8350	8675	4307	4138	Cohesionless	100	75
4	75	77.5	80	130	62.4	9000	9325	4645	4476	Cohesionless	100	72
4	80	82.5	85	130	62.4	9650	9975	4983	4814	Cohesionless	100	70
4	85	87.5	90	130	62.4	10300	10625	5321	5152	Cohesionless	100	67
4	90	92.5	95	130	62.4	10950	11275	5659	5490	Cohesionless	100	65
4	95	97.5	100	130	62.4	11600	11925	5997	5828	Cohesionless	100	63
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	30	0.74	22.2	0.85	0.89	0.00	--	--	--	0.00
2	--	--	--	--	--	--	800	0.95	0.65	2.14
2	--	--	--	--	--	--	800	0.95	0.66	2.17
2	--	--	--	--	--	--	800	0.96	0.69	2.27
2	--	--	--	--	--	--	800	0.97	0.72	2.37
2	--	--	--	--	--	--	800	0.98	0.75	2.47
2	--	--	--	--	--	--	800	0.99	0.78	2.57
3	32	0.74	23.68	0.97	0.88	2.61	--	--	--	--
3	32	0.74	23.68	0.97	0.88	3.04	--	--	--	--
3	32	0.74	23.68	0.97	0.88	3.47	--	--	--	--
3	32	0.74	23.68	0.97	0.88	3.90	--	--	--	--
3	32	0.74	23.68	0.97	0.88	4.34	--	--	--	--
4	35	0.74	25.9	1.15	0.86	6.09	--	--	--	--
4	35	0.74	25.9	1.15	0.86	6.69	--	--	--	--
4	35	0.74	25.9	1.15	0.86	7.28	--	--	--	--
4	35	0.74	25.9	1.15	0.86	7.88	--	--	--	--
4	35	0.74	25.9	1.15	0.86	8.47	--	--	--	--
4	35	0.74	25.9	1.15	0.86	9.07	--	--	--	--
4	35	0.74	25.9	1.15	0.86	9.66	--	--	--	--
4	35	0.74	25.9	1.15	0.86	10.26	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations by Layer							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	30	0.57	30	0	13.5	0.0	--	0
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
3	32	0.54	40	2041	33	33.0	--	0
3	32	0.54	40	2354	33	33.0	--	0
3	32	0.54	40	2667	33	33.0	--	0
3	32	0.54	40	2980	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6654.5	0.45	0.00	0.00	0.00	0.00	0.00
1	5	6649.5	0.45	0.00	0.00	0.00	0.00	0.00
2	10	6644.5	0.35	2.14	3.75	7.20	1.71	5.46
2	15	6639.5	0.35	2.17	7.55	7.20	1.71	9.26
2	20	6634.5	0.35	2.27	11.53	7.20	1.71	13.24
2	25	6629.5	0.35	2.37	15.68	7.20	1.71	17.39
2	30	6624.5	0.35	2.47	20.00	7.20	1.71	21.71
2	35	6619.5	0.35	2.57	24.49	7.20	1.71	26.20
3	40	6614.5	0.45	2.61	30.35	33.00	10.08	40.43
3	45	6609.5	0.45	3.04	37.19	33.00	10.08	47.26
3	50	6604.5	0.45	3.47	45.00	33.00	10.08	55.07
3	55	6599.5	0.45	3.90	53.78	33.00	10.08	63.86
3	60	6594.5	0.45	4.34	63.54	33.00	10.08	73.62
4	65	6589.5	0.45	6.09	77.25	108.00	32.98	110.23
4	70	6584.5	0.45	6.69	92.29	108.00	32.98	125.28
4	75	6579.5	0.45	7.28	108.68	108.00	32.98	141.66
4	80	6574.5	0.45	7.88	126.40	108.00	32.98	159.39
4	85	6569.5	0.45	8.47	145.47	108.00	32.98	178.45
4	90	6564.5	0.45	9.07	165.87	108.00	32.98	198.85
4	95	6559.5	0.45	9.66	187.61	108.00	32.98	220.59
4	100	6554.5	0.45	10.26	210.68	108.00	32.98	243.67
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring:	B-3
Depth to Groundwater Table [ft]:	5
Ground Elevation [ft]:	6654.5
Depth of Scour [ft]:	5 Not used in calcs
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesionless	0.45	0	30	--	5
2	Cohesive	0.35	120	--	800	35
3	Cohesionless	0.45	125	32	--	60
4	Cohesionless	0.45	130	35	--	100
5		0.45				
6		0.45				
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs			
Elevation	Depth	**B-3**	**Average**
6654.5	0	33	33
6649.5	5	5	5
6644.5	10	8	8
6639.5	15	10	10
6634.5	20	5	5
6629.5	25	8	8
6624.5	30	3	3
6619.5	35	5	5
6614.5	40	2	2
6609.5	45	5	5
6604.5	50	3	3
6599.5	55	11	11
6594.5	60	77	77
6589.5	65	100	100
6584.5	70	100	100
6579.5	75	100	100
6574.5	80	100	100
6569.5	85	100	100
6564.5	90	100	100
6559.5	95	100	100
6554.5	100	100	100

Calculation

Project No.: 17-2015-4045
Project: BIA Route N8066
Structure: Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring: B-3
Groundwater Table [ft]: 5
Depth of Scour [ft]: 5
γ_w [pcf]: 62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1		
35	2	3600	1728
60	3	6725	3293
100	4	11925	5997
0	5	11925	11925
0	6	11925	11925
0	7	11925	11925
0	8	11925	11925

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	0	0	0	0	0	Cohesionless	33	0
2	5	7.5	10	120	62.4	300	600	288	144	Cohesive	5	8
2	10	12.5	15	120	62.4	900	1200	576	432	Cohesive	8	11
2	15	17.5	20	120	62.4	1500	1800	864	720	Cohesive	10	13
2	20	22.5	25	120	62.4	2100	2400	1152	1008	Cohesive	5	6
2	25	27.5	30	120	62.4	2700	3000	1440	1296	Cohesive	8	9
2	30	32.5	35	120	62.4	3300	3600	1728	1584	Cohesive	3	3
3	35	37.5	40	125	62.4	3912.5	4225	2041	1884.5	Cohesionless	5	5
3	40	42.5	45	125	62.4	4537.5	4850	2354	2197.5	Cohesionless	2	2
3	45	47.5	50	125	62.4	5162.5	5475	2667	2510.5	Cohesionless	5	5
3	50	52.5	55	125	62.4	5787.5	6100	2980	2823.5	Cohesionless	3	3
3	55	57.5	60	125	62.4	6412.5	6725	3293	3136.5	Cohesionless	11	9
4	60	62.5	65	130	62.4	7050	7375	3631	3462	Cohesionless	77	62
4	65	67.5	70	130	62.4	7700	8025	3969	3800	Cohesionless	100	77
4	70	72.5	75	130	62.4	8350	8675	4307	4138	Cohesionless	100	75
4	75	77.5	80	130	62.4	9000	9325	4645	4476	Cohesionless	100	72
4	80	82.5	85	130	62.4	9650	9975	4983	4814	Cohesionless	100	70
4	85	87.5	90	130	62.4	10300	10625	5321	5152	Cohesionless	100	67
4	90	92.5	95	130	62.4	10950	11275	5659	5490	Cohesionless	100	65
4	95	97.5	100	130	62.4	11600	11925	5997	5828	Cohesionless	100	63
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	30	0.76	22.8	0.86	0.91	0.00	--	--	--	0.00
2	--	--	--	--	--	--	800	0.95	0.65	2.58
2	--	--	--	--	--	--	800	0.95	0.65	2.58
2	--	--	--	--	--	--	800	0.92	0.67	2.68
2	--	--	--	--	--	--	800	0.93	0.70	2.78
2	--	--	--	--	--	--	800	0.95	0.72	2.88
2	--	--	--	--	--	--	800	0.97	0.75	2.98
3	32	0.76	24.32	0.98	0.90	3.27	--	--	--	--
3	32	0.76	24.32	0.98	0.90	3.81	--	--	--	--
3	32	0.76	24.32	0.98	0.90	4.35	--	--	--	--
3	32	0.76	24.32	0.98	0.90	4.89	--	--	--	--
3	32	0.76	24.32	0.98	0.90	5.44	--	--	--	--
4	35	0.76	26.6	1.17	0.88	7.65	--	--	--	--
4	35	0.76	26.6	1.17	0.88	8.40	--	--	--	--
4	35	0.76	26.6	1.17	0.88	9.15	--	--	--	--
4	35	0.76	26.6	1.17	0.88	9.90	--	--	--	--
4	35	0.76	26.6	1.17	0.88	10.64	--	--	--	--
4	35	0.76	26.6	1.17	0.88	11.39	--	--	--	--
4	35	0.76	26.6	1.17	0.88	12.14	--	--	--	--
4	35	0.76	26.6	1.17	0.88	12.89	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations by Layer							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	30	0.57	30	0	13.5	0.0	--	0
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
3	32	0.56	40	2041	33	33.0	--	0
3	32	0.55	40	2354	33	33.0	--	0
3	32	0.54	40	2667	33	33.0	--	0
3	32	0.54	40	2980	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6654.5	0.45	0.00	0.00	0.00	0.00	0.00
1	5	6649.5	0.45	0.00	0.00	0.00	0.00	0.00
2	10	6644.5	0.35	2.58	4.52	7.20	2.48	7.00
2	15	6639.5	0.35	2.58	9.03	7.20	2.48	11.52
2	20	6634.5	0.35	2.68	13.72	7.20	2.48	16.20
2	25	6629.5	0.35	2.78	18.58	7.20	2.48	21.07
2	30	6624.5	0.35	2.88	23.62	7.20	2.48	26.10
2	35	6619.5	0.35	2.98	28.83	7.20	2.48	31.31
3	40	6614.5	0.45	3.27	36.17	33.00	14.63	50.81
3	45	6609.5	0.45	3.81	44.74	33.00	14.63	59.37
3	50	6604.5	0.45	4.35	54.53	33.00	14.63	69.16
3	55	6599.5	0.45	4.89	65.54	33.00	14.63	80.17
3	60	6594.5	0.45	5.44	77.77	33.00	14.63	92.40
4	65	6589.5	0.45	7.65	94.99	108.00	47.89	142.88
4	70	6584.5	0.45	8.40	113.89	108.00	47.89	161.78
4	75	6579.5	0.45	9.15	134.48	108.00	47.89	182.36
4	80	6574.5	0.45	9.90	156.74	108.00	47.89	204.63
4	85	6569.5	0.45	10.64	180.69	108.00	47.89	228.58
4	90	6564.5	0.45	11.39	206.32	108.00	47.89	254.21
4	95	6559.5	0.45	12.14	233.63	108.00	47.89	281.52
4	100	6554.5	0.45	12.89	262.62	108.00	47.89	310.51
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring:	B-3
Depth to Groundwater Table [ft]:	5
Ground Elevation [ft]:	6654.5
Depth of Scour [ft]:	5 Not used in calcs
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesionless	0.45	0	30	--	5
2	Cohesive	0.35	120	--	800	35
3	Cohesionless	0.45	125	32	--	60
4	Cohesionless	0.45	130	35	--	100
5		0.45				
6		0.45				
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP14x73	Select from drop down menu
Depth [in]:	13.61	
Width [in]:	14.585	
Thickness [in]:	0.505	
End Area [sf]:	0.149	(unplugged)
End Area [sf]:	1.378	(plugged)
Volume[cf/ft]:	0.149	
Steel Perimeter (C_d) [ft]:	2.599	
Soil Perimeter (C_d) [ft]:	2.1000	
δ/ϕ:	0.78	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	535	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs			
Elevation	Depth	**B-3**	**Average**
6654.5	0	33	33
6649.5	5	5	5
6644.5	10	8	8
6639.5	15	10	10
6634.5	20	5	5
6629.5	25	8	8
6624.5	30	3	3
6619.5	35	5	5
6614.5	40	2	2
6609.5	45	5	5
6604.5	50	3	3
6599.5	55	11	11
6594.5	60	77	77
6589.5	65	100	100
6584.5	70	100	100
6579.5	75	100	100
6574.5	80	100	100
6569.5	85	100	100
6564.5	90	100	100
6559.5	95	100	100
6554.5	100	100	100

			Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045		5	1		
Project:	BIA Route N8066		35	2	3600	1728
Structure:	Pier, Pile Foundation, 5 ft of Scour		60	3	6725	3293
Corresponding Boring:	B-3		100	4	11925	5997
Groundwater Table [ft]:	5		0	5	11925	11925
Depth of Scour [ft]:	5		0	6	11925	11925
γ_w [pcf]:	62.4		0	7	11925	11925
			0	8	11925	11925

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	0	0	0	0	0	Cohesionless	33	0
2	5	7.5	10	120	62.4	300	600	288	144	Cohesive	5	8
2	10	12.5	15	120	62.4	900	1200	576	432	Cohesive	8	11
2	15	17.5	20	120	62.4	1500	1800	864	720	Cohesive	10	13
2	20	22.5	25	120	62.4	2100	2400	1152	1008	Cohesive	5	6
2	25	27.5	30	120	62.4	2700	3000	1440	1296	Cohesive	8	9
2	30	32.5	35	120	62.4	3300	3600	1728	1584	Cohesive	3	3
3	35	37.5	40	125	62.4	3912.5	4225	2041	1884.5	Cohesionless	5	5
3	40	42.5	45	125	62.4	4537.5	4850	2354	2197.5	Cohesionless	2	2
3	45	47.5	50	125	62.4	5162.5	5475	2667	2510.5	Cohesionless	5	5
3	50	52.5	55	125	62.4	5787.5	6100	2980	2823.5	Cohesionless	3	3
3	55	57.5	60	125	62.4	6412.5	6725	3293	3136.5	Cohesionless	11	9
4	60	62.5	65	130	62.4	7050	7375	3631	3462	Cohesionless	77	62
4	65	67.5	70	130	62.4	7700	8025	3969	3800	Cohesionless	100	77
4	70	72.5	75	130	62.4	8350	8675	4307	4138	Cohesionless	100	75
4	75	77.5	80	130	62.4	9000	9325	4645	4476	Cohesionless	100	72
4	80	82.5	85	130	62.4	9650	9975	4983	4814	Cohesionless	100	70
4	85	87.5	90	130	62.4	10300	10625	5321	5152	Cohesionless	100	67
4	90	92.5	95	130	62.4	10950	11275	5659	5490	Cohesionless	100	65
4	95	97.5	100	130	62.4	11600	11925	5997	5828	Cohesionless	100	63
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	30	0.78	23.4	0.90	0.93	0.00	--	--	--	0.00
2	--	--	--	--	--	--	800	0.95	0.65	3.05
2	--	--	--	--	--	--	800	0.95	0.65	3.05
2	--	--	--	--	--	--	800	0.95	0.66	3.11
2	--	--	--	--	--	--	800	0.96	0.68	3.21
2	--	--	--	--	--	--	800	0.97	0.70	3.30
2	--	--	--	--	--	--	800	0.97	0.72	3.40
3	32	0.78	24.96	1.04	0.91	4.15	--	--	--	--
3	32	0.78	24.96	1.04	0.91	4.84	--	--	--	--
3	32	0.78	24.96	1.04	0.91	5.53	--	--	--	--
3	32	0.78	24.96	1.04	0.91	6.22	--	--	--	--
3	32	0.78	24.96	1.04	0.91	6.91	--	--	--	--
4	35	0.78	27.3	1.25	0.90	9.88	--	--	--	--
4	35	0.78	27.3	1.25	0.90	10.84	--	--	--	--
4	35	0.78	27.3	1.25	0.90	11.81	--	--	--	--
4	35	0.78	27.3	1.25	0.90	12.77	--	--	--	--
4	35	0.78	27.3	1.25	0.90	13.74	--	--	--	--
4	35	0.78	27.3	1.25	0.90	14.70	--	--	--	--
4	35	0.78	27.3	1.25	0.90	15.66	--	--	--	--
4	35	0.78	27.3	1.25	0.90	16.63	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations by Layer							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	30	0.57	30	0	13.5	0.0	--	0
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
2	--	--	--	--	--	--	800	7.2
3	32	0.58	40	2041	33	33.0	--	0
3	32	0.57	40	2354	33	33.0	--	0
3	32	0.56	40	2667	33	33.0	--	0
3	32	0.55	40	2980	33	33.0	--	0
3	32	0.54	40	3200	33	33.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
4	35	0.63	64	3200	108	108.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6654.5	0.45	0.00	0.00	0.00	0.00	0.00
1	5	6649.5	0.45	0.00	0.00	0.00	0.00	0.00
2	10	6644.5	0.35	3.05	5.35	7.20	3.47	8.82
2	15	6639.5	0.35	3.05	10.69	7.20	3.47	14.16
2	20	6634.5	0.35	3.11	16.13	7.20	3.47	19.61
2	25	6629.5	0.35	3.21	21.74	7.20	3.47	25.22
2	30	6624.5	0.35	3.30	27.52	7.20	3.47	31.00
2	35	6619.5	0.35	3.40	33.47	7.20	3.47	36.95
3	40	6614.5	0.45	4.15	42.82	33.00	20.47	63.29
3	45	6609.5	0.45	4.84	53.72	33.00	20.47	74.19
3	50	6604.5	0.45	5.53	66.17	33.00	20.47	86.64
3	55	6599.5	0.45	6.22	80.18	33.00	20.47	100.65
3	60	6594.5	0.45	6.91	95.73	33.00	20.47	116.20
4	65	6589.5	0.45	9.88	117.96	108.00	66.99	184.95
4	70	6584.5	0.45	10.84	142.35	108.00	66.99	209.35
4	75	6579.5	0.45	11.81	168.92	108.00	66.99	235.91
4	80	6574.5	0.45	12.77	197.66	108.00	66.99	264.65
4	85	6569.5	0.45	13.74	228.56	108.00	66.99	295.56
4	90	6564.5	0.45	14.70	261.64	108.00	66.99	328.63
4	95	6559.5	0.45	15.66	296.88	108.00	66.99	363.88
4	100	6554.5	0.45	16.63	334.30	108.00	66.99	401.29
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

NOMINAL UPLIFT CAPACITY

DRIVEN H-PILES

ABUTMENTS

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Abutment, Pile Foundation, No Scour
Corresponding Boring:	B-1/B-2
Depth to Groundwater Table [ft]:	25
Ground Elevation [ft]:	6670
Depth of Scour [ft]:	0 Not used in calcs
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total} [pcf]	ϕ [degrees]	s_u [psf]	Depth to Bottom of Layer [ft]
1	Cohesive	0.25	110	--	2500	25
2	Cohesive	0.25	120	--	800	50
3	Cohesionless	0.35	125	32	--	70
4	Cohesionless	0.35	130	35	--	100
5		0.35				
6		0.35				
7		0.35				
8		0.35				

H-Pile Inputs		
Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.00	N/A	0.10	0.70	0.086	0.70	0.94
26	0.00	N/A	0.10	0.73	0.086	0.73	0.93
27	0.00	N/A	0.10	0.76	0.086	0.76	0.92
28	0.00	N/A	0.10	0.79	0.086	0.79	0.91
29	0.00	N/A	0.10	0.82	0.086	0.82	0.90
30	0.00	N/A	0.10	0.85	0.086	0.85	0.89
31	0.00	N/A	0.10	0.91	0.086	0.91	0.88
32	0.00	N/A	0.10	0.97	0.086	0.97	0.88
33	0.00	N/A	0.10	1.03	0.086	1.03	0.87
34	0.00	N/A	0.10	1.09	0.086	1.09	0.87
35	0.00	N/A	0.10	1.15	0.086	1.15	0.86
36	0.00	N/A	0.10	1.26	0.086	1.26	0.86
37	0.00	N/A	0.10	1.37	0.086	1.37	0.85
38	0.00	N/A	0.10	1.48	0.086	1.48	0.84
39	0.00	N/A	0.10	1.59	0.086	1.59	0.83
40	0.00	N/A	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**B-1**	**B-2**	**Average**
6670	0	15	14	15
6665	5	31	34	33
6660	10	23	30	27
6655	15	18	21	20
6650	20	17	15	16
6645	25	30	9	20
6640	30	30	8	19
6635	35	6	6	6
6630	40	13	5	9
6625	45	10	0	5
6620	50	8	4	6
6615	55	6	2	4
6610	60	6	3	5
6605	65	4	46	25
6600	70	3	100	52
6595	75	45	100	73
6590	80	100	100	100
6585	85	100	100	100
6580	90	100	100	100
6575	95	100		100
6570	100	100		100

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	25	1	2750	2750
Project:	BIA Route N8066	50	2	5750	4190
Structure:	Abutment, Pile Foundation, No Scour	70	3	8250	5442
Corresponding Boring:	B-1/B-2	100	4	12150	7470
Groundwater Table [ft]:	25	0	5	12150	12150
Depth of Scour [ft]:	0	0	6	12150	12150
γ_w [pcf]:	62.4	0	7	12150	12150
		0	8	12150	12150

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	15	21
1	5	7.5	10	110	--	825	1100	1100	825	Cohesive	33	39
1	10	12.5	15	110	--	1375	1650	1650	1375	Cohesive	27	28
1	15	17.5	20	110	--	1925	2200	2200	1925	Cohesive	20	19
1	20	22.5	25	110	--	2475	2750	2750	2475	Cohesive	16	14
2	25	27.5	30	120	62.4	3050	3350	3038	2894	Cohesive	20	17
2	30	32.5	35	120	62.4	3650	3950	3326	3182	Cohesive	19	16
2	35	37.5	40	120	62.4	4250	4550	3614	3470	Cohesive	6	5
2	40	42.5	45	120	62.4	4850	5150	3902	3758	Cohesive	9	7
2	45	47.5	50	120	62.4	5450	5750	4190	4046	Cohesive	5	4
3	50	52.5	55	125	62.4	6062.5	6375	4503	4346.5	Cohesionless	6	4
3	55	57.5	60	125	62.4	6687.5	7000	4816	4659.5	Cohesionless	4	3
3	60	62.5	65	125	62.4	7312.5	7625	5129	4972.5	Cohesionless	5	3
3	65	67.5	70	125	62.4	7937.5	8250	5442	5285.5	Cohesionless	25	17
4	70	72.5	75	130	62.4	8575	8900	5780	5611	Cohesionless	52	33
4	75	77.5	80	130	62.4	9225	9550	6118	5949	Cohesionless	73	46
4	80	82.5	85	130	62.4	9875	10200	6456	6287	Cohesionless	100	61
4	85	87.5	90	130	62.4	10525	10850	6794	6625	Cohesionless	100	59
4	90	92.5	95	130	62.4	11175	11500	7132	6963	Cohesionless	100	58
4	95	97.5	100	130	62.4	11825	12150	7470	7301	Cohesionless	100	56
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.30
1	--	--	--	--	--	--	2500	0.44	1.00	3.30
1	--	--	--	--	--	--	2500	0.46	1.03	3.40
1	--	--	--	--	--	--	2500	0.51	1.14	3.75
1	--	--	--	--	--	--	2500	0.56	1.24	4.09
2	--	--	--	--	--	--	800	0.98	0.75	2.47
2	--	--	--	--	--	--	800	0.99	0.78	2.57
2	--	--	--	--	--	--	800	1.00	0.80	2.64
2	--	--	--	--	--	--	800	1.00	0.80	2.64
2	--	--	--	--	--	--	800	1.00	0.80	2.64
3	32	0.74	23.68	0.97	0.88	6.01	--	--	--	--
3	32	0.74	23.68	0.97	0.88	6.44	--	--	--	--
3	32	0.74	23.68	0.97	0.88	6.88	--	--	--	--
3	32	0.74	23.68	0.97	0.88	7.31	--	--	--	--
4	35	0.74	25.9	1.15	0.86	9.87	--	--	--	--
4	35	0.74	25.9	1.15	0.86	10.47	--	--	--	--
4	35	0.74	25.9	1.15	0.86	11.06	--	--	--	--
4	35	0.74	25.9	1.15	0.86	11.66	--	--	--	--
4	35	0.74	25.9	1.15	0.86	12.25	--	--	--	--
4	35	0.74	25.9	1.15	0.86	12.85	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6670	0.25	0.00	0.00	0.00
1	5	6665	0.25	0.00	0.00	0.00
1	10	6660	0.25	3.30	4.12	4.12
1	15	6655	0.25	3.40	8.38	8.38
1	20	6650	0.25	3.75	13.06	13.06
1	25	6645	0.25	4.09	18.16	18.16
2	30	6640	0.25	2.47	21.25	21.25
2	35	6635	0.25	2.57	24.46	24.46
2	40	6630	0.25	2.64	27.75	27.75
2	45	6625	0.25	2.64	31.05	31.05
2	50	6620	0.25	2.64	34.34	34.34
3	55	6615	0.35	6.01	44.86	44.86
3	60	6610	0.35	6.44	56.14	56.14
3	65	6605	0.35	6.88	68.17	68.17
3	70	6600	0.35	7.31	80.96	80.96
4	75	6595	0.35	9.87	98.24	98.24
4	80	6590	0.35	10.47	116.56	116.56
4	85	6585	0.35	11.06	135.92	135.92
4	90	6580	0.35	11.66	156.33	156.33
4	95	6575	0.35	12.25	177.77	177.77
4	100	6570	0.35	12.85	200.26	200.26
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Abutment, Pile Foundation, No Scour
Corresponding Boring:	B-1/B-2
Depth to Groundwater Table [ft]:	25
Ground Elevation [ft]:	6670
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	110	--	2500	25
2	Cohesive	0.25	120	--	800	50
3	Cohesionless	0.35	125	32	--	70
4	Cohesionless	0.35	130	35	--	100
5		0.35				
6		0.35				
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**B-1**	**B-2**	**Average**
6670	0	15	14	15
6665	5	31	34	33
6660	10	23	30	27
6655	15	18	21	20
6650	20	17	15	16
6645	25	30	9	20
6640	30	30	8	19
6635	35	6	6	6
6630	40	13	5	9
6625	45	10	0	5
6620	50	8	4	6
6615	55	6	2	4
6610	60	6	3	5
6605	65	4	46	25
6600	70	3	100	52
6595	75	45	100	73
6590	80	100	100	100
6585	85	100	100	100
6580	90	100	100	100
6575	95	100		100
6570	100	100		100

Project No.: 17-2015-4045
Project: BIA Route N8066
Structure: Abutment, Pile Foundation, No Scour
Corresponding Boring: B-1/B-2
Groundwater Table [ft]: 25
Depth of Scour [ft]: 0
γ_w [pcf]: 62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
25	1	2750	2750
50	2	5750	4190
70	3	8250	5442
100	4	12150	7470
0	5	12150	12150
0	6	12150	12150
0	7	12150	12150
0	8	12150	12150

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	15	21
1	5	7.5	10	110	--	825	1100	1100	825	Cohesive	33	39
1	10	12.5	15	110	--	1375	1650	1650	1375	Cohesive	27	28
1	15	17.5	20	110	--	1925	2200	2200	1925	Cohesive	20	19
1	20	22.5	25	110	--	2475	2750	2750	2475	Cohesive	16	14
2	25	27.5	30	120	62.4	3050	3350	3038	2894	Cohesive	20	17
2	30	32.5	35	120	62.4	3650	3950	3326	3182	Cohesive	19	16
2	35	37.5	40	120	62.4	4250	4550	3614	3470	Cohesive	6	5
2	40	42.5	45	120	62.4	4850	5150	3902	3758	Cohesive	9	7
2	45	47.5	50	120	62.4	5450	5750	4190	4046	Cohesive	5	4
3	50	52.5	55	125	62.4	6062.5	6375	4503	4346.5	Cohesionless	6	4
3	55	57.5	60	125	62.4	6687.5	7000	4816	4659.5	Cohesionless	4	3
3	60	62.5	65	125	62.4	7312.5	7625	5129	4972.5	Cohesionless	5	3
3	65	67.5	70	125	62.4	7937.5	8250	5442	5285.5	Cohesionless	25	17
4	70	72.5	75	130	62.4	8575	8900	5780	5611	Cohesionless	52	33
4	75	77.5	80	130	62.4	9225	9550	6118	5949	Cohesionless	73	46
4	80	82.5	85	130	62.4	9875	10200	6456	6287	Cohesionless	100	61
4	85	87.5	90	130	62.4	10525	10850	6794	6625	Cohesionless	100	59
4	90	92.5	95	130	62.4	11175	11500	7132	6963	Cohesionless	100	58
4	95	97.5	100	130	62.4	11825	12150	7470	7301	Cohesionless	100	56
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.48	1.09	4.31
1	--	--	--	--	--	--	2500	0.53	1.17	4.66
2	--	--	--	--	--	--	800	0.98	0.73	2.88
2	--	--	--	--	--	--	800	0.98	0.75	2.98
2	--	--	--	--	--	--	800	0.99	0.78	3.08
2	--	--	--	--	--	--	800	1.00	0.80	3.18
2	--	--	--	--	--	--	800	1.00	0.80	3.18
3	32	0.76	24.32	0.98	0.90	7.53	--	--	--	--
3	32	0.76	24.32	0.98	0.90	8.07	--	--	--	--
3	32	0.76	24.32	0.98	0.90	8.62	--	--	--	--
3	32	0.76	24.32	0.98	0.90	9.16	--	--	--	--
4	35	0.76	26.6	1.17	0.88	12.41	--	--	--	--
4	35	0.76	26.6	1.17	0.88	13.15	--	--	--	--
4	35	0.76	26.6	1.17	0.88	13.90	--	--	--	--
4	35	0.76	26.6	1.17	0.88	14.65	--	--	--	--
4	35	0.76	26.6	1.17	0.88	15.39	--	--	--	--
4	35	0.76	26.6	1.17	0.88	16.14	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6670	0.25	0.00	0.00	0.00
1	5	6665	0.25	0.00	0.00	0.00
1	10	6660	0.25	3.97	4.96	4.96
1	15	6655	0.25	3.97	9.93	9.93
1	20	6650	0.25	4.31	15.32	15.32
1	25	6645	0.25	4.66	21.14	21.14
2	30	6640	0.25	2.88	24.74	24.74
2	35	6635	0.25	2.98	28.47	28.47
2	40	6630	0.25	3.08	32.31	32.31
2	45	6625	0.25	3.18	36.28	36.28
2	50	6620	0.25	3.18	40.25	40.25
3	55	6615	0.35	7.53	53.44	53.44
3	60	6610	0.35	8.07	67.57	67.57
3	65	6605	0.35	8.62	82.64	82.64
3	70	6600	0.35	9.16	98.67	98.67
4	75	6595	0.35	12.41	120.38	120.38
4	80	6590	0.35	13.15	143.40	143.40
4	85	6585	0.35	13.90	167.72	167.72
4	90	6580	0.35	14.65	193.36	193.36
4	95	6575	0.35	15.39	220.30	220.30
4	100	6570	0.35	16.14	248.55	248.55
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Abutment, Pile Foundation, No Scour
Corresponding Boring:	B-1/B-2
Depth to Groundwater Table [ft]:	25
Ground Elevation [ft]:	6670
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total} [pcf]	ϕ [degrees]	s_u [psf]	Depth to Bottom of Layer [ft]
1	Cohesive	0.25	110	--	2500	25
2	Cohesive	0.25	120	--	800	50
3	Cohesionless	0.35	125	32	--	70
4	Cohesionless	0.35	130	35	--	100
5		0.35				
6		0.35				
7		0.35				
8		0.35				

H-Pile Inputs		
Pile Type:	HP14x73	Select from drop down menu
Depth [in]:	13.61	
Width [in]:	14.585	
Thickness [in]:	0.505	
End Area [sf]:	0.149	(unplugged)
End Area [sf]:	1.378	(plugged)
Volume[cf/ft]:	0.149	
Steel Perimeter (C_d) [ft]:	2.599	
Soil Perimeter (C_d) [ft]:	2.1000	
δ/ϕ:	0.78	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	535	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**B-1**	**B-2**	**Average**
6670	0	15	14	15
6665	5	31	34	33
6660	10	23	30	27
6655	15	18	21	20
6650	20	17	15	16
6645	25	30	9	20
6640	30	30	8	19
6635	35	6	6	6
6630	40	13	5	9
6625	45	10	0	5
6620	50	8	4	6
6615	55	6	2	4
6610	60	6	3	5
6605	65	4	46	25
6600	70	3	100	52
6595	75	45	100	73
6590	80	100	100	100
6585	85	100	100	100
6580	90	100	100	100
6575	95	100		100
6570	100	100		100

Calculation

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Abutment, Pile Foundation, No Scour
Corresponding Boring:	B-1/B-2
Groundwater Table [ft]:	25
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
25	1	2750	2750
50	2	5750	4190
70	3	8250	5442
100	4	12150	7470
0	5	12150	12150
0	6	12150	12150
0	7	12150	12150
0	8	12150	12150

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	15	21
1	5	7.5	10	110	--	825	1100	1100	825	Cohesive	33	39
1	10	12.5	15	110	--	1375	1650	1650	1375	Cohesive	27	28
1	15	17.5	20	110	--	1925	2200	2200	1925	Cohesive	20	19
1	20	22.5	25	110	--	2475	2750	2750	2475	Cohesive	16	14
2	25	27.5	30	120	62.4	3050	3350	3038	2894	Cohesive	20	17
2	30	32.5	35	120	62.4	3650	3950	3326	3182	Cohesive	19	16
2	35	37.5	40	120	62.4	4250	4550	3614	3470	Cohesive	6	5
2	40	42.5	45	120	62.4	4850	5150	3902	3758	Cohesive	9	7
2	45	47.5	50	120	62.4	5450	5750	4190	4046	Cohesive	5	4
3	50	52.5	55	125	62.4	6062.5	6375	4503	4346.5	Cohesionless	6	4
3	55	57.5	60	125	62.4	6687.5	7000	4816	4659.5	Cohesionless	4	3
3	60	62.5	65	125	62.4	7312.5	7625	5129	4972.5	Cohesionless	5	3
3	65	67.5	70	125	62.4	7937.5	8250	5442	5285.5	Cohesionless	25	17
4	70	72.5	75	130	62.4	8575	8900	5780	5611	Cohesionless	52	33
4	75	77.5	80	130	62.4	9225	9550	6118	5949	Cohesionless	73	46
4	80	82.5	85	130	62.4	9875	10200	6456	6287	Cohesionless	100	61
4	85	87.5	90	130	62.4	10525	10850	6794	6625	Cohesionless	100	59
4	90	92.5	95	130	62.4	11175	11500	7132	6963	Cohesionless	100	58
4	95	97.5	100	130	62.4	11825	12150	7470	7301	Cohesionless	100	56
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.46	1.04	4.89
1	--	--	--	--	--	--	2500	0.50	1.11	5.22
2	--	--	--	--	--	--	800	0.97	0.70	3.30
2	--	--	--	--	--	--	800	0.97	0.72	3.40
2	--	--	--	--	--	--	800	0.98	0.74	3.50
2	--	--	--	--	--	--	800	0.99	0.76	3.59
2	--	--	--	--	--	--	800	1.00	0.79	3.69
3	32	0.78	24.96	1.04	0.91	9.58	--	--	--	--
3	32	0.78	24.96	1.04	0.91	10.27	--	--	--	--
3	32	0.78	24.96	1.04	0.91	10.96	--	--	--	--
3	32	0.78	24.96	1.04	0.91	11.65	--	--	--	--
4	35	0.78	27.3	1.25	0.90	16.01	--	--	--	--
4	35	0.78	27.3	1.25	0.90	16.97	--	--	--	--
4	35	0.78	27.3	1.25	0.90	17.94	--	--	--	--
4	35	0.78	27.3	1.25	0.90	18.90	--	--	--	--
4	35	0.78	27.3	1.25	0.90	19.87	--	--	--	--
4	35	0.78	27.3	1.25	0.90	20.83	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6670	0.25	0.00	0.00	0.00
1	5	6665	0.25	0.00	0.00	0.00
1	10	6660	0.25	4.70	5.87	5.87
1	15	6655	0.25	4.70	11.75	11.75
1	20	6650	0.25	4.89	17.86	17.86
1	25	6645	0.25	5.22	24.39	24.39
2	30	6640	0.25	3.30	28.52	28.52
2	35	6635	0.25	3.40	32.77	32.77
2	40	6630	0.25	3.50	37.14	37.14
2	45	6625	0.25	3.59	41.63	41.63
2	50	6620	0.25	3.69	46.24	46.24
3	55	6615	0.35	9.58	63.01	63.01
3	60	6610	0.35	10.27	80.99	80.99
3	65	6605	0.35	10.96	100.17	100.17
3	70	6600	0.35	11.65	120.56	120.56
4	75	6595	0.35	16.01	148.58	148.58
4	80	6590	0.35	16.97	178.28	178.28
4	85	6585	0.35	17.94	209.67	209.67
4	90	6580	0.35	18.90	242.75	242.75
4	95	6575	0.35	19.87	277.52	277.52
4	100	6570	0.35	20.83	313.98	313.98
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

PIERS

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring:	B-3
Depth to Groundwater Table [ft]:	5
Ground Elevation [ft]:	6654.5
Depth of Scour [ft]:	5 Not used in calcs
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesionless	0.35	0	30	--	5
2	Cohesive	0.25	120	--	800	35
3	Cohesionless	0.35	125	32	--	60
4	Cohesionless	0.35	130	35	--	100
5		0.35				
6		0.35				
7		0.35				
8		0.35				

H-Pile Inputs		
Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.00	1.00	0.10	0.70	0.086	0.70	0.94
26	0.00	1.09	0.10	0.73	0.086	0.73	0.93
27	0.00	1.18	0.10	0.76	0.086	0.76	0.92
28	0.00	1.27	0.10	0.79	0.086	0.79	0.91
29	0.00	1.36	0.10	0.82	0.086	0.82	0.90
30	0.00	1.45	0.10	0.85	0.086	0.85	0.89
31	0.00	1.63	0.10	0.91	0.086	0.91	0.88
32	0.00	1.81	0.10	0.97	0.086	0.97	0.88
33	0.00	1.99	0.10	1.03	0.086	1.03	0.87
34	0.00	2.17	0.10	1.09	0.086	1.09	0.87
35	0.00	2.35	0.10	1.15	0.086	1.15	0.86
36	0.00	2.74	0.10	1.26	0.086	1.26	0.86
37	0.00	3.13	0.10	1.37	0.086	1.37	0.85
38	0.00	3.52	0.10	1.48	0.086	1.48	0.84
39	0.00	3.91	0.10	1.59	0.086	1.59	0.83
40	0.00	4.30	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs			
Elevation	Depth	**B-3**	**Average**
6654.5	0	33	33
6649.5	5	5	5
6644.5	10	8	8
6639.5	15	10	10
6634.5	20	5	5
6629.5	25	8	8
6624.5	30	3	3
6619.5	35	5	5
6614.5	40	2	2
6609.5	45	5	5
6604.5	50	3	3
6599.5	55	11	11
6594.5	60	77	77
6589.5	65	100	100
6584.5	70	100	100
6579.5	75	100	100
6574.5	80	100	100
6569.5	85	100	100
6564.5	90	100	100
6559.5	95	100	100
6554.5	100	100	100

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring:	B-3
Groundwater Table [ft]:	5
Depth of Scour [ft]:	5
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1		
35	2	3600	1728
60	3	6725	3293
100	4	11925	5997
0	5	11925	11925
0	6	11925	11925
0	7	11925	11925
0	8	11925	11925

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	0	0	0	0	0	Cohesionless	33	0
2	5	7.5	10	120	62.4	300	600	288	144	Cohesive	5	8
2	10	12.5	15	120	62.4	900	1200	576	432	Cohesive	8	11
2	15	17.5	20	120	62.4	1500	1800	864	720	Cohesive	10	13
2	20	22.5	25	120	62.4	2100	2400	1152	1008	Cohesive	5	6
2	25	27.5	30	120	62.4	2700	3000	1440	1296	Cohesive	8	9
2	30	32.5	35	120	62.4	3300	3600	1728	1584	Cohesive	3	3
3	35	37.5	40	125	62.4	3912.5	4225	2041	1884.5	Cohesionless	5	5
3	40	42.5	45	125	62.4	4537.5	4850	2354	2197.5	Cohesionless	2	2
3	45	47.5	50	125	62.4	5162.5	5475	2667	2510.5	Cohesionless	5	5
3	50	52.5	55	125	62.4	5787.5	6100	2980	2823.5	Cohesionless	3	3
3	55	57.5	60	125	62.4	6412.5	6725	3293	3136.5	Cohesionless	11	9
4	60	62.5	65	130	62.4	7050	7375	3631	3462	Cohesionless	77	62
4	65	67.5	70	130	62.4	7700	8025	3969	3800	Cohesionless	100	77
4	70	72.5	75	130	62.4	8350	8675	4307	4138	Cohesionless	100	75
4	75	77.5	80	130	62.4	9000	9325	4645	4476	Cohesionless	100	72
4	80	82.5	85	130	62.4	9650	9975	4983	4814	Cohesionless	100	70
4	85	87.5	90	130	62.4	10300	10625	5321	5152	Cohesionless	100	67
4	90	92.5	95	130	62.4	10950	11275	5659	5490	Cohesionless	100	65
4	95	97.5	100	130	62.4	11600	11925	5997	5828	Cohesionless	100	63
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_{δ}	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	30	0.74	22.2	0.85	0.89	0.00	--	--	--	0.00
2	--	--	--	--	--	--	800	0.95	0.65	2.14
2	--	--	--	--	--	--	800	0.95	0.66	2.17
2	--	--	--	--	--	--	800	0.96	0.69	2.27
2	--	--	--	--	--	--	800	0.97	0.72	2.37
2	--	--	--	--	--	--	800	0.98	0.75	2.47
2	--	--	--	--	--	--	800	0.99	0.78	2.57
3	32	0.74	23.68	0.97	0.88	2.61	--	--	--	--
3	32	0.74	23.68	0.97	0.88	3.04	--	--	--	--
3	32	0.74	23.68	0.97	0.88	3.47	--	--	--	--
3	32	0.74	23.68	0.97	0.88	3.90	--	--	--	--
3	32	0.74	23.68	0.97	0.88	4.34	--	--	--	--
4	35	0.74	25.9	1.15	0.86	6.09	--	--	--	--
4	35	0.74	25.9	1.15	0.86	6.69	--	--	--	--
4	35	0.74	25.9	1.15	0.86	7.28	--	--	--	--
4	35	0.74	25.9	1.15	0.86	7.88	--	--	--	--
4	35	0.74	25.9	1.15	0.86	8.47	--	--	--	--
4	35	0.74	25.9	1.15	0.86	9.07	--	--	--	--
4	35	0.74	25.9	1.15	0.86	9.66	--	--	--	--
4	35	0.74	25.9	1.15	0.86	10.26	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6654.5	0.35	0.00	0.00	0.00
1	5	6649.5	0.35	0.00	0.00	0.00
2	10	6644.5	0.25	2.14	2.68	2.68
2	15	6639.5	0.25	2.17	5.40	5.40
2	20	6634.5	0.25	2.27	8.23	8.23
2	25	6629.5	0.25	2.37	11.20	11.20
2	30	6624.5	0.25	2.47	14.28	14.28
2	35	6619.5	0.25	2.57	17.49	17.49
3	40	6614.5	0.35	2.61	22.05	22.05
3	45	6609.5	0.35	3.04	27.37	27.37
3	50	6604.5	0.35	3.47	33.44	33.44
3	55	6599.5	0.35	3.90	40.27	40.27
3	60	6594.5	0.35	4.34	47.86	47.86
4	65	6589.5	0.35	6.09	58.53	58.53
4	70	6584.5	0.35	6.69	70.23	70.23
4	75	6579.5	0.35	7.28	82.97	82.97
4	80	6574.5	0.35	7.88	96.76	96.76
4	85	6569.5	0.35	8.47	111.59	111.59
4	90	6564.5	0.35	9.07	127.45	127.45
4	95	6559.5	0.35	9.66	144.36	144.36
4	100	6554.5	0.35	10.26	162.31	162.31
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring:	B-3
Depth to Groundwater Table [ft]:	5
Ground Elevation [ft]:	6654.5
Depth of Scour [ft]:	5 Not used in calcs
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesionless	0.35	0	30	--	5
2	Cohesive	0.25	120	--	800	35
3	Cohesionless	0.35	125	32	--	60
4	Cohesionless	0.35	130	35	--	100
5		0.35				
6		0.35				
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs			
Elevation	Depth	**B-3**	**Average**
6654.5	0	33	33
6649.5	5	5	5
6644.5	10	8	8
6639.5	15	10	10
6634.5	20	5	5
6629.5	25	8	8
6624.5	30	3	3
6619.5	35	5	5
6614.5	40	2	2
6609.5	45	5	5
6604.5	50	3	3
6599.5	55	11	11
6594.5	60	77	77
6589.5	65	100	100
6584.5	70	100	100
6579.5	75	100	100
6574.5	80	100	100
6569.5	85	100	100
6564.5	90	100	100
6559.5	95	100	100
6554.5	100	100	100

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring:	B-3
Groundwater Table [ft]:	5
Depth of Scour [ft]:	5
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1		
35	2	3600	1728
60	3	6725	3293
100	4	11925	5997
0	5	11925	11925
0	6	11925	11925
0	7	11925	11925
0	8	11925	11925

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	0	0	0	0	0	Cohesionless	33	0
2	5	7.5	10	120	62.4	300	600	288	144	Cohesive	5	8
2	10	12.5	15	120	62.4	900	1200	576	432	Cohesive	8	11
2	15	17.5	20	120	62.4	1500	1800	864	720	Cohesive	10	13
2	20	22.5	25	120	62.4	2100	2400	1152	1008	Cohesive	5	6
2	25	27.5	30	120	62.4	2700	3000	1440	1296	Cohesive	8	9
2	30	32.5	35	120	62.4	3300	3600	1728	1584	Cohesive	3	3
3	35	37.5	40	125	62.4	3912.5	4225	2041	1884.5	Cohesionless	5	5
3	40	42.5	45	125	62.4	4537.5	4850	2354	2197.5	Cohesionless	2	2
3	45	47.5	50	125	62.4	5162.5	5475	2667	2510.5	Cohesionless	5	5
3	50	52.5	55	125	62.4	5787.5	6100	2980	2823.5	Cohesionless	3	3
3	55	57.5	60	125	62.4	6412.5	6725	3293	3136.5	Cohesionless	11	9
4	60	62.5	65	130	62.4	7050	7375	3631	3462	Cohesionless	77	62
4	65	67.5	70	130	62.4	7700	8025	3969	3800	Cohesionless	100	77
4	70	72.5	75	130	62.4	8350	8675	4307	4138	Cohesionless	100	75
4	75	77.5	80	130	62.4	9000	9325	4645	4476	Cohesionless	100	72
4	80	82.5	85	130	62.4	9650	9975	4983	4814	Cohesionless	100	70
4	85	87.5	90	130	62.4	10300	10625	5321	5152	Cohesionless	100	67
4	90	92.5	95	130	62.4	10950	11275	5659	5490	Cohesionless	100	65
4	95	97.5	100	130	62.4	11600	11925	5997	5828	Cohesionless	100	63
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	30	0.76	22.8	0.86	0.91	0.00	--	--	--	0.00
2	--	--	--	--	--	--	800	0.95	0.65	2.58
2	--	--	--	--	--	--	800	0.95	0.65	2.58
2	--	--	--	--	--	--	800	0.92	0.67	2.68
2	--	--	--	--	--	--	800	0.93	0.70	2.78
2	--	--	--	--	--	--	800	0.95	0.72	2.88
2	--	--	--	--	--	--	800	0.97	0.75	2.98
3	32	0.76	24.32	0.98	0.90	3.27	--	--	--	--
3	32	0.76	24.32	0.98	0.90	3.81	--	--	--	--
3	32	0.76	24.32	0.98	0.90	4.35	--	--	--	--
3	32	0.76	24.32	0.98	0.90	4.89	--	--	--	--
3	32	0.76	24.32	0.98	0.90	5.44	--	--	--	--
4	35	0.76	26.6	1.17	0.88	7.65	--	--	--	--
4	35	0.76	26.6	1.17	0.88	8.40	--	--	--	--
4	35	0.76	26.6	1.17	0.88	9.15	--	--	--	--
4	35	0.76	26.6	1.17	0.88	9.90	--	--	--	--
4	35	0.76	26.6	1.17	0.88	10.64	--	--	--	--
4	35	0.76	26.6	1.17	0.88	11.39	--	--	--	--
4	35	0.76	26.6	1.17	0.88	12.14	--	--	--	--
4	35	0.76	26.6	1.17	0.88	12.89	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6654.5	0.35	0.00	0.00	0.00
1	5	6649.5	0.35	0.00	0.00	0.00
2	10	6644.5	0.25	2.58	3.23	3.23
2	15	6639.5	0.25	2.58	6.45	6.45
2	20	6634.5	0.25	2.68	9.80	9.80
2	25	6629.5	0.25	2.78	13.27	13.27
2	30	6624.5	0.25	2.88	16.87	16.87
2	35	6619.5	0.25	2.98	20.59	20.59
3	40	6614.5	0.35	3.27	26.30	26.30
3	45	6609.5	0.35	3.81	32.97	32.97
3	50	6604.5	0.35	4.35	40.58	40.58
3	55	6599.5	0.35	4.89	49.14	49.14
3	60	6594.5	0.35	5.44	58.66	58.66
4	65	6589.5	0.35	7.65	72.05	72.05
4	70	6584.5	0.35	8.40	86.75	86.75
4	75	6579.5	0.35	9.15	102.76	102.76
4	80	6574.5	0.35	9.90	120.08	120.08
4	85	6569.5	0.35	10.64	138.71	138.71
4	90	6564.5	0.35	11.39	158.64	158.64
4	95	6559.5	0.35	12.14	179.88	179.88
4	100	6554.5	0.35	12.89	202.43	202.43
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs

Project No.: 17-2015-4045
Project: BIA Route N8066
Structure: Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring: B-3

Depth to Groundwater Table [ft]:	5	
Ground Elevation [ft]:	6654.5	
Depth of Scour [ft]:	5	Not used in calcs
Resistance Factor [clay]:	0.25	
Resistance Factor [sand]:	0.35	
Atmospheric Pressure (p_a) [pcf]:	2116	

Soil Layer	Soil Type	Resistance Factor	γ_{total} [pcf]	ϕ [degrees]	s_u [psf]	Depth to Bottom of Layer [ft]
1	Cohesionless	0.35	0	30	--	5
2	Cohesive	0.25	120	--	800	35
3	Cohesionless	0.35	125	32	--	60
4	Cohesionless	0.35	130	35	--	100
5		0.35				
6		0.35				
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type:	HP14x73	Select from drop down menu
Depth [in]:	13.61	
Width [in]:	14.585	
Thickness [in]:	0.505	
End Area [sf]:	0.149	(unplugged)
End Area [sf]:	1.378	(plugged)
Volume[cf/ft]:	0.149	
Steel Perimeter (C_d) [ft]:	2.599	
Soil Perimeter (C_d) [ft]:	2.1000	
δ/ϕ:	0.78	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	535	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs			
Elevation	Depth	**B-3**	**Average**
6654.5	0	33	33
6649.5	5	5	5
6644.5	10	8	8
6639.5	15	10	10
6634.5	20	5	5
6629.5	25	8	8
6624.5	30	3	3
6619.5	35	5	5
6614.5	40	2	2
6609.5	45	5	5
6604.5	50	3	3
6599.5	55	11	11
6594.5	60	77	77
6589.5	65	100	100
6584.5	70	100	100
6579.5	75	100	100
6574.5	80	100	100
6569.5	85	100	100
6564.5	90	100	100
6559.5	95	100	100
6554.5	100	100	100

Project No.:	17-2015-4045
Project:	BIA Route N8066
Structure:	Pier, Pile Foundation, 5 ft of Scour
Corresponding Boring:	B-3
Groundwater Table [ft]:	5
Depth of Scour [ft]:	5
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1		
35	2	3600	1728
60	3	6725	3293
100	4	11925	5997
0	5	11925	11925
0	6	11925	11925
0	7	11925	11925
0	8	11925	11925

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	0	0	0	0	0	Cohesionless	33	0
2	5	7.5	10	120	62.4	300	600	288	144	Cohesive	5	8
2	10	12.5	15	120	62.4	900	1200	576	432	Cohesive	8	11
2	15	17.5	20	120	62.4	1500	1800	864	720	Cohesive	10	13
2	20	22.5	25	120	62.4	2100	2400	1152	1008	Cohesive	5	6
2	25	27.5	30	120	62.4	2700	3000	1440	1296	Cohesive	8	9
2	30	32.5	35	120	62.4	3300	3600	1728	1584	Cohesive	3	3
3	35	37.5	40	125	62.4	3912.5	4225	2041	1884.5	Cohesionless	5	5
3	40	42.5	45	125	62.4	4537.5	4850	2354	2197.5	Cohesionless	2	2
3	45	47.5	50	125	62.4	5162.5	5475	2667	2510.5	Cohesionless	5	5
3	50	52.5	55	125	62.4	5787.5	6100	2980	2823.5	Cohesionless	3	3
3	55	57.5	60	125	62.4	6412.5	6725	3293	3136.5	Cohesionless	11	9
4	60	62.5	65	130	62.4	7050	7375	3631	3462	Cohesionless	77	62
4	65	67.5	70	130	62.4	7700	8025	3969	3800	Cohesionless	100	77
4	70	72.5	75	130	62.4	8350	8675	4307	4138	Cohesionless	100	75
4	75	77.5	80	130	62.4	9000	9325	4645	4476	Cohesionless	100	72
4	80	82.5	85	130	62.4	9650	9975	4983	4814	Cohesionless	100	70
4	85	87.5	90	130	62.4	10300	10625	5321	5152	Cohesionless	100	67
4	90	92.5	95	130	62.4	10950	11275	5659	5490	Cohesionless	100	65
4	95	97.5	100	130	62.4	11600	11925	5997	5828	Cohesionless	100	63
8	100	100.0	--	--	--	--	--	--	--	--	100	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	30	0.78	23.4	0.90	0.93	0.00	--	--	--	0.00
2	--	--	--	--	--	--	800	0.95	0.65	3.05
2	--	--	--	--	--	--	800	0.95	0.65	3.05
2	--	--	--	--	--	--	800	0.95	0.66	3.11
2	--	--	--	--	--	--	800	0.96	0.68	3.21
2	--	--	--	--	--	--	800	0.97	0.70	3.30
2	--	--	--	--	--	--	800	0.97	0.72	3.40
3	32	0.78	24.96	1.04	0.91	4.15	--	--	--	--
3	32	0.78	24.96	1.04	0.91	4.84	--	--	--	--
3	32	0.78	24.96	1.04	0.91	5.53	--	--	--	--
3	32	0.78	24.96	1.04	0.91	6.22	--	--	--	--
3	32	0.78	24.96	1.04	0.91	6.91	--	--	--	--
4	35	0.78	27.3	1.25	0.90	9.88	--	--	--	--
4	35	0.78	27.3	1.25	0.90	10.84	--	--	--	--
4	35	0.78	27.3	1.25	0.90	11.81	--	--	--	--
4	35	0.78	27.3	1.25	0.90	12.77	--	--	--	--
4	35	0.78	27.3	1.25	0.90	13.74	--	--	--	--
4	35	0.78	27.3	1.25	0.90	14.70	--	--	--	--
4	35	0.78	27.3	1.25	0.90	15.66	--	--	--	--
4	35	0.78	27.3	1.25	0.90	16.63	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6654.5	0.35	0.00	0.00	0.00
1	5	6649.5	0.35	0.00	0.00	0.00
2	10	6644.5	0.25	3.05	3.82	3.82
2	15	6639.5	0.25	3.05	7.64	7.64
2	20	6634.5	0.25	3.11	11.52	11.52
2	25	6629.5	0.25	3.21	15.53	15.53
2	30	6624.5	0.25	3.30	19.66	19.66
2	35	6619.5	0.25	3.40	23.91	23.91
3	40	6614.5	0.35	4.15	31.18	31.18
3	45	6609.5	0.35	4.84	39.66	39.66
3	50	6604.5	0.35	5.53	49.34	49.34
3	55	6599.5	0.35	6.22	60.23	60.23
3	60	6594.5	0.35	6.91	72.33	72.33
4	65	6589.5	0.35	9.88	89.62	89.62
4	70	6584.5	0.35	10.84	108.59	108.59
4	75	6579.5	0.35	11.81	129.26	129.26
4	80	6574.5	0.35	12.77	151.61	151.61
4	85	6569.5	0.35	13.74	175.64	175.64
4	90	6564.5	0.35	14.70	201.37	201.37
4	95	6559.5	0.35	15.66	228.78	228.78
4	100	6554.5	0.35	16.63	257.88	257.88
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

ATTACHMENT D

SAMPLE CALCULATIONS FOR SETTLEMENT OF PILES

DESIGN MEMORANDUM

Client: BIA
Sheet 1 Of 5
Project: BIAN8066(3)
Date: 6/10/16
Data For: Settlement of Piles
Work Order:
Prepared By: NC
Checked By:
File No: 17-2015-4045

amec foster wheeler

- Assumptions :

1. 4-piles - HP 12x53 - spaced at 4D
2. depth of embedment ≈ 40 ft bgs at the Abutments
3. Max Load per pile ≈ 48 kips at 40 ft bgs
4. Piles primarily supported by side resistance - assume case B per Section 10.7.2.3.1 (AASHTO)

- Settlement of Pile Groups (Section 10.7.2.3.2 of AASHTO)

using Schmertmann's Modified Method

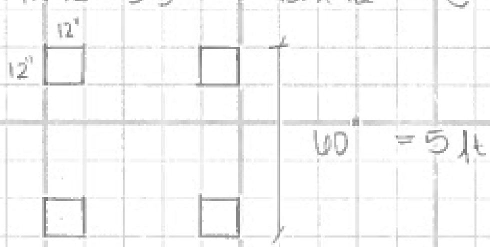
→ D' = effective depth

$D' = 2D_b/3$ (ft) → D_b = depth of embedment

$D' = 2(40\text{ ft})/3 = 26.7\text{ ft}$

→ B = width of smallest dimension of pile group

HP12x53 ≈ 12"x12" @ 4D spacing



→ B' = equivalant width = $5\text{ ft} + 2\times(26.7/4) = 18.35\text{ ft} \approx 18.5'$

→ $B' = Z'$ (for this case)

- q → 4 piles @ 48kips = 192 kips over an area $B' \times Z'$ (equivalant footing)

$q = 192\text{ kips}/[(5+2(26.7/4))(5+2(26.7/4))] \cong 0.6\text{ ksf} \cong 600\text{ psf}$

- N_{160} → SPT blow count corrected, averaged over depth B' below D_b

$D_b \cong 25\text{ ft} + (B' \approx 20\text{ ft}) \Rightarrow 25 \text{ to } 55\text{ ft}$

DESIGN MEMORANDUM

amec foster wheeler

Client: BIA

Sheet 2 Of 5

Project: BIA N8D106(3)

Date:

Data For: Settlement of Piles

Work Order:

Prepared By: NC

Checked By:

File No:

- $N_{1,60}$ ⇒ 14 to 2 (25 to 55 ft) → see attached N-Value sheet, page 4
- E-values were correlated based on Kulhawy & Mayne for clay soils from 25 to 50 ft and sand w/ fines from 50 to 55 ft.

⇒ Anticipated Settlement of the pile group is approximately 1 inch.

→ see attached Schmertmann calculation, page 5

Note: Check formulas to ensure that correct cells are used in the calculations

Depth	B-1	B-2	AVG	(AVG+MIN)/2	Lower Quartile (for comparison)
0	15	14	15	14	14.25
2.5	31	34	33	32	31.75
5	23	30	27	25	24.75
10	18	21	20	19	18.75
15	17	15	16	16	15.5
20	30	9	20	14	14.25
25	30	8	19	14	13.5
30	6	6	6	6	6
35	13	5	9	7	7
40	10	0	5	3	2.5
45	8	4	6	5	5
50	6	2	4	3	3
55	6	3	5	4	3.75
60	4	46	25	15	14.5
65	3	100	52	27	27.25
70	45	100	73	59	58.75
75	100	100	100	100	100
80	100	100	100	100	100
85	100	100	100	100	100
90	100		100	100	100
95	100		100	100	100
100			#DIV/0!	#DIV/0!	#NUM!
105			#DIV/0!	#DIV/0!	#NUM!
110			#DIV/0!	#DIV/0!	#NUM!
115			#DIV/0!	#DIV/0!	#NUM!
120			#DIV/0!	#DIV/0!	#NUM!
125			#DIV/0!	#DIV/0!	#NUM!

