Final Geotechnical Investigation and Foundation Recommendation Report
BIA Project N5001(1)1,2&4
Toadlena, NM (Navajo Nation)
BIA Order No. A17PD00484
BIA Requisition No. 0040359399
Architect – Engineer IDIQ Contract No. A16PC00091

Submitted to:

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

Submitted by:

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

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11-21-17
ARIZONA U.S.A.
Expires 12/31/2019

November 21, 2017

Project No. 17-2017-4057

November 21, 2017
Project No. 17-2017-4057

Bureau of Indian Affairs, Navajo Regional Office
Division of Acquisition
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Gallup, New Mexico 87301

Attn: Christopher Becenti, PE

Re: Final Geotechnical Investigation and Foundation Recommendation Report
BIA Project N5001(1)1,2&4
Toadlena, NM (Navajo Nation)
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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 N5001(1)1,2&4 near Toadlena, New Mexico. This work was performed in general accordance with BIA Order No. A17PD00484 dated September 18, 2017. The sections of this report include a project description, discussions of the geotechnical profile encountered at the site and comparison to previous geotechnical investigations, foundation design recommendations for the planned geosynthetic reinforced soil integrated bridge system (GRS-IBS), 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.

Registered Professional Engineer (Civil) CERTIFICATE NO. 55482 NAIDA CAUSEVIC DATE SIGNED 11-21-17 ARIZONA U.S.A. Expires 12/31/2019

Naida Causevic, PE
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 PROJECT INFORMATION AND PURPOSE

Included in this report are the results of our investigation in support of the planned bridge improvements to Bureau of Indian Affairs (BIA) Route N5001(1)1,2&4 at approximately stations 7+200 and 7+900. The project will consist of two new bridge structures: a geosynthetic reinforced soil integrated bridge system (GRS-IBS) at drainage crossing 7+193.16 and a two-span, prestressed concrete AASHTO girder bridge at drainage crossing 7+913.320.

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 and rock at the two bridge structures identified above. This report provides foundation design recommendations and construction considerations for the planned GRS-IBS, and a side-by-side comparison of the soil profile encountered during this investigation and the soil profile presented in Western Technologies Inc. (WTI) Geotechnical Evaluation for Bridge N214 Replacement Report (2002) for the Two-Span Bridge. The side-by-side comparison is necessary since the structure alignment has moved to the north of the location investigated by WTI.

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 below. 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 Section 1.0 of this report has changed, we should be notified so that we may amend our recommendations, as necessary.

2.0 FIELD INVESTIGATION

2.1 Subsurface Exploration

The subsurface exploration for this project was performed from October 9 to October 13, 2017. Field direction, sample collection and logging of borings were performed by Mark Keyes, PG of Amec Foster Wheeler Environment & Infrastructure, Inc. (Amec Foster Wheeler). Logs of the completed borings are presented in Appendix A of this report. Appendix A also includes a description of drilling and sampling procedures, and photographs of the rock core recovered from the borings. Amec Foster Wheeler advanced two borings for the proposed GRS-IBS structure and two borings for the proposed Two-Span Bridge structure to depths ranging from 11.4 to 14.7 meters below existing site grades, for a total drill footage of approximately 51.3 meters. All borings encountered rock and rock coring was performed for at least 6 meters. Locations of the borings are shown on Figures 1 and 2, the Boring Location Map, and are presented in tabular format in Table 1.

The borings were completed by Resilient Drilling Services, LLC (Resilient) with a truck-mounted CME-75 drill rig utilizing a 168-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.

Each boring location was established in the field using the proposed alignments for each 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 Appendix A. Encountered soils were visually inspected, labeled and classified in the field, and logged in general accordance with ASTM D2488, the Unified Soil Classification System and Amec Foster Wheeler procedures. 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 Appendix A.

2.2 Laboratory Testing

Laboratory tests were performed on representative bulk, split spoon and rock core samples obtained during our subsurface exploration to evaluate and characterize the site soils and rock 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 absence of an AASHTO test method, ASTM test methods were used.

- Sieve Analysis (Gradation and Minus 75-micrometer wash) (AASHTO T11, T27)
- Plasticity Index (AASHTO T89, T90)
- Moisture (AASHTO T265)
- Unconfined Compressive Strength of Rock (ASTM D7012)

A summary of the laboratory test results is presented in Table B-1 in Appendix 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. The Quaternary deposits are comprised of alluvial 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 Point Lookout Sandstone and Menefee Formation are part of the Mesaverde Group. The Point Lookout Sandstone is comprised of laminated sandstone with thin laminae of coal that is of marine and near-shore origin. The Menefee Formation is comprised of sandstone, siltstone, shale, and coal and is of continental and near-shore origin. The Mesaverde Group in the vicinity of the project area is up to 750 meters thick (Zieglar, 1955; Trauger, 1967).

Unconsolidated granular alluvial soils were encountered at the ground surface overlying the Point Lookout Sandstone during the subsurface investigation. The soils are comprised of mixtures of silt, sand, gravel, and occasional cobbles. The sandstone typically is fine-grained and gray with some thin coal laminae.