Based information provided in

Project Name:	Settelment of Piles
Project #:	17-2015-4045
Date:	6/10/2016
User:	NC

Input

Hammer Type	1	(Safety(1) or Donut(2), or Automatic(3))
Borehole Diameter	7	[in]
Sampling Method	1	(Standard sampler(1) or Sampler without liner(2))

Correction Values

C_{ER}	1.15	Correction for energy ratio
C_B	1.05	Correction for borehole diameter
C_S	1	Correction for sampling method
C_R	Function of Depth	Correction for rod length
C_N	Function of Depth	Correction for overburden = $2/(1+\sigma_{vo}/p_a)$

N_{60} N corrected for field procedures = $C_{ER}*C_B*C_S*C_R*N$

$(N_1)_{60}$ N_{60} corrected for overburden = C_N*N_{60}

N_1 N corrected for overburden $=C_N*N$

Elastic modulus is a function of Soil Type

Soil Type

1	sand with fines, silts, sandy silts, slightly cohesive mixtures
2	clean NC sands, clean fine to medium sands and slightly silty sand
3	clean OC sands, coarse sands and sands with little gravel
4	sandy gravels and gravels
5	submerged sand
6	clay
7	cemented fine-grained soils

Avg. Effec. Unit Weight (γ') 110 [pcf]

Atmospheric Pressure (p_a) 2116 [pcf]

Depth [ft]	C_R	N	N_{60}	N_{55}	C_N	N_1	$(N_1)_{60}$	Soil Type	Kulhawy & Mayne 1990 E_{N60} [ksf]	AASHTO 1996 $E_{(N1)}$ [ksf]	Bowles 1996 E_{N55} [ksf]	Hansen & Beckwith E_N [ksf]	Design Values [psf]
0	0.75	14	13	14	2.0	29	26	6	219	No Corr.	No Corr.	No Corr.	218,629
2.5	0.75	32	29	31	1.8	56	51	6	363	No Corr.	No Corr.	No Corr.	362,597
5	0.75	25	22	24	1.6	39	36	6	310	No Corr.	No Corr.	No Corr.	309,824
10	0.85	19	19	21	1.3	25	25	6	260	No Corr.	No Corr.	No Corr.	260,000
15	0.95	16	18	19	1.1	17	20	6	231	No Corr.	No Corr.	No Corr.	230,551
20	0.95	14	16	18	1.0	14	16	6	219	No Corr.	No Corr.	No Corr.	218,629
25	1	14	16	18	0.9	12	14	6	211	No Corr.	No Corr.	No Corr.	211,290
30	1	6	7	8	0.8	5	6	6	127	No Corr.	No Corr.	No Corr.	126,612
35	1	7	8	9	0.7	5.0	6	6	140	No Corr.	No Corr.	No Corr.	139,557
40	1	3	3	3	0.6	1.6	2	6	73	No Corr.	No Corr.	No Corr.	72,840
45	1	5	6	7	0.6	3.0	4	6	113	No Corr.	No Corr.	No Corr.	112,842
50	1	3	4	4	0.6	1.7	2	6	82	No Corr.	No Corr.	No Corr.	81,729
55	1	4	5	5	0.5	1.9	2	1	48	16	69	No Corr.	47,908
60	1	15	18	19	0.5	7.0	9	1	185	56	157	No Corr.	185,243
65	1	27	33	36	0.5	12.4	15	1	348	100	263	No Corr.	348,128
70	1	59	71	77	0.4	25.3	31	1	751	203	523	No Corr.	750,552
75	1	100	121	132	0.4	40.8	49	Rock	0	0	0	FALSE	1,300,000
80	1	100	121	132	0.4	38.8	47	Rock	0	0	0	FALSE	1,300,000
85	1	100	121	132	0.4	36.9	45	Rock	0	0	0	FALSE	1,300,000
90	1	100	121	132	0.4	35.2	43	Rock	0	0	0	FALSE	1,500,000
95	1	100	121	132	0.3	33.7	41	Rock	0	0	0	FALSE	1,500,000

Kulhawy and Mayne (1990) Manual on Estimating Soil Properties for Foundation Design
AASHTO (1996) Standard Specifications for Highway Bridges - 16th edition
Bowles (1996) Foundation Analysis and Design - 5th edition
Hansen and Beckwith

Schmertmann's Modified Method (1978)

Project ID: Settelment of Piles
Project # 17-2015-4045
User NC

Footing Dimensions

Width (B) [ft] 18.5

Depth to Base of Footing (D) [ft] 0

Length (L)[ft] 18.5

Depth to groundwater (ft) 0

Time Since Application of Load [yrs] 10

Average Soil Unit Weight (γ) [pcf] 120

Net Bearing Pressure
q' [psf] 600

Depth of Peak Strain
D_{ps} 9.3

$$D_{ps} = B/2 (L/B = 1)$$
$$D_{ps} = B (L/B > 10)$$
$$\text{Intermediate for } 1 < L/B \le 10$$

Initial Vertical Stress at Depth of Peak Strain Influence Factor
σ'_{vp} [psf] 533

$$\sigma'_{vp} (\text{at } z = D + D_{ps}) = \sum \gamma h - u$$

Depth of Influece
D_i 37.0

$$D_i = 2B (L/B = 1)$$
$$D_i = 4B (L/B > 10)$$
$$\text{Intermediate for } 1 < L/B \le 10$$

Effective Stress at Depth D Below the Ground Surface
σ'_D [psf] 0

$$\sigma'_D = \gamma D - u$$

Peak Strain Influence Factor
I_{zp} 0.606

$$I_{zp} = 0.5 + 0.1 \sqrt{\frac{q'}{\sigma'_{vp}}}$$

Strain Influence Factor at Surface
I_{zs} 0.10

$$I_{zs} = 0.1 (L/B = 1)$$
$$I_{zs} = 0.2 (L/B > 10)$$
$$\text{Intermediate for } 1 < L/B \le 10$$

Depth Factor
C_1 1.00

$$C_1 = 1 - 0.5 \left(\frac{\sigma'_D}{q'} \right)$$

Shape Factor
C_3 1.00

$$C_3 = 1.03 - 0.03 \frac{L}{B} \ge 0.73$$

Secondary Creep Factor
C_2 1.40

$$C_2 = 1 + 0.2 \log \left(\frac{t}{0.1} \right)$$

Layer No.	Depth Below Ground Surface: Start	Depth Below Ground Surface: End	Depth of Midlayer below footing	Thickness of Layer	Soil Modulus	Strain Influence Factor	Settlement of Layer i
				Δz_i	E_i	I_{zi}	ρ_i
	[ft]	[ft]	[ft]	[ft]	[psf]		[in]
1	0	5	2.5	5	211,290	0.24	0.06
2	5	10	7.5	5	126,612	0.51	0.20
3	10	15	12.5	5	139,557	0.54	0.19
4	15	20	17.5	5	72,840	0.43	0.29
5	20	25	22.5	5	112,842	0.32	0.14
6	25	30	27.5	5	81,729	0.21	0.13
7	30	35	32.5	5	47,908	0.10	0.10
8	35	40	37.5	5	185,243	0.00	0.00
9	40	45	42.5	5	348,128	0.00	0.00
10	45	50	47.5	5	750,552	0.00	0.00
11	50	55	52.5	5	1,300,000	0.00	0.00
12	55	60	57.5	5	1,300,000	0.00	0.00
13	60	65	62.5	5	1,300,000	0.00	0.00
14	65	70	67.5	5	1,500,000	0.00	0.00
15	70	75	72.5	5	1,500,000	0.00	0.00
16	0		0	0		0.10	0.00
17	0		0	0		0.10	0.00
						Total Settlement [in]	1.12

$$\rho_i = C_1 C_2 C_3 q' \left(\frac{I_{zi} \Delta z_i}{E_i} \right)$$

$$\rho_{TOTAL} = \sum \rho_i$$

APPENDIX B

FOUNDATION DESIGN MEMORANDUM 2
BIA ROUTE N8065(1) DRAINAGE CROSSING

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ATTACHMENTS

June 15, 2016
Project No. 17-2015-4045
Foundation Design Memorandum No. 2

Bureau of Indian Affairs, Navajo Regional Office
Division of Acquisition
PO Box 1060
301 West Hill, Room 346
Gallup, New Mexico 87301

Attn: Christopher Becenti, PE

Re: Foundation Design Memorandum – N8065(1) Drainage Crossing
BIA Project N8066(3), N8065(1) and School Spur
Black Mesa Community School, AZ (Navajo Nation)
BIA Order No. A15PD00791
BIA Requisition No. 0040235503
Architect – Engineer IDIQ Contract No. A12PC00121

1.0 INTRODUCTION

This memorandum provides recommendations for the design of the bridge structure foundations at the BIA Route N8065(1) drainage crossing, as part of the BIA N8066(3), N8065(1) and School Spur project. The foundation design was based on the geotechnical investigation segment performed at the BIA N8065(1) drainage crossing by Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler). The planned bridge structure will cross the Oraibi Wash at approximately BIA Route N8065(1) Station 0+327. The new bridge structure will be two-span and the abutments and pier will be founded on deep foundations.

2.0 FIELD INVESTIGATION

2.1 Subsurface Exploration

The subsurface exploration for this project was performed from January 12 to January 18, 2016, and February 20 to February 22, 2016. Field direction, sample collection and logging of borings were performed by Joseph Zaleski, EIT and Mark Keyes, PG of Amec Foster Wheeler. Logs of the completed borings are presented in Attachment A of this memorandum. Attachment A also includes a description of drilling and sampling procedures. Amec Foster Wheeler advanced six borings (BS-1 through BS-6) for the proposed BIA N8065(1) bridge structure to 30 meters below existing site grades, for a total drill footage of approximately 180 meters. Locations of the borings are shown on Figure 1, Boring and Resistivity Location Map, and are presented in tabular format in Table 1.

The borings were completed by Southlands Engineering, LLC (Southlands) with a specialized ATV mounted CME-75 drill rig utilizing a 210-millimeter outside-diameter continuous-flight hollow-stem auger. Completed soil borings were backfilled with soil cuttings and cement grouted in the upper 6 meters.

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www.amecfw.com

Each boring location was established in the field using the laid out proposed alignments for the roadway segment and confirmed with a handheld GPS unit in NAD 83 – UTM Zone 12N coordinates. The locations of the borings are shown on the boring logs and are presented in Attachment A. Encountered soils were visually inspected, labeled and classified in the field, and logged in general accordance with ASTM D2488 and the Unified Soil Classification System. After completion of the laboratory tests on the samples retrieved, the field logs were reviewed and modified, where necessary, to produce the final boring logs presented in Attachment A.

2.2 Laboratory Testing

Laboratory tests were performed on representative bulk, split-spoon, ring, and Shelby tube samples obtained during our subsurface exploration to evaluate and characterize the site soils for engineering analysis and design. The following tests were performed in general accordance with applicable American Association of State Highway and Transportation Officials (AASHTO) test methods. In the absence of an AASHTO test method, American Society for Testing and Materials (ASTM) test methods and Arizona (ARIZ) test methods were used.

- Sieve Analysis (Gradation and minus 75-micrometer wash) (AASHTO T11,T27)
- Plasticity Index (AASHTO T89, T90)
- Density Test (ASTM D2937)
- Moisture (AASHTO T265)
- Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils (AASHTO T296)
- pH and Resistivity (ARIZ 236b)

A summary of the laboratory test results is presented in Table B-1 in Attachment B, along with the test worksheets.

3.0 GEOTECHNICAL PROFILE

3.1 Geologic Setting

Surficial geologic units exposed within the project site include Holocene-aged and/or Pleistocene-aged Quaternary alluvial and eolian deposits and Upper Cretaceous-aged sandstone and siltstone. The Holocene deposits are comprised of stream deposits and windblown silt and sand deposited on benches, small terraces and in broad valleys. These deposits have been reworked by water. The Upper Cretaceous-aged sandstones and siltstones of the Wepo Formation are part of the Mesaverde Group. The Wepo Formation is comprised of alternating siltstone and sandstone layers of continental and near-shore origin, and to some extent coal beds of up to 1.5 meters in thickness. The siltstone is generally olive-green in color and the sandstone is typically yellowish-gray. This unit varies from 40 meters to 225 meters in thickness. (Haynes and Hackman, 1978)[1]. The Wepo Formation was not encountered at any of the borings along the N8065(1) bridge structure alignment.

[1] References are presented in Section 5.0 of this memorandum.

3.2 Geotechnical Profile

The native soils encountered during the investigation along the proposed BIA N8065(1) bridge structure alignment primarily consist of fine-grained soil mixtures, including sandy clays to clays and sandy silts, overlaying course-grained soil mixtures of sand and silty sand. The predominant soil types were combined into two groups based on their characteristics: clays and silts. The clays group consists of high-plasticity clays (CH), low-plasticity clays (CL) and clayey sands (SC). The silts group consists of sandy silt (ML), silty sand (SM) and sand with silt (SP-SM). In general, the site soils can be characterized into two layers: Layers A and B. These layers are described in detail in Sections 3.2.1 and 3.2.2. An overview of the two layers is as follows:

- Layer A is primarily expressed at the Oraibi Wash banks and extends from the surface to a depth of about 15 meters below the ground surface (bgs), and predominantly consists of a mixture of fines (particles less than the 75-micrometer sieve), including sandy clay, clayey sand, sandy silt, and silty sand.
- Layer B extends from a depth of about 15 meters to the full depth of the investigation, approximately 30 meters bgs at the wash banks, and from the surface of the wash bottom to the full depth of the investigation, approximately 30 meters bgs. Layer B predominantly consists of lower fines content and increased sand content soils. The Layer B soils are predominantly classified as silty sand. Layer B is interfingered with zones of higher fines content soils, approximately 1.5 to 3 meters in thickness, including clays and silts. A further decrease in fines was observed from a depth of about 15 meters bgs at the wash bottom with the primary soil types consisting of silty sand and sand with silt.

Unconsolidated-undrained triaxial compression (UU) tests, performed on cohesive soils encountered within the BIA N8065(1) borings, are plotted on Figure 5. Analysis of the UU test results was completed as a function of soil type and depth. The various soil layers are discussed in greater detail in the following sections. A subsurface profile of the soil borings along BIA N8065(1) is provided in Figure 6.

3.2.1 Layer A – Near Surface Clayey Soils

Layer A extends from the surface to a depth of about 15 meters bgs at the wash banks and consists primarily of clays and silts. The soil types include low plasticity clay (CL), high plasticity clay (CH), low plasticity silty (ML) and, to a lesser extent, zones of silty sand (SM) and clayey sand (SC). Layer A soils are characterized as having a fines content typically greater than 50 percent with a maximum of 97 percent. The 3 to 4.5-meter zone of ML soils encountered within borings BS-2, BS-5 and BS-6, approximately 1.5 to 3 meters bgs at the wash banks, grades to SM in zones where the fines content decrease to about 30 to 50 percent. The soils within Layer A primarily have medium to high plasticity and, to a lesser extent, zones of low and no plasticity. The zones of low and no plasticity are primarily localized to the silts. Layer A is predominantly moderately firm to very firm with some hard zones. The measured uncorrected SPT blow counts varied from 10 to 70 with an average of 25. The soils are predominantly uncemented.

UU test results performed on Layer A soils show a range of undrained shear strength from 110 to 720 kilopascal (kPa) (Figure 5). Undrained shear strength values were also developed using correlations by Terzaghi and Peck, as presented in Kulhawy and Mayne (1990), and ranged from approximately 120 to 190 kPa.

3.2.2 Layer B – Silty Sand to Sandy Silt Soils

Layer B extends from a depth of about 15 meters to the depth of the investigation (i.e. 30 meters bgs) at the wash banks and from the surface of the wash bottom to the depth of the investigation (i.e. 30 meters bgs), and predominantly consists of lower fines content and increased sand content soils. The soil types consist primarily of silty sand (SM), sand with silt (SP-SM) and, to a lesser extent, zones of sandy silt (ML) and low and high plasticity clay (CL/CH). The fines content for Layer B is typically less than 50 percent with occasional zones, approximately 1.5 to 3 meters in thickness, as high as 70 percent. A further decrease in fines, of typically less than 20 percent, was observed from a depth of about 15 meters bgs at the wash bottom. These soil types are primarily non plastic with occasional zones of medium to high plasticity. The zones of medium to high plasticity are localized to the clay soil zones typically around 24 to 27 meters bgs from the wash banks (9 to 12 meters bgs at the wash bottom).

These soils are predominantly soft to moderately firm with some firm and hard zones. The measured uncorrected SPT blow counts varied from zero (i.e., weight of hammer for a 300-millimeter interval) to refusal (i.e., 50 blows for less than a 150-millimeter interval) with a median value of 9. A further breakdown of the blow count values, excluding the zero and refusal blow counts, results in SPT blow count values that range from 2 to 32. The soils are predominantly uncemented.

Due to the nature of these soils, adequate undisturbed samples could not be obtained to perform direct shear tests or UU tests. Correlations presented in FHWA Design and Construction of Driven Pile Foundations guidelines (2006) were used to estimate friction angles of these soils. Amec Foster Wheeler typically selected the upper bound for strength estimation of the material due to the likelihood of heaving sand during sampling given that Layer B was below the groundwater table. The friction angle values used for analysis ranged from 27 to 32 degrees. At the pier, from a depth of about 15 meters bgs at the wash bottom, a friction angle of 34 degrees was used for medium-dense soils.

3.3 Groundwater and Soil Moisture Conditions

Groundwater was encountered at the drainage crossing. Moisture content tests developed as part of the density tests (ASTM D2937) and UU test (AASHTO T296) were used to evaluate the on-site soil moisture characteristics. The site soils were generally described as being slightly moist with occasional moist zones above the groundwater table, and moist to wet below the groundwater table. The measured soil moisture contents varied from 3.2 to 31.5 percent (of dry weight), with an average value of approximately 19 percent.

The groundwater level was encountered near the ground surface of the Oraibi Wash, and was fairly consistent in elevation across the wash banks.

Seasonal variations could cause fluctuations in groundwater depth and depth to groundwater could be shallower or deeper depending on the water flow in Oraibi Wash.

3.4 Site Seismicity

The project seismic criteria were determined in accordance with Section 3.10 of AASHTO (2014). The horizontal design acceleration is defined as having a 7 percent chance of exceedance during a 75-year recurrence interval. The probabilistic horizontal spectral acceleration values for the designated return period and corresponding peak horizontal ground acceleration (PGA) were obtained from the U.S. Geological Survey (USGS) seismic hazards program website (2014). The values obtained from the website are based on 2009 AASHTO Guide Specifications for Load and Resistance Factor Design (LRFD) Seismic Bridge Design and use 2002 USGS seismic hazard data. The values for the bridge structure are presented in Table 3.1.

Table 3.1: BIA N8065(1) - Seismic Design Parameters for Site Class B[1]

Period, seconds	Spectral Acceleration Value, g	Seismic Design Parameter
0.0	0.052	PGA[2]
0.2	0.112	S_s
1.0	0.033	S_1

Note:
[1] Results are based on a latitude of 36.27845 degrees and a longitude of -110.1558 degrees.
[2] PGA = peak ground acceleration

Based on the geotechnical investigation blow counts, a weighted average blow count of 13 was determined for the upper 30 meters using Method B or the N Method from Table C3.10.3.1-1 of AASHTO (2014). Site Class E was selected for the site as the weighted average blow count was between 9 and 15. Site Class E is defined as a site underlain by soft clay. The modified seismic design parameters for Site Class E are presented in Table 3.2.

Table 3.2: BIA N8065(1) - Seismic Design Parameters for Site Class E[1]

Period, seconds	Spectral Acceleration Value, g	Seismic Design Parameter
0.0	0.130	A_S
0.2	0.280	S_{DS}
1.0	0.115	S_{D1}

Note:
[1] Results are based on a latitude of 36.27845 degrees and a longitude of -110.1558 degrees.

A horizontal response spectral acceleration coefficient (S_{D1}) of 0.115 was calculated using the long-period range of acceleration spectrum coefficient (F_v). The calculated S_{D1} is less than the threshold value of 0.15g for Seismic Zone 1, Table 3.10.6-1 (AASHTO 2014).

4.0 DISCUSSION AND RECOMMENDATIONS

The following sections provide information and recommendations for foundation types for the proposed bridge structure over Oraibi Wash at BIA Route N8065(1).

4.1 Foundation Type Recommendations

Amec Foster Wheeler understands that the BIA plans to construct a bridge structure supported on deep foundations at the BIA Route N8065(1) Oraibi Wash crossing, at approximately Station 0+327. If the expected bridge loads are moderate and within the presented loads in

Section 4.2 of this memorandum, the bridge structure can be supposed on H-piles or closed-end pipe piles.

This memorandum presents recommendations for the H-pile and closed-end pipe pile foundation type alternatives in Section 4.2.

4.2 Driven Pile Design Recommendations

4.2.1 General

Recommendations are presented herein for driven H-piles and closed-end pipe piles bearing in predominantly fine-grained soils for support of the proposed bridge structure. The recommended design criteria presented herein is based on the AASHTO LRFD procedures presented in Section 10.7 of AASHTO (2014) and FHWA Design and Construction of Driven Pile Foundations guidelines (2006).

Amec Foster Wheeler evaluated if negative skin friction loads, or downdrag, needed to be included for the piles at the bridge abutments. Based on a review of the available road profile design plans provided by the BIA on September 12, 2015, the bridge abutment foundations do not penetrate fill and will be founded in native soils. Since no fill is present, settlement of the soil around the pile is not anticipated to cause downdrag. Therefore, downdrag loads were not included. If the abutment locations, as drilled, or road profile alignment changes, Amec Foster Wheeler should be notified to review the revised drawings and modify our recommendations, as necessary.

Scour depths were considered in the design and are based on discussions and e-mail correspondence with Messrs. Corwyn Henry and Harold Riley at the BIA. Scour depths for the BIA N8065(1) crossing are reported in Table 4.1 for a 100-year storm event. Scour is not anticipated at the abutments for the BIA N8065(1) bridge structure.

Table 4.1: Scour depths for Oraibi Wash BIA N8065(1) Drainage Crossing

Scour Type	100-Year Scour Depth
Piers	2 meters

The channel thalweg was identified as elevation 1957 meters. The scour depth values presented in Table 4.1 need to be confirmed by the designer once the final drainage report is available. If the recommendations in the final drainage report differ from what is presented, Amec Foster Wheeler should be contacted to revise our recommendations.

Seasonal frost depth was considered in the design of the foundations. Amec Foster Wheeler calculated a frost depth for the design based on the Arizona Department of Transportation (ADOT) Freezing Index (1989). A frost depth of approximately 1 meter was calculated based on the bridge location. A conservative frost depth of 1.5 meters was used in the design. The upper 1.5 meters were not considered to contribute to the vertical resistance of the piles at the abutments.

The following sections provide design recommendations for the strength limit state. The service limit state could not be assessed due to limited information available on foundation loads and pile group configurations. The design charts for the strength limit state are presented in Figures 4.1 through 4.12.

Section 10.7.6 of AASHTO (2014) provides direction regarding minimum pile penetration. The minimum pile penetration needs to be determined to meet the following requirements:

1. Single and pile group settlement (service limit state)
2. Lateral loading and deflection (service limit state)
3. Uplift (strength limit state)
4. Downdrag (strength limit state)
5. Scour

Uplift, downdrag and scour were considered for the development of the strength limit design charts presented in Section 4.2.2 of the memorandum.

4.2.2 Strength Limit State

Resistance factors used in the determination of the vertical resistance for H-piles and closed-end pipe piles are a function of the design methodology. The pile capacities were calculated using the Nordlund/Thurman Method for side resistance and tip resistance in cohesionless soils (AASHTO 2014: Section 10.7.3.8.6f). The α-Method was used for side resistance calculations and the tip resistance method was used for tip resistance calculations in cohesive soils as presented in Section 10.7.3.8.6 (b and e) of AASHTO (2014). The corresponding nominal bearing resistance factor for the Nordlund/Thurman Method driven pile design, for side resistance and end bearing, is 0.45 and the nominal bearing resistance factor for the α-Method is 0.35, as presented in Table 10.5.5.2.3-1 of AASHTO (2014). The resistance factors used for the vertical resistance assume redundant foundations as defined in Section 10.5.5.2 of AASHTO (2014), see Section 4.2.5 of this memorandum for details. Calculation inputs and outputs for the vertical resistance design charts are provided in Attachment C.

The uplift resistance was determined based on AASHTO (2014) Section 10.7.3.10 for single piles. Uplift on single piles should be evaluated when tensile forces are present. The resistance factors for uplift are 0.35 for cohesionless soils using the Nordlund/Thurman Method and 0.25 for cohesive soils using the α-Method. Calculation inputs and outputs for the vertical resistance design charts are provided in Attachment C. Uplift resistance of a pile group will need to be verified per Section 10.7.3.11 of AASHTO (2014) once the pile configuration and embedment depth have been determined. The nominal uplift resistance should be taken as the lesser of the sum of the individual pile uplift resistance, or the uplift resistance of the pile group considered as a block.

The vertical resistance above elevation 1971.5 meters for the abutments, and 1955 meters for the pier, was neglected during the development of the design charts due to estimated frost and/or scour depths.

The maximum factored pile strength, assuming the use of 345 megapascal (MPa) steel and a resistance factor of 0.60 (AASHTO Section 6.5.4.2), shall be less than 207 MPa.

The nominal bearing resistance of various H-piles and closed-end pipe piles for the west abutment, are presented in the foundation design charts shown in Figures 4.1 and 4.2, respectively. The design charts for the pier are presented in Figures 4.3 and 4.4 and for the east abutment in Figures 4.5 and 4.6.

The nominal uplift resistance of various H-piles and closed-end pipe piles for the west abutment, are presented in the foundation design charts shown in Figures 4.7 and 4.8, respectively. The design charts for the pier are presented in Figures 4.9 and 4.10 and for the east abutment in Figures 4.11 and 4.12.

4.2.3 Service Limit State

Service limit state for the bridge abutments and piers was not assessed due to limiting information available on the foundation loads and configurations. The service limit state will need to be examined once more information is available. Service limit state settlement of driven piles is a function of the pile group size, pile embedment depth and corresponding soil strata, and the net foundation pressure applied.

Amec Foster Wheeler has provided a sample calculation for anticipated settlement of pile foundations, assuming foundation loading and number of piles. An estimated settlement of about 0.5 inches at the east abutment was calculated for four HP12x53 H-piles, spaced at four diameters, and embedded at 40 feet below ground surface. The sample calculations are provided in Attachment D.

4.2.4 Group Effects - Axial

Design criteria for reductions in axial resistance resulting from group effects are presented in Section 10.7.3.9 of the AASHTO (2014) manual. For pile groups in clay, if the cap is not in firm contact with the ground and if the soil at the surface is soft, the individual nominal resistance of each pile shall be multiplied by an efficiency factor η, taken as:

- $\eta = 0.65$ for a center-to-center spacing of 2.5 diameters,
- $\eta = 1.0$ for a center-to-center spacing of 6.0 diameters.

For intermediate spacings, the value of η should be determined by linear interpolation.

If the cap is in firm contact with the ground, the nominal resistance of each pile does not need to be reduced. Also, if the cap is not in firm contact with the ground and if the soil is stiff, the nominal resistance of each pile does not need to be reduced.

For pile groups in cohesionless soil, if the cap is or is not in contact with the ground, the efficiency factor, η, shall be 1.0 for a center-to-center pile spacing of 2.5 diameters or greater.

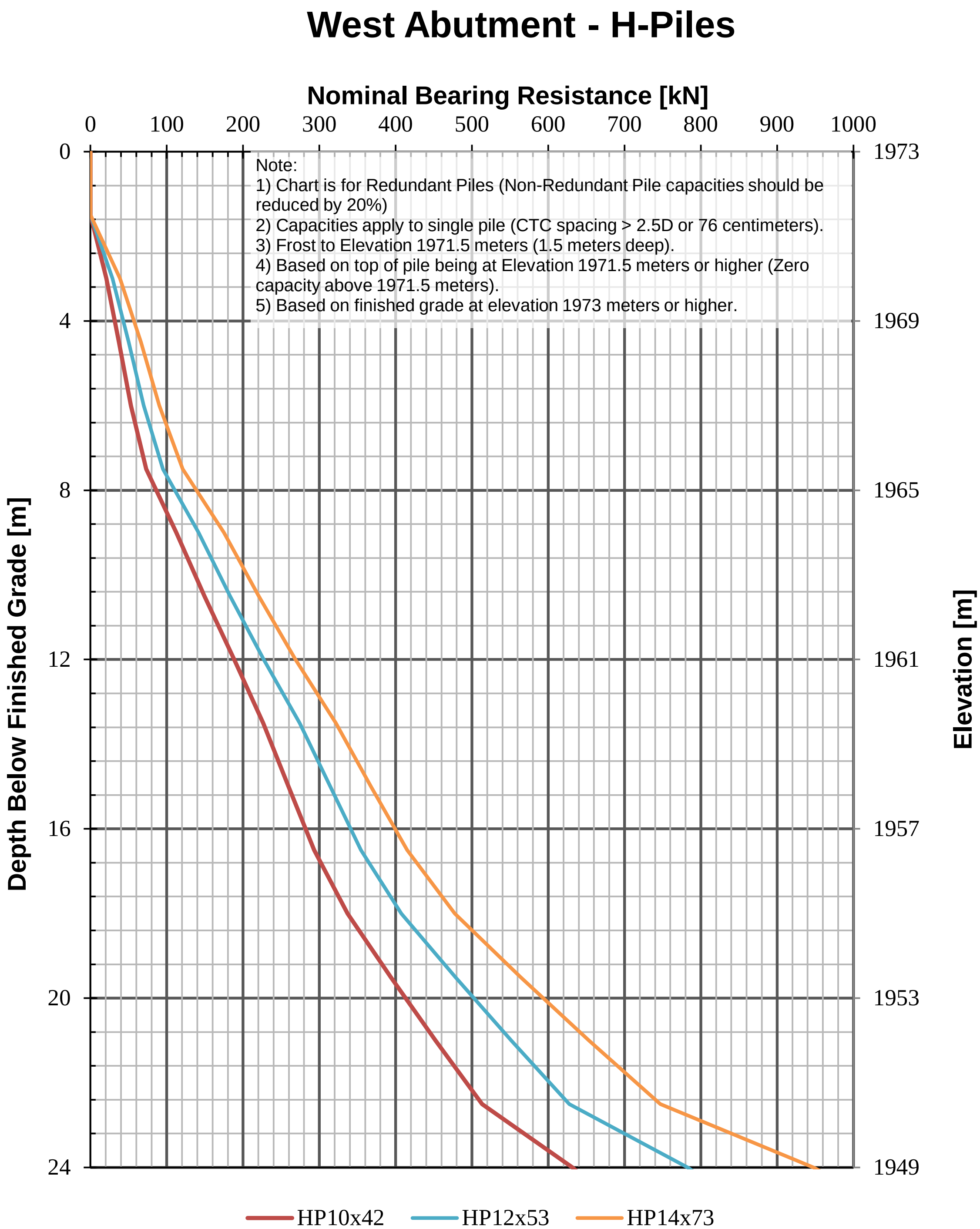

Figure 4.1: West Abutment Foundation Design Chart for Bearing Resistance – H-piles

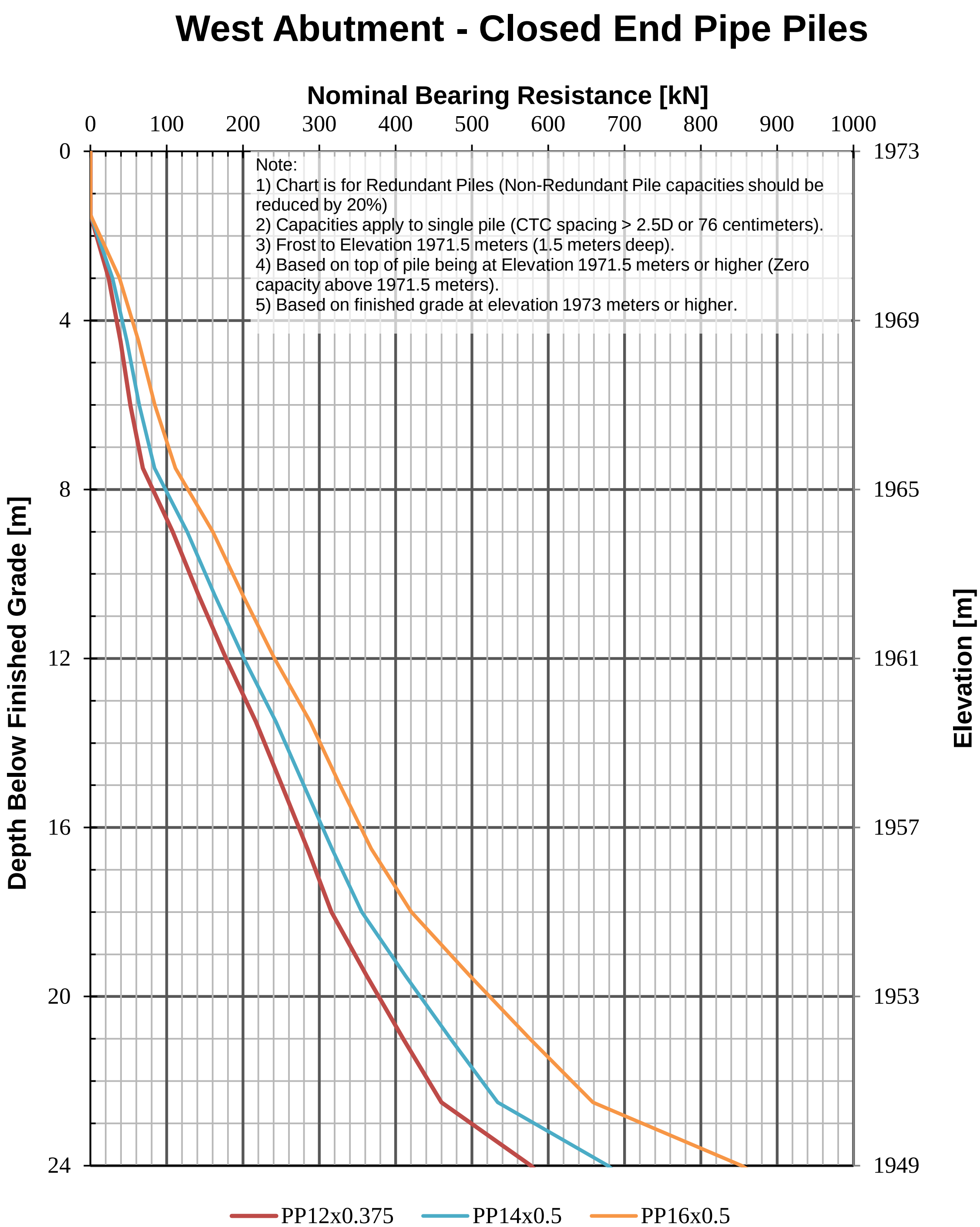

Figure 4.2: West Abutment Foundation Design Chart for Bearing Resistance – Closed-End Pipe Piles

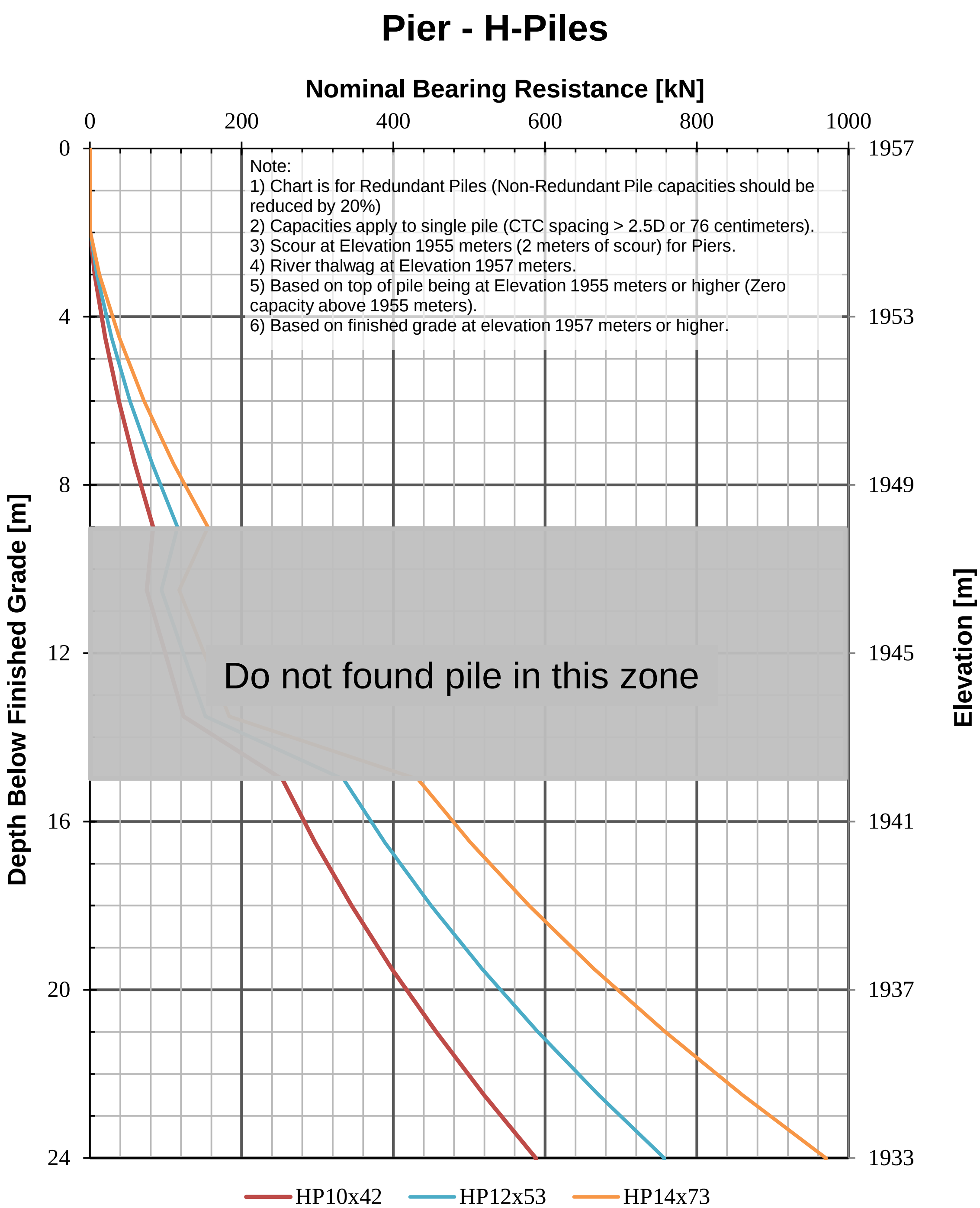

Figure 4.3: Pier Foundation Design Chart for Bearing Resistance – H-piles

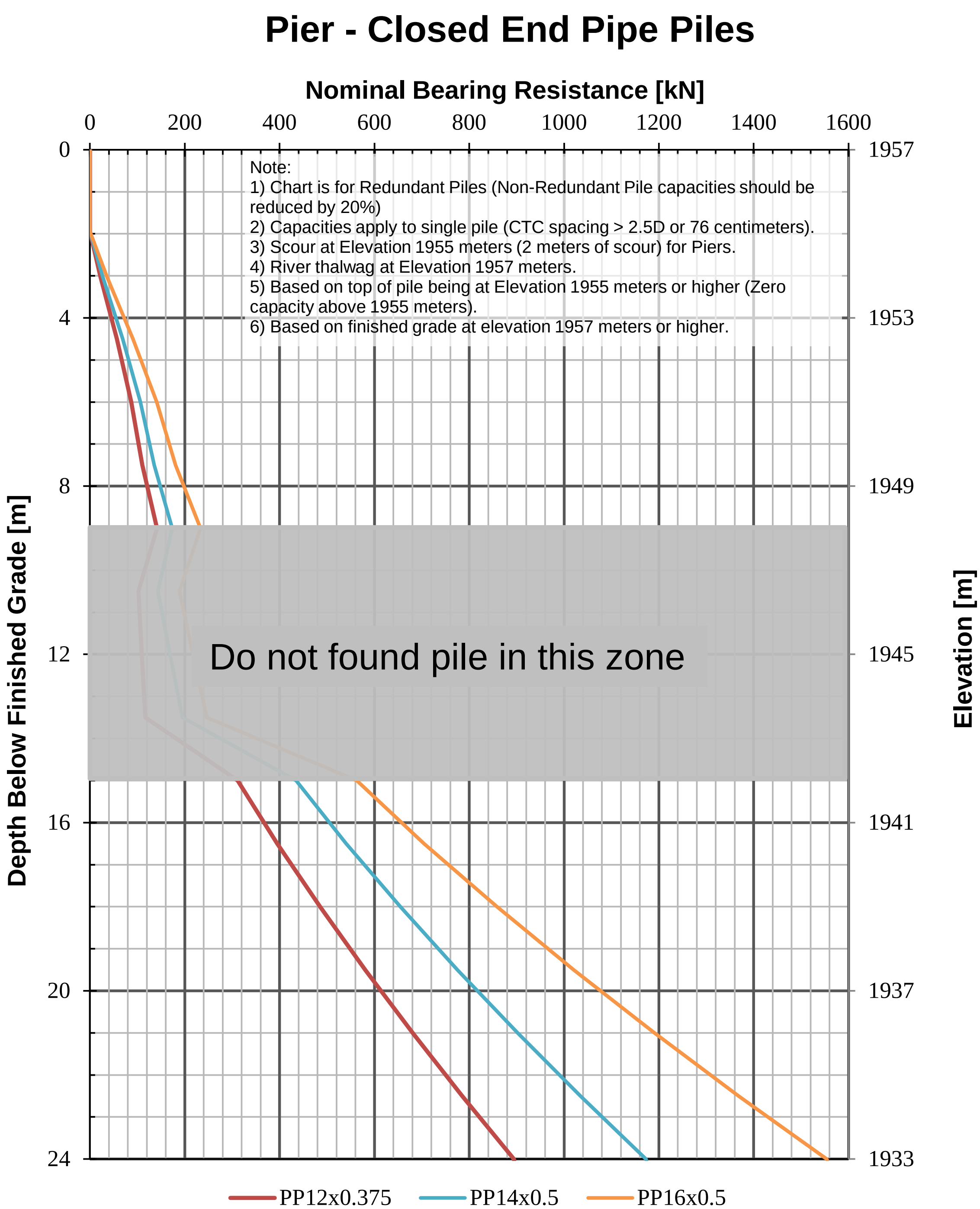

Figure 4.4: Pier Foundation Design Chart for Bearing Resistance – Closed-End Pipe Piles

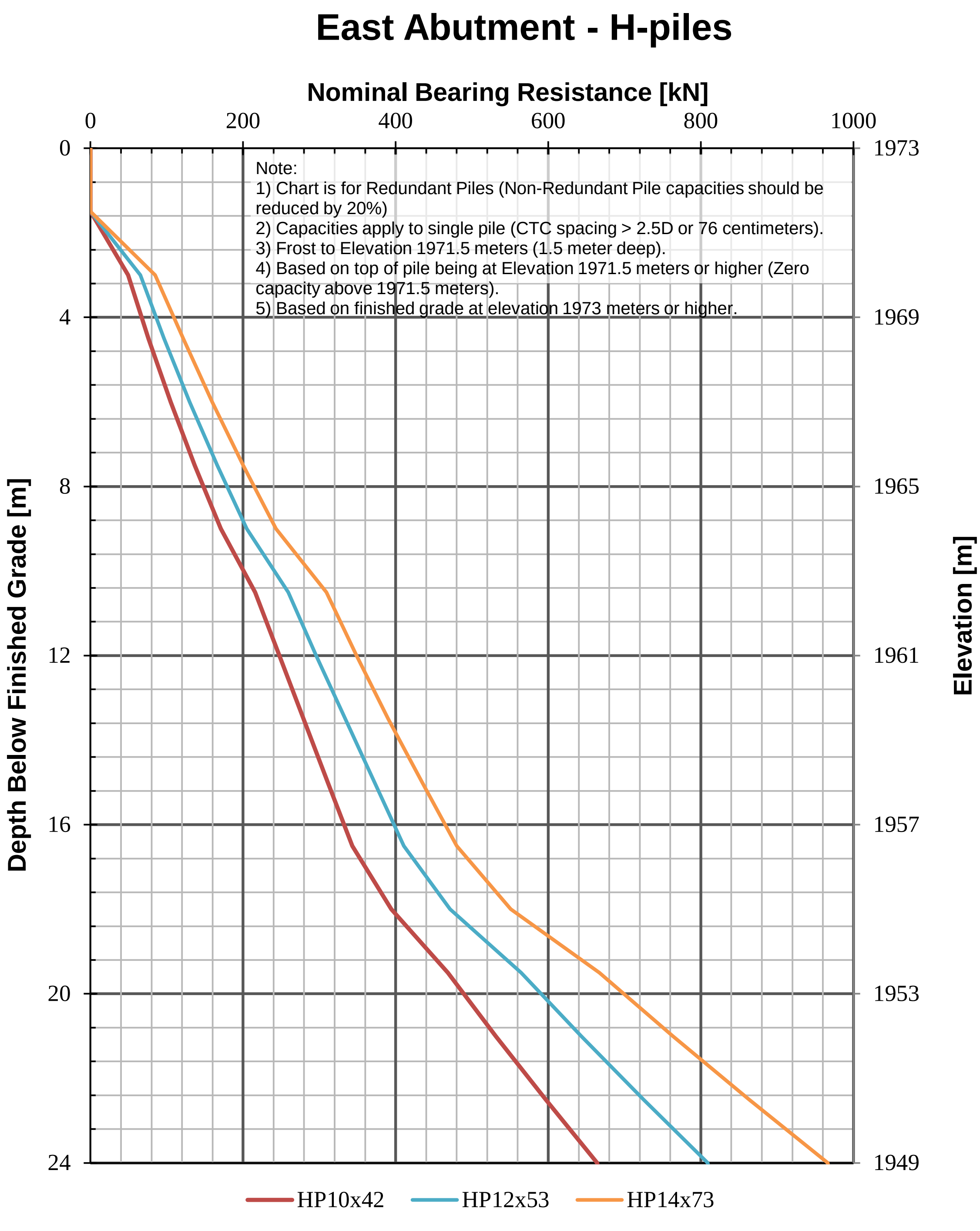

Figure 4.5: East Abutment Foundation Design Chart for Bearing Resistance – H-piles

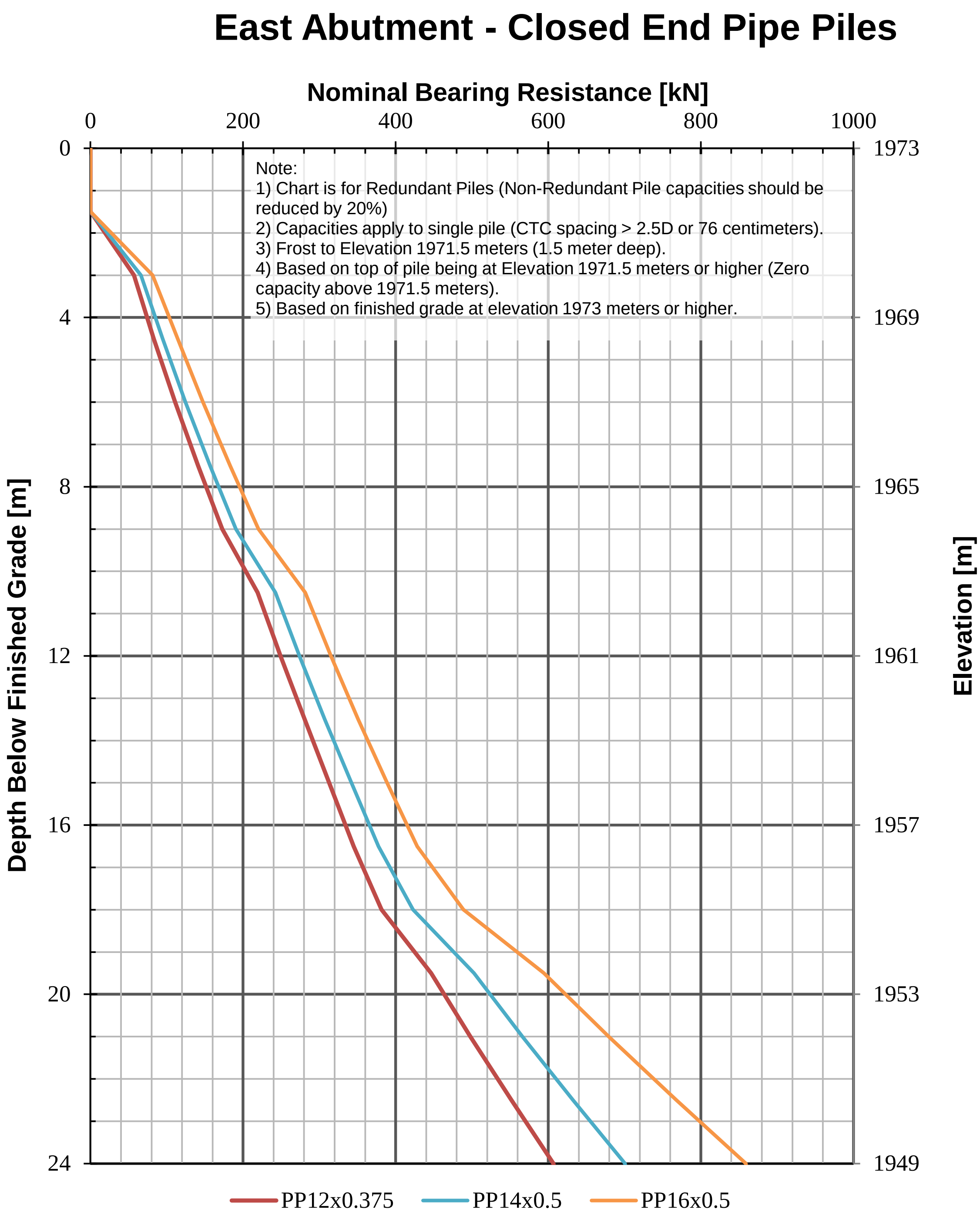

Figure 4.6: East Abutment Foundation Design Chart for Bearing Resistance – Closed-End Pipe Piles

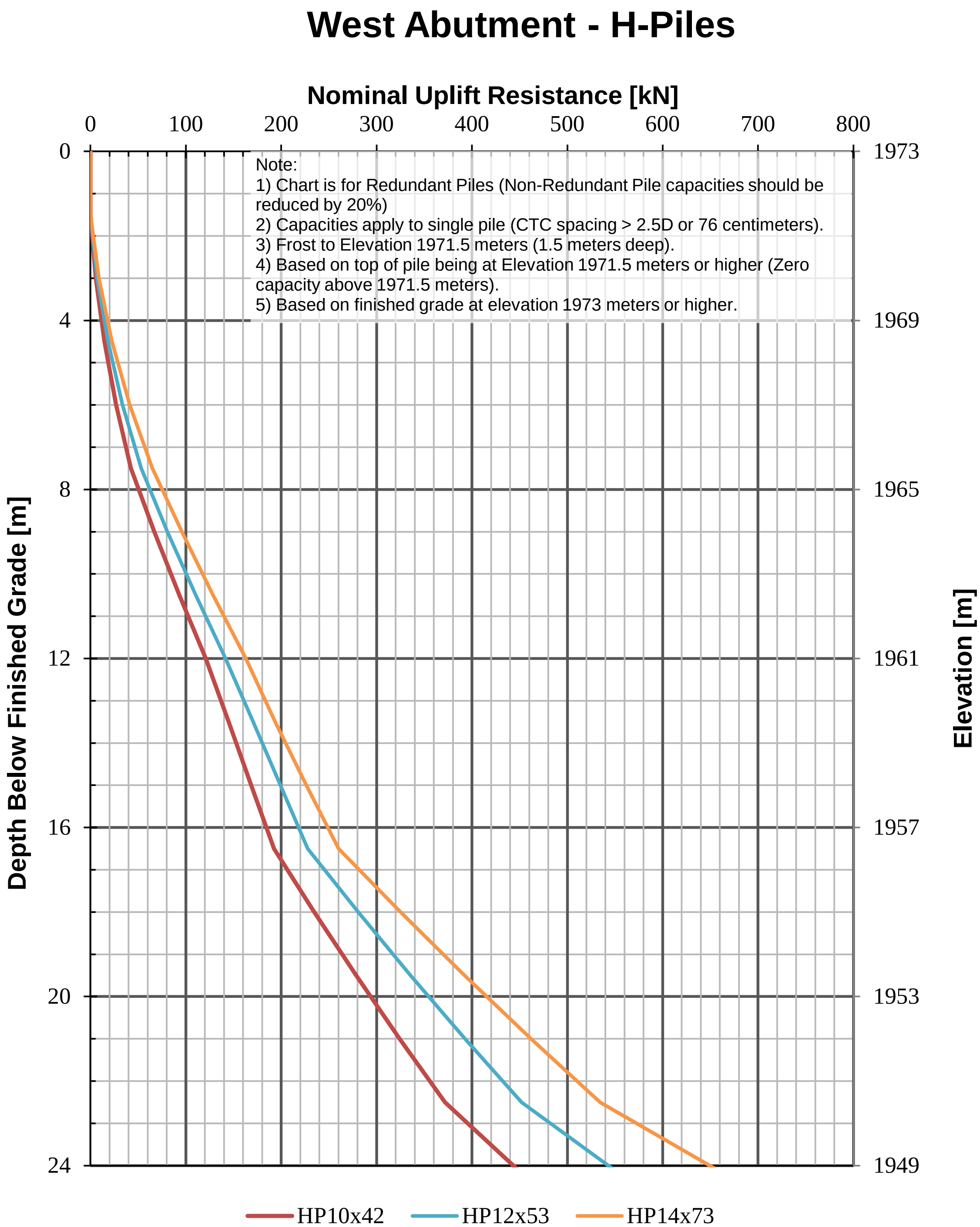

Figure 4.7: West Abutment Foundation Design Chart for Uplift Resistance – H-piles

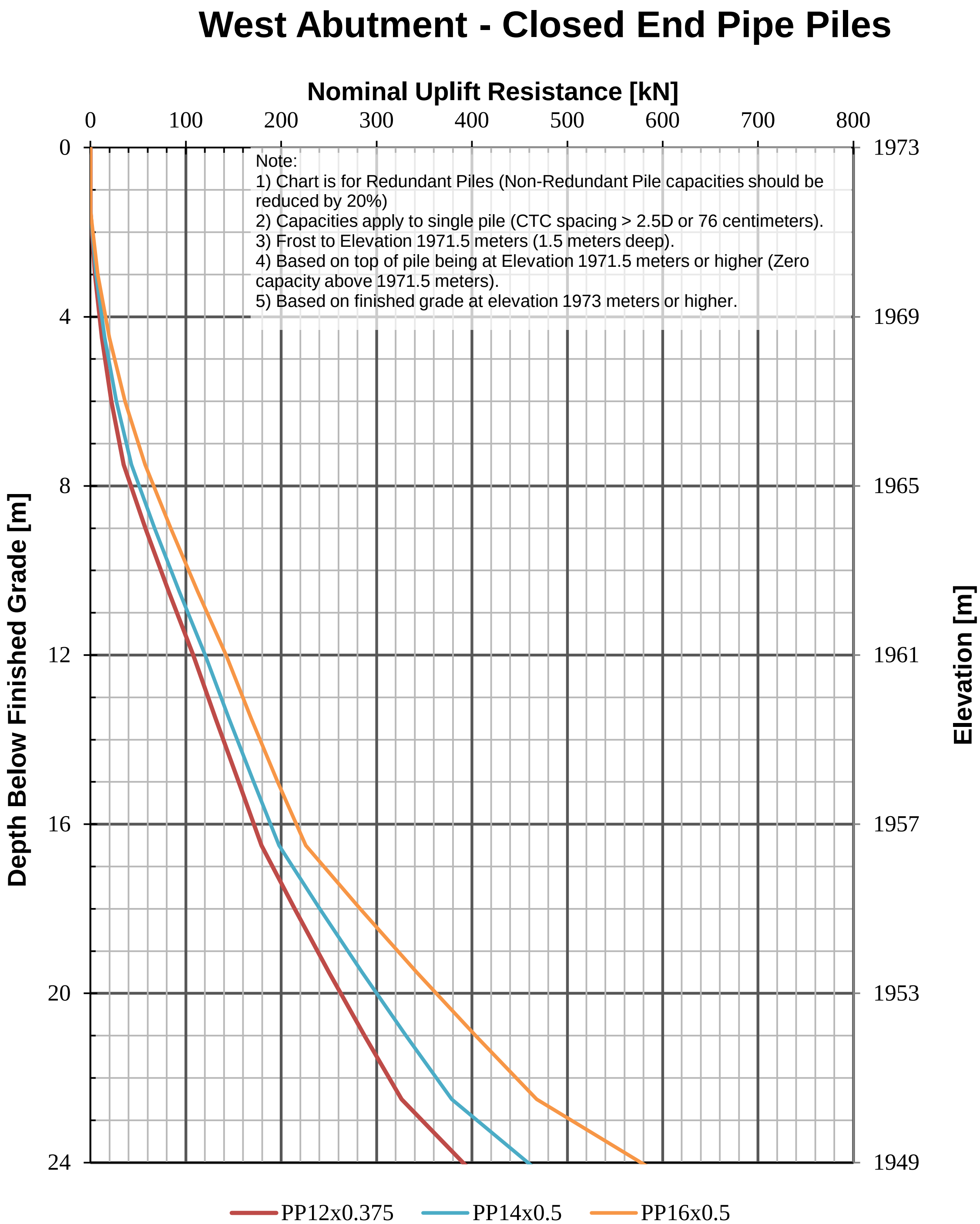

Figure 4.8: West Abutment Foundation Design Chart for Uplift Resistance – Closed-End Pipe Piles

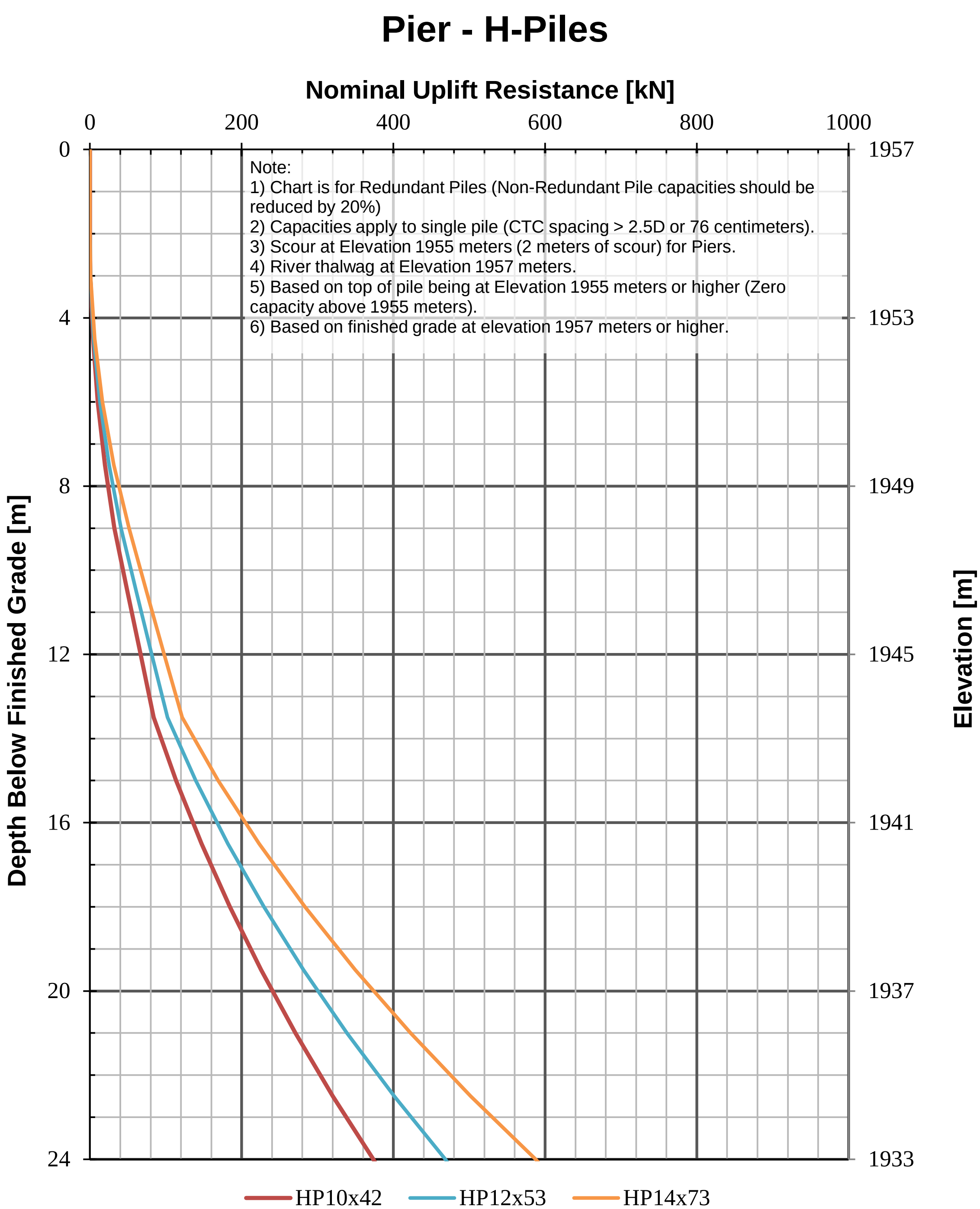

Figure 4.9: Pier Foundation Design Chart for Uplift Resistance – H-piles

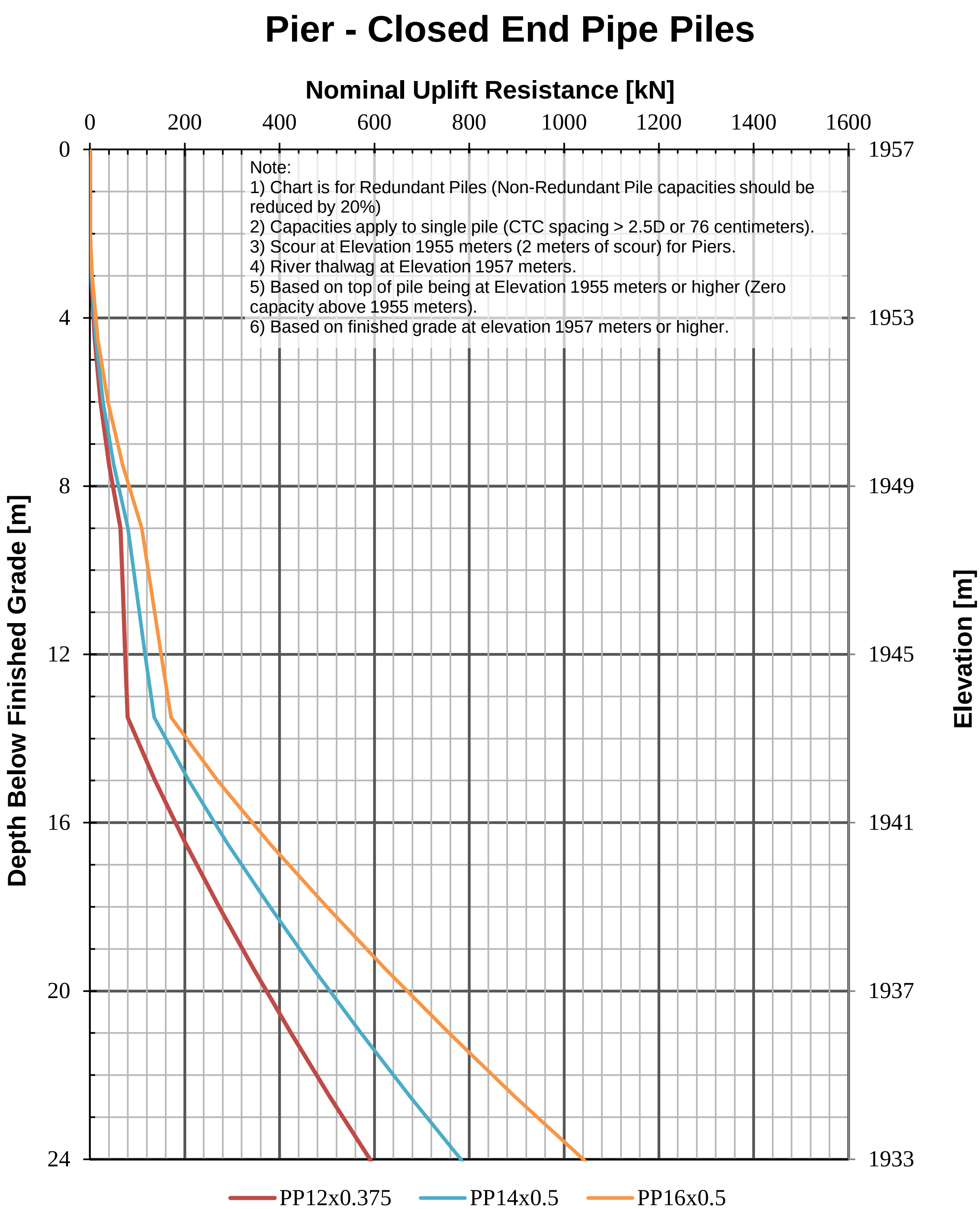

Figure 4.10: Pier Foundation Design Chart for Uplift Resistance – Closed-End Pipe Piles

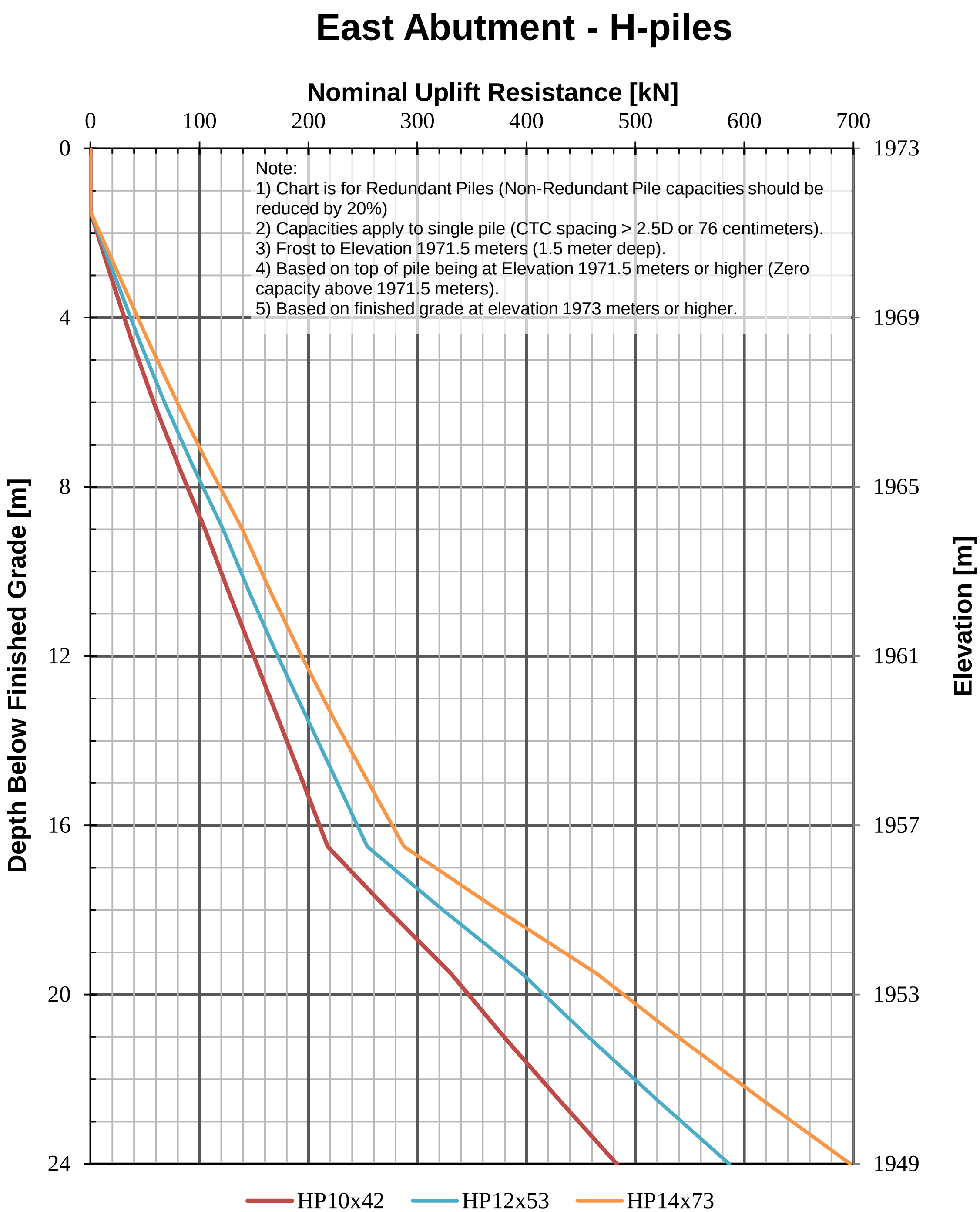

Figure 4.11: East Abutment Foundation Design Chart for Uplift Resistance – H-piles

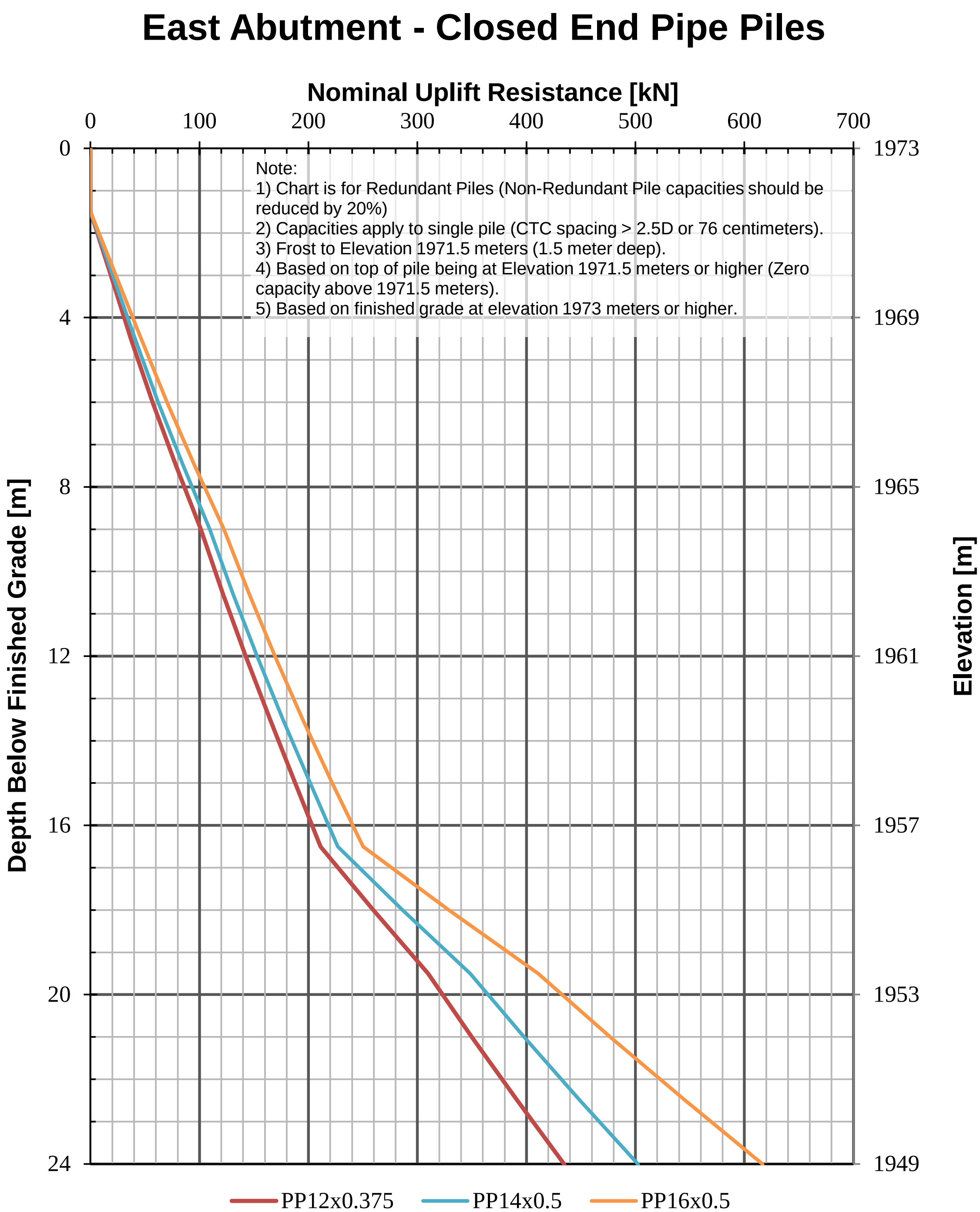

Figure 4.12: East Abutment Foundation Design Chart for Uplift Resistance – Closed-End Pipe Piles

Based on the ground conditions encountered at the site, Amec Foster Wheeler recommend using an efficiency factor η for pile groups in clay where the soil at the surface is soft due to the seasonal moisture variation of the soils at the ground surface.

In addition, for pile groups in clay, the nominal bearing resistance should be the lesser of:

- The sum of the individual nominal resistances of each pile in the group, or
- The nominal resistance of an equivalent pier consisting of the piles and the block of soil within the area bounded by the piles.

For pile groups in cohesionless soil, the nominal bearing resistance should be the sum of the resistances of all the piles in the group.

4.2.5 Redundancy of Foundations

The resistance factors used for calculating the vertical capacity may need to be modified depending upon the number of piles used at each foundation element or the redundancy of the foundations. Section 10.5.5.2.3 of AASHTO (2014) states, "If the resistance factors provided in Table 10.5.5.2.3-1 are to be applied to small pile groups, the resistance factor values in the table [Table 10.5.5.2.3-1] should be reduced by 20 percent to reflect the reduced ability for overstressing of an individual foundation element to be carried by adjacent foundation elements. The minimum size of a pile group necessary to provide significant opportunity for load sharing ranges from 2 or 3 (Isenhower and Long, 1997) to 5 (Paikowsky, et al., 2004)."

The BIA stated that a minimum of four piles will be used per foundation element, and thus the minimum group pile size requirement will be met. The strength limit state design charts, Figures 4.1 through 4.12, were prepared assuming redundancy in the foundations, and can be used without the 20 percent reduction.

4.2.6 Resistance to Lateral Load – Lateral Analysis

Lateral soil-structure interaction analyses of single piles are typically performed using the computer program LPILE (Ensoft 2012). This procedure estimates the lateral load-displacement behavior using a finite difference technique based on elastic beam column theory and soil reaction-displacement curves. Based on Reese and others (1984), the behavior of the soil surrounding the laterally loaded pile is described by lateral load-transfer functions referred to as p-y curves. The soil reaction (p) is related to the pile deflection (y) for various depths below the ground surface. In general, these curves are nonlinear and depend upon several parameters including depth, pile size and soil strength. Deflection, bending moment and shear profiles at specified intervals along the length of the pile can be computed.

An L-Pile analysis is recommended to evaluate the soil-structure interaction. Soil strength parameters for use in LPILE analyses are provided in Table 4.2.

Table 4.2: Soil Strength Parameters for LPILE Analyses – BIA N8065(1)

Elevation (meters)	Average Moist Unit Weight (kN/m^3)[1]	Friction Angle (degrees)	Undrained Shear Strength (kPa)	Soil Strain Ratio ε_{50}	Horizontal Subgrade Modulus K (kN/m^3)	Recommended Soil Type in LPILE
West Abutment						
Above 1971.5	-----	-----	-----	-----	-----	-----
1971.5 – 1965.5	1,440	27	-----	-----	2,700	Sand
1965.5 – 1961	1,600	-----	120	0.005	-----	Stiff Clay without free water
1961 – 1956.5	1,920	-----	144	0.005	-----	Stiff Clay without free water
1956.5 – 1950.5	1,760	27	-----	-----	2,700	Sand
1950 – 1947.5	1,920	32	-----	-----	13,570	Sand
Below 1947.5	1,920	-----	48	0.010	-----	Soft Clay
Piers 1 & 2						
Above 1955 (or scour depth)	-----	-----	-----	-----	-----	-----
1955 – 1948	1,920	32	-----	-----	13,570	Sand
1948 – 1943.5	1,920	-----	48	0.010	-----	Soft Clay
1943.5 – 1933	2,000	34	-----	-----	19,000	Sand
Below 1933	1,920	32	-----	-----	13,570	Sand
East Abutment						
Above 1971.5	-----	-----	-----	-----	-----	-----
1971.5-1964	1,600	-----	120	0.005	-----	Stiff Clay without free water
1964 – 1956.5	1,920	-----	192	0.005	-----	Stiff Clay without free water
1956.5 – 1953.5	1,920	30	-----	-----	8,140	Sand
1953.5 – 1949	1,760	27		-----	2,700	Sand
1949 – 1943	1,920	-----	48	0.010	-----	Soft Clay
Below 1943	2,000	32	-----	-----	13,570	Sand

Notes:
[1] Soil buoyant unit weight should be used in LPILE below the groundwater elevation. Groundwater elevation was at approximately elevation 1957 meters at the time of the geotechnical investigation. Buoyant unit weight is obtained by subtracting 1000 kilograms per cubic meter from the moist unit weight in the above table.
kg/m^3 kilogram per cubic meter, kPa = kilopascal, kN/m^3 kilonewton per cubic meter.

Where embankments, in front of piles, slope downward away from the abutment, the lateral soil resistance against piles should be reduced. It is conservatively recommended that lateral soil pressures (for loading normal to the column line) be neglected within the zone above the catch point (on the slope) of a horizontal line projected outward a distance of three pile diameters or

1.5 meters, whichever is greater (for example, a horizontal distance of 1.5 meters to the catch point on the slope for a 0.5-meter-diameter pile) from the front of the pile.

4.2.7 Group Effects – Lateral

The design of laterally loaded piles must account for the influence from adjacent piles in a group. Section 10.7.2.4 (AASHTO 2014) defines a group with respect to lateral loading as piles spaced less than five diameters center-to-center in the direction parallel and normal to the applied load. When the piles are in a group, the lateral resistance of the soil is reduced to account for the influence of adjacent piles by multiplying the values of p, of the p-y curves, by P-multiplier values (P_m). The values of P_m vary as a function of the center-to-center spacing of the piles within the group. The loading direction and spacing are shown in Figure 10.7.2.4-1 in AASHTO (2014). Recommendations for P_m values are also shown in Table 10.7.2.4-1 in AASHTO (2014).

The center-to-center pile spacing should not be less than 76 centimeters or 2.5 pile diameters. The distance from the side of any pile to the nearest edge of the pile cap should not be less than 23 centimeters.

4.2.8 Overall Stability

The overall stability of the abutments will need to be examined once more information is available on the foundation loading and pile configuration. To determine the slope stability of the slope, a friction angle of 14 degrees with a cohesion intercept of 36 kPa and a unit weight of 1760 kcm should be used for the clay soil (Layer A) strength. For the silty sand to sandy silt soil (Layer B) strength, a friction angle of 30 degrees, zero cohesion, and a unit weight of 1850 kcm. Layer A extends form the surface to a depth of about 15 meters bgs at the wash banks and layer B extends from a depth of about 15 meters to 30 meters bgs at the wash banks (Section 3.2 of this memorandum). At the west abutment, a zone of silty sand to sandy silt will need to be included from 1.5 meters to 7.5 meters bgs at the wash banks, with a friction angle of 27 degrees, zero cohesion, and a unit weight of 1440 kcm.

4.3 Construction Considerations

A test pile program at the site is strongly recommended for this project prior to construction. The purpose of the test pile program is to gather information regarding hammer/pile/soil interaction, develop driving criteria, verify the contractor’s equipment and installation procedures, determine the uplift resistance and verify the pile capacities estimated from the static analysis.

If possible, the test pile program should be performed during the design phase to confirm and verify the recommendations contained in this report, and properly evaluate the pile driving characteristics of the subsurface profile. A design stage test pile program would yield a more sophisticated design that would allow for a more cost efficient foundation design. Otherwise, consideration should be given to limit the number of piles ordered before the pile testing program is performed.

Adjustments, based upon the dynamic testing results, may need to be made to the pile capacities estimated from the static analysis in this report.

4.4 Corrosion and Degradation Potential – Steel Piles

Three soil samples at borings BS-2, BS-4 and BS-5, located within the planned pile locations, were tested to evaluate the corrosion potential on steel piles. The corrosion potential for the site was characterized using laboratory pH and electrical resistivity testing, performed in accordance with Arizona Test Method 236.

The laboratory resistivity values ranged from 212 to 1,468 ohm-centimeters (ohm-cm), and the pH values ranged from 8.3 to 8.4. Section 10.7.5 of AASHTO (2014) states that pile corrosion and/or deterioration is likely under the following site conditions:

1. Resistivity less than 2,000 ohm-cm
2. pH less than 5.5
3. pH between 5.5 and 8.5 in soils with high organic content

The site soils meet the first condition, which warrants the use of pile coatings or other protective methods. Protective coatings should be abrasion resistant. Piles can also be protected by low permeability concrete encasement, or made of special steel alloys of increased corrosion resistance.

5.0 REFERENCES

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TABLES

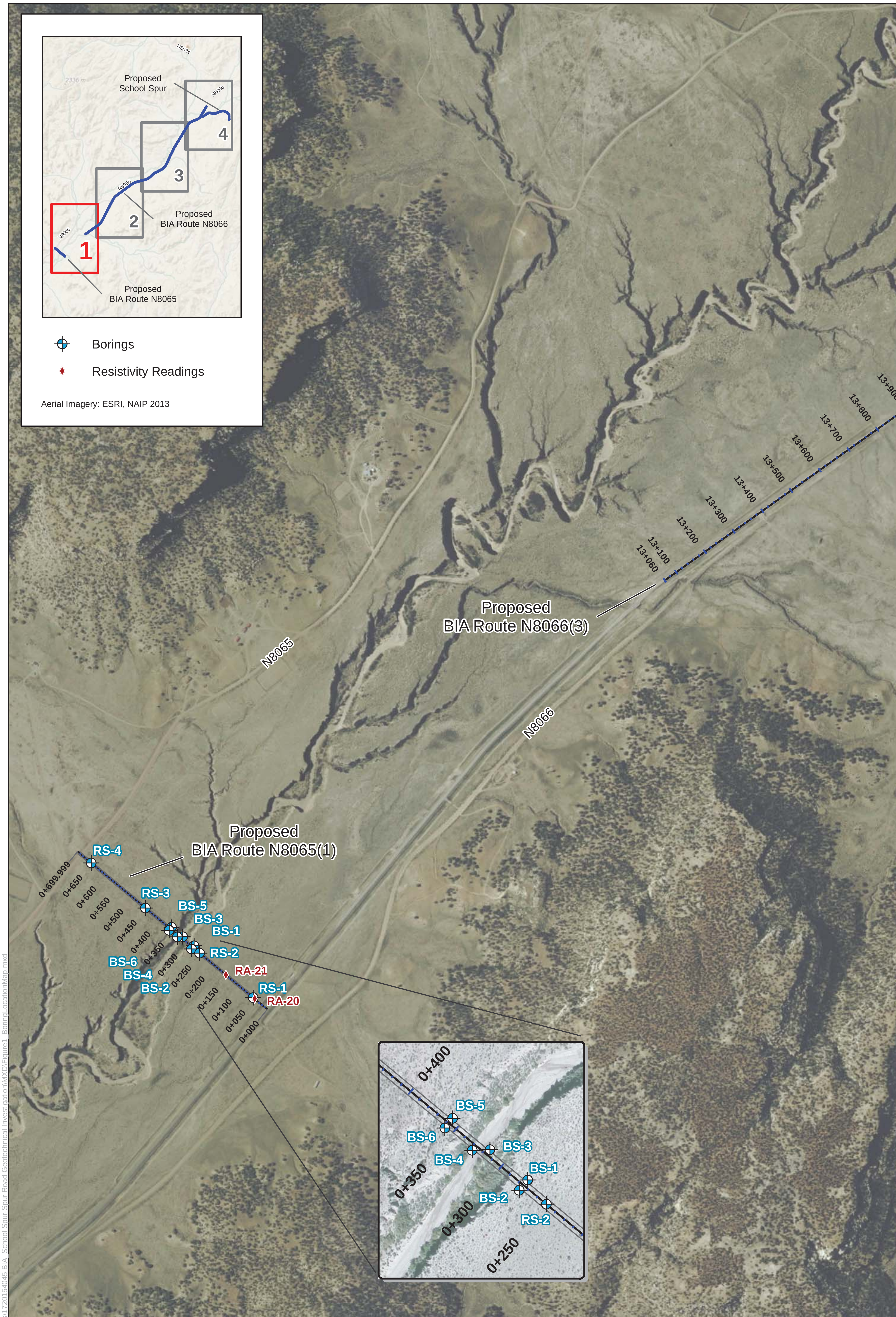
TABLE 1
Boring Locations - BIA N8065(1)

Boring Number	Station Reference	Location	Elevation (m)	Direction[1]	Offset (m)	Boring Type[2]	Structure	Targeted Boring Depth (m)	Actual Boring Depth (m)	
									Auger	Coring
BS-1	Proposed BIA Route N8065 Spur CL	0+275	1972.8	R	6	ATV	Bridge	30	30	0
BS-2	Proposed BIA Route N8065 Spur CL	0+275	1972.8	L	6	ATV	Bridge	30	30	0
BS-3	Proposed BIA Route N8065 Spur CL	0+313	1958.0	R	6	ATV	Bridge	30	30	0
BS-4	Proposed BIA Route N8065 Spur CL	0+328	1957.0	L	6	ATV	Bridge	30	30	0
BS-5	Proposed BIA Route N8065 Spur CL	0+358	1972.8	R	6	ATV	Bridge	30	30	0
BS-6	Proposed BIA Route N8065 Spur CL	0+358	1972.8	L	6	ATV	Bridge	30	30	0

[1] CL - Centerline, R - Right, L - Left

[2] ATV - Specialized ATV Mounted Drill Rig with 210mm Hollow Stem Auger

FIGURES



0 150 300 600 Meters

Job No.:	1720154045
PM:	NC
Date:	4/14/2016
Scale:	1 cm = 100 meters

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BIA Project N8066(3), N8065(1), and School Spur
Black Mesa Community School
Arizona

Boring and Resistivity Location Map

FIGURE
1

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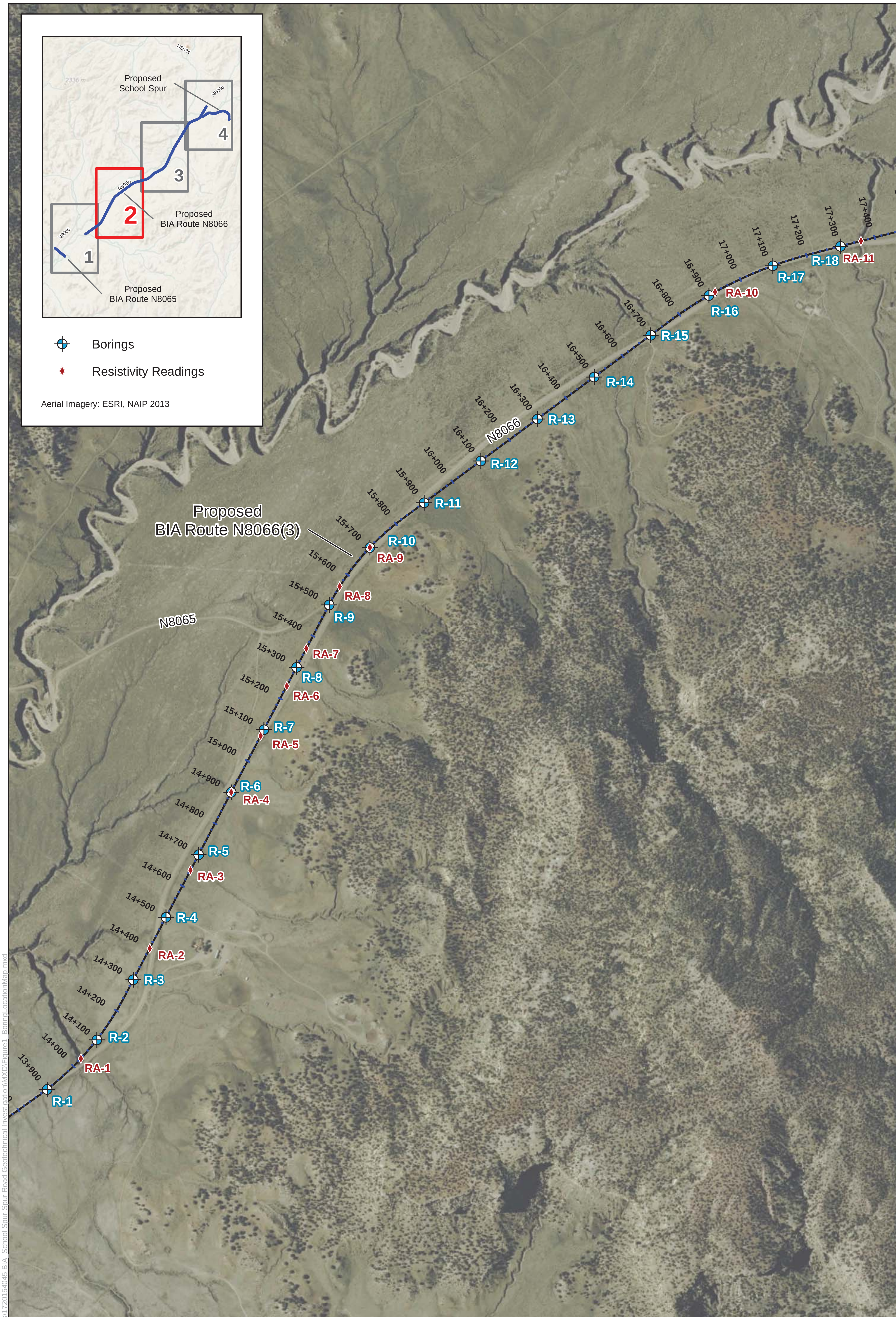

0 150 300 600 Meters

Job No.:	1720154045
PM:	NC
Date:	2/11/2016
Scale:	1 cm = 100 meters

N

The map shown here has been created with all due and reasonable care and is strictly for use with Amec Foster Wheeler Project Number 1720154045. This map has not been certified by a licensed land surveyor, and any third party use of this map comes without warranties of any kind. Amec Foster Wheeler assumes no liability, direct or indirect, whatsoever for any such third party or unintended use.

BIA Project N8066(3), N8065(1), and School Spur
Black Mesa Community School
Arizona

Boring and Resistivity Location Map

FIGURE
2

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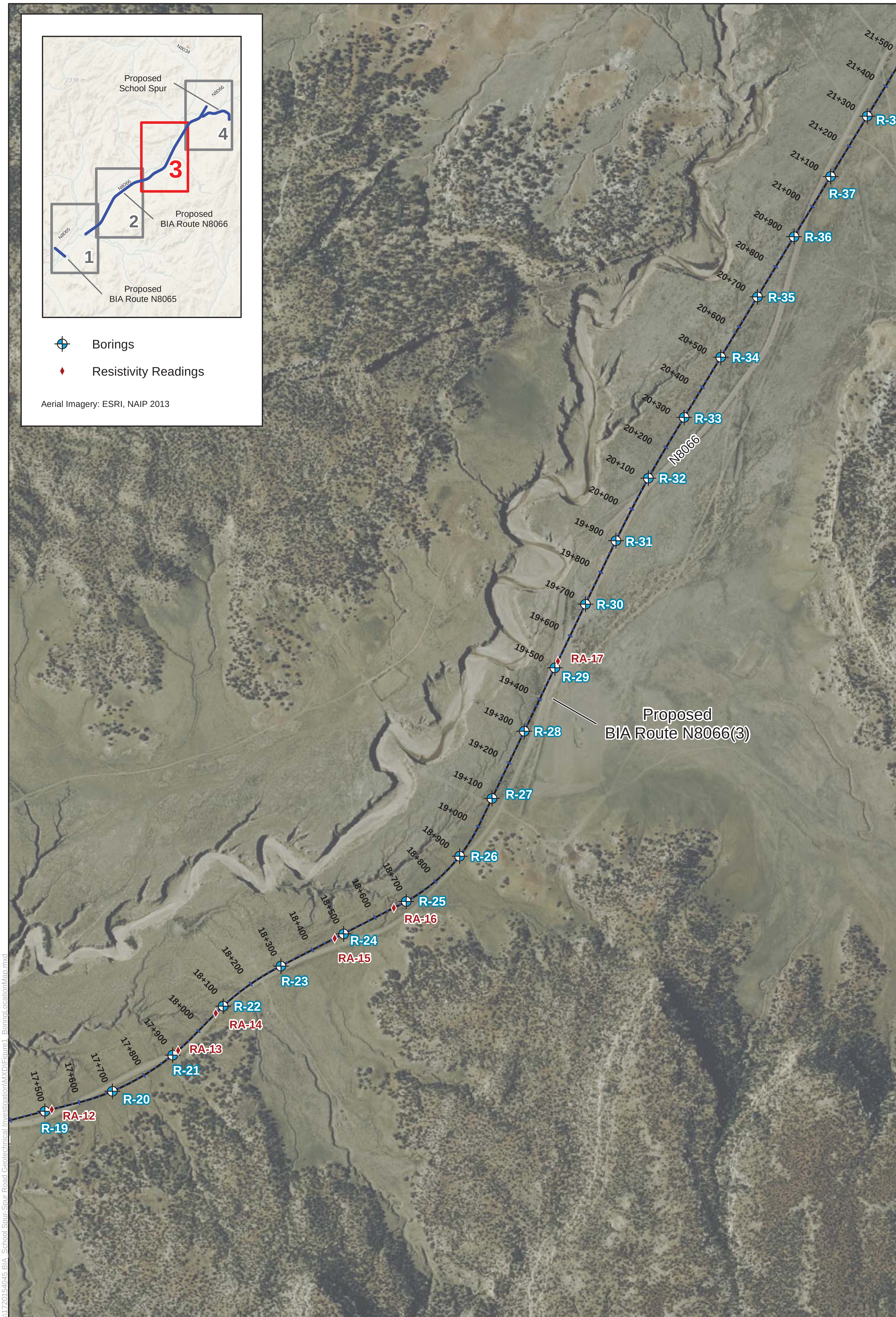
Path: X:\Projects\2015 Projects\1720154045 BIA_School Spur-Spur Road Geotechnical Investigation\MXD\Figure1_BoringLocationMap.mxd



Path: X:\Projects\2015 Projects\1720154045 BIA School Spur-Spur Road Geotechnical Investigation\MXD\Figure1_BoringLocationMap.mxd

Job No.:	1720154045
PM:	NC
Date:	2/11/2016
Scale:	1 cm = 100 meters

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BIA Project N8066(3), N8065(1), and School Spur
Black Mesa Community School
Arizona

Boring and Resistivity Location Map

FIGURE
3

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0 150 300 600
Meters

Job No.:	1720154045
PM:	NC
Date:	4/14/2016
Scale:	1 cm = 100 meters

N

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BIA Project N8066(3), N8065(1), and School Spur
Black Mesa Community School
Arizona

Boring and Resistivity Location Map

FIGURE
4

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Path: X:\Projects\2015 Projects\1720154045 BIA_School Spur-Spur Road Geotechnical Investigation\MXD\Figure1_BoringLocationMap.mxd

FIGURE 5
Summary of UU Test Results
CL Soils

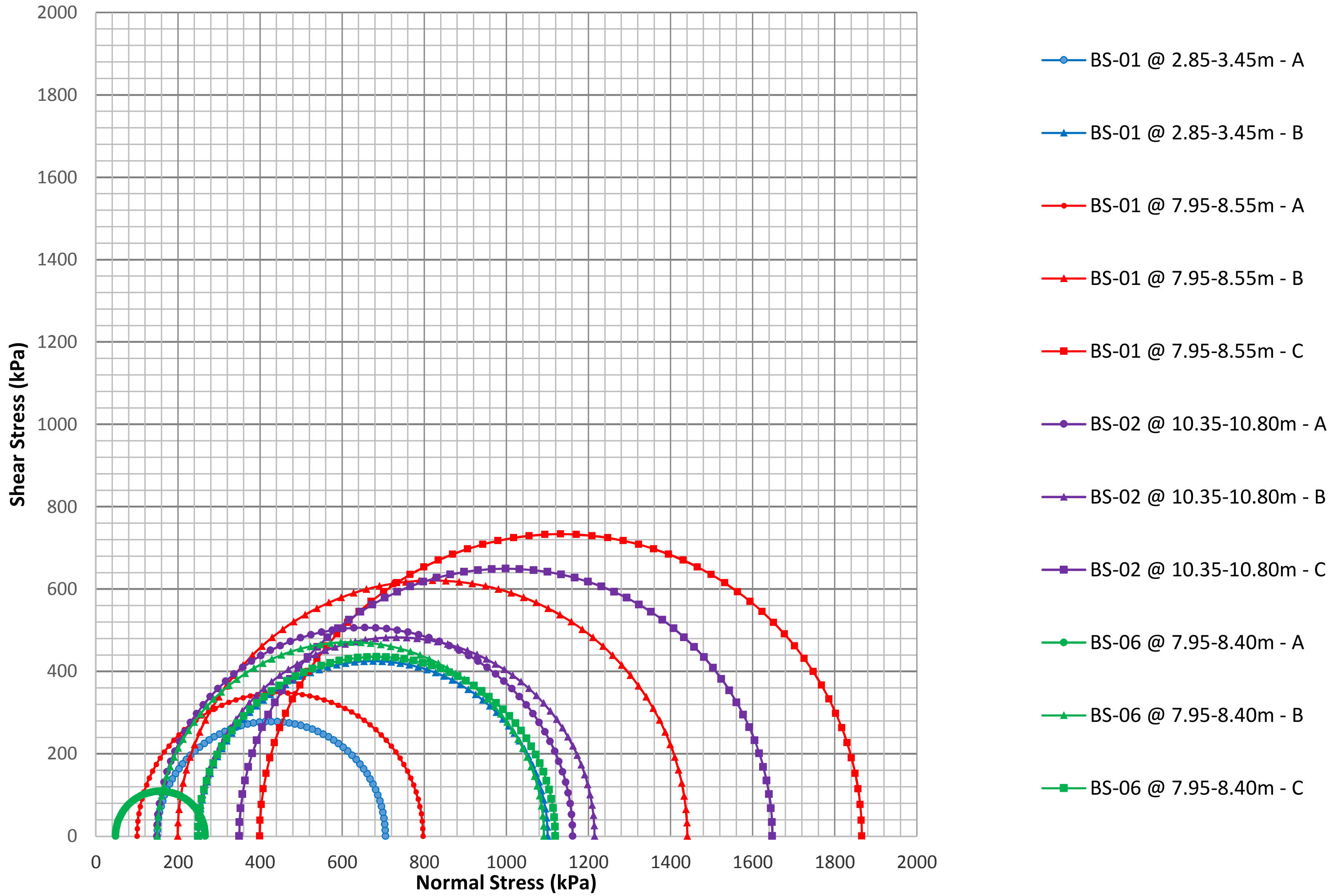


Figure 6
Subsurface Profile for BIA N8065(1)

Legend

SP-SM	ML
SM	CL
SC	CH

Groundwater Table Elevation

Boring ID	BS-1		BS-2		BS-3		BS-4		BS-5		BS-6	
Elevation	1973		1973		1957		1957		1973.2		1973.2	
(m[1])	USCS[2]	N	USCS	N	USCS	N	USCS	N	USCS	N	USCS	N
1973	CL	18	CL	26					CL/CH	24	CL	23
1971.5	CL	13	CL	14					ML/SM	14	ML/SM	12
1970	CL	18	CL	10					ML/SM	20	ML/SM	16
1968.5	CL	40	ML	18					SM	14	ML/SM	11
1967	CL	70	ML	22					SM	11	SC	12
1965.5	CL	29	ML	43					CL	28	CL	26
1964	CL	45	CL	27					CL	22	CL	20
1962.5	CL	30	CL	27					CL	17	CL	22
1961	CL	39	CL	28					CH	24	CH	31
1959.5	CL	NA	CL	40					CH	38	CH	46
1958	CL	26	SM	13	CL-ML	2	CH	6	CH	24	CH	21
1956.5	SM	22	SM	10	SM	8	SM	3	SM	9	SM	18
1955	SM	3	SM	5	SM	3	ML	3	SM	10	ML	6
1953.5	ML/SM	5	ML	0	SM	4	ML	5	ML	9	ML	7
1952	ML	4	ML	6	SM	7	ML	9	ML	11	ML	7
1950.5	ML	29	ML	4	SM	6	SP-SM	17	SM	12	SM	12
1949	SM	16	SM	14	SM	12	CH	9	SM	7	SM	14
1947.5	CL	9	SM	6	SM	13	CH	7	SM	27	CH	14
1946	CL	3	CL	11	CH	8	SM	5	SM	9	CH	8
1944.5	SM/SC	100	SM	24	SM	7	SM	5	SM	7	CH	8
1943	SM/SC	24	SM	17	SP-SM	16	SM	9	SM	7	CH	10
1941.5					CH	10	SP-SM	19				
1940					SM	19	SP-SM	23				
1938.5					SM	32	SP-SM	18				
1937					SP-SM	12	SP-SM	13				
1935.5					SM	32	SM	12				
1934					SP-SM	8	CH	12				
1932.5					SP-SM	12	SM	3				
1931					SP-SM	18	SM	6				
1929.5					CH	10	SM	11				
1928					CH	11	SM	11				
1926.5												
1925												

[1]m = meters
[2]USCS = Unified Soil Classification System
[3]NA = not available

ATTACHMENT A

FIELD INVESTIGATION

TEST DRILLING EQUIPMENT AND PROCEDURES

Description of Subsurface Exploration Methods

Auger Boring Drilling through overburden soils is performed with 6 5/8-inch O.D., 3 1/4-inch I.D. hollow stem auger or 4 1/2-inch solid stem continuous flight auger. Carbide insert teeth are normally used on bits so they can penetrate soft rock or very strongly cemented soils. A CME-75 truck-mounted drill rig is used to advance the auger. The drill rigs are powered with six-cylinder Cummins diesel engines capable of delivering about 11.4 kN-m torque to the drill spindle. The spindle is advanced with twin hydraulic rams capable of exerting 90 kN (20,000 pounds) downward force.

Generally, refusal to penetration of the auger is adopted as top of the SGC or "river-run" material or harder bedrock, which require other techniques for penetration. Grab samples or auger cuttings may be taken as necessary. Standard penetration tests or 2.42-inch diameter ring samples are taken in conjunction with the auger borings as needed, with the sampling interval and type being indicated on the boring logs.

Hammer Drill Drilling with the Hammer drill is accomplished with a Drill Systems AP-1000 drill rig advancing a double-walled drive casing with a link-belt 180 diesel pile driving hammer, having a rated energy of 8,100 foot-pounds per blow. Where noted on the boring log, the hammer is equipped with a supercharger which can boost the energy to approximately 12,000 foot-pounds per blow. The supercharger is used only in portions of the boring where blow counts are relatively high. Cuttings are removed with compressed air by a reverse circulation process, and are collected in a cyclone from which grab samples are obtained. The drive casing is either 9-inch O.D. by 6-inch I.D. or 6 5/8-inch O.D. by 4-inch I.D. and employs an expendable bit of slightly larger diameter than the O.D. of the casing. Hammer blows required to advance the drive casing are recorded in 1-foot increments, as noted on the boring logs. Standard penetration tests or 2.42-inch diameter ring samples taken are noted on the boring logs.

Core Boring Rock core samples are retrieved using a CME-75 drill rig, SAITECH GH 3 rig or Burley 2500, 4500 or 4000. The GH 3 is a portable hydraulic core drill. The GH 3 is powered by a Kohler two-cylinder 25-horsepower engine. The hydraulics motor which feeds a two-speed transmission and powers the BW spindle. This unit has a 3-foot stroke and is hand-fed with a 2,000 pound push-pull capability. The GH 3 has the capability of drilling with either B- or N-size core steel using standard or wireline systems. N-size core is the preferred size and it has a nominal O.D. of about 2 inches. The Burley 2500 and 4500 series are portable hydraulic core drills. The 4500 series is capable of a track-mounted or skid-type chassis. The Burley 2500 and 4500 series are powered by 44 and 75 HP power units, respectively, provide up to 2,000 foot-pounds (ft.-lbs.) of torque and in excess of 1,000 revolutions per minute (RPM) of spindle speed. Both rigs are capable of retrieving either N- or H-sized core using wireline systems. The N-size core has a nominal O.D. of about 2 inches and the H-size of about 2.4 inches. The Burley 4000 is a track-mounted core drill.

The CME-75 utilizes a wireline core drilling system that takes N-size cores. Using the NQ wireline system, core is recovered quickly by retrieving the core-laden inner tube through the drill string.

TEST DRILLING EQUIPMENT AND PROCEDURES (Cont.)

Sampling Procedures Dynamically driven tube samples are usually obtained at selected intervals in the borings by the ASTM D1586 test procedure. In many cases, 2-inch O.D., 1 3/8-inch I.D. samples are used to obtain the standard penetration resistance. “Undisturbed” samples of firmer soils are often obtained with 3-inch O.D. samples lined with 2.42-inch I.D. brass rings. The driving energy is generally recorded as the number of blows of a 140-pound, 30-inch free fall drop hammer required to advance the samples in 6-inch increments. However, in stratified soils, driving resistance is sometimes recorded in 2- or 3-inch increments so that soil changes and the presence of scattered gravel or cemented layers can be readily detected and the realistic penetration values obtained for consideration in design. These values are expressed in blows per 6 inches on the boring logs. "Undisturbed" sampling of softer soils is sometimes performed with thin walled Shelby tubes (ASTM D1587), pitcher samplers, Denison samplers or continuous CME samplers. Where samples of rock are required, they are obtained by NQ diamond core drilling (ASTM D2113). Tube samples are labeled and placed in watertight containers to maintain field moisture contents for testing. When necessary for testing, larger bulk samples are taken from auger cuttings. Also, representative samples are obtained from the cuttings from the hammer and Schramm drill rig.

Boring Records Drilling operations are directed by our field engineer or geologist who examines soil recovery and prepares the boring logs. Soils are visually classified in accordance with the Unified Soil Classification System (ASTM D2487), with appropriate group symbols being shown on the boring logs.

TERMINOLOGY USED TO DESCRIBE THE RELATIVE DENSITY, CONSISTENCY OR FIRMNESS OF SOILS

The terminology used on the boring logs to describe the relative density, consistency or firmness of soils relative to the standard penetration resistance is presented below. The standard penetration resistance (N) in blows per foot is obtained by the ASTM D1586 procedure using 2" O.D., 1 3/8" I.D. samplers.

1. **Relative Density.** Terms for description of relative density of cohesionless, uncemented sands and sand-gravel mixtures.

N	Relative Density
0-4	Very loose
5-10	Loose
11-30	Medium dense
31-50	Dense
50+	Very dense

2. **Relative Consistency.** Terms for description of clays which are saturated or near saturation.

N	Relative Consistency	Remarks
0-2	Very soft	Easily penetrated several inches with fist.
3-4	Soft	Easily penetrated several inches with thumb.
5-8	Medium stiff	Can be penetrated several inches with thumb with moderate effort.
9-15	Stiff	Readily indented with thumb, but penetrated only with great effort.
16-30	Very stiff	Readily indented with thumbnail.
30+	Hard	Indented only with difficulty by thumbnail.

3. **Relative Firmness.** Terms for description of partially saturated and/or cemented soils which commonly occur in the Southwest including clays, cemented granular materials, silts and silty and clayey granular soils.

N	Relative Firmness
0-4	Very soft
5-8	Soft
9-15	Moderately firm
16-30	Firm
31-50	Very firm
50+	Hard

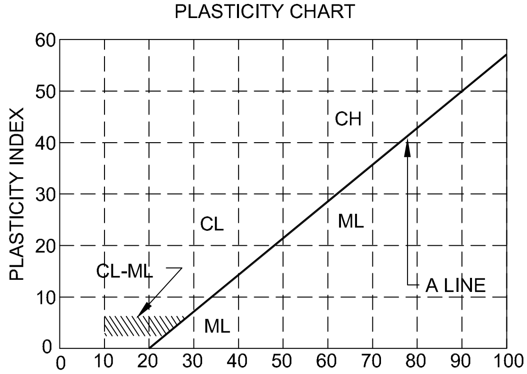
UNIFIED CLASSIFICATION SYSTEM FOR SOILS

Soils are visually classified by the United Soil Classification System on the boring logs presented in this report. Grain-size analysis and Atterberg Limits Tests are often performed on selected samples to aid in classification. The classification system is briefly outlined on this chart. For a more detailed description of the system, see " The Unified Soil Classification System " ASTM Designation: D2487

MAJOR DIVISION				GRAPH SYMBOL	GROUP SYMBOL	TYPICAL DESCRIPTION
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	**GRAVELS** (50% or less of coarse fraction passes No. 4 sieve)	**CLEAN GRAVELS** (Less than 5% passes No. 200 sieve)			GW	Well graded gravels, gravel-sized mixtures or sand-gravel-cobble mixture.
					GP	Poorly graded gravels, gravel-sized mixtures or sand-gravel-cobble mixture.
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		GM	Silty gravels, gravel-sand-silt mixture.
			Limits plot below "A" line & hatched zone on plasticity chart		GC	Clayey gravels, gravel-sand-clay mixture.
	SANDS (More than 50% of coarse fraction passes No. 4 sieve)	**CLEAN SANDS** (Less than 5% passes No. 200 sieve)			SW	Well graded sands, gravelly sands.
					SP	Poorly graded sands, gravelly sands.
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart		SM	Silty sands, sand-silt mixtures.
			Limits plot below "A" line & hatched zone on plasticity chart		SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	**SILTS** LIMITS PLOT BELOW "A" LINE & HATCH ZONE ON PLASTICITY CHART	**SILTS OF LOW PLASTICITY** (Liquid limit less than 50)			ML	Inorganic silts, clayey silts with slight plasticity.
		SILTS OF HIGH PLASTICITY (Liquid limit more than 50)			MH	Inorganic silts of high plasticity, silty soils, elastic silts.
	CLAYS LIMITS PLOT BELOW "A" LINE & HATCH ZONE ON PLASTICITY CHART	**CLAYS OF LOW PLASTICITY** (Liquid limit less than 50)			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
		CLAYS OF HIGH PLASTICITY (Liquid limit more than 50)			CH	Inorganic clays of high plasticity, fat clays, silty and sandy clays of high plasticity.

NOTE: Coarse-grained soils with between 5% to 12% passing the No. 200 sieve and fine-grained soils with limits plotting in the hatched zone on the plasticity chart to have dual symbol.

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

SOIL COMPONENT	PARTICLE SIZE RANGE
Boulders	Above 300mm (12in.)
Cobbles	300mm to 75mm (12in. to 3in.)
Gravel	75mm (3in.) to No. 4 sieve
Coarse gravel	75mm to 19mm (3in to 3/4in.)
Fine gravel	19mm (3/4in.) to No. 4 sieve
Sand	No. 4 to No. 200
Coarse	No. 4 to No. 10
Medium	No. 10 to No. 40
Fine	No. 40 to No. 200
Fines (silt or clay)	Below No. 200 sieve

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-12-16 to 1-13-16

LOCATION (M) N. 4015137.6 E. 575851.8
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S A	6-7-11			CL	moist moderately firm to very firm slightly moist below 0.6m	**CLAY,** fine grained sand, medium plasticity, brown note: some calcuim carbonate filaments below 0.8m
				S	36-22-16					
				S	5-5-8					
1.5										
								CL	slightly moist firm to very firm	**CLAY WITH SAND,** fine grained sand, medium plasticity, brown
3.0				T		1253.6	9.8			
				S	8-8-10					
4.5				S	16-17-23					
6.0				S	12-24-46				hard	note: considerable coarse grained gravel from 6.2m to 6.5m
									slightly moist	
7.5				S	12-13-16				firm	

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	17.7	15:00	1-12-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-1

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 **DATE** 1-12-16 to 1-13-16

LOCATION (M) N. 4015137.6 E. 575851.8
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CL	slightly moist firm to very firm	**CLAY WITH SAND,** continued note: increase in fines, some thin calcium carbonate filaments, light brown at 8m & below
				T	NR	1477.7	13.1			
9.0				S	13-16-29					
10.5				S	9-10-20					
12.0				S	8-13-26					
13.5				T	NR					
					30					
15.0				U	NR					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
∇	17.7	15:00	1-12-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-1

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-12-16 to 1-13-16

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LOCATION (M)	N. 4015137.6 E. 575851.8
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	1973.0m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
				S	4-12-14			CL	slightly moist firm	**CLAY WITH SAND,** continued note: medium to high plasticity at ~15m
16.5				S	14-9-13		22.3	SM	very moist firm	**SILTY SAND,** fine grained, subangular to subrounded sand, nonplastic, brown
18.0				S	3-2-1		29.6		wet below 17.7m very soft	
19.5				S	3-2-3			SM/ML	wet soft	**SILTY SAND TO SANDY SILT,** fine grained sand, subangular to subrounded, nonplastic, gray to brown
21.0				S	2-2-2			ML	wet very soft to firm	**SILT WITH SAND,** low plasticity, dark brown
22.5				S	10-17-12					note: gradational silty sand zones around 22.5m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	17.7	15:00	1-12-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-1

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 DATE 1-12-16 to 1-13-16

LOCATION (M) N. 4015137.6 E. 575851.8
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								ML	wet	**SILT WITH SAND,** continued
24.0				S	7-8-8			SM	wet firm	**SILTY SAND WITH GRAVEL,** some well graded, subangular to subrounded gravel, predominantly fine to medium grained, subangular to subrounded sand, low plasticity, gray
25.5				S	4-4-5			CL	wet stiff	**CLAY WITH SAND & SILT,** medium plasticity, gray note: clayey sand zones up to 150mm thick throughout
27.0				S	4-3 WOR *					* note: WOR - weight of rod
				U	20	1551.8	25.5			note: decrease in sand content & clayey sand zones below 28m
28.5				S	42-50/75mm			SM/SC	wet hard to firm	**SILTY SAND TO CLAYEY SAND,** fine grained, subangular to subrounded sand, low plasticity, gray
30.0				S	7-11-13					note: some fine grained gravel & some coarse grained sand below 30m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	17.7	15:00	1-12-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-1

PROJECT	BIA N8066(3), N8065(1) & School Spur Black Mesa Community School, Arizona Navajo Nation
JOB NO.	17-2015-4045
DATE	1-12-16 to 1-13-16
LOCATION (M)	N. 4015137.6 E. 575851.8
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	1973.0m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM/SC		**SILTY SAND TO CLAYEY SAND,** continued
										Stopped Auger at 30m Stopped Sampler at 31m
31.5										
33.0										
34.5										
36.0										
37.5										

GROUNDWATER

DEPTH (m)	HOUR	DATE
▽ 17.7	15:00	1-12-16
▼		

SAMPLE TYPE

A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-1

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 **DATE** 1-13-16 to 1-14-16

LOCATION (M) N. 4015128.7 E. 575844.9
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S A	9-10-16			CL	slightly moist to moist firm to moderately firm	**CLAY WITH SAND,** fine grained sand, some calcium carbonate, medium plasticity, light brown note: frozen ground from 0 to 0.5m
				S	6-9-9					
1.5				S	4-6-8					note: fine grained silty sand zones up to 150mm thick at 1.5m
3.0				S	5-5-5					note: fine grained silty sand zones below 3m note: coarse grained gravelly zone from 4.2m to 4.35m
4.5				T		1466.4	4.9	ML	slightly moist firm to very firm	**SANDY SILT,** predominantly fine grained, subangular to subrounded sand, nonplastic, light brown
				S	4-10-8					note: sand & coarse grained gravel zones up to 150mm thick below 5.3m note: clay with sand zones up to 300mm thick below 6m
6.0				S	7-9-13					
7.5				S	14-18-25					note: occasional thin calcium carbonate filaments below 7.2m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	17.55	14:00	1-13-16
▼	15.9	09:00	1-14-16

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-2

PROJECT: BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 DATE 1-13-16 to 1-14-16

LOCATION (M) N. 4015128.7 E. 575844.9
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								ML	slightly moist firm to very firm	**SANDY SILT,** continued
								CL		**CLAY WITH SAND,** trace silt, some gravel-sized calcium carbonate nodules, medium plasticity, light brown
9.0				S	10-12-15				slightly moist firm to very firm	
10.5				T		1418.7	18.0			note: occasional fine grained, subangular to subrounded gravel & increase in calcium carbonate below 10.5m
				S	10-11-16					note: medium to high plasticity clay below 10.8m
12.0				S	9-11-17					
13.5				S	9-17-23					
15.0				U	40	1713.0	14.1			

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	17.55	14:00	1-13-16
▼	15.9	09:00	1-14-16

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-2

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1-13-16 to 1-14-16

LOCATION (M) N. 4015128.7 E. 575844.9
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CL		**CLAY WITH SAND,** continued
				S	5-6-7			SM	slightly moist moderately firm	**SILTY SAND,** fine grained, subangular to subrounded sand, nonplastic, light brown
16.5				S	4-5-5				very moist moderately firm	note: trace predominantly fine grained, subangular to subrounded gravel, predominantly medium grained, subangular to subrounded sand & brown in color at 16.5m
									wet below 17.55m	
18.0				S	2-2-3				soft	
								ML		**SANDY SILT,** fine grained sand, nonplastic, gray
19.5				S	WOR *		27.6		wet very soft to soft	* note: WOR - weight of rod
										note: gradational silty sand to sandy silt below 20.4m
21.0				S	2-3-3					
22.5				S	1-1-3					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	17.55	14:00	1-13-16
▼	15.9	09:00	1-14-16

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-2

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 DATE 1-13-16 to 1-14-16

LOCATION (M) N. 4015128.7 E. 575844.9
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								ML	wet very soft	**SANDY SILT,** continued note: fine to medium grained sand zones up to 150mm thick at ~22.5m
								SM		**SILTY SAND WITH GRAVEL,** trace coarse grained, subangular to subrounded gravel, predominantly fine to medium grained, subangular to subrounded sand, nonplastic, dark gray
24.0				S	4-6-8				wet moderately firm to soft	
25.5				S	1-1-5					note: gradational sandy silt to silty sand at 25.5m
								CL		**CLAY,** medium to high plasticity, gray
27.0				S	4-5-6				wet stiff	
				U	21	1533.1	28.4			
28.5								SM		**SILTY SAND,** fine grained, subangular to subrounded, nonplastic, dark gray
				S	6-11-13				wet firm	note: decrease in fines below 29.1m note: increase in medium to coarse grained sand with trace fine grained gravel below 29.4m
30.0				S	7-5-12					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	17.55	14:00	1-13-16
▼	15.9	09:00	1-14-16

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-2

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 **DATE** 1-13-16 to 1-14-16

LOCATION (M) N. 4015128.7 E. 575844.9
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM		**SILTY SAND,** continued
										Stopped Auger at 30m Stopped Sampler at 31m
31.5										
33.0										
34.5										
36.0										
37.5										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	17.55	14:00	1-13-16
▼	15.9	09:00	1-14-16

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-2

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 DATE 2-20-16 to 2-21-16

LOCATION (M) N. 4015163.0 E. 575819.4
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1957.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S A	1-1-1			SM	slightly moist to moist very soft	**SILTY SAND,** predominantly fine to medium grained, subrounded sand, nonplastic, brown note: some roots in sample at surface
								CL-ML		
				S	2-2-3				slightly moist soft	**SANDY SILTY CLAY,** predominantly fine grained, subrounded sand, medium plasticity, brown note: up to 150mm thick clayey sand zones throughout, medium to high plasticity, dark brown note: trace gravel at 1.4m
1.5				S	3-5-3			SM		
									slightly moist to moist soft to very soft wet below 3m	**SILTY SAND,** predominantly fine grained, subrounded sand, nonplastic, brown
3.0 (▽)				S	2-2-1					
										note: clay with sand zones up to 75mm thick, medium plasticity, below 3.9m
4.5				S	1-1-3				very soft to soft	
6.0				S	3-3-4					
								SM	wet soft	**SILTY SAND,** predominantly fine to medium grained, subrounded sand, nonplastic, dark brown with black streaks
7.5				S	2-2-4					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	3	12:15	2-20-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 DATE 2-20-16 to 2-21-16

LOCATION (M) N. 4015163.0 E. 575819.4
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1957.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM	wet soft to moderately firm	**SILTY SAND,** continued note: stratified sandy silt & sandy clay zones, approximately 50mm thick throughout, black to gray
9.0				S	3-5-7					
					NR					
10.5				S	5-9-4					
								CH	wet medium stiff	**CLAY WITH SAND,** some silt, some predominantly fine grained, subrounded sand, medium to high plasticity, dark gray note: up to 150mm thick sandy silt zones throughout, nonplastic, dark gray to black
12.0				S	3-4-4					
								SM	wet soft to firm	**SILTY SAND,** predominantly fine to medium grained, subrounded sand, nonplastic, dark gray with black zones note: up to 150mm thick clay with sand zones throughout, medium to high plasticity, gray
13.5				U	8	1562.0	25.8			
				S	2-3-4					
15.0				S	3-6-10					note: decrease in fines content below 14.7m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	3	12:15	2-20-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-20-16 to 2-21-16

amec foster wheeler

LOCATION (M)	N. 4015163.0 E. 575819.4
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	1957.0m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM	wet medium stiff to very stiff	**SILTY SAND,** continued
								SP-SM	wet loose	**SAND WITH SILT,** predominantly fine to medium grained, subrounded sand, nonplastic, gray
16.5				S	5-4-6					note: change in color to yellow at 16.5m
								CH	wet very stiff	**CLAY WITH SAND,** predominantly fine grained, subrounded sand, high plasticity, dark gray
18.0				S	7-10-9					
								SM	wet very firm	**SILTY SAND WITH GRAVEL,** some predominantly fine grained, subangular to subrounded gravel, predominantly fine to medium grained, subrounded sand, nonplastic, gray note: slight increase in gravel content with depth
19.5				S	8-11-21					note: trace clay below 19.5m
								SP-SM	moist medium dense	**SAND WITH SILT,** predominantly fine to medium grained, subrounded sand, nonplastic, gray
21.0				S	3-5-7					
								SM	moist very firm	**SILTY SAND WITH GRAVEL,** considerable predominantly coarse grained, subangular to subrounded gravel, predominantly fine to medium grained, subrounded sand, nonplastic, gray
22.5				S	4-14-18					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	3	12:15	2-20-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-20-16 to 2-21-16

LOCATION (M) N. 4015163.0 E. 575819.4
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1957.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM	wet very firm	**SILTY SAND WITH GRAVEL,** continued note: up to 75mm thick sandy clay zones throughout, medium plasticity, gray
								SP-SM		**SAND WITH SILT,** predominantly fine to medium grained, subrounded sand, nonplastic, gray
24.0				S	3-3-5				wet loose to medium dense	
25.5				S	3-4-8					note: trace predominantly fine grained, subangular to subrounded gravel below 25m note: up to 75mm thick sandy silt zones throughout, nonplastic, gray below 25.5m
27.0				S	4-7-11					note: thin clay lenses throughout, medium to high plasticity, green below 27m
28.5				S	3-3-7					
								CH	wet stiff	**CLAY WITH SAND,** some predominantly fine grained, subrounded sand, high plasticity, gray note: up to 75mm thick silty sand zone throughout, nonplastic, yellowish-brown to gray
30.0				S	3-5-6					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	3	12:15	2-20-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-20-16 to 2-21-16

LOCATION (M) N. 4015163.0 E. 575819.4
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1957.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CH	wet stiff	**CLAY WITH SAND,** continued
										Stopped Auger at 30m Stopped Sampler at 31m
31.5										
33.0										
34.5										
36.0										
37.5										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	3	12:15	2-20-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-3

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 **DATE** 2-21-16 to 2-22-16

LOCATION (M) N. 4015162.4 E. 575804.3
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1957.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S	2-2-4			SP-SM	moist loose wet below 0.3m	**SAND WITH SILT,** predominantly fine to medium grained, subrounded sand, nonplastic, brown
				A				CH	wet medium stiff	**CLAY WITH SAND,** predominantly fine grained, subrounded sand, medium to high plasticity, brown with gray streaks
				S	1-2-3					
1.5				S	1-1-2			SM	wet very soft	**SILTY SAND,** predominantly fine to medium grained, subrounded sand, nonplastic, brown with black streaks note: up to 150mm thick sandy silt zones throughout, nonplastic, light brown to brown below 2.1m
3.0				S	1-1-2			ML	wet very soft to moderately firm	**SANDY SILT,** predominantly fine grained, subrounded sand, nonplastic, brown with black streaks note: up to 75mm thick sandy clay zones throughout, low to medium plasticity, gray below 3.9m
4.5				S	1-2-3					
6.0				S	1-3-6					
								SP-SM	wet medium dense	**SAND WITH SILT,** predominantly fine to medium grained, subrounded sand, uncemented, nonplastic, gray
7.5				S	5-8-9					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
∇	0.3	14:10	2-21-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-4