3.2 Geotechnical Profile

The native soils encountered during the investigation at the bridge sites primarily consist of coarse-grained soil mixtures, including silty sand, silty clayey sand and clayey sand to clayey gravel, overlaying bedrock. In general, the site soils can be characterized into two layers: Layers A and B. The soil layers are discussed in greater detail in the following sections.

A subsurface profile for the GRS-IBS is shown of Figure 3, and a subsurface profile for the Two-Span Bridge structure is shown on Figure 4. The Two-Span Bridge structure subsurface profile shows the borings from the current investigation and the 2001 WTI investigation side-by-side.

3.2.1 Layer A – Silty Sand Soils

Layer A extends from the surface to a depth of about 3 meters bgs and consists primarily of low fines (particles less than the 75-micrometer sieve) content soils, with the primary soil types consisting of silty sand (SM) and clayey sand (SC). The fines content for Layer A is typically less than 30 percent with occasional zones approaching 50 percent. These soil types are primarily non-plastic with occasional zones of low to medium plasticity. The zones of low to medium plasticity are localized to the sandy clay soil zones typically 1.5 to 3 meters bgs. These soils are predominantly moderately firm to very firm with some hard zones. The measured uncorrected SPT blow counts varied from 10 to refusal (i.e., 50 blows for less than a 150-millimeter interval) with a median value of 29. Layer A soils are uncemented. Due to the typically cohesionless nature of these soils, adequate undisturbed samples could not be obtained to perform direct shear tests.

3.2.2 Layer B – Point Lookout Sandstone

The sandstone along BIA Route N5001(1)1,2&4 was encountered at various depths along the bridge structure alignments ranging from approximately 3 meters bgs at the GRS-IBS structure to 7 meters bgs at the Two-Span Bridge structure. The sandstone at the Two-Span Bridge is comprised of laminated sandstone with thin laminae of siltstone and coal. Shale was also encountered at the Two-Span Bridge overlaying the sandstone at about 3 meters below ground surface. Photographs of the core recovered from the borings are presented in Appendix A. The Point Lookout Sandstone encountered at the bridge sites is a massive unit with few discontinuities and some 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 are identified on the logs.

The unconfined compressive strength (UCS) of the sandstone, encountered during our investigation ranged from 13,578 to 25,447 kPa. The rock at the GRS-IBS location has an average UCS of 14,774 kPa with a lower quartile of 14,500 kPa, a Geologic Strength Index (GSI) that ranges from 65 to 75, and an intact rock modulus that ranges from 711,744 to 1,149,425 kPa. The rock mass density of the sandstone at the GRS-IBS is approximately 1,915 kilograms per cubic meter (kcm). The rock at the Two-Span Bridge location has an average UCS of 21,999 kPa with a lower quartile of 20,140 kPa, a GSI that ranges from 65 to 75, and an intact rock modulus that ranges from 1,225,490 to 1,582,278 kPa. The rock mass density of the sandstone at the Two-Span Bridge is approximately 2,157 kcm. A portion of the rock encountered near the soil to rock contact was advanced through with the auger. Split-spoon samples were taken at 5-foot intervals within those depths and were typically refusal.

The minimum correlated bulk rock modulus for the sandstone, based on the GSI range and intact rock modulus, ranged from 142 to 364 MPa at the GRS-IBS structure and from 245 to 502 MPa at the Two-Span Bridge structure. The rock bulk modulus at both bridges generally increased with depth.

3.3 Groundwater and Soil Moisture Conditions

Groundwater was not encountered at either structure location within the soil portion of the borings. Groundwater within the rock could not be determined since water was used during the coring process. Moisture content tests were used to evaluate the on-site soil moisture characteristics. The site soils were generally described as being slightly moist. The measured soil moisture contents varied from 2.5 to 8.4 percent (of dry weight), with an average value of approximately 5 percent.

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

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 GRS-IBS structure and the Two-Span Bridge structure are presented in Table 3.1.

Table 3.1: Seismic Design Parameters for Site Class B[1]

Period, seconds	Spectral Acceleration Value, g	Seismic Design Parameter
0.0	0.054	PGA/ A_S
0.2	0.112	S_s/S_{DS}
1.0	0.030	S_1/S_{D1}

Note:
[1] Results are based on a latitude of 36.2314 degrees and a longitude of –108.8235 degrees for the GRS-IBS structure and a latitude of 36.2329 degrees and a longitude of -108.8156 degrees for the Two-Span Bridge structure.
PGA = peak ground acceleration

Based on the geotechnical investigation and UCS, Site Class B was selected for the two bridge sites since bedrock was encountered at shallow depths. Site Class B is defined as a site underlain by rock. The seismic design parameters for Site Class B, as presented in Table 3.1, should be used for seismic design of the respective bridge structures.

A horizontal response spectral acceleration coefficient (S_{D1}) of 0.03 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 on recommended foundation types for the proposed bridge structures.

4.1 General

4.1.1 GRS-IBS - Drainage Crossing at BIA Route N5001(1)1,2&4 (Station 7+193)

Amec Foster Wheeler understands that the BIA plans to construct a GRS-IBS bridge structure at the BIA Route N5001(1)1,2&4 drainage crossing, at approximately Station 7+193. The GRS-IBS technology consists of closely spaced layers of geosynthetic reinforcement and compacted granular fill material, which includes a reinforced soil foundation and a GRS abutment.

Amec Foster Wheeler evaluated founding the GRS-IBS on soil or bedrock through external slope stability analyses. Founding the GRS on soil resulted in inadequate factors of safety (FOS) using the minimum required width of the base. The width of the GRS base had to be increased more than a 100 percent to obtain an acceptable FOS; therefore, founding the GRS abutment on rock was the preferred option. Details are provided in Section 4.2.

4.1.2 Two-Span Bridge - Drainage Crossing at BIA Route N5001(1)1,2&4 (Station 7+931)

Amec Foster Wheeler understands that the BIA plans to construct a two-span bridge structure at the BIA Route N5001(1)1,2&4 drainage crossing, at approximately Station 7+931. Our scope does not include providing foundation design recommendations for this structure.

4.2 GRS-IBS – Preliminary Foundation Design Recommendations

The GRS-IBS should be designed in accordance with Federal Highway Administration (FHWA) Geosynthetic Reinforced Soil Integrated Bridge System Interim Implementation Guide (GRS-IBS Guide) (2012).

The recommendations presented herein only include external stability analyses of the GRS-IBS. The internal stability is the responsibility of the bridge designer. Recommendations for the external stability structure were developed in accordance with FHWA GRS-IBS Guide (2012) and AASHTO Design Specifications (2014). The GRS-IBS Guide (2012) and AASHTO (2014) should be used for internal stability calculations.

Three potential external failure mechanisms are considered. Those mechanisms include:

- Bearing resistance (Section 4.2.1);
- Overall stability (Section 4.2.2); and
- Resistance to sliding on the base of the wall (Section 4.2.3).

Each mechanism is further discussed in the aforementioned sections.

4.2.1 Bearing Resistance

The strength bearing resistance was evaluated, as recommended in Article 10.6 of AASHTO (2014), using the semi-empirical procedure developed by Carter and Kulhawy (1988). A general shear failure mode was assumed for this analysis.

Following shear strength definitions of fractured rock mass in AASHTO (2014), a rock mass angle of friction and a cohesion intercept were determined using equation 10.4.6.4-1 and a GSI range of 65 to 75, as presented in Section 3.2. The design parameters used in the analysis are summarized in Table 4.1.

Table 4.1: Spread Footing Analysis Rock Parameters

Parameter	Symbol	Value
Instantaneous Friction Angle of Rock Mass	ϕ'	58 degrees
Cohesion Intercept	c	120 kPa
Density	ρ	1915 kg/m^3
Geologic Strength Index	GSI	65-75
Unconfined Compressive Strength	q_u	14,500 kPa
Bulk Rock Mass Modulus	E_m	153 MPa
Poisson's Ratio	ν	0.2
Assumed Footing Length	L	9 m
Assumed Footing Bearing Depth	D_f	0 m
Footing Width	B	1 to 7.5 m

Bottom of footing elevations were determined based on the bedrock elevation of approximately 1830 meters. Suitable, relatively undisturbed rock elevations may vary in the field. An engineer should be present during footing excavation activities to determine appropriate excavation limits. Field conditions encountered during excavation may not match the top of undisturbed rock in the borings and should be confirmed based on actual conditions encountered during construction.

Scour depth, based on discussions with Corwyn Henry at the BIA, will not be considered in design since the channel is incised in sandstone. The sandstone at the GRS-IBS is relatively competent; however, it is still susceptible to erosion. Based on our site visit, there are signs of sandstone erosion, which have caused the overlaying alluvium to break off and fall into the channel. Amec Foster Wheeler recommends scour protection be used at the GRS-IBS abutments. The FHWA GRS-IBS recommends founding the structure below scour depth.

The following sections provide design recommendations for the strength limit state and the service limit state. The design chart is presented in Appendix C of this report.

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 factors used in the determination of the factored bearing resistance is a function of the design methodology, the subsurface and the test method used to determine the strength of the soil or rock. The resistance factor used was 0.45, as presented in Table 10.5.5.2.2-1 of AASHTO (2014) using footings on rock. The Point Lookout Sandstone is a massive unit with joints spaced more widely than the proposed foundation width. The factored bearing resistance was evaluated assuming no stress is transmitted across the vertical discontinuities and bearing resistance failure occurs by splitting beneath the foundation. Procedures presented in Chapter 3 of Carter and Kulhawy (1988) for foundations on a rock mass with wide joints were used for this analysis. The nominal bearing resistance was analyzed using a friction angle and cohesion calculated at approximately 3 meters below the rock surface, to account for the influence zone of the GRS-IBS footing footprint. A friction angle of 58 degrees and a cohesion of 120 kPa were used in bearing resistance calculations. The factored bearing resistance for various footing widths is provided in Design Chart 1, in Appendix C.

The factored bearing resistance chart presents bearing resistance as a function of effective footing width. The effective width of eccentrically loaded footings should be determined to satisfy the limiting eccentricity requirements as discussed in Section 4.3.

4.2.1.2 Service Limit State

The magnitude of foundation settlement is a function of the vertical foundation bearing pressure applied to the rock. The procedure for elastic settlement of footings on rock, as presented in Article 10.6.2.4.4 of AASHTO 2014, was used to evaluate the estimated settlements for the service limit state analysis.