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-21-16 to 2-22-16

LOCATION (M) N. 4015162.4 E. 575804.3
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1957.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SP-SM	wet medium dense	**SAND WITH SILT,** continued
								CH	wet stiff to medium stiff	**CLAY,** trace predominantly fine grained, subrounded sand, high plasticity, gray
9.0				S	3-4-5					
10.5	1.50			U	11	1476.4	31.4			note: 6.25 kg/cm^2 Torvane Shear Test
				S	4-3-4					note: up to 75mm thick sandy silt zones throughout below 11m
								SM	wet soft to moderately firm	**SILTY SAND,** trace predominantly fine grained, subangular to subrounded gravel, predominantly fine to medium grained, subrounded sand, nonplastic, gray note: sandy clay zones, medium plasticity, gray, up to 150mm thick throughout note: decrease in gravel with depth
12.0				S	1-2-3					
13.5				S	3-2-3					
15.0				U	18	1727.6	18.6			

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	0.3	14:10	2-21-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-4

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-21-16 to 2-22-16

LOCATION (M) N. 4015162.4 E. 575804.3
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1957.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM	wet	**SILTY SAND,** continued
				S	3-4-5				moderately firm to firm	
										note: up to 75mm thick sandy clay zones throughout, low to medium plasticity & gray below 15.9m
				S	7-6-13					
16.5										
								SP-SM	wet medium dense	**SAND WITH SILT,** trace predominantly coarse grained, subangular to subrounded gravel, predominantly medium grained, subrounded sand, nonplastic, gray
				S	3-8-15					
18.0										
				S	5-8-10					note: sand grades to predominantly fine to medium grained & decrease in gravel content below 19.5m
19.5										
				S	4-7-6					note: up to 150mm thick sandy silt zones throughout, nonplastic to low plasticity, gray, below 21m
21.0										
								SM		**SILTY SAND**
				S	4-4-8					
22.5										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	0.3	14:10	2-21-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-4

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 2-21-16 to 2-22-16

LOCATION (M) N. 4015162.4 E. 575804.3
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1957.0m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM	wet moderately firm	**SILTY SAND,** trace clay, predominantly fine grained, subrounded sand, nonplastic to low plasticity, gray
								CH	wet stiff	**CLAY WITH SAND,** predominantly fine grained, subrounded sand, high plasticity, gray note: up to 75mm thick sandy silt zones throughout, nonplastic, gray
24.0				S	3-4-8					
								SM	wet very soft to moderately firm	**SILTY SAND,** predominantly fine to medium grained, subrounded sand, nonplastic, gray note: up to 150mm thick sandy clay zones throughout, medium to high plasticity, gray note: up to 75mm thick sandy silt zones throughout, nonplastic, gray below 25.8m note: decrease in fines content below 26.4m note: 3.75 kg/cm^2 Torvane Shear Test
25.5	1.00			U	8	1463.7	31.5			
				S	1-2-1					
27.0				S	1-2-4					note: stratified silty sand, sandy clay & sandy silt zones up to 75mm thick throughout below 27.9m
28.5				S	5-5-6					note: up to 75mm thick sand with silt zones throughout below 29.4m
30.0				S	4-5-6					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	0.3	14:10	2-21-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-4

PROJECT	BIA N8066(3), N8065(1) & School Spur Black Mesa Community School, Arizona Navajo Nation
JOB NO.	17-2015-4045
DATE	2-21-16 to 2-22-16

amec foster wheeler

LOCATION (M)	N. 4015162.4 E. 575804.3
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	1957.0m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
			X					SM	wet	**SILTY SAND,** continued
										Stopped Auger at 30m Stopped Sampler at 31m
31.5										
33.0										
34.5										
36.0										
37.5										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	0.3	14:10	2-21-16
▼			

SAMPLE TYPE

A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-4

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 **DATE** 1/18/16

LOCATION (M) N. 4015189.5 E. 575787.5
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.2m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S A	11-12-12			CL/CH	slightly moist to moist firm to moderately firm	**CLAY,** medium to high plasticity, light brown note: frozen ground from 0 to 0.5m note: occasonal coarse grained gravel & small cobbles up to 100mm in diameter below 0.45m note: silty sand to sandy silt zones, 75mm thick, below 0.6m
				S	5-8-6					
1.5				S	5-7-7			ML/SM	slightly moist moderately firm to firm	**SILT WITH SAND locally grading TO SILTY SAND,** fine grained, subangular to subrounded sand, nonplastic, light brown
3.0				S	4-9-11					
				T		1344.5	3.2	SM	slightly moist moderately firm to firm	**SILTY SAND,** predominantly fine grained, subrounded to subangular sand, nonplastic, light brown
4.5				S	5-6-8					
6.0				S	5-4-7					note: decrease in fines at 6m
7.5				S	11-13-15					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	16.5	13:00	1-18-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-5

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 DATE 1/18/16

LOCATION (M)	N. 4015189.5 E. 575787.5
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	1973.2m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CL	slightly moist	**CLAY,** trace coal fragments, trace calcium carbonate filaments, medium to high plasticity, light brown
				U	37	1466.3	8.2		firm	
9.0				S	11-11-11					note: silty to clayey sand zones up to 150mm thick below 8.7m
10.5				S	3-7-10					note: alternating zones of medium to high plasticity clay & silty sand zones up to 150mm thick note: predominantly high plasticity clay below 11.4m
								CH	slightly moist	**CLAY WITH SAND,** some calcium carbonate filaments & small nodules, high plasticity, dark brown
12.0				U	42	1643.6	18.3		firm to very firm	
				S	10-10-14					
13.5				S	9-16-22					
15.0				S	10-11-13					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	16.5	13:00	1-18-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-5

PROJECT: BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 DATE 1/18/16

LOCATION (M) N. 4015189.5 E. 575787.5
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.2m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CH	slightly moist firm	**CLAY WITH SAND,** continued note: fine grained sandy zones, medium to high plasticity clay, dark brown to light brown at 15m
								SM		**SILTY SAND,** fine grained, subangular to angular sand, nonplastic, light brown with some reddish-brown oxidation staining
16.5				S	4-3-6				wet below 16.5m moderately firm	
18.0				S	2-3-7					note: silt & clay zones up to 100mm thick below 17.7m
								ML		**SILT WITH SAND,** fine grained sand, nonplastic, dark gray
19.5				S	4-5-4				wet moderately firm	note: weakly to moderately stratified with dark gray to black organic zones & sand-sized coal particles note: gradational silty sand to sandy silt below 20.5m
21.0				S	4-4-7					
								SM	wet moderately firm	**SILTY SAND**
22.5				S	4-4-8					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	16.5	13:00	1-18-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-5

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 DATE 1/18/16

LOCATION (M) N. 4015189.5 E. 575787.5
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.2m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
			X					SM	wet soft to firm	**SILTY SAND,** trace fine grained gravel, predomnantly fine to medium grained, subangular sand, nonplastic, dark gray note: some sand-sized coal particles
24.0			X	S	3-3-4					
										note: trace coarse grained gravel below 25.2m note: very stiff, high plasticity, dark gray clay zone from 25.65m to 25.8m
25.5			X	S	5-7-20					
27.0			X	S	2-4-5					
28.5			X	S	2-2-5					
30.0			X	S	5-3-4					note: high plasticity clay zones, up to 75mm thick, below 29.7m

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	16.5	13:00	1-18-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-5

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1/18/16

amec foster wheeler

LOCATION (M)	N. 4015189.5 E. 575787.5
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	1973.2m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM		**SILTY SAND,** continued note: coarse grained gravelly zone up to 100mm thick at 30m
										Stopped Auger at 30m Stopped Sampler at 31m
31.5										
33.0										
34.5										
36.0										
37.5										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	16.5	13:00	1-18-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-5

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 DATE 1/17/16

LOCATION (M) N. 4015181.1 E. 575781.0
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.2m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S A	11-11-12			CL	slightly moist to moist firm to moderately firm	**CLAY WITH SAND,** fine grained sand, medium to high plasticity, brown note: frozen ground from 0 to 0.5m
				S	3-4-5					
				T						
1.5										
								SM/ML	slightly moist moderately firm to firm	**SILTY SAND TO SANDY SILT,** fine grained, subangular to subrounded, nonplastic, light brown note: medium to high plasticity clayey zones, up to 75mm thick, below 2.7m
				S	5-5-7					
3.0				S	6-6-10					
4.5				S	4-5-6					
								SC	slightly moist moderately firm	**CLAYEY SAND,** fine grained, subangular to subrounded, medium plasticity, light brown
6.0				S	7-5-7					
								CL	slightly moist firm	**CLAY,** some calcium carbonate filaments, medium to high plasticity, dark brown
7.5				S	9-12-14					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	16.5	13:00	1-17-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-6

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1/17/16

amec foster wheeler

LOCATION (M)	N. 4015181.1 E. 575781.0
PROJECTION	NAD 1983 UTM Zone 12N (Meters)
RIG TYPE	CME-75
BORING TYPE	210mm Hollow Stem Auger
SURFACE EL. (M)	1973.2m ±
DATUM	NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CL	slightly moist firm	**CLAY,** continued note: trace fine grained sand below 8m
				T		1365.2	11.7			
9.0				S	9-9-11					
10.5				S	7-9-13					note: thin silty sand zones up to 75mm thick below 10.2m
								CH	slightly moist very firm to firm	**CLAY WITH SAND,** some calcium carbonate filaments, high plasticity, dark brown
12.0				S	8-11-20					
										note: considerable calcium carbonate filaments below 12.6m
13.5				U	60	1620.6	18.7			
				S	11-18-28					
15.0				S	10-10-11					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
∇	16.5	13:00	1-17-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-6

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 DATE 1/17/16

LOCATION (M) N. 4015181.1 E. 575781.0
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.2m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CH	slightly moist firm	**CLAY WITH SAND,** continued note: silty sand zones at 15m
								SM		**SILTY SAND,** predominantly fine to medium grained, subangular sand, nonplastic, brown to mottled brown
				S	7-8-10					
16.5									wet below 16.5m firm	
								ML		**SANDY SILT,** predominantly fine grained sand, nonplastic, dark brown
				S	2-3-3					
18.0									wet soft to moderately firm	note: thin high plasticity clay zones up to 50mm thick below 18m
				S	1-2-5					
19.5										note: silty sand zones below 19.8m
				S	4-3-4					
21.0										
				S	1-4-8					
22.5										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	16.5	13:00	1-17-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
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T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-6

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

amec foster wheeler

JOB NO. 17-2015-4045 **DATE** 1/17/16

LOCATION (M) N. 4015181.1 E. 575781.0
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.2m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								SM	wet moderately firm	**SILTY SAND,** trace fine grained gravel, well graded, subangular to angular sand, nonplastic, dark gray note: thin zones of silty sand with gravel, silt & high plasticity clay up to 75mm thick
24.0				S	6-7-7					
								CH	wet stiff to medium stiff	**CLAY WITH SAND,** predominantly fine grained sand, high plasticity, dark gray note: sandy silt with gravel & silt zones below 25.8m
25.5				S	1-6-8					
				U	6					
27.0				S	3-4-4					
28.5				S	1-4-4					
30.0				S	5-5-5					

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	16.5	13:00	1-17-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
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T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-6

PROJECT BIA N8066(3), N8065(1) & School Spur
Black Mesa Community School, Arizona
Navajo Nation

JOB NO. 17-2015-4045 **DATE** 1/17/16

LOCATION (M) N. 4015181.1 E. 575781.0
PROJECTION NAD 1983 UTM Zone 12N (Meters)
RIG TYPE CME-75
BORING TYPE 210mm Hollow Stem Auger
SURFACE EL. (M) 1973.2m ±
DATUM NAVD88

Depth in Meters	Pocket Penetrometer (Tons per sq ft)	Graphical Log	Sample	Sample Type	Blow Counts	Dry Density Kg. per Cubic meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
								CH		**CLAY WITH SAND ZONES,** continued
									firm to	Stopped Auger at 30m Stopped Sampler at 31m
31.5										
33.0										
34.5										
36.0										
37.5										

GROUNDWATER

	DEPTH (m)	HOUR	DATE
▽	16.5	13:00	1-17-16
▼			

SAMPLE TYPE
A - Auger cuttings; NR-No Recovery
S - 51mm O.D. 35mm I.D. tube sample.
U - 76mm O.D. 61mm I.D. tube sample.
T - 25mm O.D. thin-walled tube sample

LOG OF TEST BORING NO. BS-6

ATTACHMENT B

LABORATORY TEST RESULTS

LABORATORY TESTING PROCEDURES

Consolidation Tests Soiltest or Clockhouse apparatus of the "floating-ring" type are employed for the one-dimensional consolidation tests. They are designed to receive 1-inch high 2.5-inch O.D. brass liner rings with soil specimens as secured in the field. Procedures for the tests generally are those outlined in ASTM D2435. Loads are applied in several increments to the upper surface of the test specimen and the resulting deformations are recorded at selected time intervals for each increment. For soils which are essentially saturated, each increment of load is maintained until the deformation versus log of time curve indicates completion of primary consolidation. For partially saturated soils, each increment of load is maintained until the rate of deformation is equal or less than 1/10,000 inch per hour. Applied loads are such that each new increment is equal to the total previously applied loading. Porous stones are placed in contact with the top and bottom of the specimens to permit free addition or expulsion of water. For partially saturated soils, the tests are normally performed at in situ moisture conditions until consolidation is complete under stresses approximately equal to those which will be imposed by the combined overburden and foundation loads. The samples are then submerged to show the effect of moisture increase and the tests continued under higher loadings. Generally, the tests are continued to about twice the anticipated curve due to overburden and structural loads with a rebound curve then being established by releasing loads.

Expansion Tests The same type of consolidometer apparatus described above is used in expansion testing. Undisturbed samples contained in brass liner rings are placed in the consolidometers, subjected to appropriate surcharge loads and submerged. The loads are maintained until the expansion versus log of time curve indicates the completion of "primary swell".

Direct Shear Tests Direct shear tests are run using a Clockhouse or Soiltest apparatus of the strain-control of approximately 0.05 inch per minute. The machine is designed to receive one of the 1-inch high 2.42-inch diameter specimens obtained by tube sampling. Generally, each sample is sheared under a normal load equivalent to the effective overburden pressure at the point of sampling. In some instances, samples are sheared at several normal loads to obtain the cohesion and angle of internal friction. When necessary, samples are saturated and/or consolidated before shearing in order to approximate the anticipated controlling field loading conditions.

TABLE B-1
SUMMARY OF LABORATORY TEST RESULTS

Station Reference	Location	Offset	Direction	Boring Number	Depth (meter)		USCS/Group Symbol	Liquid Limit	Plasticity Index	Percent Fines (minus 75µm)	Moisture Content (%)	In Place Dry Density (kg/cu.m)[1]	Unconsolidated-Undrained Triaxial Compression Test on Cohesive Soils (AASHTO T296)	pH	Resistivity (ohm-cm)[2]
		meter			Begin	End									
Proposed BIA Route N8065 Spur CL	0+275	6	R	BS-01	2.85	3.45	CL	31	12	78	9.8	1253.6	X		
Proposed BIA Route N8065 Spur CL	0+275	6	R	BS-01	7.95	8.55	CL	46	25	94	13.1	1477.7	X		
Proposed BIA Route N8065 Spur CL	0+275	6	R	BS-01	16.35	16.80					22.3				
Proposed BIA Route N8065 Spur CL	0+275	6	R	BS-01	17.85	18.30	SM	NV	NP	16	29.6				
Proposed BIA Route N8065 Spur CL	0+275	6	R	BS-01	27.45	27.75					25.5	1551.8			
Proposed BIA Route N8065 Spur CL	0+275	6	L	BS-02	4.35	4.89	ML	NV	NP	55	4.93	1466.4	X		
Proposed BIA Route N8065 Spur CL	0+275	6	L	BS-02	5.85	6.30	ML	NV	NP	67					
Proposed BIA Route N8065 Spur CL	0+275	6	L	BS-02	10.35	10.80	CL	42	24	80	18	1418.7	X		
Proposed BIA Route N8065 Spur CL	0+275	6	L	BS-02	10.80	11.25								8.4	212
Proposed BIA Route N8065 Spur CL	0+275	6	L	BS-02	14.85	15.15					14.1	1713.0			
Proposed BIA Route N8065 Spur CL	0+275	6	L	BS-02	19.35	19.80	ML	NV	NP	67	27.6				
Proposed BIA Route N8065 Spur CL	0+275	6	L	BS-02	28.35	28.65					28.4	1533.1			
Proposed BIA Route N8065 Spur CL	0+313	6	R	BS-03	0.00	1.35	CL-ML	25	6	56					
Proposed BIA Route N8065 Spur CL	0+313	6	R	BS-03	13.35	13.65	CL	36	19	59	25.8	1562.0			
Proposed BIA Route N8065 Spur CL	0+313	6	R	BS-03	25.35	25.8	SM	NV	NP	18					
Proposed BIA Route N8065 Spur CL	0+328	6	L	BS-04	2.85	3.30	ML	NV	NP	55				8.3	491
Proposed BIA Route N8065 Spur CL	0+328	6	L	BS-04	7.35	7.80	SP-SM	NV	NP	11					
Proposed BIA Route N8065 Spur CL	0+328	6	L	BS-04	10.35	10.65	CH	56	34	91	31.4	1476.4			
Proposed BIA Route N8065 Spur CL	0+328	6	L	BS-04	14.85	15.15	SM	NV	NP	22	18.6	1727.6			
Proposed BIA Route N8065 Spur CL	0+328	6	L	BS-04	25.35	25.65					31.5	1463.7			
Proposed BIA Route N8065 Spur CL	0+358	6	R	BS-05	3.45	3.99	SM	NV	NP	36	3.2	1344.5	X		
Proposed BIA Route N8065 Spur CL	0+358	6	R	BS-05	4.35	4.80								8.3	1468
Proposed BIA Route N8065 Spur CL	0+358	6	R	BS-05	7.95	8.25	CL	34	15	97	8.2	1466.3			
Proposed BIA Route N8065 Spur CL	0+358	6	R	BS-05	11.85	12.15					18.3	1643.6			
Proposed BIA Route N8065 Spur CL	0+358	6	R	BS-05	16.35	16.80	SM	NV	NP	38					
Proposed BIA Route N8065 Spur CL	0+358	6	R	BS-05	26.85	27.30	SM	NV	NP	34					
Proposed BIA Route N8065 Spur CL	0+358	6	L	BS-06	1.95	2.40	SM	NV	NP	48					
Proposed BIA Route N8065 Spur CL	0+358	6	L	BS-06	7.95	8.40	CL	35	16	92	11.7	1365.2	X		
Proposed BIA Route N8065 Spur CL	0+358	6	L	BS-06	13.35	13.65					18.7	1620.6			
Proposed BIA Route N8065 Spur CL	0+358	6	L	BS-06	19.35	19.80	ML	NV	NP	59					
							MEAN	**---**	**---**	**56**	**19**	**1505**	**---**	**8.3**	**724**
							STDEV	**---**	**---**	**27**	**9.0**	**130.1**	**---**	**0.1**	**660**
							MAXIMUM	**56**	**34**	**97**	**31.5**	**1727.6**	**---**	**8.4**	**1468**
							MINIMUM	**NV**	**NP**	**11**	**3.2**	**1253.6**	**---**	**8.3**	**212**
							COUNT	**21**	**21**	**21**	**19**	**16**	**6**	**3**	**3**

[1](kg/cu.m) = kilograms per cubic meter
[2](ohm-cm) = ohm-centimeter
X = see attached test data sheet

amec foster wheeler

PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 3
DATE ASSIGNED: 2/25/16

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (AASHTO T27/T11/T89/T90)

PERCENT PASSING BY WEIGHT

				Silt or Clay	SAND								GRAVEL									COBBLES	
					Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	USCS	LL	PI	75um	150um	300um	425um	600um	1.18um	2.00mm	2.36mm	4.75mm	6.3mm	9.5mm	12.5mm	19mm	25mm	31.2mm	37.5mm	50mm	75mm	152mm	Lab #
B-3 (0.00-1.35m)	CL	36	19	72	82	97	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1010-01
BS-3 (0.00-1.35m)	CL-ML	25	6	56	78	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1010-23

amec foster wheeler
3630 E Wier Ave.
Phoenix, AZ 85040

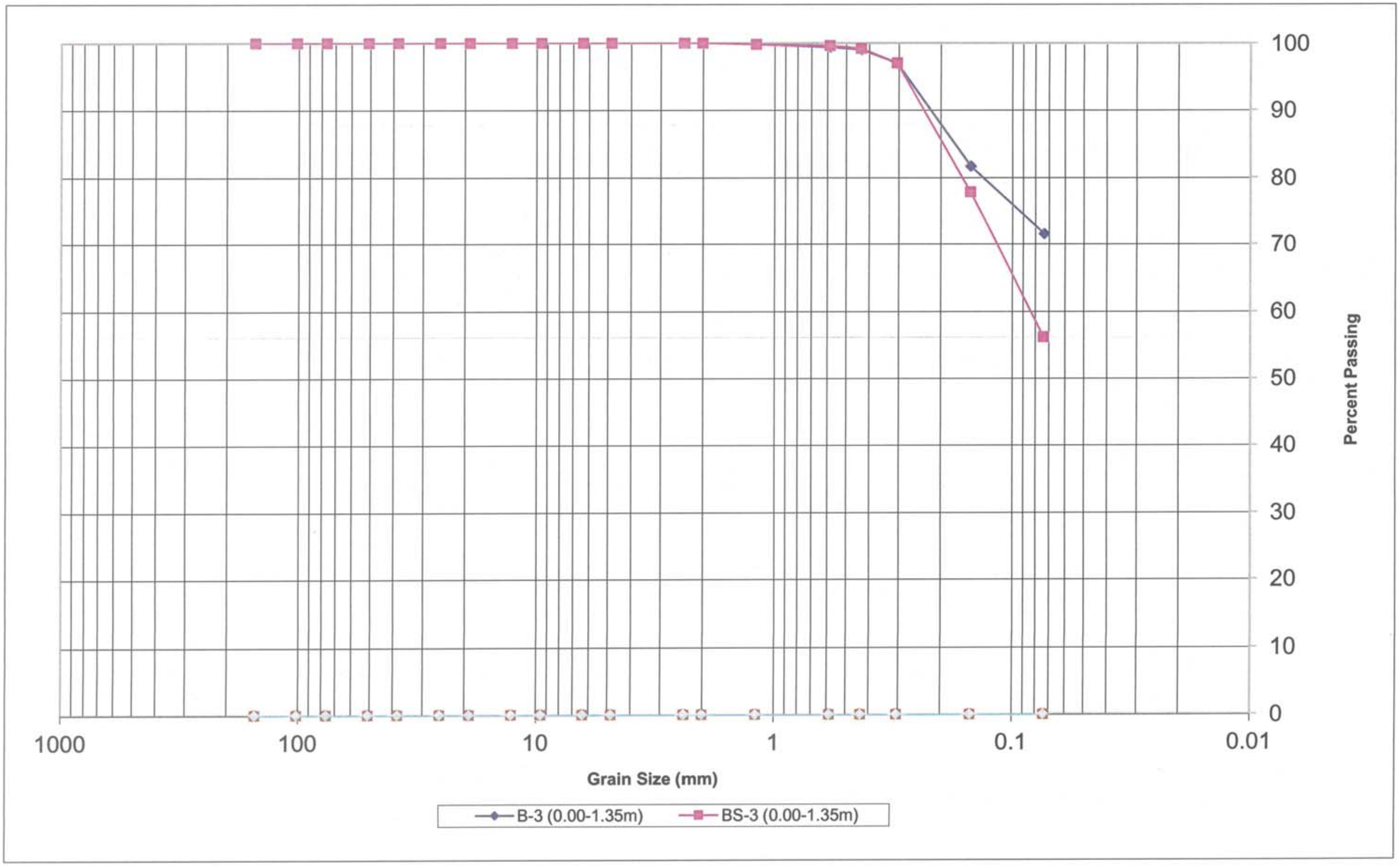
REVIEWED BY

amec foster wheeler

PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 3
DATE ASSIGNED: 2/25/16

MECHANICAL SIEVE ANALYSIS



amec foster wheeler

PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (AASHTO T27/T11/T89/T90)

PERCENT PASSING BY WEIGHT

				Silt or	SAND								GRAVEL									COBBLES	
				Clay	Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	**USCS**	**LL**	**PI**	**75um**	**150um**	**300um**	**425um**	**600um**	**1.18um**	**2.00mm**	**2.36mm**	**4.75mm**	**6.3mm**	**9.5mm**	**12.5mm**	**19mm**	**25mm**	**31.2mm**	**37.5mm**	**50mm**	**75mm**	**152mm**	**Lab #**
BS-01 (2.85-3.45m)	CL	31	12	78	93	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-05
BS-01 (7.95-8.55m)	CL	46	25	94	97	99	99	99	99	99	99	99	100	100	100	100	100	100	100	100	100	100	16-1044-10
BS-01 (17.85-18.30m)	SM	NV	NP	16	43	97	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-17
BS-02 (4.35-4.89m)	ML	NV	NP	55	78	96	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-32
BS-02 (5.85-6.30m)	ML	NV	NP	67	87	97	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-34
BS-02 (10.35-10.80m)	CL	42	24	80	86	92	93	94	94	95	95	95	95	96	97	100	100	100	100	100	100	100	16-1044-37
BS-02 (19.35-19.80m)	ML	NV	NP	67	94	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-45
BS-3 (13.35-13.65m)	CL	36	19	59	67	72	75	78	83	86	87	91	93	96	96	96	100	100	100	100	100	100	16-1044-65
BS-3 (25.35-25.80m)	SM	NV	NP	18	33	59	69	75	87	91	91	94	95	96	96	100	100	100	100	100	100	100	16-1044-74

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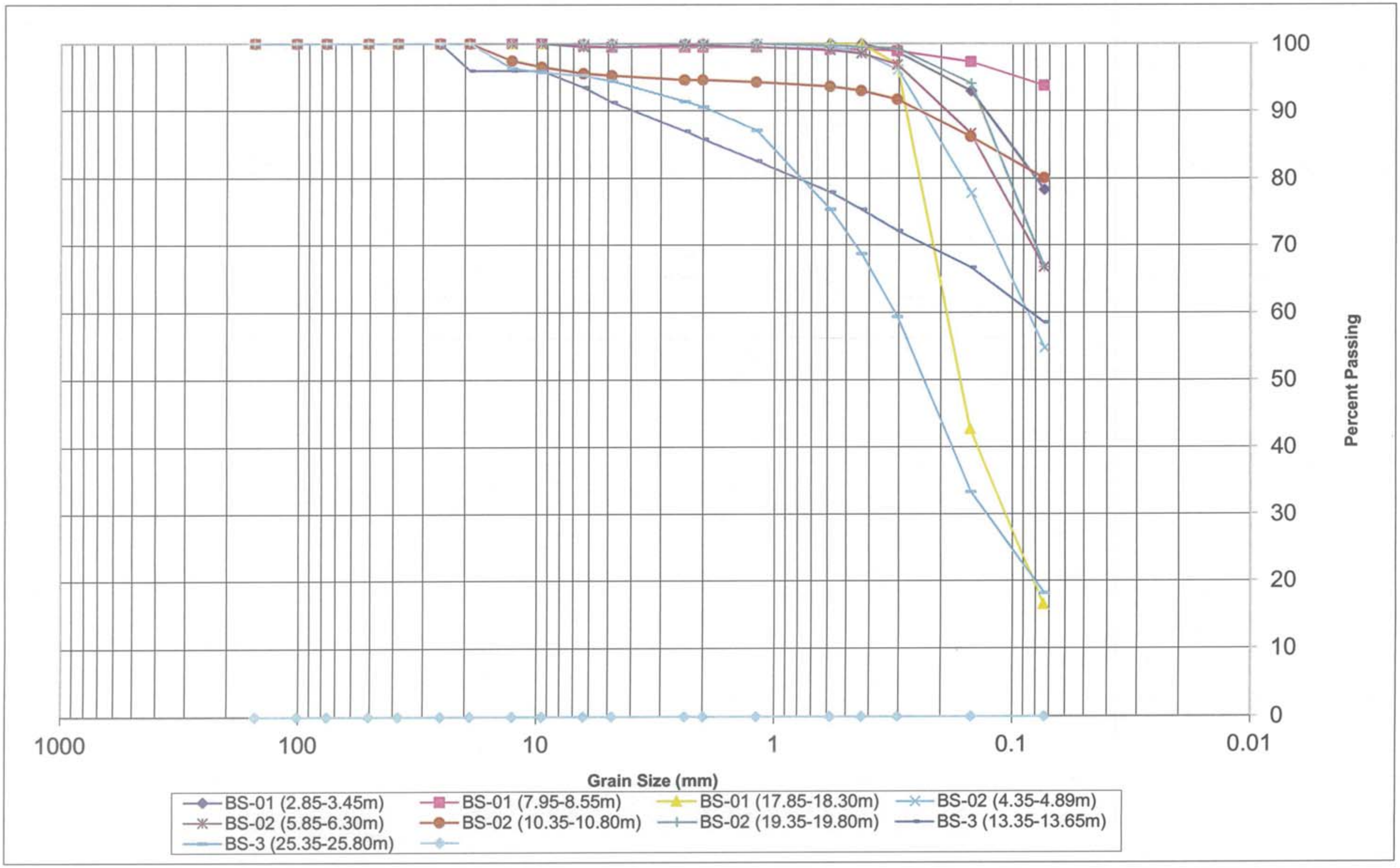
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS



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PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (AASHTO T27/T11/T89/T90)

PERCENT PASSING BY WEIGHT

				Silt or Clay	SAND									GRAVEL									COBBLES	
					Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	USCS	LL	PI	75um	150um	300um	425um	600um	1.18um	2.00mm	2.36mm	4.75mm	6.3mm	9.5mm	12.5mm	19mm	25mm	31.2mm	37.5mm	50mm	75mm	152mm	Lab #
BS-4 (2.85-3.30m)	ML	NV	NP	55	83	98	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-82
BS-4 (7.35-7.80m)	SP-SM	NV	NP	11	20	40	47	53	70	79	82	90	93	96	99	100	100	100	100	100	100	100	16-1044-85
BS-4 (10.35-10.65m)	CH	56	34	91	93	94	95	96	97	97	97	98	98	99	100	100	100	100	100	100	100	100	16-1044-87
BS-4 (14.85-15.15m)	SM	NV	NP	22	41	66	74	80	89	94	95	98	99	99	100	100	100	100	100	100	100	100	16-1044-91
BS-05 (3.45-3.99m)	SM	NV	NP	36	65	92	98	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-109
BS-05 (7.95-8.25m)	CL	34	15	97	99	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-113
BS-05 (16.35-16.80m)	SM	NV	NP	38	71	95	97	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	16-1044-120
BS-05 (26.85-27.30m)	SM	NV	NP	34	53	79	85	88	92	93	94	95	95	96	97	100	100	100	100	100	100	100	16-1044-127

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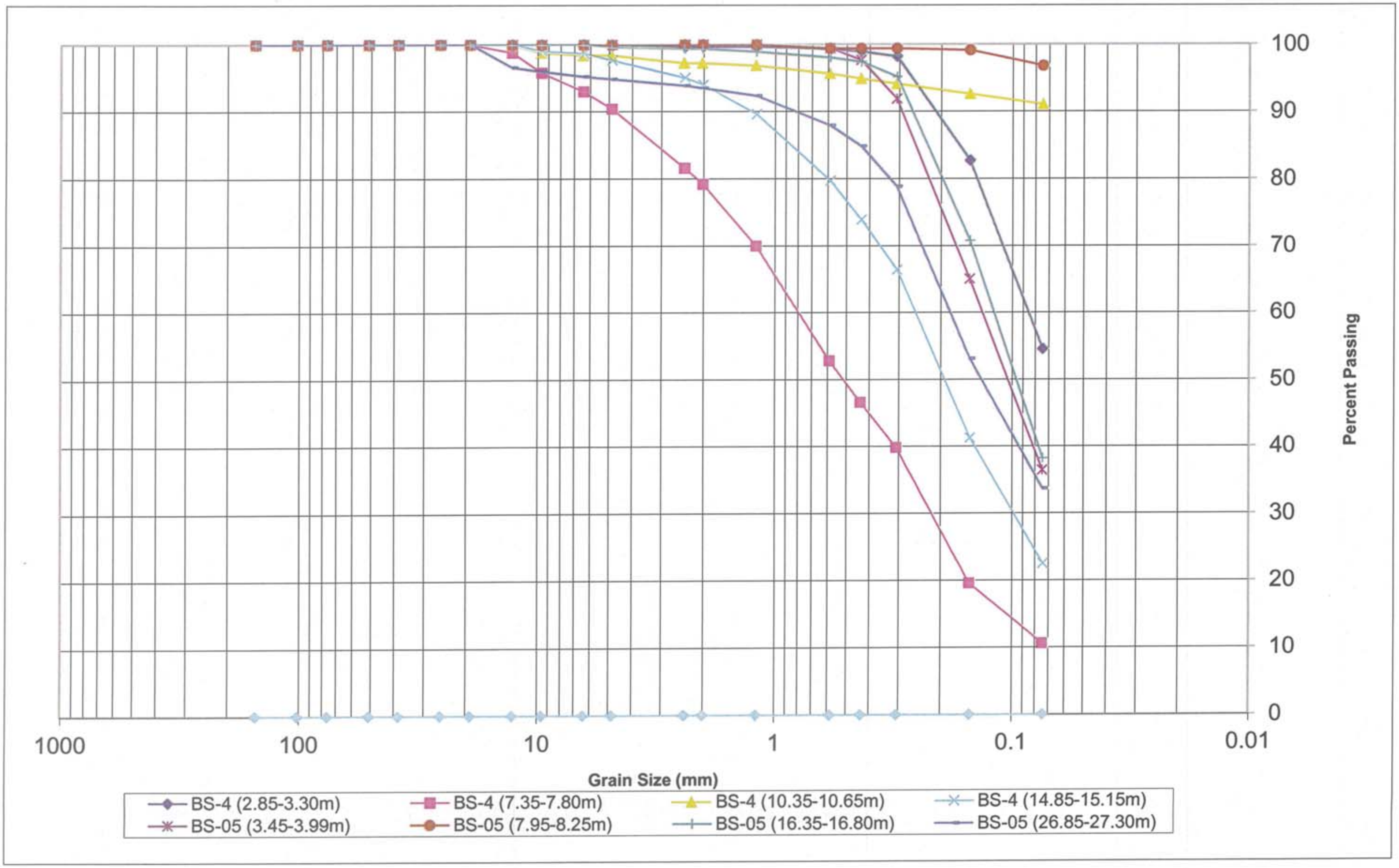
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS



PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS
GROUP SYMBOL, USCS (AASHTO T27/T11/T89/T90)

PERCENT PASSING BY WEIGHT

				Silt or Clay	SAND								GRAVEL									COBBLES	
					Fine			Medium			Coarse		Fine				Coarse						
Location & Depth	USCS	LL	PI	75um	150um	300um	425um	600um	1.18um	2.00mm	2.36mm	4.75mm	6.3mm	9.5mm	12.5mm	19mm	25mm	31.2mm	37.5mm	50mm	75mm	152mm	Lab #
BS-06 (1.95-2.40m)	SM	NV	NP	48	77	96	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-134
BS-06 (7.95-8.40m)	CL	35	16	92	98	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-139
BS-06 (19.35-19.80m)	ML	NV	NP	59	89	99	99	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-148
B-1 (2.85-3.15m)	CH	50	27	91	97	99	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-161
B-1 (4.35-4.80m)	CL	38	17	91	96	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-163
B-1 (12.45-12.75m)	CH	62	39	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-170
B-1 (17.85-18.30m)	SM	NV	NP	49	69	90	96	97	99	99	100	100	100	100	100	100	100	100	100	100	100	100	16-1044-174

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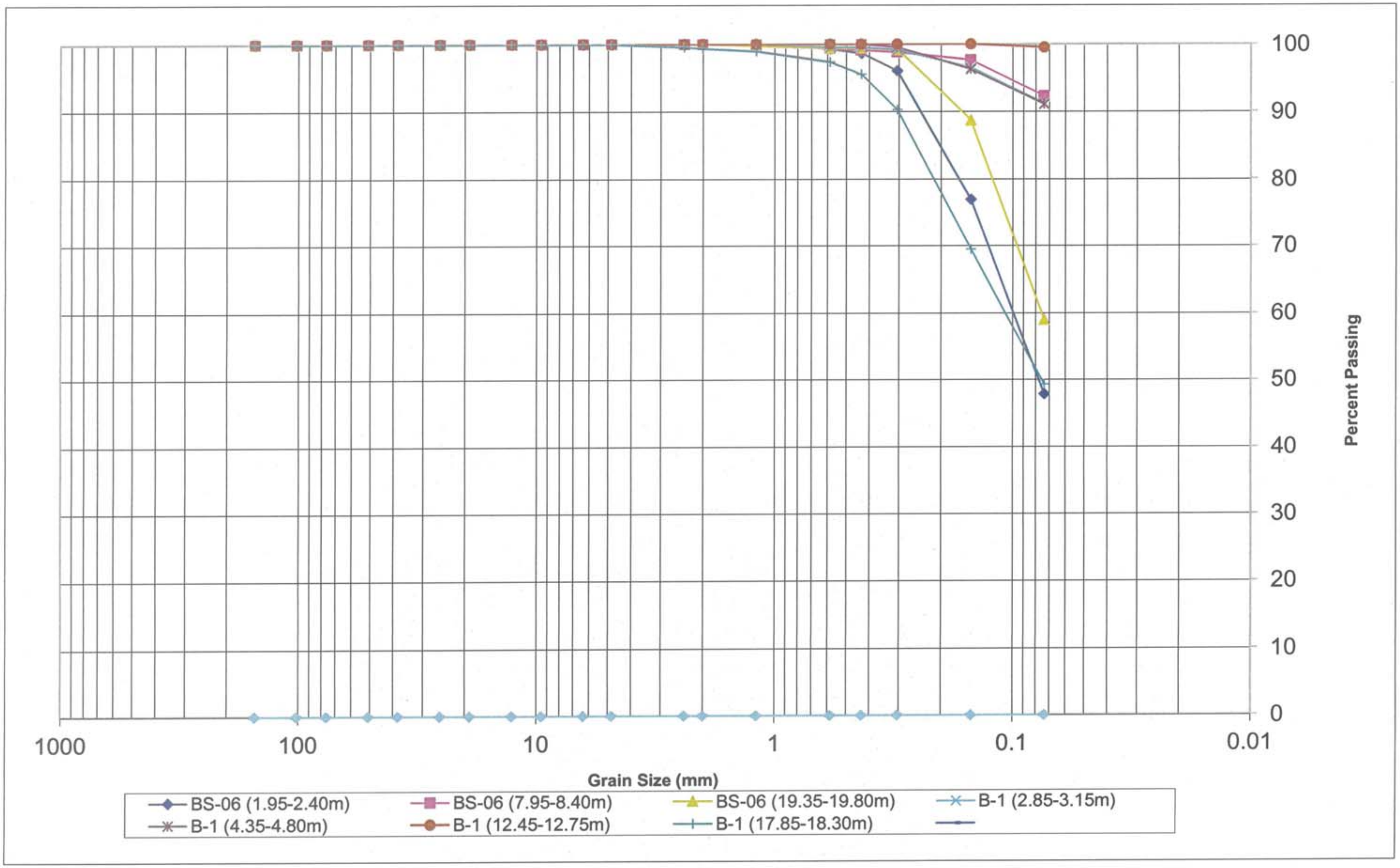
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2015-4045
WORK ORDER NO: 4
DATE ASSIGNED: 3/7/16

MECHANICAL SIEVE ANALYSIS



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PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BORING

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: SEE BELOW
DATE SAMPLED: 3/7/16

DENSITY OF SOIL IN PLACE BY THE DRIVE-CYLINDER METHOD(ASTM D2937)

LAB #	BORING	MOISTURE WET WT. (g)	MOISTURE DRY WT. (g)	MOISTURE CONTENT	NUMBER OF RINGS	WET WGT. + RINGS (g)	WEIGHT OF RINGS (g)	DRY DENSITY (kg/m³)
16-1044-24	BS-01 (27.45-27.75m)	878.7	700.1	25.5%	6	1,154.6	273.5	1551.8
16-1044-41	BS-02 (14.85-15.15m)	882.6	773.5	14.1%	6	1,140.7	256.5	1713.0
16-1044-51	BS-02 (28.35-28.65m)	887.9	691.6	28.4%	6	1,153.6	263.2	1533.1
16-1044-65	BS-3 (13.35-13.65m)	364.3	289.6	25.8%	4	776.7	184.1	1562.0
16-1044-87	BS-4 (10.35-10.65m)	310.3	236.2	31.4%	5	956.7	225.5	1476.4
16-1044-91	BS-4 (14.85-15.15m)	289.0	243.7	18.6%	6	1,198.5	271.7	1727.6
16-1044-99	BS-4 (25.35-25.65m)	867.0	659.1	31.5%	6	1,137.7	266.7	1463.7
16-1044-113	BS-05 (7.95-8.25m)	337.2	311.6	8.2%	6	983.6	265.8	1466.3
16-1044-116	BS-05 (11.85-12.15m)	878.3	742.5	18.3%	6	1,146.4	266.9	1643.6
16-1044-143	BS-06 (13.35-13.65m)	724.3	610.0	18.7%	5	946.4	221.0	1620.6
16-1044-165	B-1 (7.35-7.65m)	866.1	730.4	18.6%	6	1,132.2	263.3	1619.8
16-1044-170	B-1 (12.45-12.75m)	285.8	230.4	24.0%	4	755.0	172.6	1556.8
16-1044-248	B-5 (4.35-4.65m)	279.7	223.4	25.2%	4	760.0	173.9	1552.2
16-1044-251	B-5 (7.35-7.65m)	908.8	731.8	24.2%	6	1,170.2	260.4	1619.5

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PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL: Native Soil
SAMPLE SOURCE: See Below

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044
DATE ASSIGNED: 3/7/16

MOISTURE CONTENT OF SOIL (ASTM D2216)

LAB #	BORING & DEPTH	WET WT. (gram)	DRY WT. (gram)	MOISTURE CONTENT
16-1044-16	BS-01 (16.35-16.80m)	617.2	504.8	22.3%
16-1044-17	BS-01 (17.85-18.30m)	572.0	441.2	29.6%
16-1044-45	BS-02 (19.35-19.80m)	1162.2	910.8	27.6%

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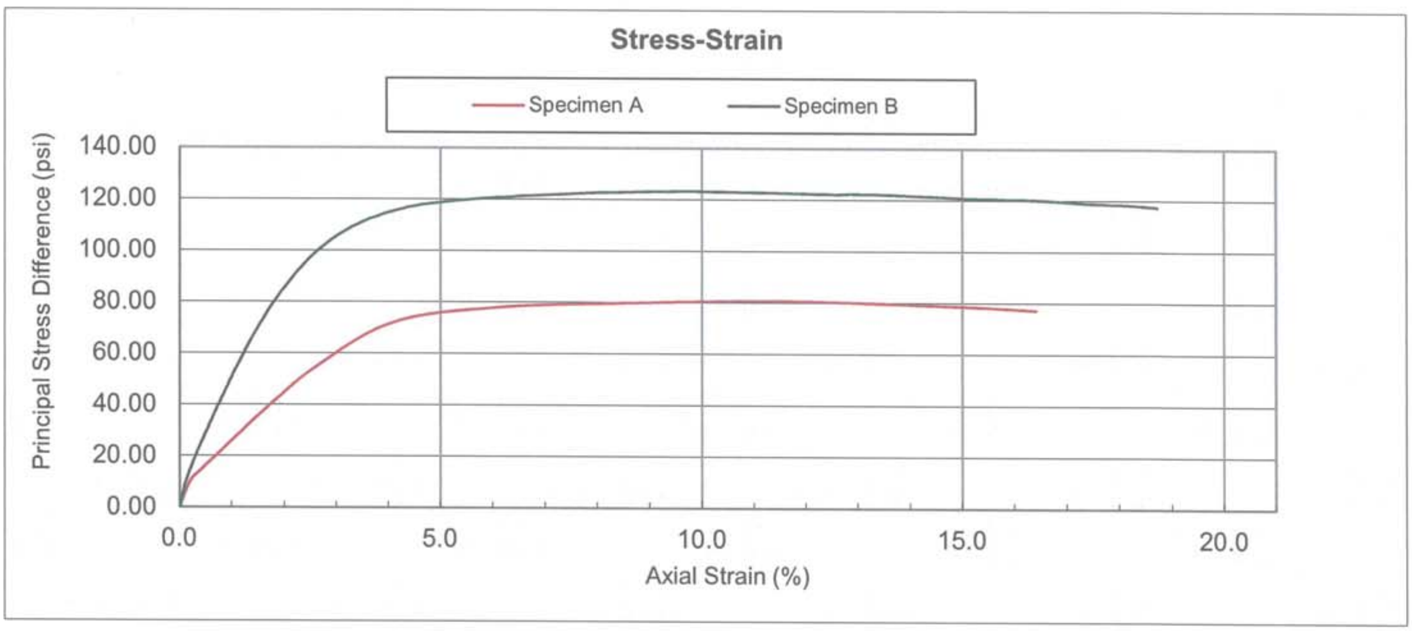
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: BS-01 (2.85-3.45m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-05
DATE SAMPLED: 3/7/2016

UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ON COHESIVE SOILS (AASHTO T296)

Initial Specimen Data	Specimen A	Specimen B	Specimen C
Water Content (%):	8.5%	7.1%	13.9%
Height (cm):	16.60	14.72	15.39
Diameter (cm):	7.35	7.33	7.34
Dry Density (kg/cu.m):	1297.7	1319.2	1144.0
Dry Density (pcf):	81.0	82.4	71.4
Void Ratio:	1.04	1.01	1.32
Saturation %:	22%	19%	28%
Saturation Method:	N/A	N/A	N/A

Test Data	Specimen A	Specimen B
B Value:	N/A	N/A
Total Back Pressure (psi):	0.0	0.0
Eff. Consolidation Stress (psi):	21.8	36.3
Strain Rate (%/min):	0.65	0.65
Axial Strain at Failure (%):	11.6	9.8
Total Major Principal Stress, σ_1 (psi):	102	160
Total Minor Principal Stress, σ_3 (psi):	22	36
Deviator Stress, $\sigma_1 - \sigma_3$ (psi):	81	123



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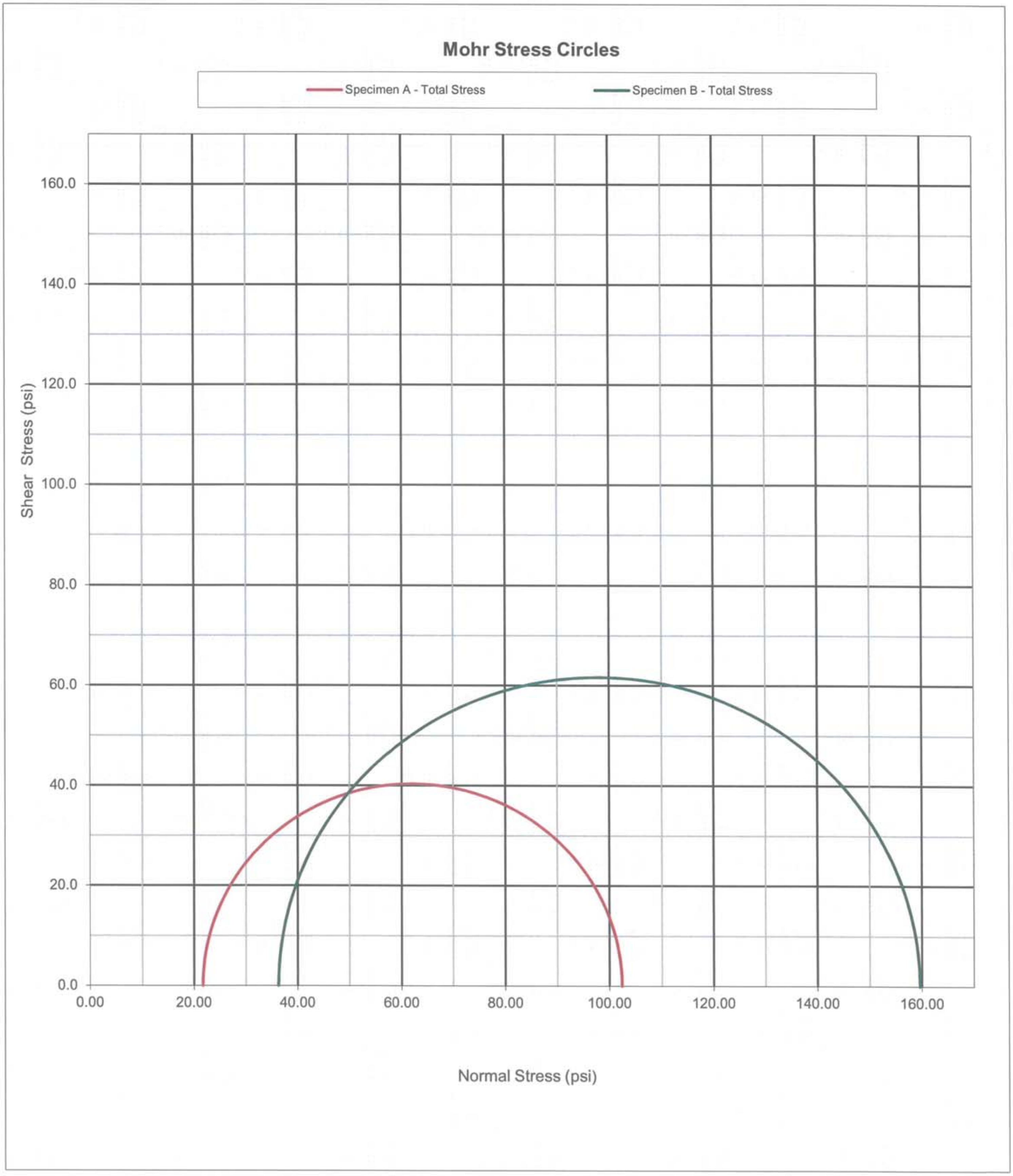
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: BS-01 (2.85-3.45m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-05
DATE SAMPLED: 3/7/2016



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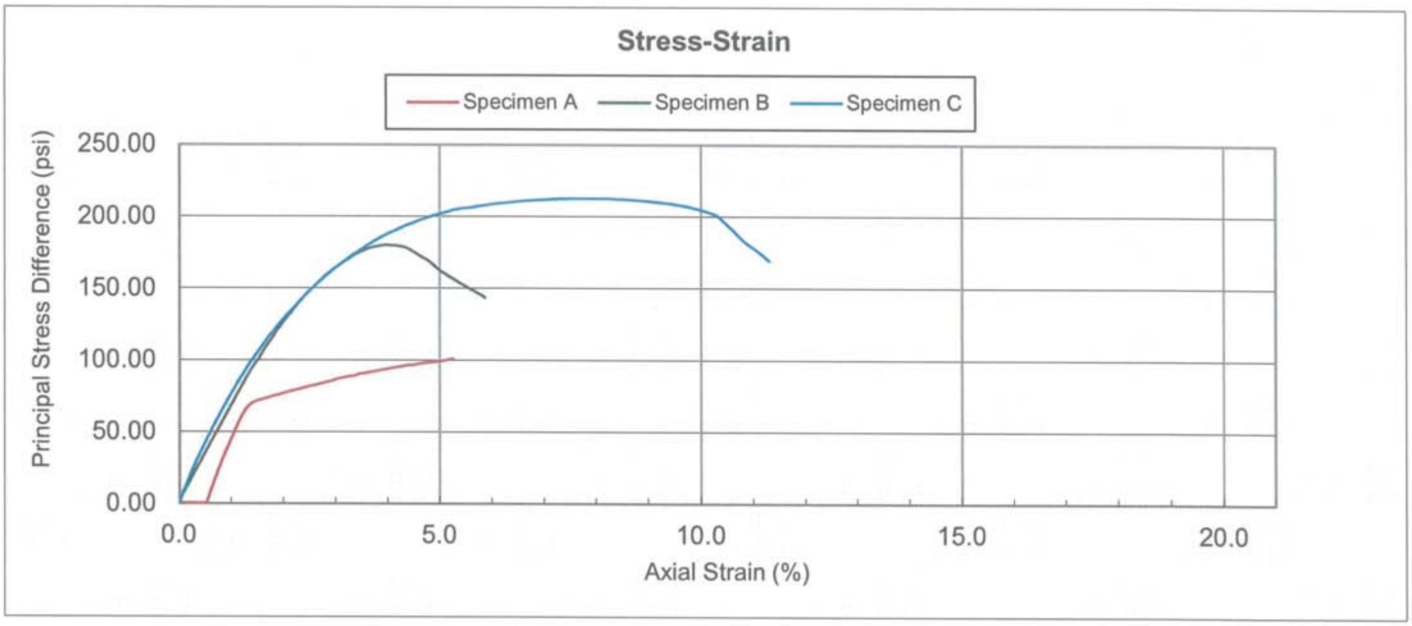
PROJECT:	BIA N8066(3), 8065(1), & School Spur	**JOB NO:**	17-2015-4045
LOCATION:	Black Mesa Community School, AZ	**WORK ORDER NO:**	4
MATERIAL TYPE:	Native Soil	**LAB NO:**	16-1044-10
SAMPLE SOURCE:	BS-01 (7.95-8.55m)	**DATE SAMPLED:**	3/7/2016
SAMPLE PREPARATION:	Insitu		

UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ON COHESIVE SOILS (AASHTO T296)

		Specimen	
Initial Specimen Data	**A**	**B**	**C**
Water Content (%):	12.5%	14.3%	12.5%
Height (cm):	15.48	15.45	14.96
Diameter (cm):	7.31	7.30	7.32
Dry Density (kg/cu.m):	1430.1	1521.3	1481.8
Dry Density (pcf):	89.3	95.0	92.5
Void Ratio:	0.85	0.74	0.79
Saturation %:	39%	51%	42%
Saturation Method:	N/A	N/A	N/A

		Specimen	
Test Data	**A**	**B**	**C**
B Value:	N/A	N/A	N/A
Total Back Pressure (psi):	0.0	0.0	0.0
Eff. Consolidation Stress (psi):	14.5	29.0	58.0
Strain Rate (%/min):	0.65	0.65	0.65
Axial Strain at Failure (%):	5.3	4.0	8.1
Total Major Principal Stress, σ_1 (psi):	116	209	271
Total Minor Principal Stress, σ_3 (psi):	15	29	58
Deviator Stress, $\sigma_1 - \sigma_3$ (psi):	101	180	213



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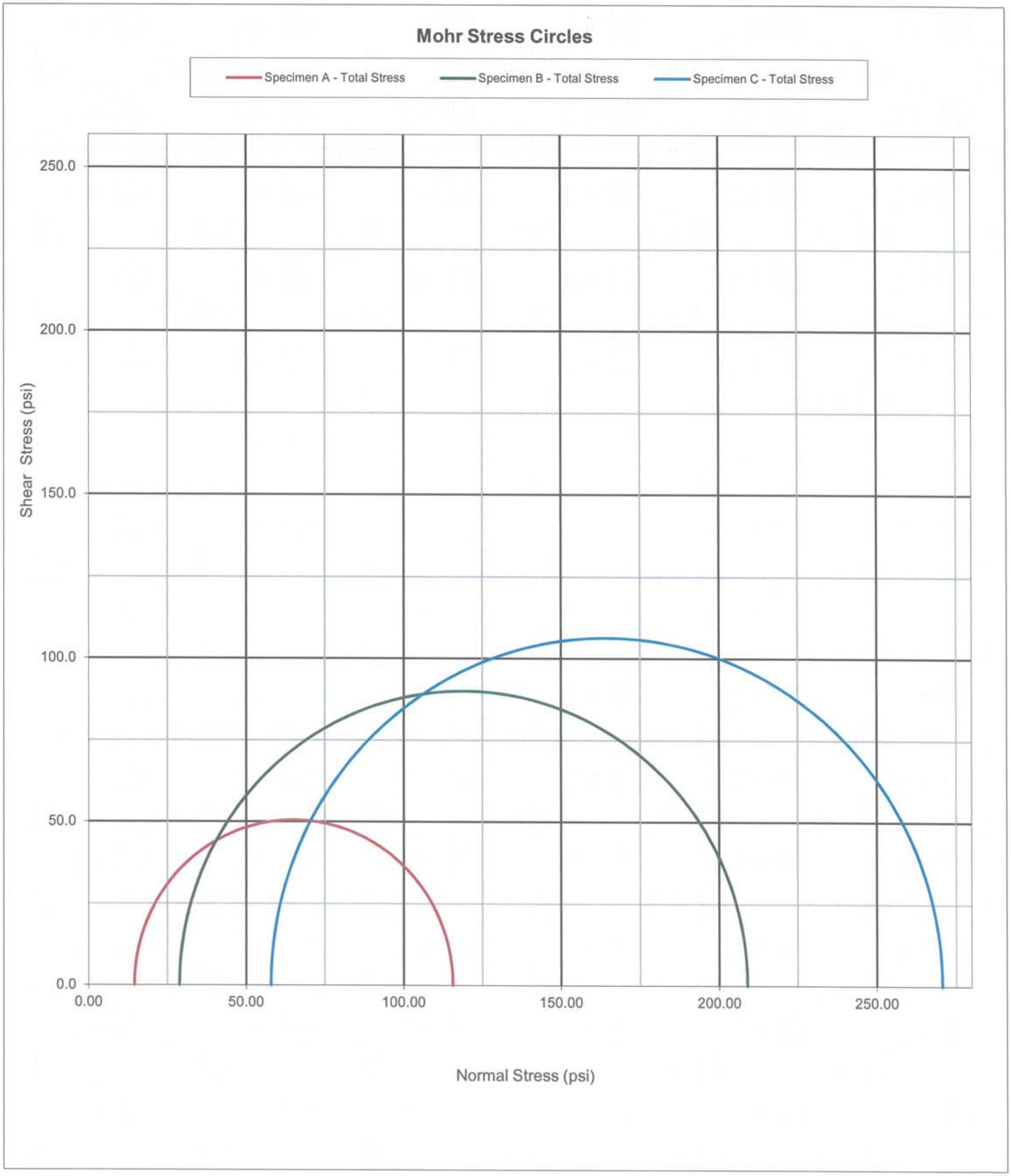
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: BS-01 (7.95-8.55m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-10
DATE SAMPLED: 3/7/2016



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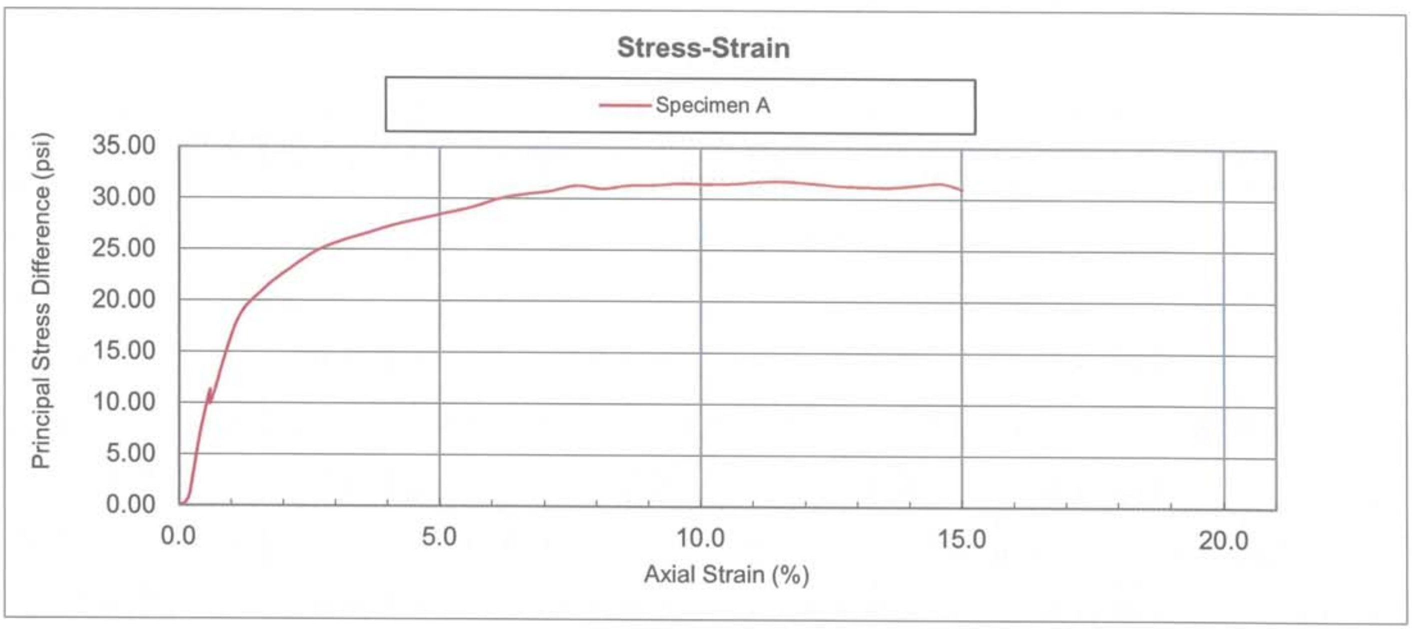
PROJECT:	BIA N8066(3), 8065(1), & School Spur	**JOB NO:**	17-2015-4045
LOCATION:	Black Mesa Community School, AZ	**WORK ORDER NO:**	4
MATERIAL TYPE:	Native Soil	**LAB NO:**	16-1044-32
SAMPLE SOURCE:	BS-02 (4.35-4.89m)	**DATE SAMPLED:**	3/7/2016
SAMPLE PREPARATION:	Insitu		

UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ON COHESIVE SOILS (AASHTO T296)

Initial Specimen Data	**Specimen A**	**Specimen B**	**Specimen C**
Water Content (%):	10.7%	3.2%	0.9%
Height (cm):	15.71	15.51	15.98
Diameter (cm):	7.30	7.29	7.32
Dry Density (kg/cu.m):	1471.8	1630.5	1296.8
Dry Density (pcf):	91.9	101.8	81.0
Void Ratio:	0.80	0.62	1.04
Saturation %:	35%	14%	2%
Saturation Method:	N/A	N/A	N/A

Test Data	**Specimen A**
B Value:	N/A
Total Back Pressure (psi):	0.0
Eff. Consolidation Stress (psi):	7.3
Strain Rate (%/min):	0.65
Axial Strain at Failure (%):	11.6
Total Major Principal Stress, σ_1 (psi):	39
Total Minor Principal Stress, σ_3 (psi):	7
Deviator Stress, $\sigma_1 - \sigma_3$ (psi):	32



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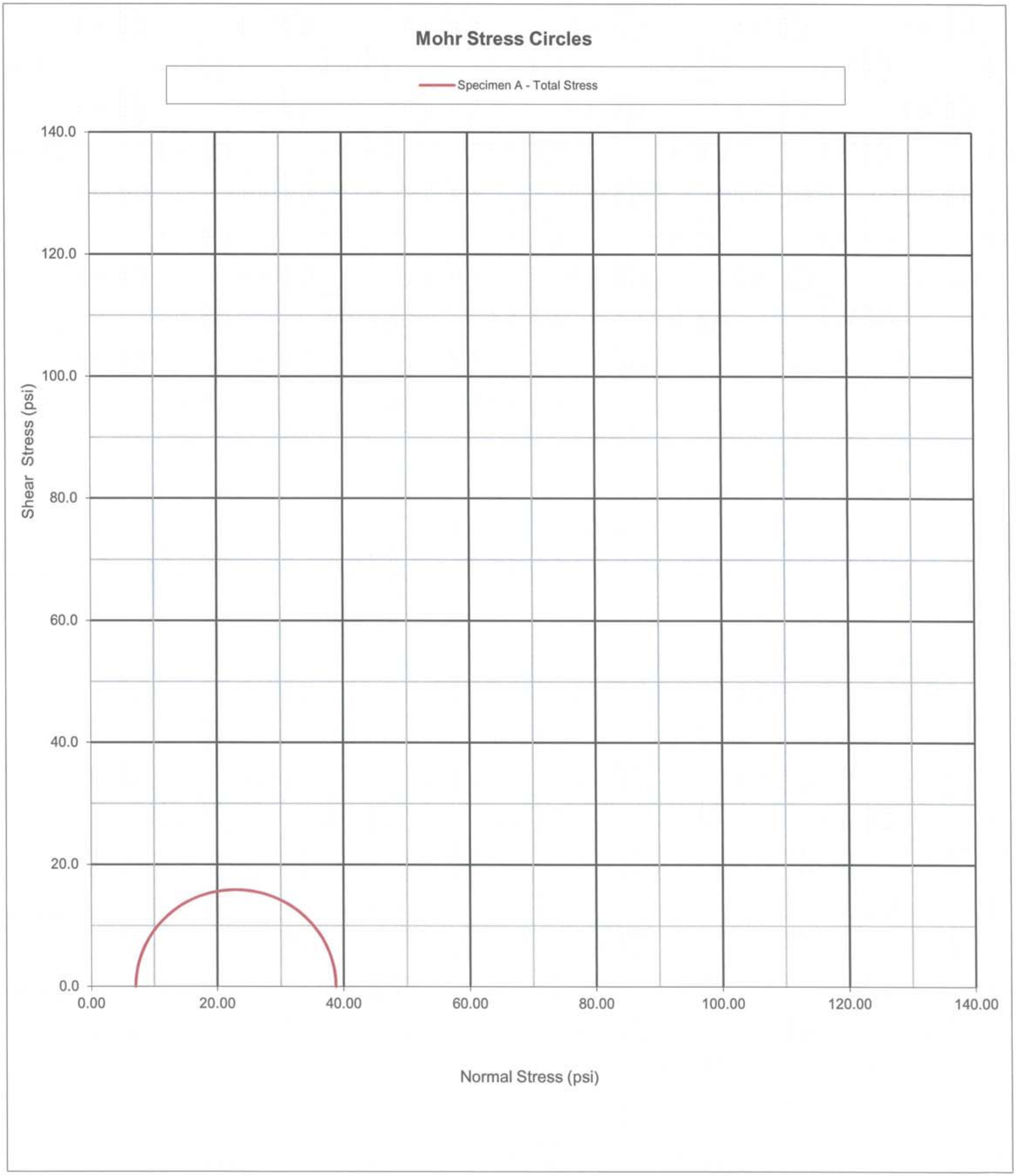
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: BS-02 (4.35-4.89m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-32
DATE SAMPLED: 3/7/2016



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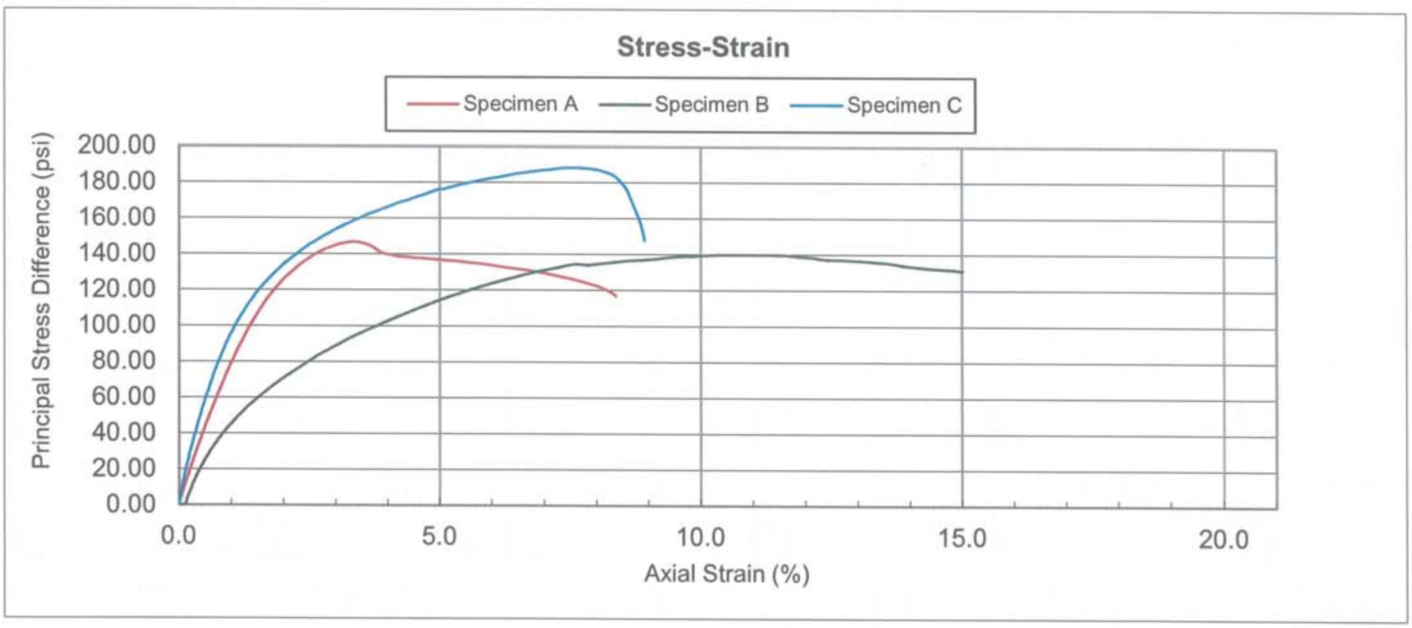
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: BS-02 (10.35-10.80m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-37
DATE SAMPLED: 3/7/2016

UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ON COHESIVE SOILS (AASHTO T296)

Initial Specimen Data	Specimen A	Specimen B	Specimen C
Water Content (%):	14.5%	22.9%	16.5%
Height (cm):	15.56	15.04	16.37
Diameter (cm):	7.31	7.31	7.30
Dry Density (kg/cu.m):	1527.4	1398.3	1519.4
Dry Density (pcf):	95.4	87.3	94.9
Void Ratio:	0.73	0.89	0.74
Saturation %:	52%	68%	59%
Saturation Method:	N/A	N/A	N/A

Test Data	Specimen A	Specimen B	Specimen C
B Value:	N/A	N/A	N/A
Total Back Pressure (psi):	0.0	0.0	0.0
Eff. Consolidation Stress (psi):	21.8	36.3	50.8
Strain Rate (%/min):	0.65	0.65	0.65
Axial Strain at Failure (%):	3.4	10.6	7.6
Total Major Principal Stress, σ_1 (psi):	169	176	239
Total Minor Principal Stress, σ_3 (psi):	22	36	51
Deviator Stress, $\sigma_1 - \sigma_3$ (psi):	147	140	188



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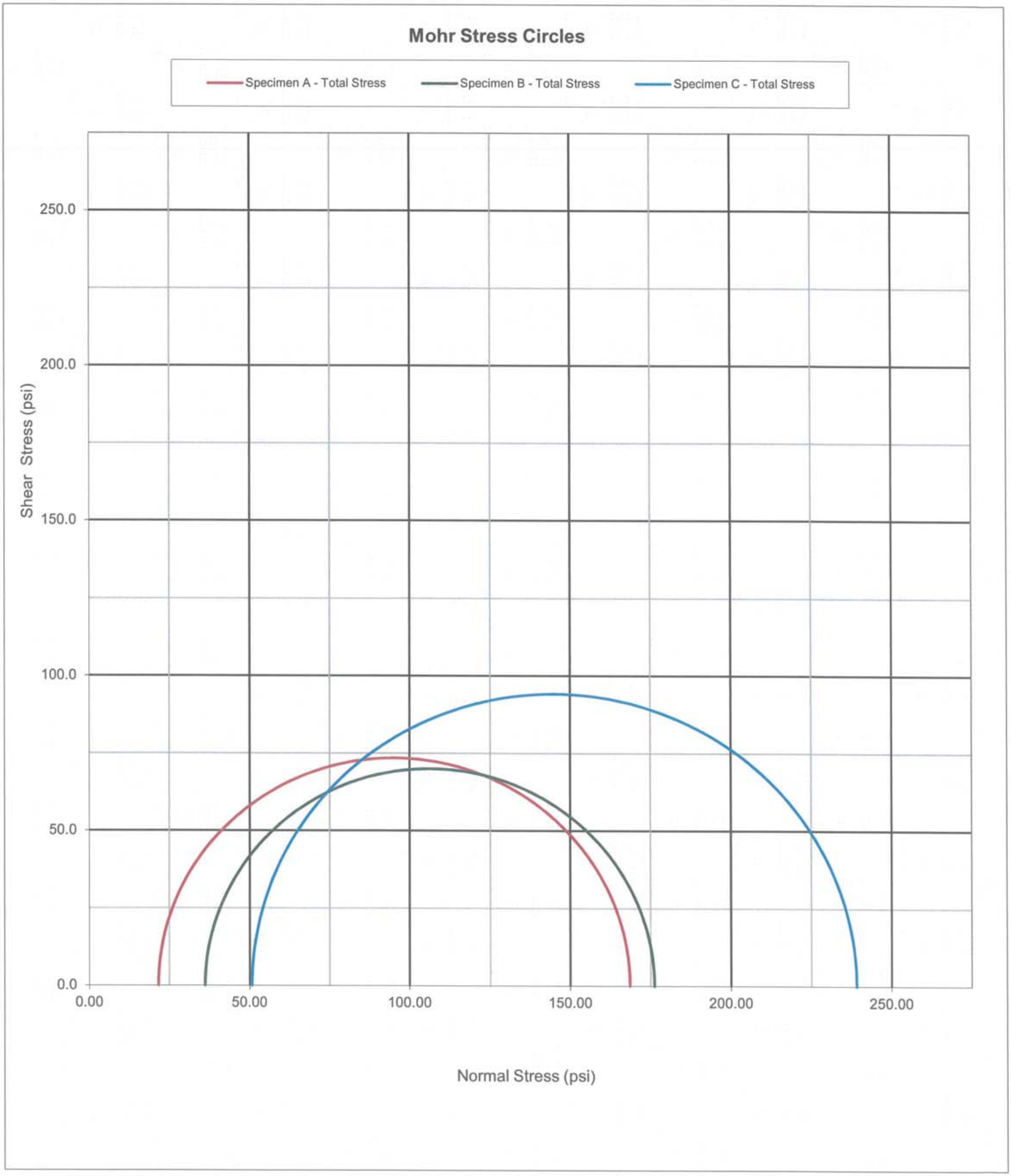
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: BS-02 (10.35-10.80m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-37
DATE SAMPLED: 3/7/2016



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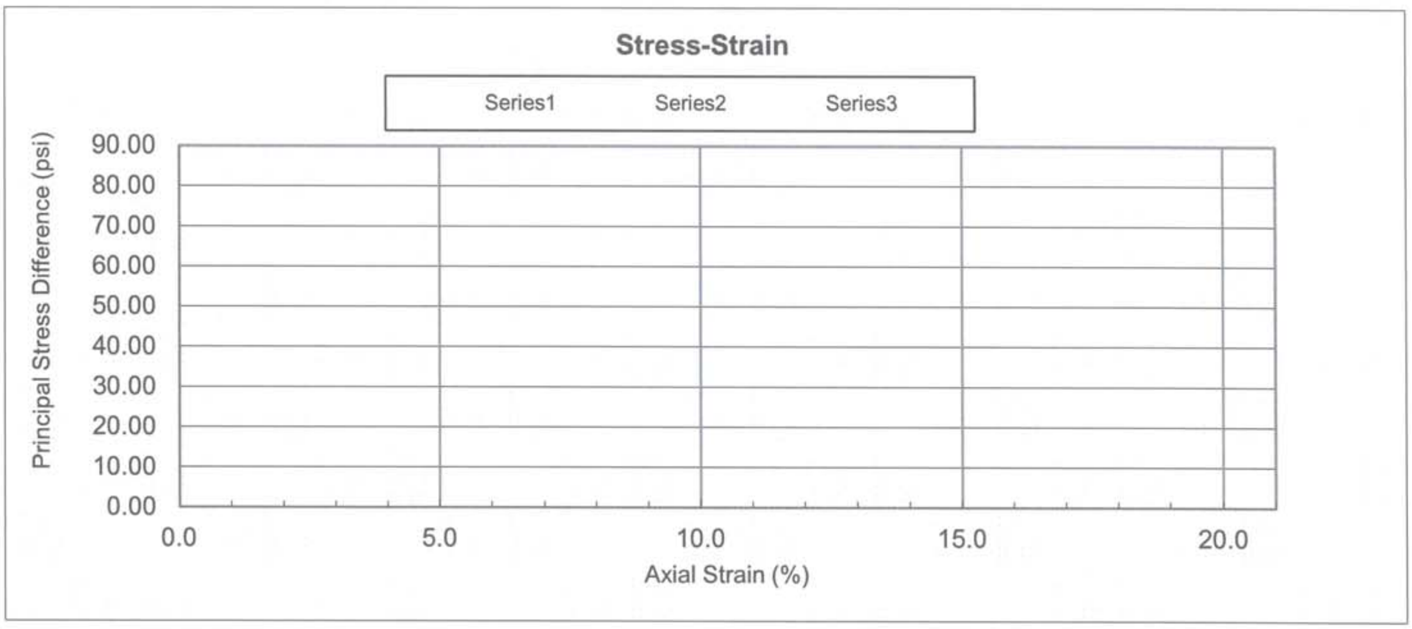
PROJECT:	BIA N8066(3), 8065(1), & School Spur	**JOB NO:**	17-2015-4045
LOCATION:	Black Mesa Community School, AZ	**WORK ORDER NO:**	4
MATERIAL TYPE:	Native Soil	**LAB NO:**	16-1044-109
SAMPLE SOURCE:	BS-05 (3.45-3.99m)	**DATE SAMPLED:**	3/7/2016
SAMPLE PREPARATION:	Insitu		

UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ON COHESIVE SOILS (AASHTO T296)

Initial Specimen Data	**Specimen A**	**Specimen B**	**Specimen C**
Water Content (%):	3.6%	3.8%	2.1%
Height (cm):	15.34	16.64	16.54
Diameter (cm):	7.32	7.31	7.30
Dry Density (kg/cu.m):	1346.6	1375.5	1311.4
Dry Density (pcf):	84.1	85.9	81.9
Void Ratio:	0.97	0.93	1.02
Saturation %:	10%	11%	6%
Saturation Method:	N/A	N/A	N/A

Test Data	**Specimen A**	**Specimen B**	**Specimen C**
B Value:			
Total Back Pressure (psi):			
Eff. Consolidation Stress (psi):			
Strain Rate (%/min):			
Axial Strain at Failure (%):			
Total Major Principal Stress, σ_1 (psi):			
Total Minor Principal Stress, σ_3 (psi):			
Deviator Stress, $\sigma_1 - \sigma_3$ (psi):			



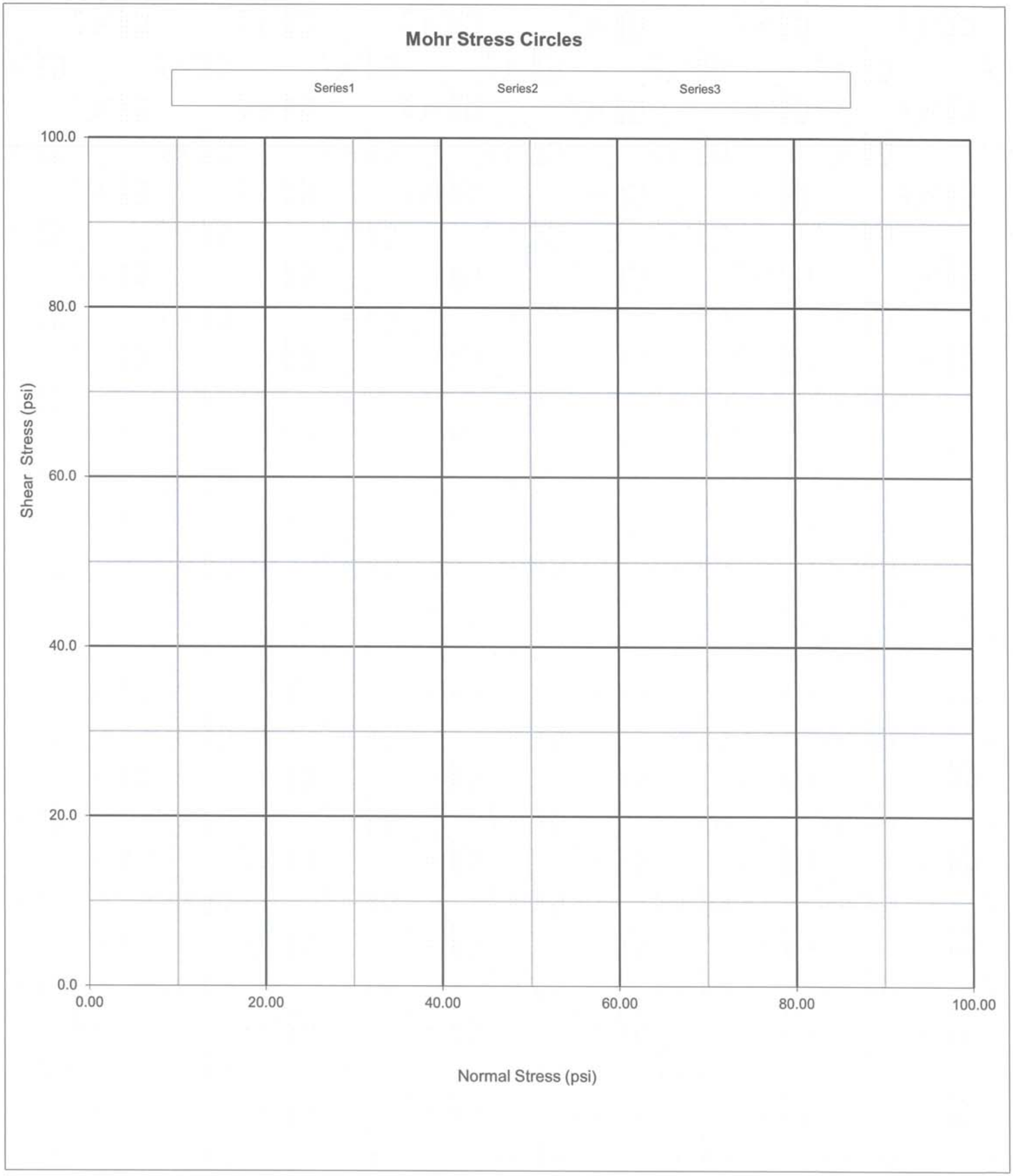
amec foster wheeler
3630 E Wier Ave.
Phoenix, AZ 85040

REVIEWED BY

amec foster wheeler

PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: BS-05 (3.45-3.99m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-109
DATE SAMPLED: 3/7/2016



amec foster wheeler

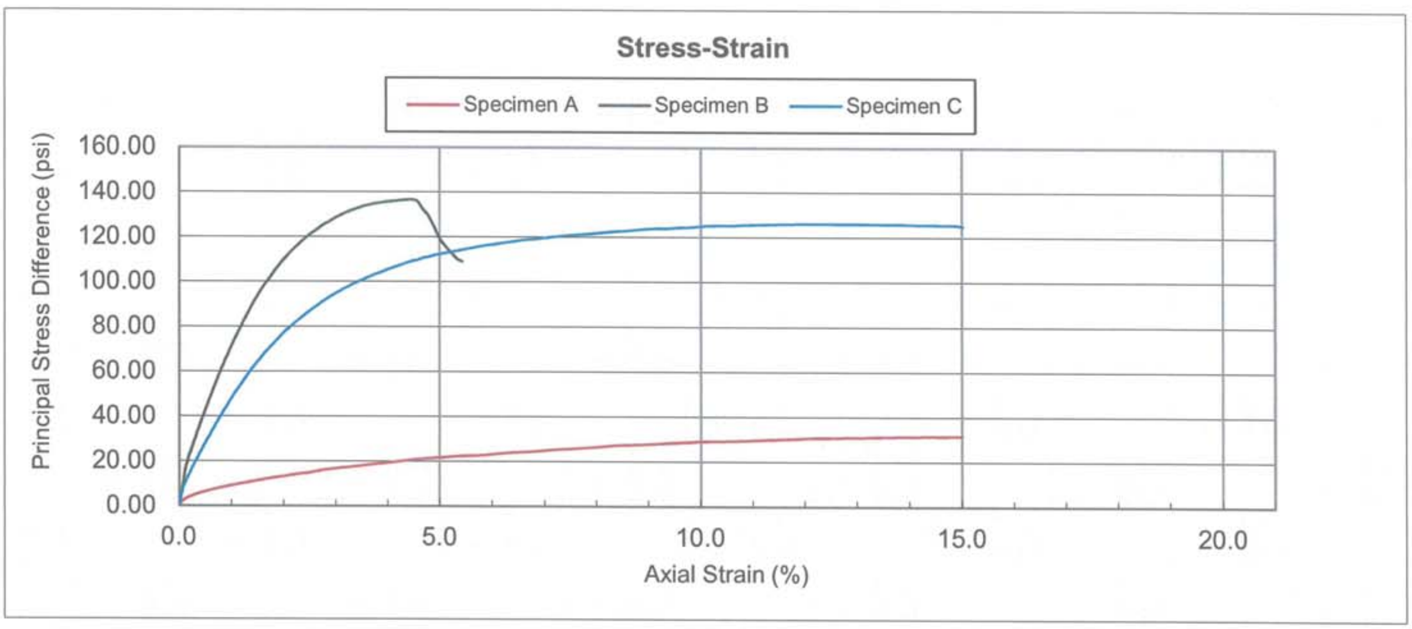
PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: BS-06 (7.95-8.40m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-139
DATE SAMPLED: 3/7/2016

UNCONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TEST ON COHESIVE SOILS (AASHTO T296)

Initial Specimen Data	Specimen A	Specimen B	Specimen C
Water Content (%):	13.9%	12.9%	8.4%
Height (cm):	15.26	15.96	16.98
Diameter (cm):	7.32	7.30	7.31
Dry Density (kg/cu.m):	1231.8	1479.7	1384.2
Dry Density (pcf):	76.9	92.4	86.4
Void Ratio:	1.15	0.79	0.91
Saturation %:	32%	43%	24%
Saturation Method:	N/A	N/A	N/A

Test Data	Specimen A	Specimen B	Specimen C
B Value:	N/A	N/A	N/A
Total Back Pressure (psi):	0.0	0.0	0.0
Eff. Consolidation Stress (psi):	14.5	29.0	43.5
Strain Rate (%/min):	0.65	0.65	0.65
Axial Strain at Failure (%):	15.0	4.5	12.4
Total Major Principal Stress, σ_1 (psi):	39	158	162
Total Minor Principal Stress, σ_3 (psi):	7	22	36
Deviator Stress, $\sigma_1 - \sigma_3$ (psi):	32	137	126



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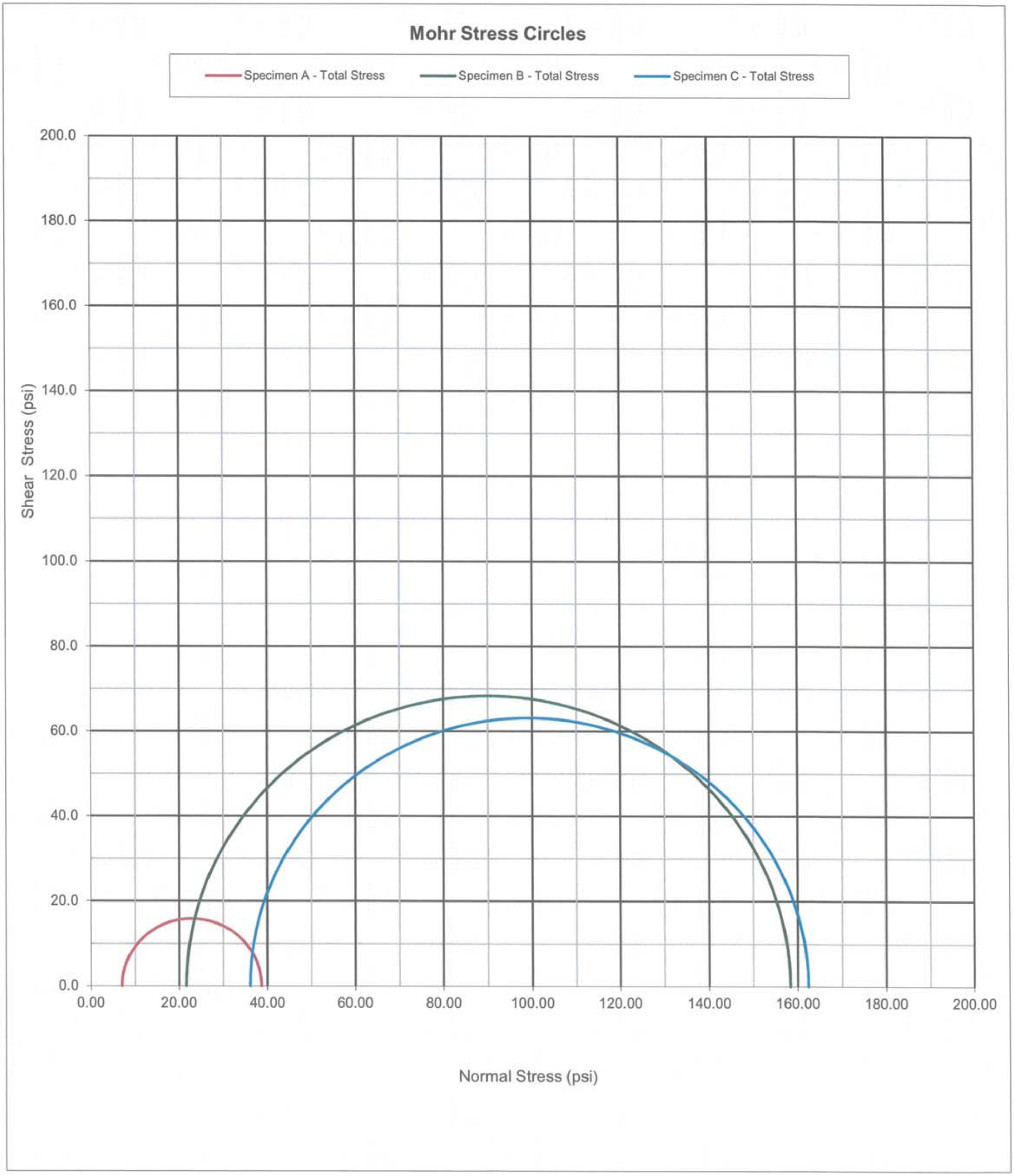
3630 E Wier Ave.
Phoenix, AZ 85040

REVIEWED BY

PROJECT: BIA N8066(3), 8065(1), & School Spur
LOCATION: Black Mesa Community School, AZ
MATERIAL TYPE: Native Soil
SAMPLE SOURCE: BS-06 (7.95-8.40m)
SAMPLE PREPARATION: Insitu

JOB NO: 17-2015-4045
WORK ORDER NO: 4
LAB NO: 16-1044-139
DATE SAMPLED: 3/7/2016



MOTZZ LABORATORY, INC.

Soil Analysis Report

Amec Foster Wheeler
Robert Kostelny
3630 E Weir Avenue
Phoenix AZ 85040

Project: 17-2015-4045 WO 4
Sampler:
Date Received: 3/7/2016
Date Reported: 3/8/2016

PO Number: 17-2015-4045

Lab Number: 916543-01 **BS-02 (10.80-11.25m) Lab# 16-1044-3**

pH & Resistivity 1:1	Method	Result	Units	Levels
pH	ARIZ 236b	8.4	SU	
Resistivity	1:1	212	ohm-cm	

Lab Number: 916543-02 **BS-04 (2.85-3.30m) Lab# 16-1044-82**

pH & Resistivity 1:1	Method	Result	Units	Levels
pH	ARIZ 236b	8.3	SU	
Resistivity	1:1	491	ohm-cm	

Lab Number: 916543-03 **BS-05 (4.35-4.80m) Lab# 16-1044-110**

pH & Resistivity 1:1	Method	Result	Units	Levels
pH	ARIZ 236b	8.3	SU	
Resistivity	1:1	1468	ohm-cm	

ATTACHMENT C

DESIGN CALCULATIONS

NOMINAL BEARING CAPACITY

DRIVEN H-PILES

WEST ABUTMENT

Site Inputs		
Project No.:	17-2015-4045	
Project:	BIA Route N8065	
Structure:	West Abutment, Pile Foundation, No Scour	
Corresponding Boring:	BS-5/BS-6	
Depth to Groundwater Table [ft]:	55	
Ground Elevation [ft]:	6473	
Depth of Scour [ft]:	0	Not used in calculations.
Resistance Factor [clay]:	0.35	
Resistance Factor [sand]:	0.45	
Atmospheric Pressure (p_a) [pcf]:	2116	

Soil Layer	Soil Type	Resistance Factor	γ_{total} [pcf]	ϕ [degrees]	s_u [psf]	Depth to Bottom of Layer [ft]
1	Cohesive	0.35	110	--	3000	5
2	Silty	0.45	90	27	--	25
3	Cohesive	0.35	100	--	2500	40
4	Cohesive	0.35	120	--	3000	55
5	Silty	0.45	110	27	--	75
6	Cohesionless	0.45	120	32	--	85
7	Cohesive	0.35	120	--	1000	100
8		0.45				

H-Pile Inputs

Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.00	1.00	0.10	0.70	0.086	0.70	0.94
26	0.00	1.09	0.10	0.73	0.086	0.73	0.93
27	0.00	1.18	0.10	0.76	0.086	0.76	0.92
28	0.00	1.27	0.10	0.79	0.086	0.79	0.91
29	0.00	1.36	0.10	0.82	0.086	0.82	0.90
30	0.00	1.45	0.10	0.85	0.086	0.85	0.89
31	0.00	1.63	0.10	0.91	0.086	0.91	0.88
32	0.00	1.81	0.10	0.97	0.086	0.97	0.88
33	0.00	1.99	0.10	1.03	0.086	1.03	0.87
34	0.00	2.17	0.10	1.09	0.086	1.09	0.87
35	0.00	2.35	0.10	1.15	0.086	1.15	0.86
36	0.00	2.74	0.10	1.26	0.086	1.26	0.86
37	0.00	3.13	0.10	1.37	0.086	1.37	0.85
38	0.00	3.52	0.10	1.48	0.086	1.48	0.84
39	0.00	3.91	0.10	1.59	0.086	1.59	0.83
40	0.00	4.30	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	5	1	550	550
Project:	BIA Route N8065	25	2	2350	2350
Structure:	West Abutment, Pile Foundation, No Scour	40	3	3850	3850
Corresponding Boring:	BS-5/BS-6	55	4	5650	5650
Groundwater Table [ft]:	55	75	5	7850	6602
Depth of Scour [ft]:	0	85	6	9050	7178
γ_w [pcf]:	62.4	100	7	10850	8042
		0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	2.64
2	27	0.74	19.98	0.76	0.92	0.73	--	--	--	--
2	27	0.74	19.98	0.76	0.92	1.16	--	--	--	--
2	27	0.74	19.98	0.76	0.92	1.58	--	--	--	--
2	27	0.74	19.98	0.76	0.92	2.01	--	--	--	--
3	--	--	--	--	--	--	2500	0.61	1.34	4.40
3	--	--	--	--	--	--	2500	0.66	1.44	4.74
3	--	--	--	--	--	--	2500	0.70	1.51	4.98
4	--	--	--	--	--	--	3000	0.50	1.30	4.28
4	--	--	--	--	--	--	3000	0.50	1.30	4.28
4	--	--	--	--	--	--	3000	0.50	1.30	4.28
5	27	0.74	19.98	0.76	0.92	5.45	--	--	--	--
5	27	0.74	19.98	0.76	0.92	5.67	--	--	--	--
5	27	0.74	19.98	0.76	0.92	5.90	--	--	--	--
5	27	0.74	19.98	0.76	0.92	6.12	--	--	--	--
6	32	0.74	23.68	0.97	0.88	9.33	--	--	--	--
6	32	0.74	23.68	0.97	0.88	9.73	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.13
7	--	--	--	--	--	--	1000	1.00	0.95	3.13
7	--	--	--	--	--	--	1000	1.00	0.95	3.13
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	27
2	27	0.5	20	1000	13.5	10.0	--	0
2	27	0.5	20	1450	13.5	13.5	--	0
2	27	0.5	20	1900	13.5	13.5	--	0
2	27	0.48	20	2350	13.5	13.5	--	0
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
6	32	0.54	40	3200	33	33.0	--	0
6	32	0.54	40	3200	33	33.0	--	0
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6463	0.45	0.73	1.65	10.00	3.05	4.70
2	15	6458	0.45	1.16	4.25	13.50	4.12	8.37
2	20	6453	0.45	1.58	7.81	13.50	4.12	11.93
2	25	6448	0.45	2.01	12.32	13.50	4.12	16.44
3	30	6443	0.35	4.40	20.03	22.50	5.34	25.37
3	35	6438	0.35	4.74	28.32	22.50	5.34	33.66
3	40	6433	0.35	4.98	37.03	22.50	5.34	42.37
4	45	6428	0.35	4.28	44.53	27.00	6.41	50.94
4	50	6423	0.35	4.28	52.02	27.00	6.41	58.44
4	55	6418	0.35	4.28	59.52	27.00	6.41	65.93
5	60	6413	0.45	5.45	71.78	13.50	4.12	75.90
5	65	6408	0.45	5.67	84.54	13.50	4.12	88.66
5	70	6403	0.45	5.90	97.80	13.50	4.12	101.93
5	75	6398	0.45	6.12	111.57	13.50	4.12	115.70
6	80	6393	0.45	9.33	132.56	33.00	10.08	142.64
6	85	6388	0.45	9.73	154.45	33.00	10.08	164.52
7	90	6383	0.35	3.13	159.92	9.00	2.14	162.06
7	95	6378	0.35	3.13	165.40	9.00	2.14	167.54
7	100	6373	0.35	3.13	170.88	9.00	2.14	173.02
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]	[m]
1	Cohesive	0.35	110	--	3000	5	1.5
2	Silty	0.45	90	27	--	25	7.5
3	Cohesive	0.35	100	--	2500	40	12.0
4	Cohesive	0.35	120	--	3000	55	16.5
5	Silty	0.45	110	27	--	75	22.5
6	Cohesionless	0.45	120	32	--	85	25.5
7	Cohesive	0.35	120	--	1000	100	30.0
8		0.45					0.0

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	BS-5	BS-6	Average
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Project No.: 17-2015-4045
Project: BIA Route N8065
Structure: West Abutment, Pile Foundation, No Scour
Corresponding Boring: BS-5/BS-6
Groundwater Table [ft]: 55
Depth of Scour [ft]: 0
γ_w [pcf]: 62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_{δ}	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	3.18
2	27	0.76	20.52	0.77	0.94	0.91	--	--	--	--
2	27	0.76	20.52	0.77	0.94	1.44	--	--	--	--
2	27	0.76	20.52	0.77	0.94	1.97	--	--	--	--
2	27	0.76	20.52	0.77	0.94	2.50	--	--	--	--
3	--	--	--	--	--	--	2500	0.57	1.26	4.98
3	--	--	--	--	--	--	2500	0.61	1.34	5.32
3	--	--	--	--	--	--	2500	0.66	1.43	5.66
4	--	--	--	--	--	--	3000	0.50	1.30	5.16
4	--	--	--	--	--	--	3000	0.50	1.30	5.16
4	--	--	--	--	--	--	3000	0.50	1.30	5.16
5	27	0.76	20.52	0.77	0.94	6.79	--	--	--	--
5	27	0.76	20.52	0.77	0.94	7.07	--	--	--	--
5	27	0.76	20.52	0.77	0.94	7.35	--	--	--	--
5	27	0.76	20.52	0.77	0.94	7.63	--	--	--	--
6	32	0.76	24.32	0.98	0.90	11.69	--	--	--	--
6	32	0.76	24.32	0.98	0.90	12.19	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.77
7	--	--	--	--	--	--	1000	1.00	0.95	3.77
7	--	--	--	--	--	--	1000	1.00	0.95	3.77
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	27
2	27	0.5	20	1000	13.5	10.0	--	0
2	27	0.5	20	1450	13.5	13.5	--	0
2	27	0.5	20	1900	13.5	13.5	--	0
2	27	0.5	20	2350	13.5	13.5	--	0
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
6	32	0.54	40	3200	33	33.0	--	0
6	32	0.54	40	3200	33	33.0	--	0
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6463	0.45	0.91	2.05	10.00	4.43	6.49
2	15	6458	0.45	1.44	5.29	13.50	5.99	11.28
2	20	6453	0.45	1.97	9.73	13.50	5.99	15.71
2	25	6448	0.45	2.50	15.35	13.50	5.99	21.34
3	30	6443	0.35	4.98	24.07	22.50	7.76	31.83
3	35	6438	0.35	5.32	33.38	22.50	7.76	41.14
3	40	6433	0.35	5.66	43.28	22.50	7.76	51.04
4	45	6428	0.35	5.16	52.32	27.00	9.31	61.63
4	50	6423	0.35	5.16	61.35	27.00	9.31	70.66
4	55	6418	0.35	5.16	70.39	27.00	9.31	79.70
5	60	6413	0.45	6.79	85.65	13.50	5.99	91.64
5	65	6408	0.45	7.07	101.55	13.50	5.99	107.54
5	70	6403	0.45	7.35	118.08	13.50	5.99	124.06
5	75	6398	0.45	7.63	135.23	13.50	5.99	141.22
6	80	6393	0.45	11.69	161.54	33.00	14.63	176.17
6	85	6388	0.45	12.19	188.96	33.00	14.63	203.59
7	90	6383	0.35	3.77	195.56	9.00	3.10	198.67
7	95	6378	0.35	3.77	202.16	9.00	3.10	205.27
7	100	6373	0.35	3.77	208.77	9.00	3.10	211.87
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	110	--	3000	5
2	Silty	0.45	90	27	--	25
3	Cohesive	0.35	100	--	2500	40
4	Cohesive	0.35	120	--	3000	55
5	Silty	0.45	110	27	--	75
6	Cohesionless	0.45	120	32	--	85
7	Cohesive	0.35	120	--	1000	100
8		0.45				

H-Pile Inputs

Pile Type:	HP14x73	Select from drop down menu
Depth [in]:	13.61	
Width [in]:	14.585	
Thickness [in]:	0.505	
End Area [sf]:	0.149	(unplugged)
End Area [sf]:	1.378	(plugged)
Volume[cf/ft]:	0.149	
Steel Perimeter (C_d) [ft]:	2.599	
Soil Perimeter (C_d) [ft]:	2.1000	
δ/ϕ:	0.78	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	535	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	3.76
2	27	0.78	21.06	0.79	0.95	1.13	--	--	--	--
2	27	0.78	21.06	0.79	0.95	1.79	--	--	--	--
2	27	0.78	21.06	0.79	0.95	2.45	--	--	--	--
2	27	0.78	21.06	0.79	0.95	3.11	--	--	--	--
3	--	--	--	--	--	--	2500	0.53	1.18	5.54
3	--	--	--	--	--	--	2500	0.57	1.25	5.87
3	--	--	--	--	--	--	2500	0.60	1.32	6.20
4	--	--	--	--	--	--	3000	0.45	1.18	5.55
4	--	--	--	--	--	--	3000	0.48	1.25	5.88
4	--	--	--	--	--	--	3000	0.50	1.30	6.11
5	27	0.78	21.06	0.79	0.95	8.43	--	--	--	--
5	27	0.78	21.06	0.79	0.95	8.78	--	--	--	--
5	27	0.78	21.06	0.79	0.95	9.13	--	--	--	--
5	27	0.78	21.06	0.79	0.95	9.48	--	--	--	--
6	32	0.78	24.96	1.04	0.91	14.87	--	--	--	--
6	32	0.78	24.96	1.04	0.91	15.51	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	4.46
7	--	--	--	--	--	--	1000	1.00	0.95	4.46
7	--	--	--	--	--	--	1000	1.00	0.95	4.46
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	27
2	27	0.5	20	1000	13.5	10.0	--	0
2	27	0.5	20	1450	13.5	13.5	--	0
2	27	0.5	20	1900	13.5	13.5	--	0
2	27	0.5	20	2350	13.5	13.5	--	0
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
6	32	0.54	40	3200	33	33.0	--	0
6	32	0.54	40	3200	33	33.0	--	0
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6463	0.45	1.13	2.55	10.00	6.20	8.75
2	15	6458	0.45	1.79	6.58	13.50	8.37	14.95
2	20	6453	0.45	2.45	12.09	13.50	8.37	20.46
2	25	6448	0.45	3.11	19.08	13.50	8.37	27.45
3	30	6443	0.35	5.54	28.78	22.50	10.86	39.64
3	35	6438	0.35	5.87	39.06	22.50	10.86	49.91
3	40	6433	0.35	6.20	49.91	22.50	10.86	60.76
4	45	6428	0.35	5.55	59.63	27.00	13.03	72.65
4	50	6423	0.35	5.88	69.91	27.00	13.03	82.94
4	55	6418	0.35	6.11	80.60	27.00	13.03	93.63
5	60	6413	0.45	8.43	99.58	13.50	8.37	107.95
5	65	6408	0.45	8.78	119.34	13.50	8.37	127.71
5	70	6403	0.45	9.13	139.88	13.50	8.37	148.26
5	75	6398	0.45	9.48	161.21	13.50	8.37	169.58
6	80	6393	0.45	14.87	194.67	33.00	20.47	215.14
6	85	6388	0.45	15.51	229.56	33.00	20.47	250.03
7	90	6383	0.35	4.46	237.37	9.00	4.34	241.71
7	95	6378	0.35	4.46	245.18	9.00	4.34	249.52
7	100	6373	0.35	4.46	252.99	9.00	4.34	257.34
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

PIER

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Depth to Groundwater Table [ft]:	6
Ground Elevation [ft]:	6420.5
Depth of Scour [ft]:	6 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	0	--	500	6.5
2	Cohesionless	0.45	120	32	--	30
3	Cohesive	0.35	120	--	1000	45
4	Cohesionless	0.45	125	34	--	80
5	Cohesionless	0.45	120	32	--	100
6		0.45				
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.00	1.00	0.10	0.70	0.086	0.70	0.94
26	0.00	1.09	0.10	0.73	0.086	0.73	0.93
27	0.00	1.18	0.10	0.76	0.086	0.76	0.92
28	0.00	1.27	0.10	0.79	0.086	0.79	0.91
29	0.00	1.36	0.10	0.82	0.086	0.82	0.90
30	0.00	1.45	0.10	0.85	0.086	0.85	0.89
31	0.00	1.63	0.10	0.91	0.086	0.91	0.88
32	0.00	1.81	0.10	0.97	0.086	0.97	0.88
33	0.00	1.99	0.10	1.03	0.086	1.03	0.87
34	0.00	2.17	0.10	1.09	0.086	1.09	0.87
35	0.00	2.35	0.10	1.15	0.086	1.15	0.86
36	0.00	2.74	0.10	1.26	0.086	1.26	0.86
37	0.00	3.13	0.10	1.37	0.086	1.37	0.85
38	0.00	3.52	0.10	1.48	0.086	1.48	0.84
39	0.00	3.91	0.10	1.59	0.086	1.59	0.83
40	0.00	4.30	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6420.5	0	2	6	4
6415.5	5	8	3	6
6410.5	10	3	3	3
6405.5	15	4	5	5
6400.5	20	7	9	8
6395.5	25	6	17	12
6390.5	30	12	9	11
6385.5	35	13	7	10
6380.5	40	8	5	7
6375.5	45	7	5	6
6370.5	50	16	9	13
6365.5	55	10	19	15
6360.5	60	19	23	21
6355.5	65	32	18	25
6350.5	70	12	13	13
6345.5	75	32	12	22
6340.5	80	8	12	10
6335.5	85	12	3	8
6330.5	90	18	6	12
6325.5	95	10	11	11
6320.5	100	11	11	11

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045				
Project:	BIA Route N8065	7	1		-31
Structure:	Piers, Pile Foundation, Scour	30	2	2820	1322
Corresponding Boring:	BS-3/BS-4	45	3	4620	2186
Groundwater Table [ft]:	6	80	4	8995	4377
Depth of Scour [ft]:	6	100	5	11395	5529
γ_w [pcf]:	62.4	0	6	11395	11395
		0	7	11395	11395
		0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	3.3	6.5	0	0	0	0	0	0	Cohesive	4	0
2	6.5	8.3	10	120	62.4	210	420	170.4	69.6	Cohesionless	6	10
2	10	12.5	15	120	62.4	720	1020	458.4	314.4	Cohesionless	3	4
2	15	17.5	20	120	62.4	1320	1620	746.4	602.4	Cohesionless	5	6
2	20	22.5	25	120	62.4	1920	2220	1034.4	890.4	Cohesionless	8	10
2	25	27.5	30	120	62.4	2520	2820	1322.4	1178.4	Cohesionless	12	13
3	30	32.5	35	120	62.4	3120	3420	1610.4	1466.4	Cohesive	11	11
3	35	37.5	40	120	62.4	3720	4020	1898.4	1754.4	Cohesive	10	10
3	40	42.5	45	120	62.4	4320	4620	2186.4	2042.4	Cohesive	7	6
4	45	47.5	50	125	62.4	4932.5	5245	2499.4	2342.9	Cohesionless	6	6
4	50	52.5	55	125	62.4	5557.5	5870	2812.4	2655.9	Cohesionless	13	11
4	55	57.5	60	125	62.4	6182.5	6495	3125.4	2968.9	Cohesionless	15	12
4	60	62.5	65	125	62.4	6807.5	7120	3438.4	3281.9	Cohesionless	21	17
4	65	67.5	70	125	62.4	7432.5	7745	3751.4	3594.9	Cohesionless	25	20
4	70	72.5	75	125	62.4	8057.5	8370	4064.4	3907.9	Cohesionless	13	10
4	75	77.5	80	125	62.4	8682.5	8995	4377.4	4220.9	Cohesionless	22	16
5	80	82.5	85	120	62.4	9295	9595	4665.4	4521.4	Cohesionless	10	7
5	85	87.5	90	120	62.4	9895	10195	4953.4	4809.4	Cohesionless	8	5
5	90	92.5	95	120	62.4	10495	10795	5241.4	5097.4	Cohesionless	12	8
5	95	97.5	100	120	62.4	11095	11395	5529.4	5385	Cohesionless	11	7
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_{δ}	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.74	23.68	0.97	0.88	0.10	--	--	--	--
2	32	0.74	23.68	0.97	0.88	0.43	--	--	--	--
2	32	0.74	23.68	0.97	0.88	0.83	--	--	--	--
2	32	0.74	23.68	0.97	0.88	1.23	--	--	--	--
2	32	0.74	23.68	0.97	0.88	1.63	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.93	3.06
3	--	--	--	--	--	--	1000	1.00	0.95	3.13
3	--	--	--	--	--	--	1000	1.00	0.95	3.13
4	34	0.74	25.16	1.09	0.87	3.83	--	--	--	--
4	34	0.74	25.16	1.09	0.87	4.34	--	--	--	--
4	34	0.74	25.16	1.09	0.87	4.85	--	--	--	--
4	34	0.74	25.16	1.09	0.87	5.36	--	--	--	--
4	34	0.74	25.16	1.09	0.87	5.87	--	--	--	--
4	34	0.74	25.16	1.09	0.87	6.38	--	--	--	--
4	34	0.74	25.16	1.09	0.87	6.89	--	--	--	--
5	32	0.74	23.68	0.97	0.88	6.25	--	--	--	--
5	32	0.74	23.68	0.97	0.88	6.65	--	--	--	--
5	32	0.74	23.68	0.97	0.88	7.05	--	--	--	--
5	32	0.74	23.68	0.97	0.88	7.45	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0
2	32	0.61	40	170.4	33	4.2	--	0
2	32	0.61	40	458.4	33	11.2	--	0
2	32	0.61	40	746.4	33	18.2	--	0
2	32	0.6	40	1034	33	24.8	--	0
2	32	0.58	40	1322	33	30.7	--	0
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
4	34	0.61	53	2499	75	75.0	--	0
4	34	0.61	53	2812	75	75.0	--	0
4	34	0.61	53	3125	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6420.5	0.35	0.00	0.00	0.00	0.00	0.00
1	6.5	6414	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6410.5	0.45	0.10	0.15	4.16	1.27	1.42
2	15	6405.5	0.45	0.43	1.13	11.18	3.42	4.55
2	20	6400.5	0.45	0.83	3.00	18.21	5.56	8.57
2	25	6395.5	0.45	1.23	5.77	24.83	7.58	13.36
2	30	6390.5	0.45	1.63	9.44	30.68	9.37	18.81
3	35	6385.5	0.35	3.06	14.80	9.00	2.14	16.93
3	40	6380.5	0.35	3.13	20.28	9.00	2.14	22.41
3	45	6375.5	0.35	3.13	25.75	9.00	2.14	27.89
4	50	6370.5	0.45	3.83	34.37	75.00	22.90	57.27
4	55	6365.5	0.45	4.34	44.13	75.00	22.90	67.03
4	60	6360.5	0.45	4.85	55.04	75.00	22.90	77.94
4	65	6355.5	0.45	5.36	67.10	75.00	22.90	90.01
4	70	6350.5	0.45	5.87	80.31	75.00	22.90	103.22
4	75	6345.5	0.45	6.38	94.68	75.00	22.90	117.58
4	80	6340.5	0.45	6.89	110.19	75.00	22.90	133.09
5	85	6335.5	0.45	6.25	124.26	33.00	10.08	134.33
5	90	6330.5	0.45	6.65	139.22	33.00	10.08	149.30
5	95	6325.5	0.45	7.05	155.08	33.00	10.08	165.16
5	100	6320.5	0.45	7.45	171.83	33.00	10.08	181.91
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!
0	0	6420.5	0.45	0.00	#VALUE!	0.00	0.00	#VALUE!
0	0	6420.5	0.45	0.00	#VALUE!	0.00	0.00	#VALUE!

Site Inputs		
Project No.:	17-2015-4045	
Project:	BIA Route N8065	
Structure:	Piers, Pile Foundation, Scour	
Corresponding Boring:	BS-3/BS-4	
Depth to Groundwater Table [ft]:	6	
Ground Elevation [ft]:	6420.5	
Depth of Scour [ft]:	6	Not used in calculations.
Resistance Factor [clay]:	0.35	
Resistance Factor [sand]:	0.45	
Atmospheric Pressure (p_a) [pcf]:	2116	

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	0	--	500	6.5
2	Cohesionless	0.45	120	32	--	30
3	Cohesive	0.35	120	--	1000	45
4	Cohesionless	0.45	125	34	--	80
5	Cohesionless	0.45	120	32	--	100
6		0.45				
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6420.5	0	2	6	4
6415.5	5	8	3	6
6410.5	10	3	3	3
6405.5	15	4	5	5
6400.5	20	7	9	8
6395.5	25	6	17	12
6390.5	30	12	9	11
6385.5	35	13	7	10
6380.5	40	8	5	7
6375.5	45	7	5	6
6370.5	50	16	9	13
6365.5	55	10	19	15
6360.5	60	19	23	21
6355.5	65	32	18	25
6350.5	70	12	13	13
6345.5	75	32	12	22
6340.5	80	8	12	10
6335.5	85	12	3	8
6330.5	90	18	6	12
6325.5	95	10	11	11
6320.5	100	11	11	11

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Groundwater Table [ft]:	6
Depth of Scour [ft]:	6
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
7	1		-31
30	2	2820	1322
45	3	4620	2186
80	4	8995	4377
100	5	11395	5529
0	6	11395	11395
0	7	11395	11395
0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	3.3	6.5	0	0	0	0	0	0	Cohesive	4	0
2	6.5	8.3	10	120	62.4	210	420	170.4	69.6	Cohesionless	6	10
2	10	12.5	15	120	62.4	720	1020	458.4	314.4	Cohesionless	3	4
2	15	17.5	20	120	62.4	1320	1620	746.4	602.4	Cohesionless	5	6
2	20	22.5	25	120	62.4	1920	2220	1034.4	890.4	Cohesionless	8	10
2	25	27.5	30	120	62.4	2520	2820	1322.4	1178.4	Cohesionless	12	13
3	30	32.5	35	120	62.4	3120	3420	1610.4	1466.4	Cohesive	11	11
3	35	37.5	40	120	62.4	3720	4020	1898.4	1754.4	Cohesive	10	10
3	40	42.5	45	120	62.4	4320	4620	2186.4	2042.4	Cohesive	7	6
4	45	47.5	50	125	62.4	4932.5	5245	2499.4	2342.9	Cohesionless	6	6
4	50	52.5	55	125	62.4	5557.5	5870	2812.4	2655.9	Cohesionless	13	11
4	55	57.5	60	125	62.4	6182.5	6495	3125.4	2968.9	Cohesionless	15	12
4	60	62.5	65	125	62.4	6807.5	7120	3438.4	3281.9	Cohesionless	21	17
4	65	67.5	70	125	62.4	7432.5	7745	3751.4	3594.9	Cohesionless	25	20
4	70	72.5	75	125	62.4	8057.5	8370	4064.4	3907.9	Cohesionless	13	10
4	75	77.5	80	125	62.4	8682.5	8995	4377.4	4220.9	Cohesionless	22	16
5	80	82.5	85	120	62.4	9295	9595	4665.4	4521.4	Cohesionless	10	7
5	85	87.5	90	120	62.4	9895	10195	4953.4	4809.4	Cohesionless	8	5
5	90	92.5	95	120	62.4	10495	10795	5241.4	5097.4	Cohesionless	12	8
5	95	97.5	100	120	62.4	11095	11395	5529.4	5385	Cohesionless	11	7
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	$K_δ$	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.76	24.32	0.98	0.90	0.12	--	--	--	--
2	32	0.76	24.32	0.98	0.90	0.54	--	--	--	--
2	32	0.76	24.32	0.98	0.90	1.04	--	--	--	--
2	32	0.76	24.32	0.98	0.90	1.54	--	--	--	--
2	32	0.76	24.32	0.98	0.90	2.04	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.90	3.57
3	--	--	--	--	--	--	1000	1.00	0.93	3.67
3	--	--	--	--	--	--	1000	1.00	0.95	3.77
4	34	0.76	25.84	1.11	0.89	4.80	--	--	--	--
4	34	0.76	25.84	1.11	0.89	5.44	--	--	--	--
4	34	0.76	25.84	1.11	0.89	6.09	--	--	--	--
4	34	0.76	25.84	1.11	0.89	6.73	--	--	--	--
4	34	0.76	25.84	1.11	0.89	7.37	--	--	--	--
4	34	0.76	25.84	1.11	0.89	8.01	--	--	--	--
4	34	0.76	25.84	1.11	0.89	8.65	--	--	--	--
5	32	0.76	24.32	0.98	0.90	7.83	--	--	--	--
5	32	0.76	24.32	0.98	0.90	8.33	--	--	--	--
5	32	0.76	24.32	0.98	0.90	8.83	--	--	--	--
5	32	0.76	24.32	0.98	0.90	9.33	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0
2	32	0.61	40	170.4	33	4.2	--	0
2	32	0.61	40	458.4	33	11.2	--	0
2	32	0.61	40	746.4	33	18.2	--	0
2	32	0.61	40	1034	33	25.2	--	0
2	32	0.6	40	1322	33	31.7	--	0
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
4	34	0.61	53	2499	75	75.0	--	0
4	34	0.61	53	2812	75	75.0	--	0
4	34	0.61	53	3125	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6420.5	0.35	0.00	0.00	0.00	0.00	0.00
1	6.5	6414	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6410.5	0.45	0.12	0.19	4.16	1.84	2.03
2	15	6405.5	0.45	0.54	1.42	11.18	4.96	6.38
2	20	6400.5	0.45	1.04	3.76	18.21	8.08	11.84
2	25	6395.5	0.45	1.54	7.24	25.24	11.19	18.43
2	30	6390.5	0.45	2.04	11.83	31.74	14.07	25.90
3	35	6385.5	0.35	3.57	18.08	9.00	3.10	21.19
3	40	6380.5	0.35	3.67	24.51	9.00	3.10	27.62
3	45	6375.5	0.35	3.77	31.11	9.00	3.10	34.22
4	50	6370.5	0.45	4.80	41.92	75.00	33.26	75.18
4	55	6365.5	0.45	5.44	54.17	75.00	33.26	87.43
4	60	6360.5	0.45	6.09	67.86	75.00	33.26	101.12
4	65	6355.5	0.45	6.73	83.00	75.00	33.26	116.26
4	70	6350.5	0.45	7.37	99.58	75.00	33.26	132.84
4	75	6345.5	0.45	8.01	117.61	75.00	33.26	150.86
4	80	6340.5	0.45	8.65	137.07	75.00	33.26	170.33
5	85	6335.5	0.45	7.83	154.70	33.00	14.63	169.33
5	90	6330.5	0.45	8.33	173.45	33.00	14.63	188.09
5	95	6325.5	0.45	8.83	193.33	33.00	14.63	207.96
5	100	6320.5	0.45	9.33	214.33	33.00	14.63	228.96
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

H-Pile Inputs		
Project No.:	17-2015-4045	
Project:	BIA Route N8065	
Structure:	Piers, Pile Foundation, Scour	
Corresponding Boring:	BS-3/BS-4	
Depth to Groundwater Table [ft]:	6	
Ground Elevation [ft]:	6420.5	
Depth of Scour [ft]:	6	Not used in calculations.
Resistance Factor [clay]:	0.35	
Resistance Factor [sand]:	0.45	
Atmospheric Pressure (p_a) [pcf]:	2116	

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	0	--	500	6.5
2	Cohesionless	0.45	120	32	--	30
3	Cohesive	0.35	120	--	1000	45
4	Cohesionless	0.45	125	34	--	80
5	Cohesionless	0.45	120	32	--	100
6		0.45				
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP14x73	Select from drop down menu
Depth [in]:	13.61	
Width [in]:	14.585	
Thickness [in]:	0.505	
End Area [sf]:	0.149	(unplugged)
End Area [sf]:	1.378	(plugged)
Volume[cf/ft]:	0.149	
Steel Perimeter (C_d) [ft]:	2.599	
Soil Perimeter (C_d) [ft]:	2.1000	
δ/ϕ:	0.78	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	535	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6420.5	0	2	6	4
6415.5	5	8	3	6
6410.5	10	3	3	3
6405.5	15	4	5	5
6400.5	20	7	9	8
6395.5	25	6	17	12
6390.5	30	12	9	11
6385.5	35	13	7	10
6380.5	40	8	5	7
6375.5	45	7	5	6
6370.5	50	16	9	13
6365.5	55	10	19	15
6360.5	60	19	23	21
6355.5	65	32	18	25
6350.5	70	12	13	13
6345.5	75	32	12	22
6340.5	80	8	12	10
6335.5	85	12	3	8
6330.5	90	18	6	12
6325.5	95	10	11	11
6320.5	100	11	11	11