Results of the analysis show that the service limit state resistance will be achieved at a displacement of less than 2.5 millimeters for factored design loads. Therefore, the service limit state is not anticipated to control and a breakdown of service load resistance values for settlements less than 2.5 millimeters was deemed unnecessary.

4.2.2 Overall Slope Stability

Overall slope stability analyses at the structure were performed by assuming the reinforced soil mass and facing to be a rigid body. The overall slope stability analysis was performed for static conditions only. Assumptions made of the abutment geometry and soil properties are tabulated in Table 4.2.

Table 4.2: GRS-IBS Geometry and Soil Properties for Stability Analysis

Parameter	Symbol	Value
GRS-IBS Geometry		
Backfill Fill Height	H	6 m
Minimum Base-to-Height Ratio	B/H	0.3
Minimum width of the base	B_{total}	1.85 m (minimum base width for L_{span}≥7.5m)
Embedment Depth	D_f	0 meter (founded on bedrock)
Retained Soil Parameters		
Friction Angle	ϕ	30 degrees
Cohesion	c	0 kPa
Average Moist Unit Weight	γ	18.9 kN/m^3
Rock Parameters[2]		
Friction Angle	ϕ	58 degrees
Cohesion	c	120 kPa
Average Moist Unit Weight	γ	18.9 kN/m^3

Notes:
[2] See Appendix D for soil stratigraphy

The overall stability was analyzed using the Morgenstern-Price method and the software Slope/W. Amec Foster Wheeler analyzed both a block and a circular slip surface for the GRS-IBS since the weak zone for the system was near the base of the wall within the first soil layer. Results of the analyses are presented on Figures D-1 and D-2 in Appendix D, along with the soil strength parameters used in design and the surcharge load due to traffic.

The analyses indicate the GRS abutment has a factor of safety of 1.5 to 1.8 for block and circular slip surfaces, respectively. These FOS are approximately equivalent to a resistance factor of 0.65 to 0.56. The calculated resistance factors are approximately equal to or less than the maximum allowable resistance factor of 0.65 specified in the FHWA GRS-IBS Guide (2012).

Potential slip surfaces passing through the abutment reinforcement (compound stability) were not considered in the global stability analyses. Internal stability evaluations are the responsibility of the bridge designer.

4.2.3 Resistance to Sliding

Sliding resistance can consist of two components: sliding along the base of the wall or along a weak layer near the base of the wall. The resistance factor for sliding depends on the resistance component, the rock type and construction method. Since the GRS abutment is layered with geotextile reinforcement, the critical friction angle will therefore be the interface friction angle between the backfill soil and reinforcement. A friction angle of the reinforced backfill (ϕ_r) of 38 degrees is recommended for determining the sliding resistance.

The sliding resistance for the GRS abutment should be calculated using equations presented in Section 4.3.6.1 in the FHWA GRS-IBS Guide (2012).

4.3 Limiting Eccentricity

The maximum allowable eccentricity, e, of loading at the strength limit state for footings should be calculated. The procedure presented in Section 4.3.6.2 of the FHWA GRS-IBS Guide should be followed to calculate e.

The footing width, B, should be taken as the length of the reinforcement soil foundation (RSF), measured as a function of the total base width of the GRS abutment including the block face (B_{total}). Since this abutment will be founded on rock, an RSF was not necessary and B should be taken as the total base width of the GRS abutments including the block face of the wall unit.

4.4 Lateral Earth Pressures

GRS-IBS abutments should be designed for active earth pressures as presented in Section 4.3.5.1 of the FHWA GRS-IBS Guide (2012). The active earth pressure should be calculated based on an effective friction angle of 30 degrees and a unit weight of 18.9 kN/m^3 for retained soil, and a minimum effective friction angle of 38 degrees and a unit weight of 19.6 kN/m^3 for GRS abutment backfill or reinforced soil.

Where appropriate, the traffic live-load surcharge and additional earth pressure on the GRS abutment wall due to the live-load surcharge should be estimated and applied as described in Section 4.3.5 of the FHWA GRS-IBS Guide (2012). The project seismic design criteria should be determined in accordance with Section 5.4 of the FHWA GRS-IBS Guide (2012), and as discussed in Section 3.0 of this report.

GRS abutment backfill should consist of crushed, hard, durable particles or fragments of stone or gravel. These materials should be free from organic matter or deleterious material such as shale or other soft particles that have poor durability. Abutment backfill used for GRS-IBS should consist of either well-graded or open-graded aggregates. It is recommended that either one of these gradations or a blend in between the two be used as backfill behind GRS abutments. Typically, open-graded aggregates are selected on GRS-IBS projects due to the relative ease of construction and favorable drainage characteristics. If the abutment will be submerged at any point in time, open-graded gravel should be used because it is free-draining. The friction angle of the backfill should be no less than 38 degrees.

Amec Foster Wheeler recommends that clean, granular, free-draining backfill be placed at the GRS abutments. Backfill should meet the grading requirements of Table 4.3, in accordance with AASHTO No. 89 open-graded backfill:

Table 4.3: Structure Backfill Gradation

Sieve Size (Square Openings)	Percent Passing by Dry Weight
12.5 mm	100
9.5 mm	90 to 100
4.75 mm	20 to 55
2.36 mm	5 to 30
1.18 mm	0 to 10
0.300 mm	0 to 5

In addition, the plasticity index should not exceed 6 when tested in accordance with the requirements of AASHTO T-90.

4.5 Construction Considerations

4.5.1 Temporary Excavations

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 C. It is recommended that unsupported temporary cut slopes in these soils be made no steeper than 1.5H:1V. Excavations below the groundwater table should conform to the site conditions during construction. If groundwater is encountered, the slopes may need to be flatter than a 1.5H:1V and the Contractor should analyze the stability to the slopes prior to 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.

5.0 REFERENCES

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TABLES

TABLE 1
Boring Locations

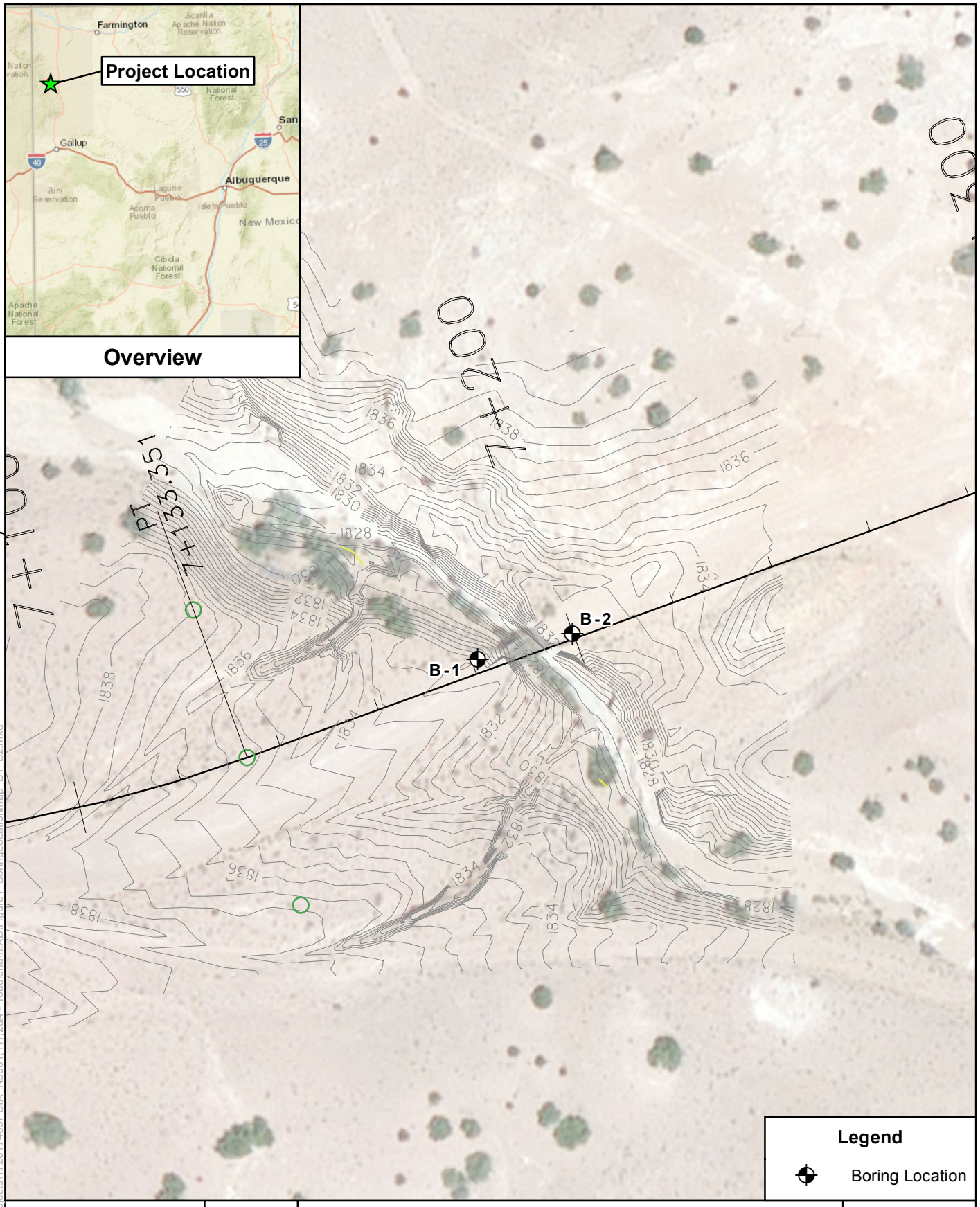
Boring Number	Station Reference	Location	Elevation (m)	Direction[1]	Offset (m)	Boring Type[2]	Structure	Targeted Boring Depth (m)	Actual Boring Depth (m)		
									Auger	Coring	Total
B-1	Proposed BIA Route N5001(1)1,2&4 CL	7+181	1832.4	L	3	HSA/HQ	GRS-IBS	30[3]	4.35	9	13.35
B-2	Proposed BIA Route N5001(1)1,2&4 CL	7+200	1832.7	L	1	HSA/HQ	GRS-IBS	30[3]	4.35	7.5	11.85
B-3	Proposed BIA Route N5001(1)1,2&4 CL	7+912	1813.4	R	5	HSA/HQ	Two-Span	30[3]	3.9	7.5	11.4
B-5	Proposed BIA Route N5001(1)1,2&4 CL	7+948	1815.7	R	7	HSA/HQ	Two-Span	30[3]	7.2	7.5	14.7