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	7	1		-31
Project:	BIA Route N8065	30	2	2820	1322
Structure:	Piers, Pile Foundation, Scour	45	3	4620	2186
Corresponding Boring:	BS-3/BS-4	80	4	8995	4377
Groundwater Table [ft]:	6	100	5	11395	5529
Depth of Scour [ft]:	6	0	6	11395	11395
γ_w [pcf]:	62.4	0	7	11395	11395
		0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	3.3	6.5	0	0	0	0	0	0	Cohesive	4	0
2	6.5	8.3	10	120	62.4	210	420	170.4	69.6	Cohesionless	6	10
2	10	12.5	15	120	62.4	720	1020	458.4	314.4	Cohesionless	3	4
2	15	17.5	20	120	62.4	1320	1620	746.4	602.4	Cohesionless	5	6
2	20	22.5	25	120	62.4	1920	2220	1034.4	890.4	Cohesionless	8	10
2	25	27.5	30	120	62.4	2520	2820	1322.4	1178.4	Cohesionless	12	13
3	30	32.5	35	120	62.4	3120	3420	1610.4	1466.4	Cohesive	11	11
3	35	37.5	40	120	62.4	3720	4020	1898.4	1754.4	Cohesive	10	10
3	40	42.5	45	120	62.4	4320	4620	2186.4	2042.4	Cohesive	7	6
4	45	47.5	50	125	62.4	4932.5	5245	2499.4	2342.9	Cohesionless	6	6
4	50	52.5	55	125	62.4	5557.5	5870	2812.4	2655.9	Cohesionless	13	11
4	55	57.5	60	125	62.4	6182.5	6495	3125.4	2968.9	Cohesionless	15	12
4	60	62.5	65	125	62.4	6807.5	7120	3438.4	3281.9	Cohesionless	21	17
4	65	67.5	70	125	62.4	7432.5	7745	3751.4	3594.9	Cohesionless	25	20
4	70	72.5	75	125	62.4	8057.5	8370	4064.4	3907.9	Cohesionless	13	10
4	75	77.5	80	125	62.4	8682.5	8995	4377.4	4220.9	Cohesionless	22	16
5	80	82.5	85	120	62.4	9295	9595	4665.4	4521.4	Cohesionless	10	7
5	85	87.5	90	120	62.4	9895	10195	4953.4	4809.4	Cohesionless	8	5
5	90	92.5	95	120	62.4	10495	10795	5241.4	5097.4	Cohesionless	12	8
5	95	97.5	100	120	62.4	11095	11395	5529.4	5385	Cohesionless	11	7
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	$K_δ$	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.78	24.96	1.04	0.91	0.15	--	--	--	--
2	32	0.78	24.96	1.04	0.91	0.69	--	--	--	--
2	32	0.78	24.96	1.04	0.91	1.33	--	--	--	--
2	32	0.78	24.96	1.04	0.91	1.96	--	--	--	--
2	32	0.78	24.96	1.04	0.91	2.60	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.87	4.10
3	--	--	--	--	--	--	1000	1.00	0.89	4.20
3	--	--	--	--	--	--	1000	1.00	0.91	4.30
4	34	0.78	26.52	1.18	0.90	6.14	--	--	--	--
4	34	0.78	26.52	1.18	0.90	6.96	--	--	--	--
4	34	0.78	26.52	1.18	0.90	7.78	--	--	--	--
4	34	0.78	26.52	1.18	0.90	8.60	--	--	--	--
4	34	0.78	26.52	1.18	0.90	9.42	--	--	--	--
4	34	0.78	26.52	1.18	0.90	10.24	--	--	--	--
4	34	0.78	26.52	1.18	0.90	11.06	--	--	--	--
5	32	0.78	24.96	1.04	0.91	9.97	--	--	--	--
5	32	0.78	24.96	1.04	0.91	10.60	--	--	--	--
5	32	0.78	24.96	1.04	0.91	11.24	--	--	--	--
5	32	0.78	24.96	1.04	0.91	11.87	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0
2	32	0.61	40	170.4	33	4.2	--	0
2	32	0.61	40	458.4	33	11.2	--	0
2	32	0.61	40	746.4	33	18.2	--	0
2	32	0.61	40	1034	33	25.2	--	0
2	32	0.61	40	1322	33	32.3	--	0
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
4	34	0.62	53	2499	75	75.0	--	0
4	34	0.61	53	2812	75	75.0	--	0
4	34	0.61	53	3125	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6420.5	0.35	0.00	0.00	0.00	0.00	0.00
1	6.5	6414	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6410.5	0.45	0.15	0.24	4.16	2.58	2.82
2	15	6405.5	0.45	0.69	1.80	11.18	6.94	8.74
2	20	6400.5	0.45	1.33	4.79	18.21	11.30	16.09
2	25	6395.5	0.45	1.96	9.21	25.24	15.66	24.86
2	30	6390.5	0.45	2.60	15.05	32.27	20.02	35.07
3	35	6385.5	0.35	4.10	22.23	9.00	4.34	26.58
3	40	6380.5	0.35	4.20	29.58	9.00	4.34	33.93
3	45	6375.5	0.35	4.30	37.11	9.00	4.34	41.45
4	50	6370.5	0.45	6.14	50.92	75.00	46.52	97.45
4	55	6365.5	0.45	6.96	66.59	75.00	46.52	113.11
4	60	6360.5	0.45	7.78	84.10	75.00	46.52	130.62
4	65	6355.5	0.45	8.60	103.46	75.00	46.52	149.98
4	70	6350.5	0.45	9.42	124.66	75.00	46.52	171.18
4	75	6345.5	0.45	10.24	147.71	75.00	46.52	194.23
4	80	6340.5	0.45	11.06	172.61	75.00	46.52	219.13
5	85	6335.5	0.45	9.97	195.03	33.00	20.47	215.50
5	90	6330.5	0.45	10.60	218.89	33.00	20.47	239.36
5	95	6325.5	0.45	11.24	244.17	33.00	20.47	264.64
5	100	6320.5	0.45	11.87	270.88	33.00	20.47	291.35
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

EAST ABUTMENT

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	100	--	2500	30
2	Cohesive	0.35	120	--	4000	55
3	Cohesionless	0.45	120	30	--	65
4	Silty	0.45	110	27	--	80
5	Cohesive	0.35	120	--	1000	95
6	Cohesionless	0.45	125	32	--	100
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.00	1.00	0.10	0.70	0.086	0.70	0.94
26	0.00	1.09	0.10	0.73	0.086	0.73	0.93
27	0.00	1.18	0.10	0.76	0.086	0.76	0.92
28	0.00	1.27	0.10	0.79	0.086	0.79	0.91
29	0.00	1.36	0.10	0.82	0.086	0.82	0.90
30	0.00	1.45	0.10	0.85	0.086	0.85	0.89
31	0.00	1.63	0.10	0.91	0.086	0.91	0.88
32	0.00	1.81	0.10	0.97	0.086	0.97	0.88
33	0.00	1.99	0.10	1.03	0.086	1.03	0.87
34	0.00	2.17	0.10	1.09	0.086	1.09	0.87
35	0.00	2.35	0.10	1.15	0.086	1.15	0.86
36	0.00	2.74	0.10	1.26	0.086	1.26	0.86
37	0.00	3.13	0.10	1.37	0.086	1.37	0.85
38	0.00	3.52	0.10	1.48	0.086	1.48	0.84
39	0.00	3.91	0.10	1.59	0.086	1.59	0.83
40	0.00	4.30	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

			Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045		30	1	3000	3000
Project:	BIA Route N8065		55	2	6000	6000
Structure:	East Abutment, Pile Foundation, No Scour		65	3	7200	6576
Corresponding Boring:	BS-1/BS-2		80	4	8850	7290
Groundwater Table [ft]:	55		95	5	10650	8154
Depth of Scour [ft]:	0		100	6	11275	8467
γ_w [pcf]:	62.4		0	7	11275	11275
			0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.30
1	--	--	--	--	--	--	2500	0.44	1.00	3.30
1	--	--	--	--	--	--	2500	0.46	1.03	3.40
1	--	--	--	--	--	--	2500	0.51	1.13	3.74
1	--	--	--	--	--	--	2500	0.56	1.23	4.07
1	--	--	--	--	--	--	2500	0.61	1.34	4.40
2	--	--	--	--	--	--	4000	0.30	1.19	3.92
2	--	--	--	--	--	--	4000	0.31	1.26	4.09
2	--	--	--	--	--	--	4000	0.31	1.26	4.09
2	--	--	--	--	--	--	4000	0.31	1.26	4.09
2	--	--	--	--	--	--	4000	0.31	1.26	4.09
3	30	0.74	22.2	0.85	0.89	7.05	--	--	--	--
3	30	0.74	22.2	0.85	0.89	7.38	--	--	--	--
4	27	0.74	19.98	0.76	0.92	6.32	--	--	--	--
4	27	0.74	19.98	0.76	0.92	6.55	--	--	--	--
4	27	0.74	19.98	0.76	0.92	6.77	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.13
5	--	--	--	--	--	--	1000	1.00	0.95	3.13
5	--	--	--	--	--	--	1000	1.00	0.95	3.13
6	32	0.74	23.68	0.97	0.88	11.49	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
3	30	0.48	30	3200	13.5	13.5	--	0
3	30	0.48	30	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
6	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
1	10	6463	0.35	3.30	5.77	22.50	5.34	11.11
1	15	6458	0.35	3.40	11.72	22.50	5.34	17.07
1	20	6453	0.35	3.74	18.26	22.50	5.34	23.61
1	25	6448	0.35	4.07	25.38	22.50	5.34	30.73
1	30	6443	0.35	4.40	33.09	22.50	5.34	38.44
2	35	6438	0.35	3.92	39.96	36.00	8.55	48.51
2	40	6433	0.35	4.09	47.11	36.00	8.55	55.66
2	45	6428	0.35	4.09	54.26	36.00	8.55	62.81
2	50	6423	0.35	4.09	61.41	36.00	8.55	69.96
2	55	6418	0.35	4.09	68.56	36.00	8.55	77.12
3	60	6413	0.45	7.05	84.43	13.50	4.12	88.55
3	65	6408	0.45	7.38	101.04	13.50	4.12	105.16
4	70	6403	0.45	6.32	115.26	13.50	4.12	119.38
4	75	6398	0.45	6.55	129.99	13.50	4.12	134.11
4	80	6393	0.45	6.77	145.22	13.50	4.12	149.34
5	85	6388	0.35	3.13	150.70	9.00	2.14	152.84
5	90	6383	0.35	3.13	156.18	9.00	2.14	158.32
5	95	6378	0.35	3.13	161.66	9.00	2.14	163.79
6	100	6373	0.45	11.49	187.51	33.00	10.08	197.59
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	100	--	2500	30
2	Cohesive	0.35	120	--	4000	55
3	Cohesionless	0.45	120	30	--	65
4	Silty	0.45	110	27	--	80
5	Cohesive	0.35	120	--	1000	95
6	Cohesionless	0.45	125	32	--	100
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
30	1	3000	3000
55	2	6000	6000
65	3	7200	6576
80	4	8850	7290
95	5	10650	8154
100	6	11275	8467
0	7	11275	11275
0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_{δ}	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.48	1.08	4.30
1	--	--	--	--	--	--	2500	0.53	1.17	4.64
1	--	--	--	--	--	--	2500	0.57	1.25	4.98
2	--	--	--	--	--	--	4000	0.29	1.10	4.36
2	--	--	--	--	--	--	4000	0.30	1.18	4.68
2	--	--	--	--	--	--	4000	0.31	1.26	4.92
2	--	--	--	--	--	--	4000	0.31	1.26	4.92
2	--	--	--	--	--	--	4000	0.31	1.26	4.92
3	30	0.76	22.8	0.86	0.91	8.81	--	--	--	--
3	30	0.76	22.8	0.86	0.91	9.22	--	--	--	--
4	27	0.76	20.52	0.77	0.94	7.87	--	--	--	--
4	27	0.76	20.52	0.77	0.94	8.15	--	--	--	--
4	27	0.76	20.52	0.77	0.94	8.43	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.77
5	--	--	--	--	--	--	1000	1.00	0.95	3.77
5	--	--	--	--	--	--	1000	1.00	0.95	3.77
6	32	0.76	24.32	0.98	0.90	14.40	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
3	30	0.48	30	3200	13.5	13.5	--	0
3	30	0.48	30	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
6	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	3200	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
1	10	6463	0.35	3.97	6.95	22.50	7.76	14.71
1	15	6458	0.35	3.97	13.89	22.50	7.76	21.65
1	20	6453	0.35	4.30	21.43	22.50	7.76	29.19
1	25	6448	0.35	4.64	29.55	22.50	7.76	37.31
1	30	6443	0.35	4.98	38.26	22.50	7.76	46.02
2	35	6438	0.35	4.36	45.89	36.00	12.42	58.30
2	40	6433	0.35	4.68	54.09	36.00	12.42	66.50
2	45	6428	0.35	4.92	62.70	36.00	12.42	75.12
2	50	6423	0.35	4.92	71.32	36.00	12.42	83.73
2	55	6418	0.35	4.92	79.94	36.00	12.42	92.35
3	60	6413	0.45	8.81	99.76	13.50	5.99	105.74
3	65	6408	0.45	9.22	120.51	13.50	5.99	126.50
4	70	6403	0.45	7.87	138.23	13.50	5.99	144.21
4	75	6398	0.45	8.15	156.58	13.50	5.99	162.56
4	80	6393	0.45	8.43	175.55	13.50	5.99	181.54
5	85	6388	0.35	3.77	182.16	9.00	3.10	185.26
5	90	6383	0.35	3.77	188.76	9.00	3.10	191.86
5	95	6378	0.35	3.77	195.36	9.00	3.10	198.46
6	100	6373	0.45	14.40	227.76	33.00	14.63	242.39
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!
0								
0								

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	100	--	2500	30
2	Cohesive	0.35	120	--	4000	55
3	Cohesionless	0.45	120	30	--	65
4	Silty	0.45	110	27	--	80
5	Cohesive	0.35	120	--	1000	95
6	Cohesionless	0.45	125	32	--	100
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	HP14x73	Select from drop down menu
Depth [in]:	13.61	
Width [in]:	14.585	
Thickness [in]:	0.505	
End Area [sf]:	0.149	(unplugged)
End Area [sf]:	1.378	(plugged)
Volume[cf/ft]:	0.149	
Steel Perimeter (C_d) [ft]:	2.599	
Soil Perimeter (C_d) [ft]:	2.1000	
δ/ϕ:	0.78	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	535	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	30	1	3000	3000
Project:	BIA Route N8065	55	2	6000	6000
Structure:	East Abutment, Pile Foundation, No Scour	65	3	7200	6576
Corresponding Boring:	BS-1/BS-2	80	4	8850	7290
Groundwater Table [ft]:	55	95	5	10650	8154
Depth of Scour [ft]:	0	100	6	11275	8467
γ_w [pcf]:	62.4	0	7	11275	11275
		0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.46	1.04	4.89
1	--	--	--	--	--	--	2500	0.50	1.11	5.21
1	--	--	--	--	--	--	2500	0.53	1.18	5.54
2	--	--	--	--	--	--	4000	0.27	1.01	4.75
2	--	--	--	--	--	--	4000	0.28	1.08	5.06
2	--	--	--	--	--	--	4000	0.29	1.14	5.38
2	--	--	--	--	--	--	4000	0.30	1.21	5.69
2	--	--	--	--	--	--	4000	0.31	1.26	5.83
3	30	0.78	23.4	0.90	0.93	11.13	--	--	--	--
3	30	0.78	23.4	0.90	0.93	11.65	--	--	--	--
4	27	0.78	21.06	0.79	0.95	9.79	--	--	--	--
4	27	0.78	21.06	0.79	0.95	10.14	--	--	--	--
4	27	0.78	21.06	0.79	0.95	10.48	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	4.46
5	--	--	--	--	--	--	1000	1.00	0.95	4.46
5	--	--	--	--	--	--	1000	1.00	0.95	4.46
6	32	0.78	24.96	1.04	0.91	18.32	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

	End-Bearing Capacity Calculations							
Layer	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
3	30	0.48	30	3200	13.5	13.5	--	0
3	30	0.48	30	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
6	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
1	10	6463	0.35	4.70	8.22	22.50	10.86	19.08
1	15	6458	0.35	4.70	16.45	22.50	10.86	27.30
1	20	6453	0.35	4.89	25.00	22.50	10.86	35.85
1	25	6448	0.35	5.21	34.12	22.50	10.86	44.98
1	30	6443	0.35	5.54	43.83	22.50	10.86	54.68
2	35	6438	0.35	4.75	52.13	36.00	17.37	69.50
2	40	6433	0.35	5.06	60.99	36.00	17.37	78.36
2	45	6428	0.35	5.38	70.40	36.00	17.37	87.76
2	50	6423	0.35	5.69	80.36	36.00	17.37	97.73
2	55	6418	0.35	5.83	90.55	36.00	17.37	107.92
3	60	6413	0.45	11.13	115.60	13.50	8.37	123.98
3	65	6408	0.45	11.65	141.82	13.50	8.37	150.20
4	70	6403	0.45	9.79	163.85	13.50	8.37	172.22
4	75	6398	0.45	10.14	186.65	13.50	8.37	195.03
4	80	6393	0.45	10.48	210.24	13.50	8.37	218.62
5	85	6388	0.35	4.46	218.06	9.00	4.34	222.40
5	90	6383	0.35	4.46	225.87	9.00	4.34	230.21
5	95	6378	0.35	4.46	233.68	9.00	4.34	238.02
6	100	6373	0.45	18.32	274.90	33.00	20.47	295.37
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!
0	0	6473	0.45	0.00	#VALUE!	0.00	0.00	#VALUE!
0	0	6473	0.45	0.00	#VALUE!	0.00	0.00	#VALUE!

CLOSED-END PIPE PILES

WEST ABUTMENT

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	110	--	3000	5
2	Silty	0.45	90	27	--	25
3	Cohesive	0.35	100	--	2500	40
4	Cohesive	0.35	120	--	3000	55
5	Silty	0.45	110	27	--	75
6	Cohesionless	0.45	120	32	--	85
7	Cohesive	0.35	120	--	1000	100
8		0.45				

Pile Inputs

Pile Type:	PP12-3/4x0.375	Select from drop down menu
Wall Thickness [in]:	0.375	
Outside Diameter [in]:	12.75	
End Area [sf]:	0.101	(open end - unplugged)
End Area [sf]:	0.887	(open end - plugged)
End Area [sf]:	0.887	(closed end)
Perimeter [ft]:	3.34	
Volume[cf/ft]:	0.887	(closed end)
δ/ϕ:	0.62	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	437	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP12-3/4x0.375		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.80	0.84	0.90	0.84	0.887	0.84	0.88
26	0.80	0.89	0.90	0.90	0.887	0.90	0.87
27	0.80	0.95	0.90	0.96	0.887	0.96	0.86
28	0.80	1.01	0.90	1.02	0.887	1.02	0.85
29	0.80	1.06	0.90	1.08	0.887	1.08	0.84
30	0.80	1.12	0.90	1.14	0.887	1.14	0.83
31	0.80	1.24	0.90	1.25	0.887	1.25	0.82
32	0.80	1.35	0.90	1.37	0.887	1.37	0.81
33	0.80	1.46	0.90	1.49	0.887	1.49	0.79
34	0.80	1.58	0.90	1.61	0.887	1.61	0.78
35	0.80	1.69	0.90	1.72	0.887	1.72	0.77
36	0.80	1.93	0.90	1.97	0.887	1.96	0.76
37	0.80	2.16	0.90	2.21	0.887	2.20	0.75
38	0.80	2.40	0.90	2.45	0.887	2.44	0.74
39	0.80	2.64	0.90	2.70	0.887	2.69	0.71
40	0.80	2.87	0.90	2.94	0.887	2.93	0.70

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	2.67
2	27	0.62	16.74	0.96	0.86	0.61	--	--	--	--
2	27	0.62	16.74	0.96	0.86	0.97	--	--	--	--
2	27	0.62	16.74	0.96	0.86	1.33	--	--	--	--
2	27	0.62	16.74	0.96	0.86	1.69	--	--	--	--
3	--	--	--	--	--	--	2500	0.56	1.23	4.11
3	--	--	--	--	--	--	2500	0.60	1.31	4.38
3	--	--	--	--	--	--	2500	0.64	1.39	4.64
4	--	--	--	--	--	--	3000	0.48	1.26	4.21
4	--	--	--	--	--	--	3000	0.50	1.30	4.34
4	--	--	--	--	--	--	3000	0.50	1.30	4.34
5	27	0.62	16.74	0.96	0.86	4.58	--	--	--	--
5	27	0.62	16.74	0.96	0.86	4.76	--	--	--	--
5	27	0.62	16.74	0.96	0.86	4.95	--	--	--	--
5	27	0.62	16.74	0.96	0.86	5.14	--	--	--	--
6	32	0.62	19.84	1.37	0.81	8.47	--	--	--	--
6	32	0.62	19.84	1.37	0.81	8.83	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.17
7	--	--	--	--	--	--	1000	1.00	0.95	3.17
7	--	--	--	--	--	--	1000	1.00	0.95	3.17
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations: Nordlund Method (Cohesionless Soils)						Cohesive Soils	
	ϕ' (deg)	α_t	N'_q	p'_v	q_L	Unit Tip Resistance (ksf)	s_u (psf)	Unit Tip Resistance (ksf)
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	27
2	27	0.5	20	1000	13.5	10.0	--	0
2	27	0.5	20	1450	13.5	13.5	--	0
2	27	0.5	20	1900	13.5	13.5	--	0
2	27	0.5	20	2350	13.5	13.5	--	0
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
6	32	0.54	40	3200	33	33.0	--	0
6	32	0.54	40	3200	33	33.0	--	0
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6463	0.45	0.61	1.38	10.00	3.99	5.37
2	15	6458	0.45	0.97	3.57	13.50	5.39	8.96
2	20	6453	0.45	1.33	6.56	13.50	5.39	11.95
2	25	6448	0.45	1.69	10.35	13.50	5.39	15.74
3	30	6443	0.35	4.11	17.54	22.50	6.98	24.52
3	35	6438	0.35	4.38	25.20	22.50	6.98	32.18
3	40	6433	0.35	4.64	33.32	22.50	6.98	40.30
4	45	6428	0.35	4.21	40.69	27.00	8.38	49.07
4	50	6423	0.35	4.34	48.29	27.00	8.38	56.67
4	55	6418	0.35	4.34	55.89	27.00	8.38	64.27
5	60	6413	0.45	4.58	66.18	13.50	5.39	71.57
5	65	6408	0.45	4.76	76.90	13.50	5.39	82.29
5	70	6403	0.45	4.95	88.05	13.50	5.39	93.44
5	75	6398	0.45	5.14	99.62	13.50	5.39	105.01
6	80	6393	0.45	8.47	118.68	33.00	13.17	131.84
6	85	6388	0.45	8.83	138.55	33.00	13.17	151.72
7	90	6383	0.35	3.17	144.10	9.00	2.79	146.90
7	95	6378	0.35	3.17	149.66	9.00	2.79	152.45
7	100	6373	0.35	3.17	155.21	9.00	2.79	158.00
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	110	--	3000	5
2	Silty	0.45	90	27	--	25
3	Cohesive	0.35	100	--	2500	40
4	Cohesive	0.35	120	--	3000	55
5	Silty	0.45	110	27	--	75
6	Cohesionless	0.45	120	32	--	85
7	Cohesive	0.35	120	--	1000	100
8		0.45				

Pile Inputs

Pile Type:	PP14x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	14.00	
End Area [sf]:	0.147	(open end - unplugged)
End Area [sf]:	1.069	(open end - plugged)
End Area [sf]:	1.069	(closed end)
Perimeter [ft]:	3.67	
Volume[cf/ft]:	1.069	(closed end)
δ/ϕ:	0.67	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	636	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP14x0.5		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	1.00	0.85	2.00	0.90	1.069	0.85	0.90
26	1.00	0.91	2.00	0.96	1.069	0.91	0.89
27	1.00	0.97	2.00	1.03	1.069	0.98	0.88
28	1.00	1.03	2.00	1.10	1.069	1.04	0.88
29	1.00	1.09	2.00	1.17	1.069	1.10	0.87
30	1.00	1.15	2.00	1.24	1.069	1.16	0.87
31	1.00	1.27	2.00	1.38	1.069	1.28	0.86
32	1.00	1.39	2.00	1.52	1.069	1.40	0.85
33	1.00	1.51	2.00	1.65	1.069	1.52	0.84
34	1.00	1.63	2.00	1.79	1.069	1.65	0.83
35	1.00	1.75	2.00	1.93	1.069	1.77	0.82
36	1.00	2.00	2.00	2.22	1.069	2.02	0.80
37	1.00	2.25	2.00	2.51	1.069	2.28	0.78
38	1.00	2.50	2.00	2.81	1.069	2.53	0.77
39	1.00	2.75	2.00	3.10	1.069	2.78	0.76
40	1.00	3.00	2.00	3.39	1.069	3.04	0.76

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_{δ}	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	2.94
2	27	0.67	18.09	0.98	0.88	0.76	--	--	--	--
2	27	0.67	18.09	0.98	0.88	1.20	--	--	--	--
2	27	0.67	18.09	0.98	0.88	1.64	--	--	--	--
2	27	0.67	18.09	0.98	0.88	2.08	--	--	--	--
3	--	--	--	--	--	--	2500	0.54	1.19	4.38
3	--	--	--	--	--	--	2500	0.58	1.27	4.65
3	--	--	--	--	--	--	2500	0.61	1.34	4.92
4	--	--	--	--	--	--	3000	0.46	1.20	4.42
4	--	--	--	--	--	--	3000	0.49	1.28	4.68
4	--	--	--	--	--	--	3000	0.50	1.30	4.77
5	27	0.67	18.09	0.98	0.88	5.65	--	--	--	--
5	27	0.67	18.09	0.98	0.88	5.88	--	--	--	--
5	27	0.67	18.09	0.98	0.88	6.11	--	--	--	--
5	27	0.67	18.09	0.98	0.88	6.34	--	--	--	--
6	32	0.67	21.44	1.40	0.85	10.79	--	--	--	--
6	32	0.67	21.44	1.40	0.85	11.25	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.49
7	--	--	--	--	--	--	1000	1.00	0.95	3.49
7	--	--	--	--	--	--	1000	1.00	0.95	3.49
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	27
2	27	0.5	20	1000	13.5	10.0	--	0
2	27	0.5	20	1450	13.5	13.5	--	0
2	27	0.5	20	1900	13.5	13.5	--	0
2	27	0.5	20	2350	13.5	13.5	--	0
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
6	32	0.54	40	3200	33	33.0	--	0
6	32	0.54	40	3200	33	33.0	--	0
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6463	0.45	0.76	1.71	10.00	4.81	6.52
2	15	6458	0.45	1.20	4.40	13.50	6.49	10.90
2	20	6453	0.45	1.64	8.09	13.50	6.49	14.59
2	25	6448	0.45	2.08	12.77	13.50	6.49	19.26
3	30	6443	0.35	4.38	20.44	22.50	8.42	28.86
3	35	6438	0.35	4.65	28.58	22.50	8.42	37.00
3	40	6433	0.35	4.92	37.18	22.50	8.42	45.60
4	45	6428	0.35	4.42	44.92	27.00	10.10	55.02
4	50	6423	0.35	4.68	53.12	27.00	10.10	63.22
4	55	6418	0.35	4.77	61.47	27.00	10.10	71.57
5	60	6413	0.45	5.65	74.17	13.50	6.49	80.66
5	65	6408	0.45	5.88	87.39	13.50	6.49	93.89
5	70	6403	0.45	6.11	101.14	13.50	6.49	107.64
5	75	6398	0.45	6.34	115.42	13.50	6.49	121.91
6	80	6393	0.45	10.79	139.69	33.00	15.87	155.57
6	85	6388	0.45	11.25	165.00	33.00	15.87	180.88
7	90	6383	0.35	3.49	171.10	9.00	3.37	174.47
7	95	6378	0.35	3.49	177.21	9.00	3.37	180.57
7	100	6373	0.35	3.49	183.31	9.00	3.37	186.67
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs		
Project No.:	17-2015-4045	
Project:	BIA Route N8065	
Structure:	West Abutment, Pile Foundation, No Scour	
Corresponding Boring:	BS-5/BS-6	
Depth to Groundwater Table [ft]:	55	
Ground Elevation [ft]:	6473	
Depth of Scour [ft]:	0	Not used in calculations.
Resistance Factor [clay]:	0.35	
Resistance Factor [sand]:	0.45	
Atmospheric Pressure (p_a) [pcf]:	2116	

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	110	--	3000	5
2	Silty	0.45	90	27	--	25
3	Cohesive	0.35	100	--	2500	40
4	Cohesive	0.35	120	--	3000	55
5	Silty	0.45	110	27	--	75
6	Cohesionless	0.45	120	32	--	85
7	Cohesive	0.35	120	--	1000	100
8		0.45				

Pile Inputs		
Pile Type:	PP16x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	16.00	
End Area [sf]:	0.169	(open end - unplugged)
End Area [sf]:	1.396	(open end - plugged)
End Area [sf]:	1.396	(closed end)
Perimeter [ft]:	4.19	
Volume[cf/ft]:	1.396	(closed end)
δ/ϕ:	0.73	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	730	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP16x0.5		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	1.00	0.85	2.00	0.90	1.396	0.87	0.92
26	1.00	0.91	2.00	0.96	1.396	0.93	0.91
27	1.00	0.97	2.00	1.03	1.396	1.00	0.90
28	1.00	1.03	2.00	1.10	1.396	1.06	0.90
29	1.00	1.09	2.00	1.17	1.396	1.13	0.89
30	1.00	1.15	2.00	1.24	1.396	1.19	0.88
31	1.00	1.27	2.00	1.38	1.396	1.32	0.87
32	1.00	1.39	2.00	1.52	1.396	1.45	0.87
33	1.00	1.51	2.00	1.65	1.396	1.58	0.86
34	1.00	1.63	2.00	1.79	1.396	1.71	0.86
35	1.00	1.75	2.00	1.93	1.396	1.84	0.85
36	1.00	2.00	2.00	2.22	1.396	2.11	0.85
37	1.00	2.25	2.00	2.51	1.396	2.38	0.84
38	1.00	2.50	2.00	2.81	1.396	2.65	0.83
39	1.00	2.75	2.00	3.10	1.396	2.92	0.82
40	1.00	3.00	2.00	3.39	1.396	3.19	0.80

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	3.35
2	27	0.73	19.71	1.00	0.90	0.98	--	--	--	--
2	27	0.73	19.71	1.00	0.90	1.56	--	--	--	--
2	27	0.73	19.71	1.00	0.90	2.13	--	--	--	--
2	27	0.73	19.71	1.00	0.90	2.70	--	--	--	--
3	--	--	--	--	--	--	2500	0.52	1.15	4.81
3	--	--	--	--	--	--	2500	0.55	1.21	5.08
3	--	--	--	--	--	--	2500	0.58	1.28	5.35
4	--	--	--	--	--	--	3000	0.43	1.13	4.75
4	--	--	--	--	--	--	3000	0.46	1.20	5.01
4	--	--	--	--	--	--	3000	0.48	1.26	5.27
5	27	0.73	19.71	1.00	0.90	7.33	--	--	--	--
5	27	0.73	19.71	1.00	0.90	7.63	--	--	--	--
5	27	0.73	19.71	1.00	0.90	7.93	--	--	--	--
5	27	0.73	19.71	1.00	0.90	8.24	--	--	--	--
6	32	0.73	23.36	1.45	0.87	14.16	--	--	--	--
6	32	0.73	23.36	1.45	0.87	14.77	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.98
7	--	--	--	--	--	--	1000	1.00	0.95	3.98
7	--	--	--	--	--	--	1000	1.00	0.95	3.98
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	27
2	27	0.5	20	1000	13.5	10.0	--	0
2	27	0.5	20	1450	13.5	13.5	--	0
2	27	0.5	20	1900	13.5	13.5	--	0
2	27	0.5	20	2350	13.5	13.5	--	0
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
3	--	--	--	--	--	--	2500	22.5
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
4	--	--	--	--	--	--	3000	27
5	27	0.38	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
5	27	0.37	20	3200	13.5	13.5	--	0
6	32	0.54	40	3200	33	33.0	--	0
6	32	0.54	40	3200	33	33.0	--	0
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
7	--	--	--	--	--	--	1000	9
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6463	0.45	0.98	2.22	10.00	6.28	8.50
2	15	6458	0.45	1.56	5.72	13.50	8.48	14.20
2	20	6453	0.45	2.13	10.50	13.50	8.48	18.99
2	25	6448	0.45	2.70	16.58	13.50	8.48	25.06
3	30	6443	0.35	4.81	25.00	22.50	11.00	36.00
3	35	6438	0.35	5.08	33.89	22.50	11.00	44.89
3	40	6433	0.35	5.35	43.25	22.50	11.00	54.25
4	45	6428	0.35	4.75	51.56	27.00	13.19	64.76
4	50	6423	0.35	5.01	60.33	27.00	13.19	73.52
4	55	6418	0.35	5.27	69.56	27.00	13.19	82.75
5	60	6413	0.45	7.33	86.05	13.50	8.48	94.53
5	65	6408	0.45	7.63	103.22	13.50	8.48	111.70
5	70	6403	0.45	7.93	121.07	13.50	8.48	129.55
5	75	6398	0.45	8.24	139.60	13.50	8.48	148.08
6	80	6393	0.45	14.16	171.47	33.00	20.73	192.20
6	85	6388	0.45	14.77	204.70	33.00	20.73	225.43
7	90	6383	0.35	3.98	211.66	9.00	4.40	216.06
7	95	6378	0.35	3.98	218.63	9.00	4.40	223.03
7	100	6373	0.35	3.98	225.59	9.00	4.40	229.99
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

PIER

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	0	--	500	6.5
2	Cohesionless	0.45	120	32	--	30
3	Cohesive	0.35	120	--	1000	45
4	Cohesionless	0.45	125	34	--	80
5	Cohesionless	0.45	120	32	--	100
6		0.45				
7		0.45				
8		0.45				

Pile Inputs

Pile Type:	PP12-3/4x0.375	Select from drop down menu
Wall Thickness [in]:	0.375	
Outside Diameter [in]:	12.75	
End Area [sf]:	0.101	(open end - unplugged)
End Area [sf]:	0.887	(open end - plugged)
End Area [sf]:	0.887	(closed end)
Perimeter [ft]:	3.34	
Volume[cf/ft]:	0.887	(closed end)
δ/ϕ:	0.62	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	437	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP12-3/4x0.375		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.80	0.84	0.90	0.84	0.887	0.84	0.88
26	0.80	0.89	0.90	0.90	0.887	0.90	0.87
27	0.80	0.95	0.90	0.96	0.887	0.96	0.86
28	0.80	1.01	0.90	1.02	0.887	1.02	0.85
29	0.80	1.06	0.90	1.08	0.887	1.08	0.84
30	0.80	1.12	0.90	1.14	0.887	1.14	0.83
31	0.80	1.24	0.90	1.25	0.887	1.25	0.82
32	0.80	1.35	0.90	1.37	0.887	1.37	0.81
33	0.80	1.46	0.90	1.49	0.887	1.49	0.79
34	0.80	1.58	0.90	1.61	0.887	1.61	0.78
35	0.80	1.69	0.90	1.72	0.887	1.72	0.77
36	0.80	1.93	0.90	1.97	0.887	1.96	0.76
37	0.80	2.16	0.90	2.21	0.887	2.20	0.75
38	0.80	2.40	0.90	2.45	0.887	2.44	0.74
39	0.80	2.64	0.90	2.70	0.887	2.69	0.71
40	0.80	2.87	0.90	2.94	0.887	2.93	0.70

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	**BS-3**	**BS-4**	**Average**
6473	0	2	6	4
6468	5	8	3	6
6463	10	3	3	3
6458	15	4	5	5
6453	20	7	9	8
6448	25	6	17	12
6443	30	12	9	11
6438	35	13	7	10
6433	40	8	5	7
6428	45	7	5	6
6423	50	16	9	13
6418	55	10	19	15
6413	60	19	23	21
6408	65	32	18	25
6403	70	12	13	13
6398	75	32	12	22
6393	80	8	12	10
6388	85	12	3	8
6383	90	18	6	12
6378	95	10	11	11
6373	100	11	11	11

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
7	1		
30	2	2820	2820
45	3	4620	4620
80	4	8995	7435
100	5	11395	8587
0	6	11395	11395
0	7	11395	11395
0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	--	0	0	0	0	Cohesive	4	0
2	5	7.5	10	120	--	300	420	420	300	Cohesionless	6	8
2	10	12.5	15	120	--	720	1020	1020	720	Cohesionless	3	4
2	15	17.5	20	120	--	1320	1620	1620	1320	Cohesionless	5	5
2	20	22.5	25	120	--	1920	2220	2220	1920	Cohesionless	8	8
2	25	27.5	30	120	--	2520	2820	2820	2520	Cohesionless	12	10
3	30	32.5	35	120	--	3120	3420	3420	3120	Cohesive	11	9
3	35	37.5	40	120	--	3720	4020	4020	3720	Cohesive	10	8
3	40	42.5	45	120	--	4320	4620	4620	4320	Cohesive	7	5
4	45	47.5	50	125	--	4932.5	5245	5245	4932.5	Cohesionless	6	4
4	50	52.5	55	125	--	5557.5	5870	5870	5557.5	Cohesionless	13	8
4	55	57.5	60	125	62.4	6182.5	6495	6183	6026.5	Cohesionless	15	9
4	60	62.5	65	125	62.4	6807.5	7120	6496	6339.5	Cohesionless	21	13
4	65	67.5	70	125	62.4	7432.5	7745	6809	6652.5	Cohesionless	25	15
4	70	72.5	75	125	62.4	8057.5	8370	7122	6965.5	Cohesionless	13	7
4	75	77.5	80	125	62.4	8682.5	8995	7435	7278.5	Cohesionless	22	12
5	80	82.5	85	120	62.4	9295	9595	7723	7579	Cohesionless	10	5
5	85	87.5	90	120	62.4	9895	10195	8011	7867	Cohesionless	8	4
5	90	92.5	95	120	62.4	10495	10795	8299	8155	Cohesionless	12	6
5	95	97.5	100	120	62.4	11095	11395	8587	8443	Cohesionless	11	5
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (ksf)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.62	19.84	1.37	0.81	0.38	--	--	--	--
2	32	0.62	19.84	1.37	0.81	0.90	--	--	--	--
2	32	0.62	19.84	1.37	0.81	1.66	--	--	--	--
2	32	0.62	19.84	1.37	0.81	2.41	--	--	--	--
2	32	0.62	19.84	1.37	0.81	3.16	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.89	0.89
3	--	--	--	--	--	--	1000	1.00	0.91	0.91
3	--	--	--	--	--	--	1000	1.00	0.94	0.94
4	34	0.62	21.08	1.61	0.78	7.42	--	--	--	--
4	34	0.62	21.08	1.61	0.78	8.36	--	--	--	--
4	34	0.62	21.08	1.61	0.78	9.07	--	--	--	--
4	34	0.62	21.08	1.61	0.78	9.54	--	--	--	--
4	34	0.62	21.08	1.61	0.78	10.01	--	--	--	--
4	34	0.62	21.08	1.61	0.78	10.48	--	--	--	--
4	34	0.62	21.08	1.61	0.78	10.95	--	--	--	--
5	32	0.62	19.84	1.37	0.81	9.52	--	--	--	--
5	32	0.62	19.84	1.37	0.81	9.88	--	--	--	--
5	32	0.62	19.84	1.37	0.81	10.24	--	--	--	--
5	32	0.62	19.84	1.37	0.81	10.60	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0
2	32	0.61	40	420	33	10.2	--	0
2	32	0.61	40	1020	33	24.9	--	0
2	32	0.61	40	1620	33	33.0	--	0
2	32	0.61	40	2220	33	33.0	--	0
2	32	0.6	40	2820	33	33.0	--	0
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
4	34	0.62	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6463	0.45	0.38	0.85	10.25	4.09	4.94
2	15	6458	0.45	0.90	2.88	24.89	9.93	12.81
2	20	6453	0.45	1.66	6.61	33.00	13.17	19.78
2	25	6448	0.45	2.41	12.03	33.00	13.17	25.20
2	30	6443	0.45	3.16	19.15	33.00	13.17	32.32
3	35	6438	0.35	0.89	20.71	9.00	2.79	23.51
3	40	6433	0.35	0.91	22.31	9.00	2.79	25.11
3	45	6428	0.35	0.94	23.96	9.00	2.79	26.75
4	50	6423	0.45	7.42	40.66	75.00	29.92	70.58
4	55	6418	0.45	8.36	59.48	75.00	29.92	89.40
4	60	6413	0.45	9.07	79.89	75.00	29.92	109.81
4	65	6408	0.45	9.54	101.35	75.00	29.92	131.28
4	70	6403	0.45	10.01	123.88	75.00	29.92	153.81
4	75	6398	0.45	10.48	147.47	75.00	29.92	177.39
4	80	6393	0.45	10.95	172.12	75.00	29.92	202.04
5	85	6388	0.45	9.52	193.53	33.00	13.17	206.69
5	90	6383	0.45	9.88	215.75	33.00	13.17	228.92
5	95	6378	0.45	10.24	238.79	33.00	13.17	251.96
5	100	6373	0.45	10.60	262.64	33.00	13.17	275.81
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	0	--	500	6.5
2	Cohesionless	0.45	120	32	--	30
3	Cohesive	0.35	120	--	1000	45
4	Cohesionless	0.45	125	34	--	80
5	Cohesionless	0.45	120	32	--	100
6		0.45				
7		0.45				
8		0.45				

Pile Inputs

Pile Type:	PP14x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	14.00	
End Area [sf]:	0.147	(open end - unplugged)
End Area [sf]:	1.069	(open end - plugged)
End Area [sf]:	1.069	(closed end)
Perimeter [ft]:	3.67	
Volume[cf/ft]:	1.069	(closed end)
δ/ϕ:	0.67	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	636	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP14x0.5		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	1.00	0.85	2.00	0.90	1.069	0.85	0.90
26	1.00	0.91	2.00	0.96	1.069	0.91	0.89
27	1.00	0.97	2.00	1.03	1.069	0.98	0.88
28	1.00	1.03	2.00	1.10	1.069	1.04	0.88
29	1.00	1.09	2.00	1.17	1.069	1.10	0.87
30	1.00	1.15	2.00	1.24	1.069	1.16	0.87
31	1.00	1.27	2.00	1.38	1.069	1.28	0.86
32	1.00	1.39	2.00	1.52	1.069	1.40	0.85
33	1.00	1.51	2.00	1.65	1.069	1.52	0.84
34	1.00	1.63	2.00	1.79	1.069	1.65	0.83
35	1.00	1.75	2.00	1.93	1.069	1.77	0.82
36	1.00	2.00	2.00	2.22	1.069	2.02	0.80
37	1.00	2.25	2.00	2.51	1.069	2.28	0.78
38	1.00	2.50	2.00	2.81	1.069	2.53	0.77
39	1.00	2.75	2.00	3.10	1.069	2.78	0.76
40	1.00	3.00	2.00	3.39	1.069	3.04	0.76

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6473	0	2	6	4
6468	5	8	3	6
6463	10	3	3	3
6458	15	4	5	5
6453	20	7	9	8
6448	25	6	17	12
6443	30	12	9	11
6438	35	13	7	10
6433	40	8	5	7
6428	45	7	5	6
6423	50	16	9	13
6418	55	10	19	15
6413	60	19	23	21
6408	65	32	18	25
6403	70	12	13	13
6398	75	32	12	22
6393	80	8	12	10
6388	85	12	3	8
6383	90	18	6	12
6378	95	10	11	11
6373	100	11	11	11

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	7	1		
Project:	BIA Route N8065	30	2	2820	2820
Structure:	Piers, Pile Foundation, Scour	45	3	4620	4620
Corresponding Boring:	BS-3/BS-4	80	4	8995	7435
Groundwater Table [ft]:	55	100	5	11395	8587
Depth of Scour [ft]:	0	0	6	11395	11395
γ_w [pcf]:	62.4	0	7	11395	11395
		0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	--	0	0	0	0	Cohesive	4	0
2	5	7.5	10	120	--	300	420	420	300	Cohesionless	6	8
2	10	12.5	15	120	--	720	1020	1020	720	Cohesionless	3	4
2	15	17.5	20	120	--	1320	1620	1620	1320	Cohesionless	5	5
2	20	22.5	25	120	--	1920	2220	2220	1920	Cohesionless	8	8
2	25	27.5	30	120	--	2520	2820	2820	2520	Cohesionless	12	10
3	30	32.5	35	120	--	3120	3420	3420	3120	Cohesive	11	9
3	35	37.5	40	120	--	3720	4020	4020	3720	Cohesive	10	8
3	40	42.5	45	120	--	4320	4620	4620	4320	Cohesive	7	5
4	45	47.5	50	125	--	4932.5	5245	5245	4932.5	Cohesionless	6	4
4	50	52.5	55	125	--	5557.5	5870	5870	5557.5	Cohesionless	13	8
4	55	57.5	60	125	62.4	6182.5	6495	6183	6026.5	Cohesionless	15	9
4	60	62.5	65	125	62.4	6807.5	7120	6496	6339.5	Cohesionless	21	13
4	65	67.5	70	125	62.4	7432.5	7745	6809	6652.5	Cohesionless	25	15
4	70	72.5	75	125	62.4	8057.5	8370	7122	6965.5	Cohesionless	13	7
4	75	77.5	80	125	62.4	8682.5	8995	7435	7278.5	Cohesionless	22	12
5	80	82.5	85	120	62.4	9295	9595	7723	7579	Cohesionless	10	5
5	85	87.5	90	120	62.4	9895	10195	8011	7867	Cohesionless	8	4
5	90	92.5	95	120	62.4	10495	10795	8299	8155	Cohesionless	12	6
5	95	97.5	100	120	62.4	11095	11395	8587	8443	Cohesionless	11	5
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.67	21.44	1.40	0.85	0.48	--	--	--	--
2	32	0.67	21.44	1.40	0.85	1.15	--	--	--	--
2	32	0.67	21.44	1.40	0.85	2.11	--	--	--	--
2	32	0.67	21.44	1.40	0.85	3.07	--	--	--	--
2	32	0.67	21.44	1.40	0.85	4.03	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.88	3.22
3	--	--	--	--	--	--	1000	1.00	0.90	3.30
3	--	--	--	--	--	--	1000	1.00	0.92	3.38
4	34	0.67	22.78	1.65	0.83	9.57	--	--	--	--
4	34	0.67	22.78	1.65	0.83	10.79	--	--	--	--
4	34	0.67	22.78	1.65	0.83	11.70	--	--	--	--
4	34	0.67	22.78	1.65	0.83	12.30	--	--	--	--
4	34	0.67	22.78	1.65	0.83	12.91	--	--	--	--
4	34	0.67	22.78	1.65	0.83	13.52	--	--	--	--
4	34	0.67	22.78	1.65	0.83	14.12	--	--	--	--
5	32	0.67	21.44	1.40	0.85	12.12	--	--	--	--
5	32	0.67	21.44	1.40	0.85	12.58	--	--	--	--
5	32	0.67	21.44	1.40	0.85	13.04	--	--	--	--
5	32	0.67	21.44	1.40	0.85	13.50	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0
2	32	0.61	40	420	33	10.2	--	0
2	32	0.61	40	1020	33	24.9	--	0
2	32	0.61	40	1620	33	33.0	--	0
2	32	0.61	40	2220	33	33.0	--	0
2	32	0.61	40	2820	33	33.0	--	0
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
4	34	0.62	53	3200	75	75.0	--	0
4	34	0.62	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6463	0.45	0.48	1.08	10.25	4.93	6.01
2	15	6458	0.45	1.15	3.67	24.89	11.97	15.64
2	20	6453	0.45	2.11	8.42	33.00	15.87	24.29
2	25	6448	0.45	3.07	15.33	33.00	15.87	31.20
2	30	6443	0.45	4.03	24.40	33.00	15.87	40.27
3	35	6438	0.35	3.22	30.04	9.00	3.37	33.41
3	40	6433	0.35	3.30	35.82	9.00	3.37	39.19
3	45	6428	0.35	3.38	41.74	9.00	3.37	45.10
4	50	6423	0.45	9.57	63.27	75.00	36.08	99.35
4	55	6418	0.45	10.79	87.54	75.00	36.08	123.62
4	60	6413	0.45	11.70	113.86	75.00	36.08	149.93
4	65	6408	0.45	12.30	141.54	75.00	36.08	177.62
4	70	6403	0.45	12.91	170.58	75.00	36.08	206.66
4	75	6398	0.45	13.52	201.00	75.00	36.08	237.08
4	80	6393	0.45	14.12	232.78	75.00	36.08	268.86
5	85	6388	0.45	12.12	260.05	33.00	15.87	275.93
5	90	6383	0.45	12.58	288.36	33.00	15.87	304.23
5	95	6378	0.45	13.04	317.70	33.00	15.87	333.58
5	100	6373	0.45	13.50	348.08	33.00	15.87	363.96
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	0	--	500	6.5
2	Cohesionless	0.45	120	32	--	30
3	Cohesive	0.35	120	--	1000	45
4	Cohesionless	0.45	125	34	--	80
5	Cohesionless	0.45	120	32	--	100
6		0.45				
7		0.45				
8		0.45				

Pile Inputs

Pile Type:	PP16x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	16.00	
End Area [sf]:	0.169	(open end - unplugged)
End Area [sf]:	1.396	(open end - plugged)
End Area [sf]:	1.396	(closed end)
Perimeter [ft]:	4.19	
Volume[cf/ft]:	1.396	(closed end)
δ/ϕ:	0.73	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	730	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP16x0.5		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	1.00	0.85	2.00	0.90	1.396	0.87	0.92
26	1.00	0.91	2.00	0.96	1.396	0.93	0.91
27	1.00	0.97	2.00	1.03	1.396	1.00	0.90
28	1.00	1.03	2.00	1.10	1.396	1.06	0.90
29	1.00	1.09	2.00	1.17	1.396	1.13	0.89
30	1.00	1.15	2.00	1.24	1.396	1.19	0.88
31	1.00	1.27	2.00	1.38	1.396	1.32	0.87
32	1.00	1.39	2.00	1.52	1.396	1.45	0.87
33	1.00	1.51	2.00	1.65	1.396	1.58	0.86
34	1.00	1.63	2.00	1.79	1.396	1.71	0.86
35	1.00	1.75	2.00	1.93	1.396	1.84	0.85
36	1.00	2.00	2.00	2.22	1.396	2.11	0.85
37	1.00	2.25	2.00	2.51	1.396	2.38	0.84
38	1.00	2.50	2.00	2.81	1.396	2.65	0.83
39	1.00	2.75	2.00	3.10	1.396	2.92	0.82
40	1.00	3.00	2.00	3.39	1.396	3.19	0.80

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6473	0	2	6	4
6468	5	8	3	6
6463	10	3	3	3
6458	15	4	5	5
6453	20	7	9	8
6448	25	6	17	12
6443	30	12	9	11
6438	35	13	7	10
6433	40	8	5	7
6428	45	7	5	6
6423	50	16	9	13
6418	55	10	19	15
6413	60	19	23	21
6408	65	32	18	25
6403	70	12	13	13
6398	75	32	12	22
6393	80	8	12	10
6388	85	12	3	8
6383	90	18	6	12
6378	95	10	11	11
6373	100	11	11	11

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
7	1		
30	2	2820	2820
45	3	4620	4620
80	4	8995	7435
100	5	11395	8587
0	6	11395	11395
0	7	11395	11395
0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	--	0	0	0	0	Cohesive	4	0
2	5	7.5	10	120	--	300	420	420	300	Cohesionless	6	8
2	10	12.5	15	120	--	720	1020	1020	720	Cohesionless	3	4
2	15	17.5	20	120	--	1320	1620	1620	1320	Cohesionless	5	5
2	20	22.5	25	120	--	1920	2220	2220	1920	Cohesionless	8	8
2	25	27.5	30	120	--	2520	2820	2820	2520	Cohesionless	12	10
3	30	32.5	35	120	--	3120	3420	3420	3120	Cohesive	11	9
3	35	37.5	40	120	--	3720	4020	4020	3720	Cohesive	10	8
3	40	42.5	45	120	--	4320	4620	4620	4320	Cohesive	7	5
4	45	47.5	50	125	--	4932.5	5245	5245	4932.5	Cohesionless	6	4
4	50	52.5	55	125	--	5557.5	5870	5870	5557.5	Cohesionless	13	8
4	55	57.5	60	125	62.4	6182.5	6495	6183	6026.5	Cohesionless	15	9
4	60	62.5	65	125	62.4	6807.5	7120	6496	6339.5	Cohesionless	21	13
4	65	67.5	70	125	62.4	7432.5	7745	6809	6652.5	Cohesionless	25	15
4	70	72.5	75	125	62.4	8057.5	8370	7122	6965.5	Cohesionless	13	7
4	75	77.5	80	125	62.4	8682.5	8995	7435	7278.5	Cohesionless	22	12
5	80	82.5	85	120	62.4	9295	9595	7723	7579	Cohesionless	10	5
5	85	87.5	90	120	62.4	9895	10195	8011	7867	Cohesionless	8	4
5	90	92.5	95	120	62.4	10495	10795	8299	8155	Cohesionless	12	6
5	95	97.5	100	120	62.4	11095	11395	8587	8443	Cohesionless	11	5
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.73	23.36	1.45	0.87	0.63	--	--	--	--
2	32	0.73	23.36	1.45	0.87	1.51	--	--	--	--
2	32	0.73	23.36	1.45	0.87	2.77	--	--	--	--
2	32	0.73	23.36	1.45	0.87	4.03	--	--	--	--
2	32	0.73	23.36	1.45	0.87	5.29	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.86	3.61
3	--	--	--	--	--	--	1000	1.00	0.88	3.69
3	--	--	--	--	--	--	1000	1.00	0.90	3.77
4	34	0.73	24.82	1.71	0.86	12.74	--	--	--	--
4	34	0.73	24.82	1.71	0.86	14.35	--	--	--	--
4	34	0.73	24.82	1.71	0.86	15.56	--	--	--	--
4	34	0.73	24.82	1.71	0.86	16.37	--	--	--	--
4	34	0.73	24.82	1.71	0.86	17.18	--	--	--	--
4	34	0.73	24.82	1.71	0.86	17.99	--	--	--	--
4	34	0.73	24.82	1.71	0.86	18.79	--	--	--	--
5	32	0.73	23.36	1.45	0.87	15.91	--	--	--	--
5	32	0.73	23.36	1.45	0.87	16.52	--	--	--	--
5	32	0.73	23.36	1.45	0.87	17.12	--	--	--	--
5	32	0.73	23.36	1.45	0.87	17.73	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0
2	32	0.61	40	420	33	10.2	--	0
2	32	0.61	40	1020	33	24.9	--	0
2	32	0.61	40	1620	33	33.0	--	0
2	32	0.61	40	2220	33	33.0	--	0
2	32	0.61	40	2820	33	33.0	--	0
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
3	--	--	--	--	--	--	1000	9
4	34	0.62	53	3200	75	75.0	--	0
4	34	0.62	53	3200	75	75.0	--	0
4	34	0.62	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
4	34	0.61	53	3200	75	75.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
5	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
2	10	6463	0.45	0.63	1.42	10.25	6.44	7.86
2	15	6458	0.45	1.51	4.82	24.89	15.64	20.46
2	20	6453	0.45	2.77	11.05	33.00	20.73	31.79
2	25	6448	0.45	4.03	20.12	33.00	20.73	40.86
2	30	6443	0.45	5.29	32.03	33.00	20.73	52.76
3	35	6438	0.35	3.61	38.35	9.00	4.40	42.75
3	40	6433	0.35	3.69	44.82	9.00	4.40	49.21
3	45	6428	0.35	3.77	51.41	9.00	4.40	55.81
4	50	6423	0.45	12.74	80.07	75.00	47.12	127.19
4	55	6418	0.45	14.35	112.36	75.00	47.12	159.48
4	60	6413	0.45	15.56	147.37	75.00	47.12	194.49
4	65	6408	0.45	16.37	184.20	75.00	47.12	231.32
4	70	6403	0.45	17.18	222.85	75.00	47.12	269.97
4	75	6398	0.45	17.99	263.32	75.00	47.12	310.44
4	80	6393	0.45	18.79	305.60	75.00	47.12	352.73
5	85	6388	0.45	15.91	341.41	33.00	20.73	362.14
5	90	6383	0.45	16.52	378.57	33.00	20.73	399.30
5	95	6378	0.45	17.12	417.09	33.00	20.73	437.83
5	100	6373	0.45	17.73	456.98	33.00	20.73	477.71
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

EAST ABUTMENT

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	100	--	2500	30
2	Cohesive	0.35	120	--	4000	55
3	Cohesionless	0.45	120	30	--	65
4	Silty	0.45	110	27	--	80
5	Cohesive	0.35	120	--	1000	95
6	Cohesionless	0.45	125	32	--	100
7		0.45				
8		0.45				

Pile Inputs

Pile Type:	PP12-3/4x0.375	Select from drop down menu
Wall Thickness [in]:	0.375	
Outside Diameter [in]:	12.75	
End Area [sf]:	0.101	(open end - unplugged)
End Area [sf]:	0.887	(open end - plugged)
End Area [sf]:	0.887	(closed end)
Perimeter [ft]:	3.34	
Volume[cf/ft]:	0.887	(closed end)
δ/ϕ:	0.62	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	437	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP12-3/4x0.375		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.80	0.84	0.90	0.84	0.887	0.84	0.88
26	0.80	0.89	0.90	0.90	0.887	0.90	0.87
27	0.80	0.95	0.90	0.96	0.887	0.96	0.86
28	0.80	1.01	0.90	1.02	0.887	1.02	0.85
29	0.80	1.06	0.90	1.08	0.887	1.08	0.84
30	0.80	1.12	0.90	1.14	0.887	1.14	0.83
31	0.80	1.24	0.90	1.25	0.887	1.25	0.82
32	0.80	1.35	0.90	1.37	0.887	1.37	0.81
33	0.80	1.46	0.90	1.49	0.887	1.49	0.79
34	0.80	1.58	0.90	1.61	0.887	1.61	0.78
35	0.80	1.69	0.90	1.72	0.887	1.72	0.77
36	0.80	1.93	0.90	1.97	0.887	1.96	0.76
37	0.80	2.16	0.90	2.21	0.887	2.20	0.75
38	0.80	2.40	0.90	2.45	0.887	2.44	0.74
39	0.80	2.64	0.90	2.70	0.887	2.69	0.71
40	0.80	2.87	0.90	2.94	0.887	2.93	0.70

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
30	1	3000	3000
55	2	6000	6000
65	3	7200	6576
80	4	8850	7290
95	5	10650	8154
100	6	11275	8467
0	7	11275	11275
0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	$K_δ$	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.34
1	--	--	--	--	--	--	2500	0.44	1.00	3.34
1	--	--	--	--	--	--	2500	0.44	1.00	3.34
1	--	--	--	--	--	--	2500	0.48	1.07	3.57
1	--	--	--	--	--	--	2500	0.52	1.15	3.84
1	--	--	--	--	--	--	2500	0.56	1.23	4.11
2	--	--	--	--	--	--	4000	0.28	1.07	3.57
2	--	--	--	--	--	--	4000	0.29	1.14	3.82
2	--	--	--	--	--	--	4000	0.30	1.22	4.07
2	--	--	--	--	--	--	4000	0.31	1.26	4.14
2	--	--	--	--	--	--	4000	0.31	1.26	4.14
3	30	0.62	18.6	1.14	0.83	6.18	--	--	--	--
3	30	0.62	18.6	1.14	0.83	6.47	--	--	--	--
4	27	0.62	16.74	0.96	0.86	5.31	--	--	--	--
4	27	0.62	16.74	0.96	0.86	5.50	--	--	--	--
4	27	0.62	16.74	0.96	0.86	5.69	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.17
5	--	--	--	--	--	--	1000	1.00	0.95	3.17
5	--	--	--	--	--	--	1000	1.00	0.95	3.17
6	32	0.62	19.84	1.37	0.81	10.43	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

	End-Bearing Capacity Calculations							
Layer	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
3	30	0.48	30	3200	13.5	13.5	--	0
3	30	0.48	30	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
6	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
1	10	6463	0.35	3.34	5.85	22.50	6.98	12.83
1	15	6458	0.35	3.34	11.69	22.50	6.98	18.67
1	20	6453	0.35	3.57	17.94	22.50	6.98	24.93
1	25	6448	0.35	3.84	24.67	22.50	6.98	31.65
1	30	6443	0.35	4.11	31.86	22.50	6.98	38.84
2	35	6438	0.35	3.57	38.10	36.00	11.17	49.27
2	40	6433	0.35	3.82	44.79	36.00	11.17	55.96
2	45	6428	0.35	4.07	51.91	36.00	11.17	63.08
2	50	6423	0.35	4.14	59.15	36.00	11.17	70.33
2	55	6418	0.35	4.14	66.40	36.00	11.17	77.57
3	60	6413	0.45	6.18	80.31	13.50	5.39	85.69
3	65	6408	0.45	6.47	94.86	13.50	5.39	100.25
4	70	6403	0.45	5.31	106.81	13.50	5.39	112.20
4	75	6398	0.45	5.50	119.18	13.50	5.39	124.57
4	80	6393	0.45	5.69	131.98	13.50	5.39	137.37
5	85	6388	0.35	3.17	137.53	9.00	2.79	140.33
5	90	6383	0.35	3.17	143.09	9.00	2.79	145.88
5	95	6378	0.35	3.17	148.64	9.00	2.79	151.43
6	100	6373	0.45	10.43	172.12	33.00	13.17	185.28
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	100	--	2500	30
2	Cohesive	0.35	120	--	4000	55
3	Cohesionless	0.45	120	30	--	65
4	Silty	0.45	110	27	--	80
5	Cohesive	0.35	120	--	1000	95
6	Cohesionless	0.45	125	32	--	100
7		0.45				
8		0.45				

H-Pile Inputs

Pile Type:	PP14x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	14.00	
End Area [sf]:	0.147	(open end - unplugged)
End Area [sf]:	1.069	(open end - plugged)
End Area [sf]:	1.069	(closed end)
Perimeter [ft]:	3.67	
Volume[cf/ft]:	1.069	(closed end)
δ/ϕ:	0.67	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	636	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP14x0.5		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	1.00	0.85	2.00	0.90	1.069	0.85	0.90
26	1.00	0.91	2.00	0.96	1.069	0.91	0.89
27	1.00	0.97	2.00	1.03	1.069	0.98	0.88
28	1.00	1.03	2.00	1.10	1.069	1.04	0.88
29	1.00	1.09	2.00	1.17	1.069	1.10	0.87
30	1.00	1.15	2.00	1.24	1.069	1.16	0.87
31	1.00	1.27	2.00	1.38	1.069	1.28	0.86
32	1.00	1.39	2.00	1.52	1.069	1.40	0.85
33	1.00	1.51	2.00	1.65	1.069	1.52	0.84
34	1.00	1.63	2.00	1.79	1.069	1.65	0.83
35	1.00	1.75	2.00	1.93	1.069	1.77	0.82
36	1.00	2.00	2.00	2.22	1.069	2.02	0.80
37	1.00	2.25	2.00	2.51	1.069	2.28	0.78
38	1.00	2.50	2.00	2.81	1.069	2.53	0.77
39	1.00	2.75	2.00	3.10	1.069	2.78	0.76
40	1.00	3.00	2.00	3.39	1.069	3.04	0.76