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

[2] HSA/HQ - 168mm Hollow Stem Auger and HQ sized rock coring

[3] 30 meters or 6 meters into rock

FIGURES



Legend

Boring Location

Job No.:	1720174057
PM:	NC
Date:	11/2/2017
Scale:	1 cm = 10 meters

BIA Project N5001(1)1,2&4
Toadlena, New Mexico

Boring Location Map
Borings B-1 and B-2

FIGURE
1

amec foster wheeler

Path: X:\Projects\2017 Projects\1720174057 BIA N5001(1)1,2&4 Toadlena\MXD\Figure1 BoringLocationMap B1 B2.mxd

Overview

7+900

EVT7+914.3270.00

EVT7+950.2930.00

8+000

B-3

B-5

Legend

Boring Location

Job No.:	1720174057
PM:	NC
Date:	11/2/2017
Scale:	1 cm = 10 meters

BIA Project N5001(1)1,2&4
Toadlena, New Mexico

Boring Location Map
Borings B-3 and B-5

FIGURE
2

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Path: X:\Projects\2017 Projects\1720174057 BIA - N5001(1)1,2&4 - Toadlena\MXD\Figure2_BoringLocationMap_B3_B5.mxd

Figure 3
Subsurface Profile
BIA Project N5001(1)1,2&4 - GRS-IBS

	B-1 (AFW) , Abut 1			B-2 (AFW), Abut 2		
Elevation (m)	USCS/ Rock Type	N/**RQD**	UCS (kPa)	USCS/ Rock Type	N/**RQD**	UCS (kPa)
1833						
1832.7				SM		
1832.4	SM	10		SM		
1832.1	SM			SM		
1831.8	SM			SM		
1831.5	SM			SM		
1831.2	SM			SC-SM	38	
1830.9	SM	13		SC-SM		
1830.6	SM			SC-SM		
1830.3	SM			SC-SM		
1830	SM			SC-SM		
1829.7	SM			Sandstone	50/5"	
1829.4	SM	50/5"		Sandstone		
1829.1	Sandstone			Sandstone		
1828.8	Sandstone			Sandstone		
1828.5	Sandstone			Sandstone		
1828.2	Sandstone			Sandstone	**50**	
1827.9	Sandstone	**20**		Sandstone		
1827.6	Sandstone			Sandstone		15,088
1827.3	Sandstone			Sandstone		
1827	Sandstone		14,807	Sandstone		
1826.7	Sandstone			Sandstone	**100**	
1826.4	Sandstone	**50**		Sandstone		
1826.1	Sandstone			Sandstone		
1825.8	Sandstone			Sandstone		
1825.5	Sandstone			Sandstone		
1825.2	Sandstone			Sandstone	**100**	
1824.9	Sandstone	**90**		Sandstone		
1824.6	Sandstone		13,578	Sandstone		
1824.3	Sandstone			Sandstone		
1824	Sandstone			Sandstone		
1823.7	Sandstone			Sandstone	**80**	
1823.4	Sandstone	**100**		Sandstone		
1823.1	Sandstone			Sandstone		
1822.8	Sandstone			Sandstone		
1822.5	Sandstone			Sandstone		
1822.2	Sandstone			Sandstone	**90**	
1821.9	Sandstone	**100**		Sandstone		15,621
1821.6	Sandstone			Sandstone		
1821.3	Sandstone			Sandstone		
1821	Sandstone			Sandstone		
1820.7	Sandstone					
1820.4	Sandstone	**100**				
1820.1	Sandstone					
1819.8	Sandstone					
1819.5	Sandstone					
1819.2	Sandstone					
1818.9	Sandstone					

Legend	
SM	Silty Sand
SC-SM	Silty Clayey Sand
Sandstone	Point Lookout Sandstone
USCS/Rock Type	Unified Soil Classification or Rock Type
N/**RQD**	N-value or **Rock Quality Designation**
UCS	Unconfined Compressive Strength
AMF	Amec Foster Wheeler Borings

Figure 4
Subsurface Profile Side-by-Side
BIA Project N5001(1)1,2&4 - Two-Span Bridge Structure

Elevation (m)	B-3 (AFW) , Abut 1			Boring No. 1 (WT), Abut 1			Boring No. 2 (WT), Abut 1			Boring No. 3 (WT), Pier			Boring No. 4 (WT), Pier			B-5 (AFW), Abut 2			Boring No. 5 (WT), Abut 2			B-6 (WT), Abut 2			Elevation (m)
	USCS/ Rock Type	N/**RQD**	UCS (kPa)	USCS/ Rock Type	N/**RQD**	UCS (kPa)	USCS/ Rock Type	N/**RQD**	UCS (kPa)	USCS/ Rock Type	N/**RQD**	UCS (kPa)	USCS/ Rock Type	N/**RQD**	UCS (kPa)	USCS/ Rock Type	N/**RQD**	UCS (kPa)	USCS/ Rock Type	N/**RQD**	UCS (kPa)	USCS/ Rock Type	N/**RQD**	UCS (kPa)	
1817																									1817
1816.7																						GM			1816.7
1816.4																			SM			GM			1816.4
1816.1																			SM			GM			1816.1
1815.8																SM			GM			GM			1815.8
1815.5																SM			GM			GM			1815.5
1815.2																SM			GM			GM	9		1815.2
1814.9				SM			SM									SM			GM	71		GM			1814.9
1814.6				SM			SM									SM			GM			GM			1814.6
1814.3				SM			SM									SM	65		Sandstone			Sandstone			1814.3
1814				SM			SM									SM			Sandstone			Sandstone			1814
1813.7				SM			SM									SC/GC			Sandstone			Sandstone	50/6"		1813.7
1813.4	SM			SM	20		SM	5								SC/GC			Sandstone	50/6"		Sandstone			1813.4
1813.1	SM			SM			SM			Fill			Fill			SC/GC	29		Sandstone			Sandstone			1813.1
1812.8	SM			SM			SM			Fill			Fill			SC/GC			Sandstone			Sandstone			1812.8
1812.5	SM			SM			SM			SM			SW			SC/GC			Shale			Sandstone			1812.5
1812.2	SM			SM			SM			SM			SW			SC/GC			Shale			Sandstone	50/3"		1812.2
1811.9	SM	24		Coal	50/3"		Shale	50/3"		SM			SW			SC/GC			Shale	50/5"		Sandstone			1811.9
1811.6	SM			Coal			Shale			SM			SW	31		Shale	50/5"		Coal			Sandstone			1811.6
1811.3	SM			Coal			Sandstone			SM			SW			Shale			Coal			Shale			1811.3
1811	SM			Sandstone			Sandstone			Coal	50/4"		Shale			Shale			Coal			Shale			1811
1810.7	Shale	50/2"		Sandstone			Sandstone			Coal			Sandstone			Shale			Coal			Shale	50/3"		1810.7
1810.4	Shale			Sandstone	50/2"		Sandstone	50/1"		Coal			Sandstone			Shale			Coal	50/4"		Shale	**36**		1810.4
1810.1	Shale			Sandstone	**88**		Sandstone	**42**		Sandstone	50/2"		Coal	50/5"		Shale	50/2"		Shale			Shale			1810.1
1809.8	Shale			Sandstone			Sandstone			Sandstone	**84**		Coal			Shale			Shale			Shale			1809.8
1809.5	Sandstone	**95**	20,782	Sandstone			Sandstone			Sandstone			Sandstone			Shale			Shale			Shale			1809.5
1809.2	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Shale			Shale			Shale			1809.2
1808.9	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Shale			Shale	50/4"		Shale			1808.9
1808.6	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone	50/2"		Sandstone	**60**		Coal	**48**		Shale			1808.6
1808.3	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone	**76**		Sandstone			Coal			Shale			1808.3
1808	Sandstone	**100**		Sandstone			Sandstone			Sandstone			Sandstone			Sandstone		18,212	Sandstone			Shale			1808
1807.7	Sandstone			Sandstone			Sandstone	**95**		Sandstone			Sandstone			Sandstone			Sandstone			Shale			1807.7
1807.4	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone	**87**		1807.4
1807.1	Sandstone			Sandstone	**93**		Sandstone			Sandstone			Sandstone			Sandstone	**100**		Sandstone			Sandstone			1807.1
1806.8	Sandstone			Sandstone			Sandstone			Sandstone	**94**		Sandstone			Sandstone			Sandstone			Sandstone			1806.8
1806.5	Sandstone	**90**		Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			1806.5
1806.2	Sandstone			Sandstone		25,442	Sandstone			Sandstone			Sandstone			Sandstone			Shale			Sandstone			1806.2
1805.9	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			1805.9
1805.6	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone	**100**		Sandstone	**100**		Sandstone	**92**		Sandstone			1805.6
1805.3	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			1805.3
1805	Sandstone	**100**		Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			1805
1804.7	Sandstone			Sandstone			Sandstone	**93**		Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			1804.7
1804.4	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			1804.4
1804.1	Sandstone			Sandstone			Sandstone			Sandstone			Sandstone			Sandstone	**100**		Sandstone						1804.1
1803.8	Sandstone						Sandstone			Sandstone			Sandstone		29,792	Sandstone			Sandstone		27,965				1803.8
1803.5	Sandstone	**85**					Sandstone						Sandstone			Sandstone		23,556	Sandstone						1803.5
1803.2	Sandstone						Sandstone						Sandstone			Sandstone	**90**		Sandstone						1803.2
1802.9	Sandstone						Sandstone						Sandstone			Sandstone			Sandstone						1802.9
1802.6	Sandstone		25,447				Sandstone						Sandstone			Sandstone	**90**		Sandstone						1802.6
1802.3	Sandstone						Sandstone						Sandstone			Sandstone									1802.3
1802	Sandstone						Sandstone									Sandstone									1802
1801.7							Sandstone									Sandstone									1801.7
1801.4																Sandstone									1801.4
1801.1																Sandstone									1801.1

Legend

SM	Silty Sand
GM	Silty Gravel
SW	Sand
Fill	Fill
SC/GC	Clayey Sand to Clayey Gravel
Shale	Point Lookout Sandstone
Coal	Point Lookout Sandstone
Sandstone	Point Lookout Sandstone
USCS/Rock Type	Unified Soil Classification or Rock Type
N/**RQD**	N-value or **Rock Quality Designation**
UCS	Unconfined Compressive Strength
AMF	Amec Foster Wheeler Borings
WT	Western Technologies Borings