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
30	1	3000	3000
55	2	6000	6000
65	3	7200	6576
80	4	8850	7290
95	5	10650	8154
100	6	11275	8467
0	7	11275	11275
0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_{δ}	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.67
1	--	--	--	--	--	--	2500	0.44	1.00	3.67
1	--	--	--	--	--	--	2500	0.44	1.00	3.67
1	--	--	--	--	--	--	2500	0.46	1.05	3.85
1	--	--	--	--	--	--	2500	0.50	1.12	4.12
1	--	--	--	--	--	--	2500	0.54	1.19	4.38
2	--	--	--	--	--	--	4000	0.28	1.03	3.77
2	--	--	--	--	--	--	4000	0.29	1.10	4.02
2	--	--	--	--	--	--	4000	0.30	1.17	4.28
2	--	--	--	--	--	--	4000	0.31	1.24	4.50
2	--	--	--	--	--	--	4000	0.31	1.26	4.55
3	30	0.67	20.1	1.16	0.87	7.81	--	--	--	--
3	30	0.67	20.1	1.16	0.87	8.18	--	--	--	--
4	27	0.67	18.09	0.98	0.88	6.55	--	--	--	--
4	27	0.67	18.09	0.98	0.88	6.78	--	--	--	--
4	27	0.67	18.09	0.98	0.88	7.02	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.49
5	--	--	--	--	--	--	1000	1.00	0.95	3.49
5	--	--	--	--	--	--	1000	1.00	0.95	3.49
6	32	0.67	21.44	1.40	0.85	13.29	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
3	30	0.48	30	3200	13.5	13.5	--	0
3	30	0.48	30	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
6	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
1	10	6463	0.35	3.67	6.42	22.50	8.42	14.84
1	15	6458	0.35	3.67	12.85	22.50	8.42	21.26
1	20	6453	0.35	3.85	19.58	22.50	8.42	28.00
1	25	6448	0.35	4.12	26.78	22.50	8.42	35.20
1	30	6443	0.35	4.38	34.45	22.50	8.42	42.87
2	35	6438	0.35	3.77	41.05	36.00	13.47	54.52
2	40	6433	0.35	4.02	48.09	36.00	13.47	61.56
2	45	6428	0.35	4.28	55.58	36.00	13.47	69.05
2	50	6423	0.35	4.50	63.46	36.00	13.47	76.93
2	55	6418	0.35	4.55	71.42	36.00	13.47	84.89
3	60	6413	0.45	7.81	89.00	13.50	6.49	95.49
3	65	6408	0.45	8.18	107.40	13.50	6.49	113.89
4	70	6403	0.45	6.55	122.14	13.50	6.49	128.63
4	75	6398	0.45	6.78	137.40	13.50	6.49	143.90
4	80	6393	0.45	7.02	153.19	13.50	6.49	159.69
5	85	6388	0.35	3.49	159.29	9.00	3.37	162.66
5	90	6383	0.35	3.49	165.39	9.00	3.37	168.76
5	95	6378	0.35	3.49	171.50	9.00	3.37	174.86
6	100	6373	0.45	13.29	201.40	33.00	15.87	217.27
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.35
Resistance Factor [sand]:	0.45
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.35	100	--	2500	30
2	Cohesive	0.35	120	--	4000	55
3	Cohesionless	0.45	120	30	--	65
4	Silty	0.45	110	27	--	80
5	Cohesive	0.35	120	--	1000	95
6	Cohesionless	0.45	125	32	--	100
7		0.45				
8		0.45				

Pile Inputs		
Pile Type:	PP16x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	16.00	
End Area [sf]:	0.169	(open end - unplugged)
End Area [sf]:	1.396	(open end - plugged)
End Area [sf]:	1.396	(closed end)
Perimeter [ft]:	4.19	
Volume[cf/ft]:	1.396	(closed end)
δ/ϕ:	0.73	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	730	

	K_{δ}				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP16x0.5		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	1.00	0.85	2.00	0.90	1.396	0.87	0.92
26	1.00	0.91	2.00	0.96	1.396	0.93	0.91
27	1.00	0.97	2.00	1.03	1.396	1.00	0.90
28	1.00	1.03	2.00	1.10	1.396	1.06	0.90
29	1.00	1.09	2.00	1.17	1.396	1.13	0.89
30	1.00	1.15	2.00	1.24	1.396	1.19	0.88
31	1.00	1.27	2.00	1.38	1.396	1.32	0.87
32	1.00	1.39	2.00	1.52	1.396	1.45	0.87
33	1.00	1.51	2.00	1.65	1.396	1.58	0.86
34	1.00	1.63	2.00	1.79	1.396	1.71	0.86
35	1.00	1.75	2.00	1.93	1.396	1.84	0.85
36	1.00	2.00	2.00	2.22	1.396	2.11	0.85
37	1.00	2.25	2.00	2.51	1.396	2.38	0.84
38	1.00	2.50	2.00	2.81	1.396	2.65	0.83
39	1.00	2.75	2.00	3.10	1.396	2.92	0.82
40	1.00	3.00	2.00	3.39	1.396	3.19	0.80

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

			Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045		30	1	3000	3000
Project:	BIA Route N8065		55	2	6000	6000
Structure:	East Abutment, Pile Foundation, No Scour		65	3	7200	6576
Corresponding Boring:	BS-1/BS-2		80	4	8850	7290
Groundwater Table [ft]:	55		95	5	10650	8154
Depth of Scour [ft]:	0		100	6	11275	8467
γ_w [pcf]:	62.4		0	7	11275	11275
			0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer										
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (ksf)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	4.19
1	--	--	--	--	--	--	2500	0.44	1.00	4.19
1	--	--	--	--	--	--	2500	0.44	1.00	4.19
1	--	--	--	--	--	--	2500	0.45	1.02	4.28
1	--	--	--	--	--	--	2500	0.48	1.09	4.55
1	--	--	--	--	--	--	2500	0.52	1.15	4.81
2	--	--	--	--	--	--	4000	0.27	0.97	4.08
2	--	--	--	--	--	--	4000	0.28	1.04	4.34
2	--	--	--	--	--	--	4000	0.29	1.10	4.60
2	--	--	--	--	--	--	4000	0.30	1.16	4.85
2	--	--	--	--	--	--	4000	0.30	1.22	5.10
3	30	0.73	21.9	1.19	0.88	10.08	--	--	--	--
3	30	0.73	21.9	1.19	0.88	10.56	--	--	--	--
4	27	0.73	19.71	1.00	0.90	8.51	--	--	--	--
4	27	0.73	19.71	1.00	0.90	8.81	--	--	--	--
4	27	0.73	19.71	1.00	0.90	9.11	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.98
5	--	--	--	--	--	--	1000	1.00	0.95	3.98
5	--	--	--	--	--	--	1000	1.00	0.95	3.98
6	32	0.73	23.36	1.45	0.87	17.45	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	End-Bearing Capacity Calculations							
	Nordlund Method (Cohesionless Soils)					Unit Tip Resistance (ksf)	Cohesive Soils	Unit Tip Resistance (ksf)
	ϕ' (deg)	α_t	N'_q	p'_v	q_L		s_u (psf)	
1	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
1	--	--	--	--	--	--	2500	22.5
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
2	--	--	--	--	--	--	4000	36
3	30	0.5	30	3200	13.5	13.5	--	0
3	30	0.48	30	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
4	27	0.37	20	3200	13.5	13.5	--	0
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
5	--	--	--	--	--	--	1000	9
6	32	0.54	40	3200	33	33.0	--	0
8	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Unit Tip Resistance (ksf)	Pile Tip Resistance (kips)	Nominal Bearing Resistance of Piles (kips)
1	0	6473	0.35	0.00	0.00	0.00	0.00	0.00
1	5	6468	0.35	0.00	0.00	0.00	0.00	0.00
1	10	6463	0.35	4.19	7.33	22.50	11.00	18.33
1	15	6458	0.35	4.19	14.67	22.50	11.00	25.66
1	20	6453	0.35	4.28	22.15	22.50	11.00	33.15
1	25	6448	0.35	4.55	30.11	22.50	11.00	41.10
1	30	6443	0.35	4.81	38.53	22.50	11.00	49.53
2	35	6438	0.35	4.08	45.68	36.00	17.59	63.27
2	40	6433	0.35	4.34	53.27	36.00	17.59	70.86
2	45	6428	0.35	4.60	61.31	36.00	17.59	78.90
2	50	6423	0.35	4.85	69.80	36.00	17.59	87.39
2	55	6418	0.35	5.10	78.72	36.00	17.59	96.31
3	60	6413	0.45	10.08	101.41	13.50	8.48	109.89
3	65	6408	0.45	10.56	125.16	13.50	8.48	133.64
4	70	6403	0.45	8.51	144.30	13.50	8.48	152.78
4	75	6398	0.45	8.81	164.11	13.50	8.48	172.60
4	80	6393	0.45	9.11	184.61	13.50	8.48	193.09
5	85	6388	0.35	3.98	191.58	9.00	4.40	195.98
5	90	6383	0.35	3.98	198.54	9.00	4.40	202.94
5	95	6378	0.35	3.98	205.51	9.00	4.40	209.91
6	100	6373	0.45	17.45	244.77	33.00	20.73	265.50
8	--	#VALUE!	0.45	--	#VALUE!	--	#VALUE!	#VALUE!

NOMINAL UPLIFT CAPACITY

DRIVEN H-PILES

WEST ABUTMENT

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	110	--	3000	5
2	Silty	0.35	90	27	--	25
3	Cohesive	0.25	100	--	2500	40
4	Cohesive	0.25	120	--	3000	55
5	Silty	0.35	110	27	--	75
6	Cohesionless	0.35	120	32	--	85
7	Cohesive	0.25	120	--	1000	100
8		0.35				

H-Pile Inputs

Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.00	1.00	0.10	0.70	0.086	0.70	0.94
26	0.00	1.09	0.10	0.73	0.086	0.73	0.93
27	0.00	1.18	0.10	0.76	0.086	0.76	0.92
28	0.00	1.27	0.10	0.79	0.086	0.79	0.91
29	0.00	1.36	0.10	0.82	0.086	0.82	0.90
30	0.00	1.45	0.10	0.85	0.086	0.85	0.89
31	0.00	1.63	0.10	0.91	0.086	0.91	0.88
32	0.00	1.81	0.10	0.97	0.086	0.97	0.88
33	0.00	1.99	0.10	1.03	0.086	1.03	0.87
34	0.00	2.17	0.10	1.09	0.086	1.09	0.87
35	0.00	2.35	0.10	1.15	0.086	1.15	0.86
36	0.00	2.74	0.10	1.26	0.086	1.26	0.86
37	0.00	3.13	0.10	1.37	0.086	1.37	0.85
38	0.00	3.52	0.10	1.48	0.086	1.48	0.84
39	0.00	3.91	0.10	1.59	0.086	1.59	0.83
40	0.00	4.30	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	2.64
2	27	0.74	19.98	0.76	0.92	0.73	--	--	--	--
2	27	0.74	19.98	0.76	0.92	1.16	--	--	--	--
2	27	0.74	19.98	0.76	0.92	1.58	--	--	--	--
2	27	0.74	19.98	0.76	0.92	2.01	--	--	--	--
3	--	--	--	--	--	--	2500	0.61	1.34	4.40
3	--	--	--	--	--	--	2500	0.66	1.44	4.74
3	--	--	--	--	--	--	2500	0.70	1.51	4.98
4	--	--	--	--	--	--	3000	0.50	1.30	4.28
4	--	--	--	--	--	--	3000	0.50	1.30	4.28
4	--	--	--	--	--	--	3000	0.50	1.30	4.28
5	27	0.74	19.98	0.76	0.92	5.45	--	--	--	--
5	27	0.74	19.98	0.76	0.92	5.67	--	--	--	--
5	27	0.74	19.98	0.76	0.92	5.90	--	--	--	--
5	27	0.74	19.98	0.76	0.92	6.12	--	--	--	--
6	32	0.74	23.68	0.97	0.88	9.33	--	--	--	--
6	32	0.74	23.68	0.97	0.88	9.73	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.13
7	--	--	--	--	--	--	1000	1.00	0.95	3.13
7	--	--	--	--	--	--	1000	1.00	0.95	3.13
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
2	10	6463	0.35	0.73	1.28	1.28
2	15	6458	0.35	1.16	3.30	3.30
2	20	6453	0.35	1.58	6.07	6.07
2	25	6448	0.35	2.01	9.58	9.58
3	30	6443	0.25	4.40	15.09	15.09
3	35	6438	0.25	4.74	21.01	21.01
3	40	6433	0.25	4.98	27.23	27.23
4	45	6428	0.25	4.28	32.59	32.59
4	50	6423	0.25	4.28	37.94	37.94
4	55	6418	0.25	4.28	43.30	43.30
5	60	6413	0.35	5.45	52.83	52.83
5	65	6408	0.35	5.67	62.75	62.75
5	70	6403	0.35	5.90	73.07	73.07
5	75	6398	0.35	6.12	83.78	83.78
6	80	6393	0.35	9.33	100.11	100.11
6	85	6388	0.35	9.73	117.13	117.13
7	90	6383	0.25	3.13	121.04	121.04
7	95	6378	0.25	3.13	124.95	124.95
7	100	6373	0.25	3.13	128.87	128.87
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total} [pcf]	ϕ [degrees]	s_u [psf]	Depth to Bottom of Layer [ft]	Depth to Bottom of Layer [m]
1	Cohesive	0.25	110	--	3000	5	1.5
2	Silty	0.35	90	27	--	25	7.5
3	Cohesive	0.25	100	--	2500	40	12.0
4	Cohesive	0.25	120	--	3000	55	16.5
5	Silty	0.35	110	27	--	75	22.5
6	Cohesionless	0.35	120	32	--	85	25.5
7	Cohesive	0.25	120	--	1000	100	30.0
8		0.35					0.0

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Calculation

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	3.18
2	27	0.76	20.52	0.77	0.94	0.91	--	--	--	--
2	27	0.76	20.52	0.77	0.94	1.44	--	--	--	--
2	27	0.76	20.52	0.77	0.94	1.97	--	--	--	--
2	27	0.76	20.52	0.77	0.94	2.50	--	--	--	--
3	--	--	--	--	--	--	2500	0.57	1.26	4.98
3	--	--	--	--	--	--	2500	0.61	1.34	5.32
3	--	--	--	--	--	--	2500	0.66	1.43	5.66
4	--	--	--	--	--	--	3000	0.50	1.30	5.16
4	--	--	--	--	--	--	3000	0.50	1.30	5.16
4	--	--	--	--	--	--	3000	0.50	1.30	5.16
5	27	0.76	20.52	0.77	0.94	6.79	--	--	--	--
5	27	0.76	20.52	0.77	0.94	7.07	--	--	--	--
5	27	0.76	20.52	0.77	0.94	7.35	--	--	--	--
5	27	0.76	20.52	0.77	0.94	7.63	--	--	--	--
6	32	0.76	24.32	0.98	0.90	11.69	--	--	--	--
6	32	0.76	24.32	0.98	0.90	12.19	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.77
7	--	--	--	--	--	--	1000	1.00	0.95	3.77
7	--	--	--	--	--	--	1000	1.00	0.95	3.77
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
2	10	6463	0.35	0.91	1.60	1.60
2	15	6458	0.35	1.44	4.12	4.12
2	20	6453	0.35	1.97	7.56	7.56
2	25	6448	0.35	2.50	11.94	11.94
3	30	6443	0.25	4.98	18.17	18.17
3	35	6438	0.25	5.32	24.82	24.82
3	40	6433	0.25	5.66	31.89	31.89
4	45	6428	0.25	5.16	38.34	38.34
4	50	6423	0.25	5.16	44.80	44.80
4	55	6418	0.25	5.16	51.25	51.25
5	60	6413	0.35	6.79	63.12	63.12
5	65	6408	0.35	7.07	75.49	75.49
5	70	6403	0.35	7.35	88.34	88.34
5	75	6398	0.35	7.63	101.69	101.69
6	80	6393	0.35	11.69	122.14	122.14
6	85	6388	0.35	12.19	143.48	143.48
7	90	6383	0.25	3.77	148.19	148.19
7	95	6378	0.25	3.77	152.91	152.91
7	100	6373	0.25	3.77	157.62	157.62
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	110	--	3000	5
2	Silty	0.35	90	27	--	25
3	Cohesive	0.25	100	--	2500	40
4	Cohesive	0.25	120	--	3000	55
5	Silty	0.35	110	27	--	75
6	Cohesionless	0.35	120	32	--	85
7	Cohesive	0.25	120	--	1000	100
8		0.35				

H-Pile Inputs

Pile Type:	HP14x73	Select from drop down menu
Depth [in]:	13.61	
Width [in]:	14.585	
Thickness [in]:	0.505	
End Area [sf]:	0.149	(unplugged)
End Area [sf]:	1.378	(plugged)
Volume[cf/ft]:	0.149	
Steel Perimeter (C_d) [ft]:	2.599	
Soil Perimeter (C_d) [ft]:	2.1000	
δ/ϕ:	0.78	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	535	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	BS-5	BS-6	Average
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Calculation

Project No.: 17-2015-4045
Project: BIA Route N8065
Structure: West Abutment, Pile Foundation, No Scour
Corresponding Boring: BS-5/BS-6
Groundwater Table [ft]: 55
Depth of Scour [ft]: 0
γ_w [pcf]: 62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	$K_δ$	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	3.76
2	27	0.78	21.06	0.79	0.95	1.13	--	--	--	--
2	27	0.78	21.06	0.79	0.95	1.79	--	--	--	--
2	27	0.78	21.06	0.79	0.95	2.45	--	--	--	--
2	27	0.78	21.06	0.79	0.95	3.11	--	--	--	--
3	--	--	--	--	--	--	2500	0.53	1.18	5.54
3	--	--	--	--	--	--	2500	0.57	1.25	5.87
3	--	--	--	--	--	--	2500	0.60	1.32	6.20
4	--	--	--	--	--	--	3000	0.45	1.18	5.55
4	--	--	--	--	--	--	3000	0.48	1.25	5.88
4	--	--	--	--	--	--	3000	0.50	1.30	6.11
5	27	0.78	21.06	0.79	0.95	8.43	--	--	--	--
5	27	0.78	21.06	0.79	0.95	8.78	--	--	--	--
5	27	0.78	21.06	0.79	0.95	9.13	--	--	--	--
5	27	0.78	21.06	0.79	0.95	9.48	--	--	--	--
6	32	0.78	24.96	1.04	0.91	14.87	--	--	--	--
6	32	0.78	24.96	1.04	0.91	15.51	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	4.46
7	--	--	--	--	--	--	1000	1.00	0.95	4.46
7	--	--	--	--	--	--	1000	1.00	0.95	4.46
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
2	10	6463	0.35	1.13	1.98	1.98
2	15	6458	0.35	1.79	5.12	5.12
2	20	6453	0.35	2.45	9.40	9.40
2	25	6448	0.35	3.11	14.84	14.84
3	30	6443	0.25	5.54	21.77	21.77
3	35	6438	0.25	5.87	29.11	29.11
3	40	6433	0.25	6.20	36.86	36.86
4	45	6428	0.25	5.55	43.80	43.80
4	50	6423	0.25	5.88	51.15	51.15
4	55	6418	0.25	6.11	58.78	58.78
5	60	6413	0.35	8.43	73.54	73.54
5	65	6408	0.35	8.78	88.91	88.91
5	70	6403	0.35	9.13	104.89	104.89
5	75	6398	0.35	9.48	121.48	121.48
6	80	6393	0.35	14.87	147.50	147.50
6	85	6388	0.35	15.51	174.64	174.64
7	90	6383	0.25	4.46	180.22	180.22
7	95	6378	0.25	4.46	185.80	185.80
7	100	6373	0.25	4.46	191.38	191.38
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

PIER

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Depth to Groundwater Table [ft]:	6
Ground Elevation [ft]:	6420.5
Depth of Scour [ft]:	6 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	0	--	500	6.5
2	Cohesionless	0.35	120	32	--	30
3	Cohesive	0.25	120	--	1000	45
4	Cohesionless	0.35	125	34	--	80
5	Cohesionless	0.35	120	32	--	100
6		0.35				
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.00	1.00	0.10	0.70	0.086	0.70	0.94
26	0.00	1.09	0.10	0.73	0.086	0.73	0.93
27	0.00	1.18	0.10	0.76	0.086	0.76	0.92
28	0.00	1.27	0.10	0.79	0.086	0.79	0.91
29	0.00	1.36	0.10	0.82	0.086	0.82	0.90
30	0.00	1.45	0.10	0.85	0.086	0.85	0.89
31	0.00	1.63	0.10	0.91	0.086	0.91	0.88
32	0.00	1.81	0.10	0.97	0.086	0.97	0.88
33	0.00	1.99	0.10	1.03	0.086	1.03	0.87
34	0.00	2.17	0.10	1.09	0.086	1.09	0.87
35	0.00	2.35	0.10	1.15	0.086	1.15	0.86
36	0.00	2.74	0.10	1.26	0.086	1.26	0.86
37	0.00	3.13	0.10	1.37	0.086	1.37	0.85
38	0.00	3.52	0.10	1.48	0.086	1.48	0.84
39	0.00	3.91	0.10	1.59	0.086	1.59	0.83
40	0.00	4.30	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	BS-3	BS-4	Average
6420.5	0	2	6	4
6415.5	5	8	3	6
6410.5	10	3	3	3
6405.5	15	4	5	5
6400.5	20	7	9	8
6395.5	25	6	17	12
6390.5	30	12	9	11
6385.5	35	13	7	10
6380.5	40	8	5	7
6375.5	45	7	5	6
6370.5	50	16	9	13
6365.5	55	10	19	15
6360.5	60	19	23	21
6355.5	65	32	18	25
6350.5	70	12	13	13
6345.5	75	32	12	22
6340.5	80	8	12	10
6335.5	85	12	3	8
6330.5	90	18	6	12
6325.5	95	10	11	11
6320.5	100	11	11	11

Calculation

Project No.: 17-2015-4045
Project: BIA Route N8065
Structure: Piers, Pile Foundation, Scour
Corresponding Boring: BS-3/BS-4
Groundwater Table [ft]: 6
Depth of Scour [ft]: 6
γ_w [pcf]: 62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
7	1		-31
30	2	2820	1322
45	3	4620	2186
80	4	8995	4377
100	5	11395	5529
0	6	11395	11395
0	7	11395	11395
0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	3.3	6.5	0	0	0	0	0	0	Cohesive	4	0
2	6.5	8.3	10	120	62.4	210	420	170.4	69.6	Cohesionless	6	10
2	10	12.5	15	120	62.4	720	1020	458.4	314.4	Cohesionless	3	4
2	15	17.5	20	120	62.4	1320	1620	746.4	602.4	Cohesionless	5	6
2	20	22.5	25	120	62.4	1920	2220	1034.4	890.4	Cohesionless	8	10
2	25	27.5	30	120	62.4	2520	2820	1322.4	1178.4	Cohesionless	12	13
3	30	32.5	35	120	62.4	3120	3420	1610.4	1466.4	Cohesive	11	11
3	35	37.5	40	120	62.4	3720	4020	1898.4	1754.4	Cohesive	10	10
3	40	42.5	45	120	62.4	4320	4620	2186.4	2042.4	Cohesive	7	6
4	45	47.5	50	125	62.4	4932.5	5245	2499.4	2342.9	Cohesionless	6	6
4	50	52.5	55	125	62.4	5557.5	5870	2812.4	2655.9	Cohesionless	13	11
4	55	57.5	60	125	62.4	6182.5	6495	3125.4	2968.9	Cohesionless	15	12
4	60	62.5	65	125	62.4	6807.5	7120	3438.4	3281.9	Cohesionless	21	17
4	65	67.5	70	125	62.4	7432.5	7745	3751.4	3594.9	Cohesionless	25	20
4	70	72.5	75	125	62.4	8057.5	8370	4064.4	3907.9	Cohesionless	13	10
4	75	77.5	80	125	62.4	8682.5	8995	4377.4	4220.9	Cohesionless	22	16
5	80	82.5	85	120	62.4	9295	9595	4665.4	4521.4	Cohesionless	10	7
5	85	87.5	90	120	62.4	9895	10195	4953.4	4809.4	Cohesionless	8	5
5	90	92.5	95	120	62.4	10495	10795	5241.4	5097.4	Cohesionless	12	8
5	95	97.5	100	120	62.4	11095	11395	5529.4	5385	Cohesionless	11	7
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.74	23.68	0.97	0.88	0.10	--	--	--	--
2	32	0.74	23.68	0.97	0.88	0.43	--	--	--	--
2	32	0.74	23.68	0.97	0.88	0.83	--	--	--	--
2	32	0.74	23.68	0.97	0.88	1.23	--	--	--	--
2	32	0.74	23.68	0.97	0.88	1.63	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.93	3.06
3	--	--	--	--	--	--	1000	1.00	0.95	3.13
3	--	--	--	--	--	--	1000	1.00	0.95	3.13
4	34	0.74	25.16	1.09	0.87	3.83	--	--	--	--
4	34	0.74	25.16	1.09	0.87	4.34	--	--	--	--
4	34	0.74	25.16	1.09	0.87	4.85	--	--	--	--
4	34	0.74	25.16	1.09	0.87	5.36	--	--	--	--
4	34	0.74	25.16	1.09	0.87	5.87	--	--	--	--
4	34	0.74	25.16	1.09	0.87	6.38	--	--	--	--
4	34	0.74	25.16	1.09	0.87	6.89	--	--	--	--
5	32	0.74	23.68	0.97	0.88	6.25	--	--	--	--
5	32	0.74	23.68	0.97	0.88	6.65	--	--	--	--
5	32	0.74	23.68	0.97	0.88	7.05	--	--	--	--
5	32	0.74	23.68	0.97	0.88	7.45	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6420.5	0.25	0.00	0.00	0.00
1	6.5	6414	0.25	0.00	0.00	0.00
2	10	6410.5	0.35	0.10	0.12	0.12
2	15	6405.5	0.35	0.43	0.88	0.88
2	20	6400.5	0.35	0.83	2.34	2.34
2	25	6395.5	0.35	1.23	4.49	4.49
2	30	6390.5	0.35	1.63	7.34	7.34
3	35	6385.5	0.25	3.06	11.17	11.17
3	40	6380.5	0.25	3.13	15.08	15.08
3	45	6375.5	0.25	3.13	19.00	19.00
4	50	6370.5	0.35	3.83	25.69	25.69
4	55	6365.5	0.35	4.34	33.29	33.29
4	60	6360.5	0.35	4.85	41.77	41.77
4	65	6355.5	0.35	5.36	51.15	51.15
4	70	6350.5	0.35	5.87	61.43	61.43
4	75	6345.5	0.35	6.38	72.60	72.60
4	80	6340.5	0.35	6.89	84.67	84.67
5	85	6335.5	0.35	6.25	95.61	95.61
5	90	6330.5	0.35	6.65	107.25	107.25
5	95	6325.5	0.35	7.05	119.58	119.58
5	100	6320.5	0.35	7.45	132.61	132.61
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs		
Project No.:	17-2015-4045	
Project:	BIA Route N8065	
Structure:	Piers, Pile Foundation, Scour	
Corresponding Boring:	BS-3/BS-4	
Depth to Groundwater Table [ft]:	6	
Ground Elevation [ft]:	6420.5	
Depth of Scour [ft]:	6	Not used in calculations.
Resistance Factor [clay]:	0.25	
Resistance Factor [sand]:	0.35	
Atmospheric Pressure (p_a) [pcf]:	2116	

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	0	--	500	6.5
2	Cohesionless	0.35	120	32	--	30
3	Cohesive	0.25	120	--	1000	45
4	Cohesionless	0.35	125	34	--	80
5	Cohesionless	0.35	120	32	--	100
6		0.35				
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6420.5	0	2	6	4
6415.5	5	8	3	6
6410.5	10	3	3	3
6405.5	15	4	5	5
6400.5	20	7	9	8
6395.5	25	6	17	12
6390.5	30	12	9	11
6385.5	35	13	7	10
6380.5	40	8	5	7
6375.5	45	7	5	6
6370.5	50	16	9	13
6365.5	55	10	19	15
6360.5	60	19	23	21
6355.5	65	32	18	25
6350.5	70	12	13	13
6345.5	75	32	12	22
6340.5	80	8	12	10
6335.5	85	12	3	8
6330.5	90	18	6	12
6325.5	95	10	11	11
6320.5	100	11	11	11

			Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045		7	1		-31
Project:	BIA Route N8065		30	2	2820	1322
Structure:	Piers, Pile Foundation, Scour		45	3	4620	2186
Corresponding Boring:	BS-3/BS-4		80	4	8995	4377
Groundwater Table [ft]:	6		100	5	11395	5529
Depth of Scour [ft]:	6		0	6	11395	11395
γ_w [pcf]:	62.4		0	7	11395	11395
			0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	3.3	6.5	0	0	0	0	0	0	Cohesive	4	0
2	6.5	8.3	10	120	62.4	210	420	170.4	69.6	Cohesionless	6	10
2	10	12.5	15	120	62.4	720	1020	458.4	314.4	Cohesionless	3	4
2	15	17.5	20	120	62.4	1320	1620	746.4	602.4	Cohesionless	5	6
2	20	22.5	25	120	62.4	1920	2220	1034.4	890.4	Cohesionless	8	10
2	25	27.5	30	120	62.4	2520	2820	1322.4	1178.4	Cohesionless	12	13
3	30	32.5	35	120	62.4	3120	3420	1610.4	1466.4	Cohesive	11	11
3	35	37.5	40	120	62.4	3720	4020	1898.4	1754.4	Cohesive	10	10
3	40	42.5	45	120	62.4	4320	4620	2186.4	2042.4	Cohesive	7	6
4	45	47.5	50	125	62.4	4932.5	5245	2499.4	2342.9	Cohesionless	6	6
4	50	52.5	55	125	62.4	5557.5	5870	2812.4	2655.9	Cohesionless	13	11
4	55	57.5	60	125	62.4	6182.5	6495	3125.4	2968.9	Cohesionless	15	12
4	60	62.5	65	125	62.4	6807.5	7120	3438.4	3281.9	Cohesionless	21	17
4	65	67.5	70	125	62.4	7432.5	7745	3751.4	3594.9	Cohesionless	25	20
4	70	72.5	75	125	62.4	8057.5	8370	4064.4	3907.9	Cohesionless	13	10
4	75	77.5	80	125	62.4	8682.5	8995	4377.4	4220.9	Cohesionless	22	16
5	80	82.5	85	120	62.4	9295	9595	4665.4	4521.4	Cohesionless	10	7
5	85	87.5	90	120	62.4	9895	10195	4953.4	4809.4	Cohesionless	8	5
5	90	92.5	95	120	62.4	10495	10795	5241.4	5097.4	Cohesionless	12	8
5	95	97.5	100	120	62.4	11095	11395	5529.4	5385	Cohesionless	11	7
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	$K_δ$	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.76	24.32	0.98	0.90	0.12	--	--	--	--
2	32	0.76	24.32	0.98	0.90	0.54	--	--	--	--
2	32	0.76	24.32	0.98	0.90	1.04	--	--	--	--
2	32	0.76	24.32	0.98	0.90	1.54	--	--	--	--
2	32	0.76	24.32	0.98	0.90	2.04	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.90	3.57
3	--	--	--	--	--	--	1000	1.00	0.93	3.67
3	--	--	--	--	--	--	1000	1.00	0.95	3.77
4	34	0.76	25.84	1.11	0.89	4.80	--	--	--	--
4	34	0.76	25.84	1.11	0.89	5.44	--	--	--	--
4	34	0.76	25.84	1.11	0.89	6.09	--	--	--	--
4	34	0.76	25.84	1.11	0.89	6.73	--	--	--	--
4	34	0.76	25.84	1.11	0.89	7.37	--	--	--	--
4	34	0.76	25.84	1.11	0.89	8.01	--	--	--	--
4	34	0.76	25.84	1.11	0.89	8.65	--	--	--	--
5	32	0.76	24.32	0.98	0.90	7.83	--	--	--	--
5	32	0.76	24.32	0.98	0.90	8.33	--	--	--	--
5	32	0.76	24.32	0.98	0.90	8.83	--	--	--	--
5	32	0.76	24.32	0.98	0.90	9.33	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6420.5	0.25	0.00	0.00	0.00
1	6.5	6414	0.25	0.00	0.00	0.00
2	10	6410.5	0.35	0.12	0.15	0.15
2	15	6405.5	0.35	0.54	1.10	1.10
2	20	6400.5	0.35	1.04	2.93	2.93
2	25	6395.5	0.35	1.54	5.63	5.63
2	30	6390.5	0.35	2.04	9.20	9.20
3	35	6385.5	0.25	3.57	13.67	13.67
3	40	6380.5	0.25	3.67	18.26	18.26
3	45	6375.5	0.25	3.77	22.98	22.98
4	50	6370.5	0.35	4.80	31.38	31.38
4	55	6365.5	0.35	5.44	40.91	40.91
4	60	6360.5	0.35	6.09	51.56	51.56
4	65	6355.5	0.35	6.73	63.33	63.33
4	70	6350.5	0.35	7.37	76.23	76.23
4	75	6345.5	0.35	8.01	90.25	90.25
4	80	6340.5	0.35	8.65	105.39	105.39
5	85	6335.5	0.35	7.83	119.10	119.10
5	90	6330.5	0.35	8.33	133.68	133.68
5	95	6325.5	0.35	8.83	149.14	149.14
5	100	6320.5	0.35	9.33	165.47	165.47
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

H-Pile Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Depth to Groundwater Table [ft]:	6
Ground Elevation [ft]:	6420.5
Depth of Scour [ft]:	6 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	0	--	500	6.5
2	Cohesionless	0.35	120	32	--	30
3	Cohesive	0.25	120	--	1000	45
4	Cohesionless	0.35	125	34	--	80
5	Cohesionless	0.35	120	32	--	100
6		0.35				
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type: HP14x73 Select from drop down menu
Depth [in]: 13.61
Width [in]: 14.585
Thickness [in]: 0.505
End Area [sf]: 0.149 (unplugged)
End Area [sf]: 1.378 (plugged)
Volume[cf/ft]: 0.149
Steel Perimeter (C_d) [ft]: 2.599
Soil Perimeter (C_d) [ft]: 2.1000
δ/ϕ: 0.78 Figure 9.10
Yield Strength [ksi]: 50 7200 ksf
Resistance Factor: 0.50 AASHTO Section 6.5.4.2
Factored Pile Strength [kips]: 535

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6420.5	0	2	6	4
6415.5	5	8	3	6
6410.5	10	3	3	3
6405.5	15	4	5	5
6400.5	20	7	9	8
6395.5	25	6	17	12
6390.5	30	12	9	11
6385.5	35	13	7	10
6380.5	40	8	5	7
6375.5	45	7	5	6
6370.5	50	16	9	13
6365.5	55	10	19	15
6360.5	60	19	23	21
6355.5	65	32	18	25
6350.5	70	12	13	13
6345.5	75	32	12	22
6340.5	80	8	12	10
6335.5	85	12	3	8
6330.5	90	18	6	12
6325.5	95	10	11	11
6320.5	100	11	11	11

Calculation

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	7	1		-31
Project:	BIA Route N8065	30	2	2820	1322
Structure:	Piers, Pile Foundation, Scour	45	3	4620	2186
Corresponding Boring:	BS-3/BS-4	80	4	8995	4377
Groundwater Table [ft]:	6	100	5	11395	5529
Depth of Scour [ft]:	6	0	6	11395	11395
γ_w [pcf]:	62.4	0	7	11395	11395
		0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	3.3	6.5	0	0	0	0	0	0	Cohesive	4	0
2	6.5	8.3	10	120	62.4	210	420	170.4	69.6	Cohesionless	6	10
2	10	12.5	15	120	62.4	720	1020	458.4	314.4	Cohesionless	3	4
2	15	17.5	20	120	62.4	1320	1620	746.4	602.4	Cohesionless	5	6
2	20	22.5	25	120	62.4	1920	2220	1034.4	890.4	Cohesionless	8	10
2	25	27.5	30	120	62.4	2520	2820	1322.4	1178.4	Cohesionless	12	13
3	30	32.5	35	120	62.4	3120	3420	1610.4	1466.4	Cohesive	11	11
3	35	37.5	40	120	62.4	3720	4020	1898.4	1754.4	Cohesive	10	10
3	40	42.5	45	120	62.4	4320	4620	2186.4	2042.4	Cohesive	7	6
4	45	47.5	50	125	62.4	4932.5	5245	2499.4	2342.9	Cohesionless	6	6
4	50	52.5	55	125	62.4	5557.5	5870	2812.4	2655.9	Cohesionless	13	11
4	55	57.5	60	125	62.4	6182.5	6495	3125.4	2968.9	Cohesionless	15	12
4	60	62.5	65	125	62.4	6807.5	7120	3438.4	3281.9	Cohesionless	21	17
4	65	67.5	70	125	62.4	7432.5	7745	3751.4	3594.9	Cohesionless	25	20
4	70	72.5	75	125	62.4	8057.5	8370	4064.4	3907.9	Cohesionless	13	10
4	75	77.5	80	125	62.4	8682.5	8995	4377.4	4220.9	Cohesionless	22	16
5	80	82.5	85	120	62.4	9295	9595	4665.4	4521.4	Cohesionless	10	7
5	85	87.5	90	120	62.4	9895	10195	4953.4	4809.4	Cohesionless	8	5
5	90	92.5	95	120	62.4	10495	10795	5241.4	5097.4	Cohesionless	12	8
5	95	97.5	100	120	62.4	11095	11395	5529.4	5385	Cohesionless	11	7
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.78	24.96	1.04	0.91	0.15	--	--	--	--
2	32	0.78	24.96	1.04	0.91	0.69	--	--	--	--
2	32	0.78	24.96	1.04	0.91	1.33	--	--	--	--
2	32	0.78	24.96	1.04	0.91	1.96	--	--	--	--
2	32	0.78	24.96	1.04	0.91	2.60	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.87	4.10
3	--	--	--	--	--	--	1000	1.00	0.89	4.20
3	--	--	--	--	--	--	1000	1.00	0.91	4.30
4	34	0.78	26.52	1.18	0.90	6.14	--	--	--	--
4	34	0.78	26.52	1.18	0.90	6.96	--	--	--	--
4	34	0.78	26.52	1.18	0.90	7.78	--	--	--	--
4	34	0.78	26.52	1.18	0.90	8.60	--	--	--	--
4	34	0.78	26.52	1.18	0.90	9.42	--	--	--	--
4	34	0.78	26.52	1.18	0.90	10.24	--	--	--	--
4	34	0.78	26.52	1.18	0.90	11.06	--	--	--	--
5	32	0.78	24.96	1.04	0.91	9.97	--	--	--	--
5	32	0.78	24.96	1.04	0.91	10.60	--	--	--	--
5	32	0.78	24.96	1.04	0.91	11.24	--	--	--	--
5	32	0.78	24.96	1.04	0.91	11.87	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6420.5	0.25	0.00	0.00	0.00
1	6.5	6414	0.25	0.00	0.00	0.00
2	10	6410.5	0.35	0.15	0.19	0.19
2	15	6405.5	0.35	0.69	1.40	1.40
2	20	6400.5	0.35	1.33	3.72	3.72
2	25	6395.5	0.35	1.96	7.16	7.16
2	30	6390.5	0.35	2.60	11.71	11.71
3	35	6385.5	0.25	4.10	16.84	16.84
3	40	6380.5	0.25	4.20	22.09	22.09
3	45	6375.5	0.25	4.30	27.46	27.46
4	50	6370.5	0.35	6.14	38.21	38.21
4	55	6365.5	0.35	6.96	50.39	50.39
4	60	6360.5	0.35	7.78	64.01	64.01
4	65	6355.5	0.35	8.60	79.07	79.07
4	70	6350.5	0.35	9.42	95.56	95.56
4	75	6345.5	0.35	10.24	113.49	113.49
4	80	6340.5	0.35	11.06	132.85	132.85
5	85	6335.5	0.35	9.97	150.29	150.29
5	90	6330.5	0.35	10.60	168.84	168.84
5	95	6325.5	0.35	11.24	188.51	188.51
5	100	6320.5	0.35	11.87	209.28	209.28
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

EAST ABUTMENT

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	100	--	2500	30
2	Cohesive	0.25	120	--	4000	55
3	Cohesionless	0.35	120	30	--	65
4	Silty	0.35	110	27	--	80
5	Cohesive	0.25	120	--	1000	95
6	Cohesionless	0.35	125	32	--	100
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type:	HP10x42	Select from drop down menu
Depth [in]:	9.7	
Width [in]:	10.075	
Thickness [in]:	0.42	
End Area [sf]:	0.086	(unplugged)
End Area [sf]:	0.679	(plugged)
Volume[cf/ft]:	0.086	
Steel Perimeter (C_d) [ft]:	1.819	
Soil Perimeter (C_d) [ft]:	1.4767	
δ/ϕ:	0.74	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	310	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP10x42		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.00	1.00	0.10	0.70	0.086	0.70	0.94
26	0.00	1.09	0.10	0.73	0.086	0.73	0.93
27	0.00	1.18	0.10	0.76	0.086	0.76	0.92
28	0.00	1.27	0.10	0.79	0.086	0.79	0.91
29	0.00	1.36	0.10	0.82	0.086	0.82	0.90
30	0.00	1.45	0.10	0.85	0.086	0.85	0.89
31	0.00	1.63	0.10	0.91	0.086	0.91	0.88
32	0.00	1.81	0.10	0.97	0.086	0.97	0.88
33	0.00	1.99	0.10	1.03	0.086	1.03	0.87
34	0.00	2.17	0.10	1.09	0.086	1.09	0.87
35	0.00	2.35	0.10	1.15	0.086	1.15	0.86
36	0.00	2.74	0.10	1.26	0.086	1.26	0.86
37	0.00	3.13	0.10	1.37	0.086	1.37	0.85
38	0.00	3.52	0.10	1.48	0.086	1.48	0.84
39	0.00	3.91	0.10	1.59	0.086	1.59	0.83
40	0.00	4.30	0.10	1.70	0.086	1.70	0.81

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

Calculation

			Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045		30	1	3000	3000
Project:	BIA Route N8065		55	2	6000	6000
Structure:	East Abutment, Pile Foundation, No Scour		65	3	7200	6576
Corresponding Boring:	BS-1/BS-2		80	4	8850	7290
Groundwater Table [ft]:	55		95	5	10650	8154
Depth of Scour [ft]:	0		100	6	11275	8467
γ_w [pcf]:	62.4		0	7	11275	11275
			0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.30
1	--	--	--	--	--	--	2500	0.44	1.00	3.30
1	--	--	--	--	--	--	2500	0.46	1.03	3.40
1	--	--	--	--	--	--	2500	0.51	1.13	3.74
1	--	--	--	--	--	--	2500	0.56	1.23	4.07
1	--	--	--	--	--	--	2500	0.61	1.34	4.40
2	--	--	--	--	--	--	4000	0.30	1.19	3.92
2	--	--	--	--	--	--	4000	0.31	1.26	4.09
2	--	--	--	--	--	--	4000	0.31	1.26	4.09
2	--	--	--	--	--	--	4000	0.31	1.26	4.09
2	--	--	--	--	--	--	4000	0.31	1.26	4.09
3	30	0.74	22.2	0.85	0.89	7.05	--	--	--	--
3	30	0.74	22.2	0.85	0.89	7.38	--	--	--	--
4	27	0.74	19.98	0.76	0.92	6.32	--	--	--	--
4	27	0.74	19.98	0.76	0.92	6.55	--	--	--	--
4	27	0.74	19.98	0.76	0.92	6.77	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.13
5	--	--	--	--	--	--	1000	1.00	0.95	3.13
5	--	--	--	--	--	--	1000	1.00	0.95	3.13
6	32	0.74	23.68	0.97	0.88	11.49	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
1	10	6463	0.25	3.30	4.12	4.12
1	15	6458	0.25	3.40	8.37	8.37
1	20	6453	0.25	3.74	13.04	13.04
1	25	6448	0.25	4.07	18.13	18.13
1	30	6443	0.25	4.40	23.64	23.64
2	35	6438	0.25	3.92	28.54	28.54
2	40	6433	0.25	4.09	33.65	33.65
2	45	6428	0.25	4.09	38.76	38.76
2	50	6423	0.25	4.09	43.87	43.87
2	55	6418	0.25	4.09	48.97	48.97
3	60	6413	0.35	7.05	61.31	61.31
3	65	6408	0.35	7.38	74.23	74.23
4	70	6403	0.35	6.32	85.29	85.29
4	75	6398	0.35	6.55	96.75	96.75
4	80	6393	0.35	6.77	108.59	108.59
5	85	6388	0.25	3.13	112.51	112.51
5	90	6383	0.25	3.13	116.42	116.42
5	95	6378	0.25	3.13	120.34	120.34
6	100	6373	0.35	11.49	140.45	140.45
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs		
Project No.:	17-2015-4045	
Project:	BIA Route N8065	
Structure:	East Abutment, Pile Foundation, No Scour	
Corresponding Boring:	BS-1/BS-2	
Depth to Groundwater Table [ft]:	55	
Ground Elevation [ft]:	6473	
Depth of Scour [ft]:	0	Not used in calculations.
Resistance Factor [clay]:	0.25	
Resistance Factor [sand]:	0.35	
Atmospheric Pressure (p_a) [pcf]:	2116	

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	100	--	2500	30
2	Cohesive	0.25	120	--	4000	55
3	Cohesionless	0.35	120	30	--	65
4	Silty	0.35	110	27	--	80
5	Cohesive	0.25	120	--	1000	95
6	Cohesionless	0.35	125	32	--	100
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type:	HP12x53	Select from drop down menu
Depth [in]:	11.78	
Width [in]:	12.045	
Thickness [in]:	0.435	
End Area [sf]:	0.108	(unplugged)
End Area [sf]:	0.985	(plugged)
Volume[cf/ft]:	0.108	
Steel Perimeter (C_d) [ft]:	2.153	
Soil Perimeter (C_d) [ft]:	1.8183	
δ/ϕ:	0.76	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	388	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP12x53		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.10	0.70	0.20	0.75	0.108	0.71	0.95
26	0.10	0.73	0.20	0.78	0.108	0.74	0.94
27	0.10	0.76	0.20	0.82	0.108	0.77	0.94
28	0.10	0.79	0.20	0.86	0.108	0.80	0.93
29	0.10	0.82	0.20	0.90	0.108	0.83	0.92
30	0.10	0.85	0.20	0.94	0.108	0.86	0.91
31	0.10	0.91	0.20	1.02	0.108	0.92	0.90
32	0.10	0.97	0.20	1.10	0.108	0.98	0.90
33	0.10	1.03	0.20	1.17	0.108	1.04	0.89
34	0.10	1.09	0.20	1.25	0.108	1.11	0.89
35	0.10	1.15	0.20	1.33	0.108	1.17	0.88
36	0.10	1.26	0.20	1.48	0.108	1.28	0.87
37	0.10	1.37	0.20	1.63	0.108	1.40	0.86
38	0.10	1.48	0.20	1.79	0.108	1.51	0.86
39	0.10	1.59	0.20	1.94	0.108	1.63	0.85
40	0.10	1.70	0.20	2.09	0.108	1.74	0.84

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

Calculation

Project No.: 17-2015-4045
Project: BIA Route N8065
Structure: East Abutment, Pile Foundation, No Scour
Corresponding Boring: BS-1/BS-2
Groundwater Table [ft]: 55
Depth of Scour [ft]: 0
γ_w [pcf]: 62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
30	1	3000	3000
55	2	6000	6000
65	3	7200	6576
80	4	8850	7290
95	5	10650	8154
100	6	11275	8467
0	7	11275	11275
0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	φ' (deg)	δ/φ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.44	1.00	3.97
1	--	--	--	--	--	--	2500	0.48	1.08	4.30
1	--	--	--	--	--	--	2500	0.53	1.17	4.64
1	--	--	--	--	--	--	2500	0.57	1.25	4.98
2	--	--	--	--	--	--	4000	0.29	1.10	4.36
2	--	--	--	--	--	--	4000	0.30	1.18	4.68
2	--	--	--	--	--	--	4000	0.31	1.26	4.92
2	--	--	--	--	--	--	4000	0.31	1.26	4.92
2	--	--	--	--	--	--	4000	0.31	1.26	4.92
3	30	0.76	22.8	0.86	0.91	8.81	--	--	--	--
3	30	0.76	22.8	0.86	0.91	9.22	--	--	--	--
4	27	0.76	20.52	0.77	0.94	7.87	--	--	--	--
4	27	0.76	20.52	0.77	0.94	8.15	--	--	--	--
4	27	0.76	20.52	0.77	0.94	8.43	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.77
5	--	--	--	--	--	--	1000	1.00	0.95	3.77
5	--	--	--	--	--	--	1000	1.00	0.95	3.77
6	32	0.76	24.32	0.98	0.90	14.40	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
1	10	6463	0.25	3.97	4.96	4.96
1	15	6458	0.25	3.97	9.92	9.92
1	20	6453	0.25	4.30	15.30	15.30
1	25	6448	0.25	4.64	21.11	21.11
1	30	6443	0.25	4.98	27.33	27.33
2	35	6438	0.25	4.36	32.78	32.78
2	40	6433	0.25	4.68	38.63	38.63
2	45	6428	0.25	4.92	44.79	44.79
2	50	6423	0.25	4.92	50.94	50.94
2	55	6418	0.25	4.92	57.10	57.10
3	60	6413	0.35	8.81	72.51	72.51
3	65	6408	0.35	9.22	88.65	88.65
4	70	6403	0.35	7.87	102.44	102.44
4	75	6398	0.35	8.15	116.71	116.71
4	80	6393	0.35	8.43	131.47	131.47
5	85	6388	0.25	3.77	136.18	136.18
5	90	6383	0.25	3.77	140.90	140.90
5	95	6378	0.25	3.77	145.61	145.61
6	100	6373	0.35	14.40	170.81	170.81
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	100	--	2500	30
2	Cohesive	0.25	120	--	4000	55
3	Cohesionless	0.35	120	30	--	65
4	Silty	0.35	110	27	--	80
5	Cohesive	0.25	120	--	1000	95
6	Cohesionless	0.35	125	32	--	100
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type:	HP14x73	Select from drop down menu
Depth [in]:	13.61	
Width [in]:	14.585	
Thickness [in]:	0.505	
End Area [sf]:	0.149	(unplugged)
End Area [sf]:	1.378	(plugged)
Volume[cf/ft]:	0.149	
Steel Perimeter (C_d) [ft]:	2.599	
Soil Perimeter (C_d) [ft]:	2.1000	
δ/ϕ:	0.78	Figure 9.10
Yield Strength [ksi]:	50	7200 ksf
Resistance Factor:	0.50	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	535	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				HP14x73		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.10	0.70	0.20	0.75	0.149	0.73	0.96
26	0.10	0.73	0.20	0.78	0.149	0.76	0.96
27	0.10	0.76	0.20	0.82	0.149	0.79	0.95
28	0.10	0.79	0.20	0.86	0.149	0.83	0.94
29	0.10	0.82	0.20	0.90	0.149	0.87	0.94
30	0.10	0.85	0.20	0.94	0.149	0.90	0.93
31	0.10	0.91	0.20	1.02	0.149	0.97	0.92
32	0.10	0.97	0.20	1.10	0.149	1.04	0.91
33	0.10	1.03	0.20	1.17	0.149	1.11	0.91
34	0.10	1.09	0.20	1.25	0.149	1.18	0.90
35	0.10	1.15	0.20	1.33	0.149	1.25	0.90
36	0.10	1.26	0.20	1.48	0.149	1.39	0.89
37	0.10	1.37	0.20	1.63	0.149	1.52	0.88
38	0.10	1.48	0.20	1.79	0.149	1.66	0.88
39	0.10	1.59	0.20	1.94	0.149	1.79	0.87
40	0.10	1.70	0.20	2.09	0.149	1.92	0.87

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
30	1	3000	3000
55	2	6000	6000
65	3	7200	6576
80	4	8850	7290
95	5	10650	8154
100	6	11275	8467
0	7	11275	11275
0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.44	1.00	4.70
1	--	--	--	--	--	--	2500	0.46	1.04	4.89
1	--	--	--	--	--	--	2500	0.50	1.11	5.21
1	--	--	--	--	--	--	2500	0.53	1.18	5.54
2	--	--	--	--	--	--	4000	0.27	1.01	4.75
2	--	--	--	--	--	--	4000	0.28	1.08	5.06
2	--	--	--	--	--	--	4000	0.29	1.14	5.38
2	--	--	--	--	--	--	4000	0.30	1.21	5.69
2	--	--	--	--	--	--	4000	0.31	1.26	5.83
3	30	0.78	23.4	0.90	0.93	11.13	--	--	--	--
3	30	0.78	23.4	0.90	0.93	11.65	--	--	--	--
4	27	0.78	21.06	0.79	0.95	9.79	--	--	--	--
4	27	0.78	21.06	0.79	0.95	10.14	--	--	--	--
4	27	0.78	21.06	0.79	0.95	10.48	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	4.46
5	--	--	--	--	--	--	1000	1.00	0.95	4.46
5	--	--	--	--	--	--	1000	1.00	0.95	4.46
6	32	0.78	24.96	1.04	0.91	18.32	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
1	10	6463	0.25	4.70	5.87	5.87
1	15	6458	0.25	4.70	11.75	11.75
1	20	6453	0.25	4.89	17.86	17.86
1	25	6448	0.25	5.21	24.37	24.37
1	30	6443	0.25	5.54	31.30	31.30
2	35	6438	0.25	4.75	37.24	37.24
2	40	6433	0.25	5.06	43.56	43.56
2	45	6428	0.25	5.38	50.28	50.28
2	50	6423	0.25	5.69	57.40	57.40
2	55	6418	0.25	5.83	64.68	64.68
3	60	6413	0.35	11.13	84.16	84.16
3	65	6408	0.35	11.65	104.56	104.56
4	70	6403	0.35	9.79	121.69	121.69
4	75	6398	0.35	10.14	139.43	139.43
4	80	6393	0.35	10.48	157.77	157.77
5	85	6388	0.25	4.46	163.35	163.35
5	90	6383	0.25	4.46	168.93	168.93
5	95	6378	0.25	4.46	174.51	174.51
6	100	6373	0.35	18.32	206.57	206.57
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

CLOSED-END PIPE PILES

WEST ABUTMENT

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	110	--	3000	5
2	Silty	0.35	90	27	--	25
3	Cohesive	0.25	100	--	2500	40
4	Cohesive	0.25	120	--	3000	55
5	Silty	0.35	110	27	--	75
6	Cohesionless	0.35	120	32	--	85
7	Cohesive	0.25	120	--	1000	100
8		0.35				

Pile Inputs

Pile Type:	PP12-3/4x0.375	Select from drop down menu
Wall Thickness [in]:	0.375	
Outside Diameter [in]:	12.75	
End Area [sf]:	0.101	(open end - unplugged)
End Area [sf]:	0.887	(open end - plugged)
End Area [sf]:	0.887	(closed end)
Perimeter [ft]:	3.34	
Volume[cf/ft]:	0.887	(closed end)
δ/ϕ:	0.62	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	437	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP12-3/4x0.375		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.80	0.84	0.90	0.84	0.887	0.84	0.88
26	0.80	0.89	0.90	0.90	0.887	0.90	0.87
27	0.80	0.95	0.90	0.96	0.887	0.96	0.86
28	0.80	1.01	0.90	1.02	0.887	1.02	0.85
29	0.80	1.06	0.90	1.08	0.887	1.08	0.84
30	0.80	1.12	0.90	1.14	0.887	1.14	0.83
31	0.80	1.24	0.90	1.25	0.887	1.25	0.82
32	0.80	1.35	0.90	1.37	0.887	1.37	0.81
33	0.80	1.46	0.90	1.49	0.887	1.49	0.79
34	0.80	1.58	0.90	1.61	0.887	1.61	0.78
35	0.80	1.69	0.90	1.72	0.887	1.72	0.77
36	0.80	1.93	0.90	1.97	0.887	1.96	0.76
37	0.80	2.16	0.90	2.21	0.887	2.20	0.75
38	0.80	2.40	0.90	2.45	0.887	2.44	0.74
39	0.80	2.64	0.90	2.70	0.887	2.69	0.71
40	0.80	2.87	0.90	2.94	0.887	2.93	0.70

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Project No.: 17-2015-4045
Project: BIA Route N8065
Structure: West Abutment, Pile Foundation, No Scour
Corresponding Boring: BS-5/BS-6
Groundwater Table [ft]: 55
Depth of Scour [ft]: 0
γ_w [pcf]: 62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	φ' (deg)	δ/φ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	2.67
2	27	0.62	16.74	0.96	0.86	0.61	--	--	--	--
2	27	0.62	16.74	0.96	0.86	0.97	--	--	--	--
2	27	0.62	16.74	0.96	0.86	1.33	--	--	--	--
2	27	0.62	16.74	0.96	0.86	1.69	--	--	--	--
3	--	--	--	--	--	--	2500	0.56	1.23	4.11
3	--	--	--	--	--	--	2500	0.60	1.31	4.38
3	--	--	--	--	--	--	2500	0.64	1.39	4.64
4	--	--	--	--	--	--	3000	0.48	1.26	4.21
4	--	--	--	--	--	--	3000	0.50	1.30	4.34
4	--	--	--	--	--	--	3000	0.50	1.30	4.34
5	27	0.62	16.74	0.96	0.86	4.58	--	--	--	--
5	27	0.62	16.74	0.96	0.86	4.76	--	--	--	--
5	27	0.62	16.74	0.96	0.86	4.95	--	--	--	--
5	27	0.62	16.74	0.96	0.86	5.14	--	--	--	--
6	32	0.62	19.84	1.37	0.81	8.47	--	--	--	--
6	32	0.62	19.84	1.37	0.81	8.83	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.17
7	--	--	--	--	--	--	1000	1.00	0.95	3.17
7	--	--	--	--	--	--	1000	1.00	0.95	3.17
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
2	10	6463	0.35	0.61	1.08	1.08
2	15	6458	0.35	0.97	2.78	2.78
2	20	6453	0.35	1.33	5.10	5.10
2	25	6448	0.35	1.69	8.05	8.05
3	30	6443	0.25	4.11	13.19	13.19
3	35	6438	0.25	4.38	18.66	18.66
3	40	6433	0.25	4.64	24.46	24.46
4	45	6428	0.25	4.21	29.72	29.72
4	50	6423	0.25	4.34	35.15	35.15
4	55	6418	0.25	4.34	40.58	40.58
5	60	6413	0.35	4.58	48.59	48.59
5	65	6408	0.35	4.76	56.92	56.92
5	70	6403	0.35	4.95	65.59	65.59
5	75	6398	0.35	5.14	74.59	74.59
6	80	6393	0.35	8.47	89.41	89.41
6	85	6388	0.35	8.83	104.87	104.87
7	90	6383	0.25	3.17	108.84	108.84
7	95	6378	0.25	3.17	112.80	112.80
7	100	6373	0.25	3.17	116.77	116.77
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	110	--	3000	5
2	Silty	0.35	90	27	--	25
3	Cohesive	0.25	100	--	2500	40
4	Cohesive	0.25	120	--	3000	55
5	Silty	0.35	110	27	--	75
6	Cohesionless	0.35	120	32	--	85
7	Cohesive	0.25	120	--	1000	100
8		0.35				

Pile Inputs

Pile Type:	PP14x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	14.00	
End Area [sf]:	0.147	(open end - unplugged)
End Area [sf]:	1.069	(open end - plugged)
End Area [sf]:	1.069	(closed end)
Perimeter [ft]:	3.67	
Volume[cf/ft]:	1.069	(closed end)
δ/ϕ:	0.67	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	636	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP14x0.5		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	1.00	0.85	2.00	0.90	1.069	0.85	0.90
26	1.00	0.91	2.00	0.96	1.069	0.91	0.89
27	1.00	0.97	2.00	1.03	1.069	0.98	0.88
28	1.00	1.03	2.00	1.10	1.069	1.04	0.88
29	1.00	1.09	2.00	1.17	1.069	1.10	0.87
30	1.00	1.15	2.00	1.24	1.069	1.16	0.87
31	1.00	1.27	2.00	1.38	1.069	1.28	0.86
32	1.00	1.39	2.00	1.52	1.069	1.40	0.85
33	1.00	1.51	2.00	1.65	1.069	1.52	0.84
34	1.00	1.63	2.00	1.79	1.069	1.65	0.83
35	1.00	1.75	2.00	1.93	1.069	1.77	0.82
36	1.00	2.00	2.00	2.22	1.069	2.02	0.80
37	1.00	2.25	2.00	2.51	1.069	2.28	0.78
38	1.00	2.50	2.00	2.81	1.069	2.53	0.77
39	1.00	2.75	2.00	3.10	1.069	2.78	0.76
40	1.00	3.00	2.00	3.39	1.069	3.04	0.76

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Calculation

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	2.94
2	27	0.67	18.09	0.98	0.88	0.76	--	--	--	--
2	27	0.67	18.09	0.98	0.88	1.20	--	--	--	--
2	27	0.67	18.09	0.98	0.88	1.64	--	--	--	--
2	27	0.67	18.09	0.98	0.88	2.08	--	--	--	--
3	--	--	--	--	--	--	2500	0.54	1.19	4.38
3	--	--	--	--	--	--	2500	0.58	1.27	4.65
3	--	--	--	--	--	--	2500	0.61	1.34	4.92
4	--	--	--	--	--	--	3000	0.46	1.20	4.42
4	--	--	--	--	--	--	3000	0.49	1.28	4.68
4	--	--	--	--	--	--	3000	0.50	1.30	4.77
5	27	0.67	18.09	0.98	0.88	5.65	--	--	--	--
5	27	0.67	18.09	0.98	0.88	5.88	--	--	--	--
5	27	0.67	18.09	0.98	0.88	6.11	--	--	--	--
5	27	0.67	18.09	0.98	0.88	6.34	--	--	--	--
6	32	0.67	21.44	1.40	0.85	10.79	--	--	--	--
6	32	0.67	21.44	1.40	0.85	11.25	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.49
7	--	--	--	--	--	--	1000	1.00	0.95	3.49
7	--	--	--	--	--	--	1000	1.00	0.95	3.49
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
2	10	6463	0.35	0.76	1.33	1.33
2	15	6458	0.35	1.20	3.42	3.42
2	20	6453	0.35	1.64	6.29	6.29
2	25	6448	0.35	2.08	9.93	9.93
3	30	6443	0.25	4.38	15.41	15.41
3	35	6438	0.25	4.65	21.22	21.22
3	40	6433	0.25	4.92	27.37	27.37
4	45	6428	0.25	4.42	32.90	32.90
4	50	6423	0.25	4.68	38.75	38.75
4	55	6418	0.25	4.77	44.72	44.72
5	60	6413	0.35	5.65	54.60	54.60
5	65	6408	0.35	5.88	64.88	64.88
5	70	6403	0.35	6.11	75.58	75.58
5	75	6398	0.35	6.34	86.68	86.68
6	80	6393	0.35	10.79	105.56	105.56
6	85	6388	0.35	11.25	125.24	125.24
7	90	6383	0.25	3.49	129.60	129.60
7	95	6378	0.25	3.49	133.96	133.96
7	100	6373	0.25	3.49	138.32	138.32
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	110	--	3000	5
2	Silty	0.35	90	27	--	25
3	Cohesive	0.25	100	--	2500	40
4	Cohesive	0.25	120	--	3000	55
5	Silty	0.35	110	27	--	75
6	Cohesionless	0.35	120	32	--	85
7	Cohesive	0.25	120	--	1000	100
8		0.35				

Pile Inputs		
Pile Type:	PP16x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	16.00	
End Area [sf]:	0.169	(open end - unplugged)
End Area [sf]:	1.396	(open end - plugged)
End Area [sf]:	1.396	(closed end)
Perimeter [ft]:	4.19	
Volume[cf/ft]:	1.396	(closed end)
δ/ϕ:	0.73	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	730	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP16x0.5		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	1.00	0.85	2.00	0.90	1.396	0.87	0.92
26	1.00	0.91	2.00	0.96	1.396	0.93	0.91
27	1.00	0.97	2.00	1.03	1.396	1.00	0.90
28	1.00	1.03	2.00	1.10	1.396	1.06	0.90
29	1.00	1.09	2.00	1.17	1.396	1.13	0.89
30	1.00	1.15	2.00	1.24	1.396	1.19	0.88
31	1.00	1.27	2.00	1.38	1.396	1.32	0.87
32	1.00	1.39	2.00	1.52	1.396	1.45	0.87
33	1.00	1.51	2.00	1.65	1.396	1.58	0.86
34	1.00	1.63	2.00	1.79	1.396	1.71	0.86
35	1.00	1.75	2.00	1.93	1.396	1.84	0.85
36	1.00	2.00	2.00	2.22	1.396	2.11	0.85
37	1.00	2.25	2.00	2.51	1.396	2.38	0.84
38	1.00	2.50	2.00	2.81	1.396	2.65	0.83
39	1.00	2.75	2.00	3.10	1.396	2.92	0.82
40	1.00	3.00	2.00	3.39	1.396	3.19	0.80

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-5**	**BS-6**	**Average**
6473	0	24	23	24
6468	5	14	12	13
6463	10	20	16	18
6458	15	14	11	13
6453	20	11	12	12
6448	25	28	26	27
6443	30	22	20	21
6438	35	17	22	20
6433	40	24	31	28
6428	45	38	46	42
6423	50	24	21	23
6418	55	9	18	14
6413	60	10	6	8
6408	65	9	7	8
6403	70	11	7	9
6398	75	12	12	12
6393	80	7	14	11
6388	85	27	14	21
6383	90	9	8	9
6378	95	7	8	8
6373	100	7	10	9

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	West Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-5/BS-6
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
5	1	550	550
25	2	2350	2350
40	3	3850	3850
55	4	5650	5650
75	5	7850	6602
85	6	9050	7178
100	7	10850	8042
0	8	10850	10850

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	110	--	275	550	550	275	Cohesive	24	34
2	5	7.5	10	90	--	775	1000	1000	775	Silty	13	16
2	10	12.5	15	90	--	1225	1450	1450	1225	Silty	18	20
2	15	17.5	20	90	--	1675	1900	1900	1675	Silty	13	13
2	20	22.5	25	90	--	2125	2350	2350	2125	Silty	12	11
3	25	27.5	30	100	--	2600	2850	2850	2600	Cohesive	27	24
3	30	32.5	35	100	--	3100	3350	3350	3100	Cohesive	21	17
3	35	37.5	40	100	--	3600	3850	3850	3600	Cohesive	20	15
4	40	42.5	45	120	--	4150	4450	4450	4150	Cohesive	28	20
4	45	47.5	50	120	--	4750	5050	5050	4750	Cohesive	42	29
4	50	52.5	55	120	--	5350	5650	5650	5350	Cohesive	23	15
5	55	57.5	60	110	62.4	5925	6200	5888	5769	Silty	14	9
5	60	62.5	65	110	62.4	6475	6750	6126	6007	Silty	8	5
5	65	67.5	70	110	62.4	7025	7300	6364	6245	Silty	8	5
5	70	72.5	75	110	62.4	7575	7850	6602	6483	Silty	9	5
6	75	77.5	80	120	62.4	8150	8450	6890	6746	Cohesionless	12	7
6	80	82.5	85	120	62.4	8750	9050	7178	7034	Cohesionless	11	6
7	85	87.5	90	120	62.4	9350	9650	7466	7322	Cohesive	21	12
7	90	92.5	95	120	62.4	9950	10250	7754	7610	Cohesive	9	5
7	95	97.5	100	120	62.4	10550	10850	8042	7898	Cohesive	8	4
8	100	100.0	--	--	--	--	--	--	--	--	9	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	φ' (deg)	δ/φ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	3000	0.30	0.80	3.35
2	27	0.73	19.71	1.00	0.90	0.98	--	--	--	--
2	27	0.73	19.71	1.00	0.90	1.56	--	--	--	--
2	27	0.73	19.71	1.00	0.90	2.13	--	--	--	--
2	27	0.73	19.71	1.00	0.90	2.70	--	--	--	--
3	--	--	--	--	--	--	2500	0.52	1.15	4.81
3	--	--	--	--	--	--	2500	0.55	1.21	5.08
3	--	--	--	--	--	--	2500	0.58	1.28	5.35
4	--	--	--	--	--	--	3000	0.43	1.13	4.75
4	--	--	--	--	--	--	3000	0.46	1.20	5.01
4	--	--	--	--	--	--	3000	0.48	1.26	5.27
5	27	0.73	19.71	1.00	0.90	7.33	--	--	--	--
5	27	0.73	19.71	1.00	0.90	7.63	--	--	--	--
5	27	0.73	19.71	1.00	0.90	7.93	--	--	--	--
5	27	0.73	19.71	1.00	0.90	8.24	--	--	--	--
6	32	0.73	23.36	1.45	0.87	14.16	--	--	--	--
6	32	0.73	23.36	1.45	0.87	14.77	--	--	--	--
7	--	--	--	--	--	--	1000	1.00	0.95	3.98
7	--	--	--	--	--	--	1000	1.00	0.95	3.98
7	--	--	--	--	--	--	1000	1.00	0.95	3.98
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
2	10	6463	0.35	0.98	1.72	1.72
2	15	6458	0.35	1.56	4.45	4.45
2	20	6453	0.35	2.13	8.17	8.17
2	25	6448	0.35	2.70	12.89	12.89
3	30	6443	0.25	4.81	18.91	18.91
3	35	6438	0.25	5.08	25.26	25.26
3	40	6433	0.25	5.35	31.95	31.95
4	45	6428	0.25	4.75	37.88	37.88
4	50	6423	0.25	5.01	44.14	44.14
4	55	6418	0.25	5.27	50.74	50.74
5	60	6413	0.35	7.33	63.56	63.56
5	65	6408	0.35	7.63	76.92	76.92
5	70	6403	0.35	7.93	90.80	90.80
5	75	6398	0.35	8.24	105.21	105.21
6	80	6393	0.35	14.16	130.00	130.00
6	85	6388	0.35	14.77	155.84	155.84
7	90	6383	0.25	3.98	160.82	160.82
7	95	6378	0.25	3.98	165.80	165.80
7	100	6373	0.25	3.98	170.77	170.77
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

PIER

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	Piers, Pile Foundation, Scour
Corresponding Boring:	BS-3/BS-4
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	0	--	500	6.5
2	Cohesionless	0.35	120	32	--	30
3	Cohesive	0.25	120	--	1000	45
4	Cohesionless	0.35	125	34	--	80
5	Cohesionless	0.35	120	32	--	100
6		0.35				
7		0.35				
8		0.35				

Pile Inputs

Pile Type:	PP12-3/4x0.375	Select from drop down menu
Wall Thickness [in]:	0.375	
Outside Diameter [in]:	12.75	
End Area [sf]:	0.101	(open end - unplugged)
End Area [sf]:	0.887	(open end - plugged)
End Area [sf]:	0.887	(closed end)
Perimeter [ft]:	3.34	
Volume[cf/ft]:	0.887	(closed end)
δ/ϕ:	0.62	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	437	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP12-3/4x0.375		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	0.80	0.84	0.90	0.84	0.887	0.84	0.88
26	0.80	0.89	0.90	0.90	0.887	0.90	0.87
27	0.80	0.95	0.90	0.96	0.887	0.96	0.86
28	0.80	1.01	0.90	1.02	0.887	1.02	0.85
29	0.80	1.06	0.90	1.08	0.887	1.08	0.84
30	0.80	1.12	0.90	1.14	0.887	1.14	0.83
31	0.80	1.24	0.90	1.25	0.887	1.25	0.82
32	0.80	1.35	0.90	1.37	0.887	1.37	0.81
33	0.80	1.46	0.90	1.49	0.887	1.49	0.79
34	0.80	1.58	0.90	1.61	0.887	1.61	0.78
35	0.80	1.69	0.90	1.72	0.887	1.72	0.77
36	0.80	1.93	0.90	1.97	0.887	1.96	0.76
37	0.80	2.16	0.90	2.21	0.887	2.20	0.75
38	0.80	2.40	0.90	2.45	0.887	2.44	0.74
39	0.80	2.64	0.90	2.70	0.887	2.69	0.71
40	0.80	2.87	0.90	2.94	0.887	2.93	0.70

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6473	0	2	6	4
6468	5	8	3	6
6463	10	3	3	3
6458	15	4	5	5
6453	20	7	9	8
6448	25	6	17	12
6443	30	12	9	11
6438	35	13	7	10
6433	40	8	5	7
6428	45	7	5	6
6423	50	16	9	13
6418	55	10	19	15
6413	60	19	23	21
6408	65	32	18	25
6403	70	12	13	13
6398	75	32	12	22
6393	80	8	12	10
6388	85	12	3	8
6383	90	18	6	12
6378	95	10	11	11
6373	100	11	11	11

Project No.: 17-2015-4045
Project: BIA Route N8065
Structure: Piers, Pile Foundation, Scour
Corresponding Boring: BS-3/BS-4
Groundwater Table [ft]: 55
Depth of Scour [ft]: 0
γ_w [pcf]: 62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
7	1		
30	2	2820	2820
45	3	4620	4620
80	4	8995	7435
100	5	11395	8587
0	6	11395	11395
0	7	11395	11395
0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	--	0	0	0	0	Cohesive	4	0
2	5	7.5	10	120	--	300	420	420	300	Cohesionless	6	8
2	10	12.5	15	120	--	720	1020	1020	720	Cohesionless	3	4
2	15	17.5	20	120	--	1320	1620	1620	1320	Cohesionless	5	5
2	20	22.5	25	120	--	1920	2220	2220	1920	Cohesionless	8	8
2	25	27.5	30	120	--	2520	2820	2820	2520	Cohesionless	12	10
3	30	32.5	35	120	--	3120	3420	3420	3120	Cohesive	11	9
3	35	37.5	40	120	--	3720	4020	4020	3720	Cohesive	10	8
3	40	42.5	45	120	--	4320	4620	4620	4320	Cohesive	7	5
4	45	47.5	50	125	--	4932.5	5245	5245	4932.5	Cohesionless	6	4
4	50	52.5	55	125	--	5557.5	5870	5870	5557.5	Cohesionless	13	8
4	55	57.5	60	125	62.4	6182.5	6495	6183	6026.5	Cohesionless	15	9
4	60	62.5	65	125	62.4	6807.5	7120	6496	6339.5	Cohesionless	21	13
4	65	67.5	70	125	62.4	7432.5	7745	6809	6652.5	Cohesionless	25	15
4	70	72.5	75	125	62.4	8057.5	8370	7122	6965.5	Cohesionless	13	7
4	75	77.5	80	125	62.4	8682.5	8995	7435	7278.5	Cohesionless	22	12
5	80	82.5	85	120	62.4	9295	9595	7723	7579	Cohesionless	10	5
5	85	87.5	90	120	62.4	9895	10195	8011	7867	Cohesionless	8	4
5	90	92.5	95	120	62.4	10495	10795	8299	8155	Cohesionless	12	6
5	95	97.5	100	120	62.4	11095	11395	8587	8443	Cohesionless	11	5
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (ksf)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.62	19.84	1.37	0.81	0.38	--	--	--	--
2	32	0.62	19.84	1.37	0.81	0.90	--	--	--	--
2	32	0.62	19.84	1.37	0.81	1.66	--	--	--	--
2	32	0.62	19.84	1.37	0.81	2.41	--	--	--	--
2	32	0.62	19.84	1.37	0.81	3.16	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.89	0.89
3	--	--	--	--	--	--	1000	1.00	0.91	0.91
3	--	--	--	--	--	--	1000	1.00	0.94	0.94
4	34	0.62	21.08	1.61	0.78	7.42	--	--	--	--
4	34	0.62	21.08	1.61	0.78	8.36	--	--	--	--
4	34	0.62	21.08	1.61	0.78	9.07	--	--	--	--
4	34	0.62	21.08	1.61	0.78	9.54	--	--	--	--
4	34	0.62	21.08	1.61	0.78	10.01	--	--	--	--
4	34	0.62	21.08	1.61	0.78	10.48	--	--	--	--
4	34	0.62	21.08	1.61	0.78	10.95	--	--	--	--
5	32	0.62	19.84	1.37	0.81	9.52	--	--	--	--
5	32	0.62	19.84	1.37	0.81	9.88	--	--	--	--
5	32	0.62	19.84	1.37	0.81	10.24	--	--	--	--
5	32	0.62	19.84	1.37	0.81	10.60	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
2	10	6463	0.35	0.38	0.66	0.66
2	15	6458	0.35	0.90	2.24	2.24
2	20	6453	0.35	1.66	5.14	5.14
2	25	6448	0.35	2.41	9.36	9.36
2	30	6443	0.35	3.16	14.90	14.90
3	35	6438	0.25	0.89	16.01	16.01
3	40	6433	0.25	0.91	17.16	17.16
3	45	6428	0.25	0.94	18.33	18.33
4	50	6423	0.35	7.42	31.32	31.32
4	55	6418	0.35	8.36	45.96	45.96
4	60	6413	0.35	9.07	61.83	61.83
4	65	6408	0.35	9.54	78.53	78.53
4	70	6403	0.35	10.01	96.05	96.05
4	75	6398	0.35	10.48	114.39	114.39
4	80	6393	0.35	10.95	133.56	133.56
5	85	6388	0.35	9.52	150.22	150.22
5	90	6383	0.35	9.88	167.50	167.50
5	95	6378	0.35	10.24	185.42	185.42
5	100	6373	0.35	10.60	203.97	203.97
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs		
Project No.:	17-2015-4045	
Project:	BIA Route N8065	
Structure:	Piers, Pile Foundation, Scour	
Corresponding Boring:	BS-3/BS-4	
Depth to Groundwater Table [ft]:	55	
Ground Elevation [ft]:	6473	
Depth of Scour [ft]:	0	Not used in calculations.
Resistance Factor [clay]:	0.25	
Resistance Factor [sand]:	0.35	
Atmospheric Pressure (p_a) [pcf]:	2116	

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	0	--	500	6.5
2	Cohesionless	0.35	120	32	--	30
3	Cohesive	0.25	120	--	1000	45
4	Cohesionless	0.35	125	34	--	80
5	Cohesionless	0.35	120	32	--	100
6		0.35				
7		0.35				
8		0.35				

Pile Inputs		
Pile Type:	PP14x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	14.00	
End Area [sf]:	0.147	(open end - unplugged)
End Area [sf]:	1.069	(open end - plugged)
End Area [sf]:	1.069	(closed end)
Perimeter [ft]:	3.67	
Volume[cf/ft]:	1.069	(closed end)
δ/ϕ:	0.67	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	636	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP14x0.5		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	1.00	0.85	2.00	0.90	1.069	0.85	0.90
26	1.00	0.91	2.00	0.96	1.069	0.91	0.89
27	1.00	0.97	2.00	1.03	1.069	0.98	0.88
28	1.00	1.03	2.00	1.10	1.069	1.04	0.88
29	1.00	1.09	2.00	1.17	1.069	1.10	0.87
30	1.00	1.15	2.00	1.24	1.069	1.16	0.87
31	1.00	1.27	2.00	1.38	1.069	1.28	0.86
32	1.00	1.39	2.00	1.52	1.069	1.40	0.85
33	1.00	1.51	2.00	1.65	1.069	1.52	0.84
34	1.00	1.63	2.00	1.79	1.069	1.65	0.83
35	1.00	1.75	2.00	1.93	1.069	1.77	0.82
36	1.00	2.00	2.00	2.22	1.069	2.02	0.80
37	1.00	2.25	2.00	2.51	1.069	2.28	0.78
38	1.00	2.50	2.00	2.81	1.069	2.53	0.77
39	1.00	2.75	2.00	3.10	1.069	2.78	0.76
40	1.00	3.00	2.00	3.39	1.069	3.04	0.76

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6473	0	2	6	4
6468	5	8	3	6
6463	10	3	3	3
6458	15	4	5	5
6453	20	7	9	8
6448	25	6	17	12
6443	30	12	9	11
6438	35	13	7	10
6433	40	8	5	7
6428	45	7	5	6
6423	50	16	9	13
6418	55	10	19	15
6413	60	19	23	21
6408	65	32	18	25
6403	70	12	13	13
6398	75	32	12	22
6393	80	8	12	10
6388	85	12	3	8
6383	90	18	6	12
6378	95	10	11	11
6373	100	11	11	11

Calculation

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	7	1		
Project:	BIA Route N8065	30	2	2820	2820
Structure:	Piers, Pile Foundation, Scour	45	3	4620	4620
Corresponding Boring:	BS-3/BS-4	80	4	8995	7435
Groundwater Table [ft]:	55	100	5	11395	8587
Depth of Scour [ft]:	0	0	6	11395	11395
γ_w [pcf]:	62.4	0	7	11395	11395
		0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	--	0	0	0	0	Cohesive	4	0
2	5	7.5	10	120	--	300	420	420	300	Cohesionless	6	8
2	10	12.5	15	120	--	720	1020	1020	720	Cohesionless	3	4
2	15	17.5	20	120	--	1320	1620	1620	1320	Cohesionless	5	5
2	20	22.5	25	120	--	1920	2220	2220	1920	Cohesionless	8	8
2	25	27.5	30	120	--	2520	2820	2820	2520	Cohesionless	12	10
3	30	32.5	35	120	--	3120	3420	3420	3120	Cohesive	11	9
3	35	37.5	40	120	--	3720	4020	4020	3720	Cohesive	10	8
3	40	42.5	45	120	--	4320	4620	4620	4320	Cohesive	7	5
4	45	47.5	50	125	--	4932.5	5245	5245	4932.5	Cohesionless	6	4
4	50	52.5	55	125	--	5557.5	5870	5870	5557.5	Cohesionless	13	8
4	55	57.5	60	125	62.4	6182.5	6495	6183	6026.5	Cohesionless	15	9
4	60	62.5	65	125	62.4	6807.5	7120	6496	6339.5	Cohesionless	21	13
4	65	67.5	70	125	62.4	7432.5	7745	6809	6652.5	Cohesionless	25	15
4	70	72.5	75	125	62.4	8057.5	8370	7122	6965.5	Cohesionless	13	7
4	75	77.5	80	125	62.4	8682.5	8995	7435	7278.5	Cohesionless	22	12
5	80	82.5	85	120	62.4	9295	9595	7723	7579	Cohesionless	10	5
5	85	87.5	90	120	62.4	9895	10195	8011	7867	Cohesionless	8	4
5	90	92.5	95	120	62.4	10495	10795	8299	8155	Cohesionless	12	6
5	95	97.5	100	120	62.4	11095	11395	8587	8443	Cohesionless	11	5
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.67	21.44	1.40	0.85	0.48	--	--	--	--
2	32	0.67	21.44	1.40	0.85	1.15	--	--	--	--
2	32	0.67	21.44	1.40	0.85	2.11	--	--	--	--
2	32	0.67	21.44	1.40	0.85	3.07	--	--	--	--
2	32	0.67	21.44	1.40	0.85	4.03	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.88	3.22
3	--	--	--	--	--	--	1000	1.00	0.90	3.30
3	--	--	--	--	--	--	1000	1.00	0.92	3.38
4	34	0.67	22.78	1.65	0.83	9.57	--	--	--	--
4	34	0.67	22.78	1.65	0.83	10.79	--	--	--	--
4	34	0.67	22.78	1.65	0.83	11.70	--	--	--	--
4	34	0.67	22.78	1.65	0.83	12.30	--	--	--	--
4	34	0.67	22.78	1.65	0.83	12.91	--	--	--	--
4	34	0.67	22.78	1.65	0.83	13.52	--	--	--	--
4	34	0.67	22.78	1.65	0.83	14.12	--	--	--	--
5	32	0.67	21.44	1.40	0.85	12.12	--	--	--	--
5	32	0.67	21.44	1.40	0.85	12.58	--	--	--	--
5	32	0.67	21.44	1.40	0.85	13.04	--	--	--	--
5	32	0.67	21.44	1.40	0.85	13.50	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
2	10	6463	0.35	0.48	0.84	0.84
2	15	6458	0.35	1.15	2.85	2.85
2	20	6453	0.35	2.11	6.55	6.55
2	25	6448	0.35	3.07	11.92	11.92
2	30	6443	0.35	4.03	18.97	18.97
3	35	6438	0.25	3.22	23.01	23.01
3	40	6433	0.25	3.30	27.13	27.13
3	45	6428	0.25	3.38	31.36	31.36
4	50	6423	0.35	9.57	48.11	48.11
4	55	6418	0.35	10.79	66.99	66.99
4	60	6413	0.35	11.70	87.45	87.45
4	65	6408	0.35	12.30	108.98	108.98
4	70	6403	0.35	12.91	131.58	131.58
4	75	6398	0.35	13.52	155.23	155.23
4	80	6393	0.35	14.12	179.95	179.95
5	85	6388	0.35	12.12	201.16	201.16
5	90	6383	0.35	12.58	223.18	223.18
5	95	6378	0.35	13.04	246.00	246.00
5	100	6373	0.35	13.50	269.63	269.63
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs		
Project No.:	17-2015-4045	
Project:	BIA Route N8065	
Structure:	Piers, Pile Foundation, Scour	
Corresponding Boring:	BS-3/BS-4	
Depth to Groundwater Table [ft]:	55	
Ground Elevation [ft]:	6473	
Depth of Scour [ft]:	0	Not used in calculations.
Resistance Factor [clay]:	0.25	
Resistance Factor [sand]:	0.35	
Atmospheric Pressure (p_a) [pcf]:	2116	

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	0	--	500	6.5
2	Cohesionless	0.35	120	32	--	30
3	Cohesive	0.25	120	--	1000	45
4	Cohesionless	0.35	125	34	--	80
5	Cohesionless	0.35	120	32	--	100
6		0.35				
7		0.35				
8		0.35				

Pile Inputs		
Pile Type:	PP16x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	16.00	
End Area [sf]:	0.169	(open end - unplugged)
End Area [sf]:	1.396	(open end - plugged)
End Area [sf]:	1.396	(closed end)
Perimeter [ft]:	4.19	
Volume[cf/ft]:	1.396	(closed end)
δ/ϕ:	0.73	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	730	

	K_{δ}				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP16x0.5		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	1.00	0.85	2.00	0.90	1.396	0.87	0.92
26	1.00	0.91	2.00	0.96	1.396	0.93	0.91
27	1.00	0.97	2.00	1.03	1.396	1.00	0.90
28	1.00	1.03	2.00	1.10	1.396	1.06	0.90
29	1.00	1.09	2.00	1.17	1.396	1.13	0.89
30	1.00	1.15	2.00	1.24	1.396	1.19	0.88
31	1.00	1.27	2.00	1.38	1.396	1.32	0.87
32	1.00	1.39	2.00	1.52	1.396	1.45	0.87
33	1.00	1.51	2.00	1.65	1.396	1.58	0.86
34	1.00	1.63	2.00	1.79	1.396	1.71	0.86
35	1.00	1.75	2.00	1.93	1.396	1.84	0.85
36	1.00	2.00	2.00	2.22	1.396	2.11	0.85
37	1.00	2.25	2.00	2.51	1.396	2.38	0.84
38	1.00	2.50	2.00	2.81	1.396	2.65	0.83
39	1.00	2.75	2.00	3.10	1.396	2.92	0.82
40	1.00	3.00	2.00	3.39	1.396	3.19	0.80

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-3**	**BS-4**	**Average**
6473	0	2	6	4
6468	5	8	3	6
6463	10	3	3	3
6458	15	4	5	5
6453	20	7	9	8
6448	25	6	17	12
6443	30	12	9	11
6438	35	13	7	10
6433	40	8	5	7
6428	45	7	5	6
6423	50	16	9	13
6418	55	10	19	15
6413	60	19	23	21
6408	65	32	18	25
6403	70	12	13	13
6398	75	32	12	22
6393	80	8	12	10
6388	85	12	3	8
6383	90	18	6	12
6378	95	10	11	11
6373	100	11	11	11

Calculation

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	7	1		
Project:	BIA Route N8065	30	2	2820	2820
Structure:	Piers, Pile Foundation, Scour	45	3	4620	4620
Corresponding Boring:	BS-3/BS-4	80	4	8995	7435
Groundwater Table [ft]:	55	100	5	11395	8587
Depth of Scour [ft]:	0	0	6	11395	11395
γ_w [pcf]:	62.4	0	7	11395	11395
		0	8	11395	11395

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	0	--	0	0	0	0	Cohesive	4	0
2	5	7.5	10	120	--	300	420	420	300	Cohesionless	6	8
2	10	12.5	15	120	--	720	1020	1020	720	Cohesionless	3	4
2	15	17.5	20	120	--	1320	1620	1620	1320	Cohesionless	5	5
2	20	22.5	25	120	--	1920	2220	2220	1920	Cohesionless	8	8
2	25	27.5	30	120	--	2520	2820	2820	2520	Cohesionless	12	10
3	30	32.5	35	120	--	3120	3420	3420	3120	Cohesive	11	9
3	35	37.5	40	120	--	3720	4020	4020	3720	Cohesive	10	8
3	40	42.5	45	120	--	4320	4620	4620	4320	Cohesive	7	5
4	45	47.5	50	125	--	4932.5	5245	5245	4932.5	Cohesionless	6	4
4	50	52.5	55	125	--	5557.5	5870	5870	5557.5	Cohesionless	13	8
4	55	57.5	60	125	62.4	6182.5	6495	6183	6026.5	Cohesionless	15	9
4	60	62.5	65	125	62.4	6807.5	7120	6496	6339.5	Cohesionless	21	13
4	65	67.5	70	125	62.4	7432.5	7745	6809	6652.5	Cohesionless	25	15
4	70	72.5	75	125	62.4	8057.5	8370	7122	6965.5	Cohesionless	13	7
4	75	77.5	80	125	62.4	8682.5	8995	7435	7278.5	Cohesionless	22	12
5	80	82.5	85	120	62.4	9295	9595	7723	7579	Cohesionless	10	5
5	85	87.5	90	120	62.4	9895	10195	8011	7867	Cohesionless	8	4
5	90	92.5	95	120	62.4	10495	10795	8299	8155	Cohesionless	12	6
5	95	97.5	100	120	62.4	11095	11395	8587	8443	Cohesionless	11	5
8	100	100.0	--	--	--	--	--	--	--	--	11	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	500	0.98	0.40	0.00
2	32	0.73	23.36	1.45	0.87	0.63	--	--	--	--
2	32	0.73	23.36	1.45	0.87	1.51	--	--	--	--
2	32	0.73	23.36	1.45	0.87	2.77	--	--	--	--
2	32	0.73	23.36	1.45	0.87	4.03	--	--	--	--
2	32	0.73	23.36	1.45	0.87	5.29	--	--	--	--
3	--	--	--	--	--	--	1000	1.00	0.86	3.61
3	--	--	--	--	--	--	1000	1.00	0.88	3.69
3	--	--	--	--	--	--	1000	1.00	0.90	3.77
4	34	0.73	24.82	1.71	0.86	12.74	--	--	--	--
4	34	0.73	24.82	1.71	0.86	14.35	--	--	--	--
4	34	0.73	24.82	1.71	0.86	15.56	--	--	--	--
4	34	0.73	24.82	1.71	0.86	16.37	--	--	--	--
4	34	0.73	24.82	1.71	0.86	17.18	--	--	--	--
4	34	0.73	24.82	1.71	0.86	17.99	--	--	--	--
4	34	0.73	24.82	1.71	0.86	18.79	--	--	--	--
5	32	0.73	23.36	1.45	0.87	15.91	--	--	--	--
5	32	0.73	23.36	1.45	0.87	16.52	--	--	--	--
5	32	0.73	23.36	1.45	0.87	17.12	--	--	--	--
5	32	0.73	23.36	1.45	0.87	17.73	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
2	10	6463	0.35	0.63	1.10	1.10
2	15	6458	0.35	1.51	3.75	3.75
2	20	6453	0.35	2.77	8.60	8.60
2	25	6448	0.35	4.03	15.65	15.65
2	30	6443	0.35	5.29	24.91	24.91
3	35	6438	0.25	3.61	29.43	29.43
3	40	6433	0.25	3.69	34.04	34.04
3	45	6428	0.25	3.77	38.76	38.76
4	50	6423	0.35	12.74	61.05	61.05
4	55	6418	0.35	14.35	86.16	86.16
4	60	6413	0.35	15.56	113.39	113.39
4	65	6408	0.35	16.37	142.04	142.04
4	70	6403	0.35	17.18	172.10	172.10
4	75	6398	0.35	17.99	203.57	203.57
4	80	6393	0.35	18.79	236.46	236.46
5	85	6388	0.35	15.91	264.31	264.31
5	90	6383	0.35	16.52	293.21	293.21
5	95	6378	0.35	17.12	323.18	323.18
5	100	6373	0.35	17.73	354.20	354.20
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

EAST ABUTMENT

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	100	--	2500	30
2	Cohesive	0.25	120	--	4000	55
3	Cohesionless	0.35	120	30	--	65
4	Silty	0.35	110	27	--	80
5	Cohesive	0.25	120	--	1000	95
6	Cohesionless	0.35	125	32	--	100
7		0.35				
8		0.35				

Pile Inputs

Pile Type:	PP12-3/4x0.375	Select from drop down menu
Wall Thickness [in]:	0.375	
Outside Diameter [in]:	12.75	
End Area [sf]:	0.101	(open end - unplugged)
End Area [sf]:	0.887	(open end - plugged)
End Area [sf]:	0.887	(closed end)
Perimeter [ft]:	3.34	
Volume[cf/ft]:	0.887	(closed end)
δ/ϕ:	0.62	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	437	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP12-3/4x0.375		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	0.80	0.84	0.90	0.84	0.887	0.84	0.88
26	0.80	0.89	0.90	0.90	0.887	0.90	0.87
27	0.80	0.95	0.90	0.96	0.887	0.96	0.86
28	0.80	1.01	0.90	1.02	0.887	1.02	0.85
29	0.80	1.06	0.90	1.08	0.887	1.08	0.84
30	0.80	1.12	0.90	1.14	0.887	1.14	0.83
31	0.80	1.24	0.90	1.25	0.887	1.25	0.82
32	0.80	1.35	0.90	1.37	0.887	1.37	0.81
33	0.80	1.46	0.90	1.49	0.887	1.49	0.79
34	0.80	1.58	0.90	1.61	0.887	1.61	0.78
35	0.80	1.69	0.90	1.72	0.887	1.72	0.77
36	0.80	1.93	0.90	1.97	0.887	1.96	0.76
37	0.80	2.16	0.90	2.21	0.887	2.20	0.75
38	0.80	2.40	0.90	2.45	0.887	2.44	0.74
39	0.80	2.64	0.90	2.70	0.887	2.69	0.71
40	0.80	2.87	0.90	2.94	0.887	2.93	0.70

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

		Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
Project No.:	17-2015-4045	30	1	3000	3000
Project:	BIA Route N8065	55	2	6000	6000
Structure:	East Abutment, Pile Foundation, No Scour	65	3	7200	6576
Corresponding Boring:	BS-1/BS-2	80	4	8850	7290
Groundwater Table [ft]:	55	95	5	10650	8154
Depth of Scour [ft]:	0	100	6	11275	8467
γ_w [pcf]:	62.4	0	7	11275	11275
		0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.34
1	--	--	--	--	--	--	2500	0.44	1.00	3.34
1	--	--	--	--	--	--	2500	0.44	1.00	3.34
1	--	--	--	--	--	--	2500	0.48	1.07	3.57
1	--	--	--	--	--	--	2500	0.52	1.15	3.84
1	--	--	--	--	--	--	2500	0.56	1.23	4.11
2	--	--	--	--	--	--	4000	0.28	1.07	3.57
2	--	--	--	--	--	--	4000	0.29	1.14	3.82
2	--	--	--	--	--	--	4000	0.30	1.22	4.07
2	--	--	--	--	--	--	4000	0.31	1.26	4.14
2	--	--	--	--	--	--	4000	0.31	1.26	4.14
3	30	0.62	18.6	1.14	0.83	6.18	--	--	--	--
3	30	0.62	18.6	1.14	0.83	6.47	--	--	--	--
4	27	0.62	16.74	0.96	0.86	5.31	--	--	--	--
4	27	0.62	16.74	0.96	0.86	5.50	--	--	--	--
4	27	0.62	16.74	0.96	0.86	5.69	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.17
5	--	--	--	--	--	--	1000	1.00	0.95	3.17
5	--	--	--	--	--	--	1000	1.00	0.95	3.17
6	32	0.62	19.84	1.37	0.81	10.43	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
1	10	6463	0.25	3.34	4.18	4.18
1	15	6458	0.25	3.34	8.35	8.35
1	20	6453	0.25	3.57	12.82	12.82
1	25	6448	0.25	3.84	17.62	17.62
1	30	6443	0.25	4.11	22.75	22.75
2	35	6438	0.25	3.57	27.21	27.21
2	40	6433	0.25	3.82	31.99	31.99
2	45	6428	0.25	4.07	37.08	37.08
2	50	6423	0.25	4.14	42.25	42.25
2	55	6418	0.25	4.14	47.43	47.43
3	60	6413	0.35	6.18	58.24	58.24
3	65	6408	0.35	6.47	69.57	69.57
4	70	6403	0.35	5.31	78.86	78.86
4	75	6398	0.35	5.50	88.48	88.48
4	80	6393	0.35	5.69	98.44	98.44
5	85	6388	0.25	3.17	102.40	102.40
5	90	6383	0.25	3.17	106.37	106.37
5	95	6378	0.25	3.17	110.33	110.33
6	100	6373	0.35	10.43	128.60	128.60
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs	
Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	100	--	2500	30
2	Cohesive	0.25	120	--	4000	55
3	Cohesionless	0.35	120	30	--	65
4	Silty	0.35	110	27	--	80
5	Cohesive	0.25	120	--	1000	95
6	Cohesionless	0.35	125	32	--	100
7		0.35				
8		0.35				

H-Pile Inputs

Pile Type:	PP14x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	14.00	
End Area [sf]:	0.147	(open end - unplugged)
End Area [sf]:	1.069	(open end - plugged)
End Area [sf]:	1.069	(closed end)
Perimeter [ft]:	3.67	
Volume[cf/ft]:	1.069	(closed end)
δ/ϕ:	0.67	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	636	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP14x0.5		
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	C_F
25	1.00	0.85	2.00	0.90	1.069	0.85	0.90
26	1.00	0.91	2.00	0.96	1.069	0.91	0.89
27	1.00	0.97	2.00	1.03	1.069	0.98	0.88
28	1.00	1.03	2.00	1.10	1.069	1.04	0.88
29	1.00	1.09	2.00	1.17	1.069	1.10	0.87
30	1.00	1.15	2.00	1.24	1.069	1.16	0.87
31	1.00	1.27	2.00	1.38	1.069	1.28	0.86
32	1.00	1.39	2.00	1.52	1.069	1.40	0.85
33	1.00	1.51	2.00	1.65	1.069	1.52	0.84
34	1.00	1.63	2.00	1.79	1.069	1.65	0.83
35	1.00	1.75	2.00	1.93	1.069	1.77	0.82
36	1.00	2.00	2.00	2.22	1.069	2.02	0.80
37	1.00	2.25	2.00	2.51	1.069	2.28	0.78
38	1.00	2.50	2.00	2.81	1.069	2.53	0.77
39	1.00	2.75	2.00	3.10	1.069	2.78	0.76
40	1.00	3.00	2.00	3.39	1.069	3.04	0.76

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs				
Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Groundwater Table [ft]:	55
Depth of Scour [ft]:	0
γ_w [pcf]:	62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
30	1	3000	3000
55	2	6000	6000
65	3	7200	6576
80	4	8850	7290
95	5	10650	8154
100	6	11275	8467
0	7	11275	11275
0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

	Skin Friction Calculations by Layer									
Layer	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (kips/ft)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	3.67
1	--	--	--	--	--	--	2500	0.44	1.00	3.67
1	--	--	--	--	--	--	2500	0.44	1.00	3.67
1	--	--	--	--	--	--	2500	0.46	1.05	3.85
1	--	--	--	--	--	--	2500	0.50	1.12	4.12
1	--	--	--	--	--	--	2500	0.54	1.19	4.38
2	--	--	--	--	--	--	4000	0.28	1.03	3.77
2	--	--	--	--	--	--	4000	0.29	1.10	4.02
2	--	--	--	--	--	--	4000	0.30	1.17	4.28
2	--	--	--	--	--	--	4000	0.31	1.24	4.50
2	--	--	--	--	--	--	4000	0.31	1.26	4.55
3	30	0.67	20.1	1.16	0.87	7.81	--	--	--	--
3	30	0.67	20.1	1.16	0.87	8.18	--	--	--	--
4	27	0.67	18.09	0.98	0.88	6.55	--	--	--	--
4	27	0.67	18.09	0.98	0.88	6.78	--	--	--	--
4	27	0.67	18.09	0.98	0.88	7.02	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.49
5	--	--	--	--	--	--	1000	1.00	0.95	3.49
5	--	--	--	--	--	--	1000	1.00	0.95	3.49
6	32	0.67	21.44	1.40	0.85	13.29	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
1	10	6463	0.25	3.67	4.59	4.59
1	15	6458	0.25	3.67	9.18	9.18
1	20	6453	0.25	3.85	13.99	13.99
1	25	6448	0.25	4.12	19.13	19.13
1	30	6443	0.25	4.38	24.61	24.61
2	35	6438	0.25	3.77	29.32	29.32
2	40	6433	0.25	4.02	34.35	34.35
2	45	6428	0.25	4.28	39.70	39.70
2	50	6423	0.25	4.50	45.33	45.33
2	55	6418	0.25	4.55	51.02	51.02
3	60	6413	0.35	7.81	64.69	64.69
3	65	6408	0.35	8.18	79.00	79.00
4	70	6403	0.35	6.55	90.46	90.46
4	75	6398	0.35	6.78	102.33	102.33
4	80	6393	0.35	7.02	114.61	114.61
5	85	6388	0.25	3.49	118.97	118.97
5	90	6383	0.25	3.49	123.33	123.33
5	95	6378	0.25	3.49	127.69	127.69
6	100	6373	0.35	13.29	150.95	150.95
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

Site Inputs

Project No.:	17-2015-4045
Project:	BIA Route N8065
Structure:	East Abutment, Pile Foundation, No Scour
Corresponding Boring:	BS-1/BS-2
Depth to Groundwater Table [ft]:	55
Ground Elevation [ft]:	6473
Depth of Scour [ft]:	0 Not used in calculations.
Resistance Factor [clay]:	0.25
Resistance Factor [sand]:	0.35
Atmospheric Pressure (p_a) [pcf]:	2116

Soil Layer	Soil Type	Resistance Factor	γ_{total}	ϕ	s_u	Depth to Bottom of Layer
			[pcf]	[degrees]	[psf]	[ft]
1	Cohesive	0.25	100	--	2500	30
2	Cohesive	0.25	120	--	4000	55
3	Cohesionless	0.35	120	30	--	65
4	Silty	0.35	110	27	--	80
5	Cohesive	0.25	120	--	1000	95
6	Cohesionless	0.35	125	32	--	100
7		0.35				
8		0.35				

Pile Inputs		
Pile Type:	PP16x0.5	Select from drop down menu
Wall Thickness [in]:	0.500	
Outside Diameter [in]:	16.00	
End Area [sf]:	0.169	(open end - unplugged)
End Area [sf]:	1.396	(open end - plugged)
End Area [sf]:	1.396	(closed end)
Perimeter [ft]:	4.19	
Volume[cf/ft]:	1.396	(closed end)
δ/ϕ:	0.73	Figure 9.10
Yield Strenght [ksi]:	50	7200 ksf
Resistance Factor:	0.60	AASHTO Section 6.5.4.2
Factored Pile Strength [kips]:	730	

	K_δ				Interpolation**		
	Values from Table 9-4 (V in cf/ft)				PP16x0.5		C_F
ϕ' (deg)	V_{low}	$K_{\delta,Low}$	V_{high}	$K_{\delta,high}$	V_{actual}	$K_{\delta,actual}$	
25	1.00	0.85	2.00	0.90	1.396	0.87	0.92
26	1.00	0.91	2.00	0.96	1.396	0.93	0.91
27	1.00	0.97	2.00	1.03	1.396	1.00	0.90
28	1.00	1.03	2.00	1.10	1.396	1.06	0.90
29	1.00	1.09	2.00	1.17	1.396	1.13	0.89
30	1.00	1.15	2.00	1.24	1.396	1.19	0.88
31	1.00	1.27	2.00	1.38	1.396	1.32	0.87
32	1.00	1.39	2.00	1.52	1.396	1.45	0.87
33	1.00	1.51	2.00	1.65	1.396	1.58	0.86
34	1.00	1.63	2.00	1.79	1.396	1.71	0.86
35	1.00	1.75	2.00	1.93	1.396	1.84	0.85
36	1.00	2.00	2.00	2.22	1.396	2.11	0.85
37	1.00	2.25	2.00	2.51	1.396	2.38	0.84
38	1.00	2.50	2.00	2.81	1.396	2.65	0.83
39	1.00	2.75	2.00	3.10	1.396	2.92	0.82
40	1.00	3.00	2.00	3.39	1.396	3.19	0.80

**This uses log-linear interpolation based on Appendix F.2.1.2 of the FHWA Driven Piles Manual

N-Value Inputs

Elevation	Depth	**BS-1**	**BS-2**	**Average**
6473	0	18	26	22
6468	5	13	14	14
6463	10	18	10	14
6458	15	40	18	29
6453	20	70	22	46
6448	25	29	43	36
6443	30	45	27	36
6438	35	30	27	29
6433	40	39	28	34
6428	45	33	40	37
6423	50	30	13	22
6418	55	26	10	18
6413	60	3	5	4
6408	65	5	0	3
6403	70	4	6	5
6398	75	29	4	17
6393	80	16	14	15
6388	85	9	6	8
6383	90	7	11	9
6378	95	100	24	62
6373	100	24	17	21

Project No.: 17-2015-4045
Project: BIA Route N8065
Structure: East Abutment, Pile Foundation, No Scour
Corresponding Boring: BS-1/BS-2
Groundwater Table [ft]: 55
Depth of Scour [ft]: 0
γ_w [pcf]: 62.4

Bottom of Layer	Soil Layer	$(\sigma_o)_{bottom}$ [psf]	$(\sigma_o')_{bottom}$ [psf]
30	1	3000	3000
55	2	6000	6000
65	3	7200	6576
80	4	8850	7290
95	5	10650	8154
100	6	11275	8467
0	7	11275	11275
0	8	11275	11275

Layer	Layer Depths (ft)			γ_t (pcf)	γ_w (pcf)	$\sigma_{v,mid}$ (psf)	$\sigma_{v,bottom}$ (psf)	$\sigma'_{v,bottom}$ (psf)	$\sigma'_{v,mid}$ (psf)	Material Type	N	N'
		Middle	End									
1	0	0	0	0	0	0	0	0	0	0	0	0
1	0	2.5	5	100	--	250	500	500	250	Cohesive	22	32
1	5	7.5	10	100	--	750	1000	1000	750	Cohesive	14	17
1	10	12.5	15	100	--	1250	1500	1500	1250	Cohesive	14	15
1	15	17.5	20	100	--	1750	2000	2000	1750	Cohesive	29	29
1	20	22.5	25	100	--	2250	2500	2500	2250	Cohesive	46	43
1	25	27.5	30	100	--	2750	3000	3000	2750	Cohesive	36	31
2	30	32.5	35	120	--	3300	3600	3600	3300	Cohesive	36	29
2	35	37.5	40	120	--	3900	4200	4200	3900	Cohesive	29	21
2	40	42.5	45	120	--	4500	4800	4800	4500	Cohesive	34	24
2	45	47.5	50	120	--	5100	5400	5400	5100	Cohesive	37	24
2	50	52.5	55	120	--	5700	6000	6000	5700	Cohesive	22	14
3	55	57.5	60	120	62.4	6300	6600	6288	6144	Cohesionless	18	11
3	60	62.5	65	120	62.4	6900	7200	6576	6432	Cohesionless	4	2
4	65	67.5	70	110	62.4	7475	7750	6814	6695	Silty	3	1
4	70	72.5	75	110	62.4	8025	8300	7052	6933	Silty	5	3
4	75	77.5	80	110	62.4	8575	8850	7290	7171	Silty	17	9
5	80	82.5	85	120	62.4	9150	9450	7578	7434	Cohesive	15	8
5	85	87.5	90	120	62.4	9750	10050	7866	7722	Cohesive	8	4
5	90	92.5	95	120	62.4	10350	10650	8154	8010	Cohesive	9	5
6	95	97.5	100	125	62.4	10962.5	11275	8467	8311	Cohesionless	62	32
8	100	100.0	--	--	--	--	--	--	--	--	21	--

Layer	Skin Friction Calculations by Layer									
	Nordlund Method (Cohesionless Soils)					Unit Side Resistance (kips/ft)	Alpha Method (Cohesive Soils)			Unit Side Resistance (ksf)
	ϕ' (deg)	δ/ϕ	δ	K_δ	C_F		s_u (psf)	α	C_a (ksf)	
1	0	0	0	0	0	0	0	0	0	0
1	--	--	--	--	--	--	2500	0.44	1.00	4.19
1	--	--	--	--	--	--	2500	0.44	1.00	4.19
1	--	--	--	--	--	--	2500	0.44	1.00	4.19
1	--	--	--	--	--	--	2500	0.45	1.02	4.28
1	--	--	--	--	--	--	2500	0.48	1.09	4.55
1	--	--	--	--	--	--	2500	0.52	1.15	4.81
2	--	--	--	--	--	--	4000	0.27	0.97	4.08
2	--	--	--	--	--	--	4000	0.28	1.04	4.34
2	--	--	--	--	--	--	4000	0.29	1.10	4.60
2	--	--	--	--	--	--	4000	0.30	1.16	4.85
2	--	--	--	--	--	--	4000	0.30	1.22	5.10
3	30	0.73	21.9	1.19	0.88	10.08	--	--	--	--
3	30	0.73	21.9	1.19	0.88	10.56	--	--	--	--
4	27	0.73	19.71	1.00	0.90	8.51	--	--	--	--
4	27	0.73	19.71	1.00	0.90	8.81	--	--	--	--
4	27	0.73	19.71	1.00	0.90	9.11	--	--	--	--
5	--	--	--	--	--	--	1000	1.00	0.95	3.98
5	--	--	--	--	--	--	1000	1.00	0.95	3.98
5	--	--	--	--	--	--	1000	1.00	0.95	3.98
6	32	0.73	23.36	1.45	0.87	17.45	--	--	--	--
8	--	--	--	--	--	--	--	--	--	--

Layer	Depth (ft)	Elevation (ft)	Resistance Factor	Unit Side Resistance (kips/ft)	Pile Side Resistance (kips)	Uplift Resistance of Piles (kips)
1	0	6473	0.25	0.00	0.00	0.00
1	5	6468	0.25	0.00	0.00	0.00
1	10	6463	0.25	4.19	5.24	5.24
1	15	6458	0.25	4.19	10.48	10.48
1	20	6453	0.25	4.28	15.82	15.82
1	25	6448	0.25	4.55	21.51	21.51
1	30	6443	0.25	4.81	27.52	27.52
2	35	6438	0.25	4.08	32.63	32.63
2	40	6433	0.25	4.34	38.05	38.05
2	45	6428	0.25	4.60	43.79	43.79
2	50	6423	0.25	4.85	49.86	49.86
2	55	6418	0.25	5.10	56.23	56.23
3	60	6413	0.35	10.08	73.87	73.87
3	65	6408	0.35	10.56	92.35	92.35
4	70	6403	0.35	8.51	107.23	107.23
4	75	6398	0.35	8.81	122.65	122.65
4	80	6393	0.35	9.11	138.59	138.59
5	85	6388	0.25	3.98	143.56	143.56
5	90	6383	0.25	3.98	148.54	148.54
5	95	6378	0.25	3.98	153.52	153.52
6	100	6373	0.35	17.45	184.05	184.05
8	--	#VALUE!	0.35	--	#VALUE!	#VALUE!

ATTACHMENT D

SAMPLE CALCULATIONS FOR SETTLEMENT OF PILES

DESIGN MEMORANDUM

Client: BHA
Project: N8065(1)
Data For: Settlement of Piles
Prepared By: NC Checked By:
Sheet 1 Of 5
Date: 6/10/16
Work Order:
File No: 17-2015-4045

amec foster wheeler

- Assumptions
  1. 4-piles - HP12x53 - spaced at 4D
  2. Depth of embedment ≈ 40 ft bgs at the East Abutment
  3. Max Load per pile ≈ 67 kips at 40ft bgs
  4. Piles primarily supported by side resistance - assume case B per AASHTO Section 10.7.2.3.1

- Settlement of Group (Section 10.7.2.3.2 of AASHTO)

  • using hmertmann's Modified Method

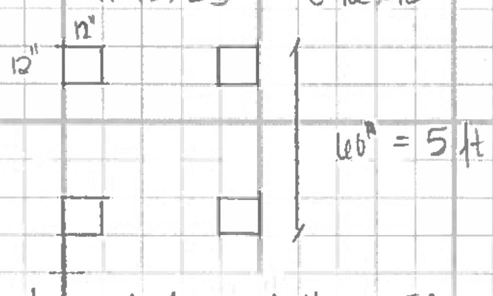
  → $D' =$ effective depth

  $= 2D_b/3$ (ft) → $D_b =$ depth of embedment

  $D' = 2(40\text{ft})/3 = 26.7$ ft

  → $B =$ width of smallest dimension of pile group

  HP12x53 ≈ 12"x12" @ 4D spacing



  → $B' =$ equivalant width $= 5\text{ft} + 2\times(26.7/4) = 18.35$ ft ≈ 18.5 ft
  → $B' = Z'$ (for this case)

• q ⇒ 4 piles at 67kips = 268 kips over an area $B' \times Z'$ (equivalant footing)

  $q = 268\text{kips}/[(5\text{ft} + 2(26.7/4))(5\text{ft} + 2(26.7/4))] = 0.8$ ksf ≈ 800 psf

• $N_{1,60}$ ⇒ SPT blow count corrected & averaged over B' below D_b

  $D_b \approx 25$ ft + ($B' \approx 20$ ft) ⇒ 25 to 55 ft

DESIGN MEMORANDUM

Client: BIA

Project: BIAN8065(1)

Data For: Settlement of Piles

Prepared By: NC

Checked By:

Date:

Work Order:

File No:

amec foster wheeler

- $N_{1(60)}$ ⇒ 33 to 2 (25 to 55 ft) see attached N-Values sheet, page 4
- E-Values were correlated based on Kulhawy and Mayne for clay soils from 25 to 55 ft and 95 to 100 ft, and sand with fines from 55 to 95 feet.

⇒ Anticipated Settlement of the pile group is approximately 1/2 inch

→ see attached Schmertmann calculation, page 5

Note: Check formulas to ensure that correct cells are used in the calculations

Depth	BS-1	BS-2	AVG	(AVG+MIN)/2	Lower Quartile (for comparison)
0	18	26	22	20	20
2.5	13	14	14	13	13.25
5	18	10	14	12	12
10	40	18	29	24	23.5
15	70	22	46	34	34
20	29	43	36	33	32.5
25	45	27	36	32	31.5
30	30	27	29	28	27.75
35	39	28	34	31	30.75
40	33	40	37	35	34.75
45	26	13	20	16	16.25
50	22	10	16	13	13
55	3	5	4	4	3.5
60	5	0	3	1	1.25
65	4	6	5	5	4.5
70	29	4	17	10	10.25
75	16	14	15	15	14.5
80	9	6	8	7	6.75
85	3	11	7	5	5
90	100	24	62	43	43
95	24	17	21	19	18.75
100			#DIV/0!	#DIV/0!	#NUM!
105			#DIV/0!	#DIV/0!	#NUM!
110			#DIV/0!	#DIV/0!	#NUM!
115			#DIV/0!	#DIV/0!	#NUM!
120			#DIV/0!	#DIV/0!	#NUM!
125			#DIV/0!	#DIV/0!	#NUM!

Based information provided in

Project Name:	Settlement of Piles
Project #:	17-2015-4045
Date:	6/10/2016
User:	NC

Input

Hammer Type	1	(Safety(1) or Donut(2), or Automatic(3))
Borehole Diameter	7	[in]
Sampling Method	1	(Standard sampler(1) or Sampler without liner(2))

Correction Values

C_{ER}	1.15	Correction for energy ratio
C_B	1.05	Correction for borehole diameter
C_S	1	Correction for sampling method
C_R	Function of Depth	Correction for rod length
C_N	Function of Depth	Correction for overburden = $2/(1+\sigma_{vo}/p_a)$

N_{60} N corrected for field procedures = $C_{ER}*C_B*C_S*C_R*N$

$(N_1)_{60}$ N_{60} corrected for overburden = C_N*N_{60}

N_1 N corrected for overburden = C_N*N

Elastic modulus is a function of Soil Type

Soil Type

1	sand with fines, silts, sandy silts, slightly cohesive mixtures
2	clean NC sands, clean fine to medium sands and slightly silty sand
3	clean OC sands, coarse sands and sands with little gravel
4	sandy gravels and gravels
5	submerged sand
6	clay
7	cemented fine-grained soils

Avg. Effec. Unit Weight (γ') 110 [pcf]

Atmospheric Pressure (p_a) 2116 [pcf]

Depth [ft]	C_R	N	N_{60}	N_{55}	C_N	N_1	$(N_1)_{60}$	Soil Type	Kulhawy & Mayne 1990 E_{N60} [ksf]	AASHTO 1996 $E_{(N1)}$ [ksf]	Bowles 1996 E_{N55} [ksf]	Hansen & Beckwith E_N [ksf]	Design Values [psf]
0	0.75	20	18	20	2.0	40	36	6	271	No Corr.	No Corr.	No Corr.	270,815
2.5	0.75	13	12	13	1.8	23	21	6	209	No Corr.	No Corr.	No Corr.	208,810
5	0.75	12	11	12	1.6	19	17	6	196	No Corr.	No Corr.	No Corr.	196,144
10	0.85	24	24	26	1.3	31	32	6	300	No Corr.	No Corr.	No Corr.	299,849
15	0.95	34	39	43	1.1	38	44	6	379	No Corr.	No Corr.	No Corr.	378,619
20	0.95	33	37	41	1.0	32	37	6	368	No Corr.	No Corr.	No Corr.	367,983
25	1	32	38	41	0.9	27	33	6	361	No Corr.	No Corr.	No Corr.	360,791
30	1	28	34	37	0.8	22	26	6	333	No Corr.	No Corr.	No Corr.	333,038
35	1	31	37	41	0.7	21.8	26	6	355	No Corr.	No Corr.	No Corr.	355,343
40	1	35	42	46	0.6	22.6	27	6	384	No Corr.	No Corr.	No Corr.	383,872
45	1	16	20	21	0.6	9.7	12	6	238	No Corr.	No Corr.	No Corr.	237,535
50	1	13	16	17	0.6	7.2	9	6	206	No Corr.	No Corr.	No Corr.	206,314
55	1	4	4	5	0.5	1.8	2	6	90	No Corr.	No Corr.	No Corr.	90,085
60	1	1	2	2	0.5	0.6	1	1	16	5	48	No Corr.	15,969
65	1	5	5	6	0.5	2.1	2	1	57	16	75	No Corr.	57,489
70	1	10	12	14	0.4	4.4	5	1	131	35	122	No Corr.	130,947
75	1	15	18	19	0.4	5.9	7	1	185	47	157	No Corr.	185,243
80	1	7	8	9	0.4	2.6	3	1	86	21	93	No Corr.	86,234
85	1	5	6	7	0.4	1.8	2	1	64	15	79	No Corr.	63,877
90	1	43	52	57	0.4	15.1	18	1	549	121	393	No Corr.	549,340
95	1	19	23	25	0.3	6.3	8	6	260	No Corr.	No Corr.	No Corr.	260,000

Kulhawy and Mayne (1990) Manual on Estimating Soil Properties for Foundation Design
AASHTO (1996) Standard Specifications for Highway Bridges - 16th edition
Bowles (1996) Foundation Analysis and Design - 5th edition
Hansen and Beckwith

Schmertmann's Modified Method (1978)

Project ID: Settlement of Piles
Project # 17-2015-4045
User NC

Footing Dimensions
Width (B) [ft] 18.5
Length (L)[ft] 18.5
Depth to Base of Footing (D) [ft] 0

Depth to groundwater (ft) 0
Time Since Application of Load [yrs] 10
Average Soil Unit Weight (γ) [pcf] 120

Net Bearing Pressure
q' [psf] 800

Depth of Peak Strain
D_{ps} 9.3

$$D_{ps} = B/2(L/B = 1)$$
$$D_{ps} = B(L/B > 10)$$
$$\text{Intermediate for } 1 < L/B \le 10$$

Initial Vertical Stress at Depth of Peak Strain Influence Factor
σ'_{vp} [psf] 533

$$\sigma'_{vp}(\text{at } z = D + D_{ps}) = \sum \gamma h - u$$

Depth of Influece
D_i 37.0

$$D_i = 2B(L/B = 1)$$
$$D_i = 4B(L/B > 10)$$
$$\text{Intermediate for } 1 < L/B \le 10$$

Effective Stress at Depth D Below the Ground Surface
σ'_D [psf] 0

$$\sigma'_D = \gamma D - u$$

Peak Strain Influence Factor
I_{zp} 0.623

$$I_{zp} = 0.5 + 0.1\sqrt{\frac{q'}{\sigma'_{vp}}}$$

Strain Influence Factor at Surface
I_{zs} 0.10

$$I_{zs} = 0.1(L/B = 1)$$
$$I_{zs} = 0.2(L/B > 10)$$
$$\text{Intermediate for } 1 < L/B \le 10$$

Depth Factor
C_1 1.00

$$C_1 = 1 - 0.5\left(\frac{\sigma'_D}{q'}\right)$$

Shape Factor
C_3 1.00

$$C_3 = 1.03 - 0.03\frac{L}{B} \ge 0.73$$

Secondary Creep Factor
C_2 1.40

$$C_2 = 1 + 0.2\log\left(\frac{t}{0.1}\right)$$

Layer No.	Depth Below Ground Surface: Start [ft]	Depth Below Ground Surface: End [ft]	Depth of Midlayer below footing [ft]	Thickness of Layer Δz_i [ft]	Soil Modulus E_i [psf]	Strain Influence Factor I_{zi}	Settlement of Layer i ρ_i [in]
1	0	5	2.5	5	360,791	0.24	0.04
2	5	10	7.5	5	333,038	0.52	0.11
3	10	15	12.5	5	355,343	0.55	0.10
4	15	20	17.5	5	383,872	0.44	0.08
5	20	25	22.5	5	237,535	0.33	0.09
6	25	30	27.5	5	206,314	0.21	0.07
7	30	35	32.5	5	90,085	0.10	0.08
8	35	40	37.5	5	15,969	0.00	0.00
9	40	45	42.5	5	57,489	0.00	0.00
10	45	50	47.5	5	130,947	0.00	0.00
11	50	55	52.5	5	185,243	0.00	0.00
12	55	60	57.5	5	86,234	0.00	0.00
13	60	65	62.5	5	63,877	0.00	0.00
14	65	70	67.5	5	549,340	0.00	0.00
15	70	75	72.5	5	260,000	0.00	0.00
16	0		0	0		0.10	0.00
17	0		0	0		0.10	0.00
						Total Settlement [in]	**0.57**

$$\rho_i = C_1 C_2 C_3 q'\left(\frac{I_{zi}\Delta z_i}{E_i}\right)$$

$$\rho_{TOTAL} = \sum \rho_i$$