APPENDIX A

FIELD INVESTIGATION

FIELD INVESTIGATION EQUIPMENT AND PROCEDURES

Description of Subsurface Exploration Methods

Auger Boring – Drilling through soils is generally performed with a drill rig equipped with a hollow stem auger. Central Mine Equipment (CME), Diedrich and Mobile drill rigs are trade names of different brands. Typically carbide insert teeth are used to penetrate soft rock or strongly cemented soils. A truck-mounted or track-mounted drill rig is used to advance the auger. The size of the auger and the make and model of the drill rig used are indicated on the boring log.

Refusal to penetration of the auger typically occurs when sand, gravels, and cobbles (locally referred to as SGC) or "river-run" material, cobbles & boulders, cemented soils, or harder bedrock are encountered. Grab samples or auger cuttings may be taken as necessary. Samples as described in Samples Procedures are taken as needed, with the sampling interval and type being indicated on the boring logs.

Core Boring – Rock core drilling is accomplished utilizing a wireline system, whereby core is recovered by retrieving the core-laden inner tube through the drill string. SAITECH GH 3 Burley, or CME are trade names of different brands. The drill rig can be either truck-mounted, track-mounted or skid-type chassis. Typically N-size core, with a nominal O.D. of about 2 inches, or H-size core, with a nominal O.D. of about 2.4 inches, is obtained. The sample interval and type are identified on the boring log.

Sampling Procedures

Dynamically driven tube samples are obtained at selected intervals in the borings. In many cases, 2-inch O.D., 1 3/8-inch I.D. samples are used to obtain the standard penetration resistance in accordance with ASTM D1586. "Undisturbed" samples are often obtained with 3-inch O.D. samples lined with 2.42-inch I.D. brass rings in accordance with ASTM D3550. The driving energy is generally recorded as the number of blows of a 140-pound, 30-inch free fall drop above ground hammer required to advance the samples in 6-inch increments. 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). Where samples of rock are required, they are obtained by 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.

Boring Records

Field operations are directed by our field engineer or geologist who examines soil recovery and prepares the boring logs. Soils are visually classified in general accordance with the Description and Identification of Soils (Visual-Manual Procedure) (ASTM D2488), the Unified Soil Classification System (ASTM D2487) and Amec Foster Wheeler procedures, with appropriate group symbols being shown on the boring logs.

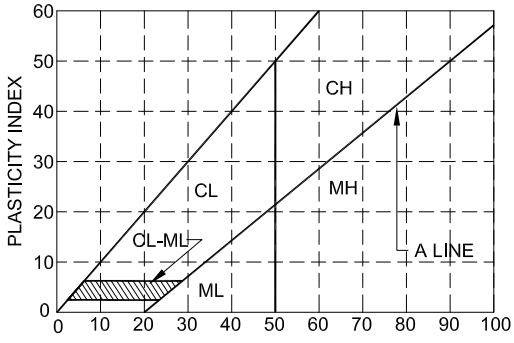
UNIFIED CLASSIFICATION SYSTEM FOR SOILS

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 (More than 50% of coarse fraction retained on 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)	PI <4 or plots below "A" line		GM	Silty gravels, gravel-sand-silt mixture.
			PI >7 and plots on or above "A" line		GC	Clayey gravels, gravel-sand-clay mixture.
	SANDS (50% or more 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)	PI <4 or plots below "A" line		SM	Silty sands, sand-silt mixtures.
			PI >7 and plots on or above "A" line		SC	Clayey sands, sand-clay mixtures.
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)	SILTS PI <4 or plots below "A" line	SILTS OF LOW PLASTICITY (Liquid limit less than 50)			ML	Inorganic silts, clayey silts with slight plasticity.
		SILTS OF HIGH PLASTICITY (Liquid limit 50 or more)			MH	Inorganic silts of high plasticity, silty soils, elastic silts.
	CLAYS PI >7 and plots on or above "A" line	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 50 or more)			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 have a dual symbol.

PLASTICITY CHART



DEFINITIONS OF SOIL FRACTIONS

Amount Modifiers	
Rare	<2%
Occasional	<5%
Trace	10%
Some	20%
Considerable	30%

Term	Size (mm)	Sieve Size
Boulders	>300	>12 in
Cobbles	75 to 300	3 to 12 in
Gravel (coarse)	19 to 75	3/4 to 3 in
Gravel (fine)	4.75 to 19	#4 to 3/4 in
Sand (coarse)	2 to 4.75	#10 to #4
Sand (medium)	0.425 to 2	#40 to #10
Sand (fine)	0.075 to 0.425	#200 to #40
Silt/Clay	<0.075	<#200

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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. When a modified California sampler is used (ASTM D3550), an approximate N-value is obtained by multiplying by two-thirds.

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 that 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

TERMINOLOGY USED TO DESCRIBE CEMENTATION

Uncemented	No reaction to HCl, or easily broken with finger pressure
Weakly	Reacts with HCl, and some calcium carbonate filaments, and possibly nodules, and crumbles with moderate finger pressure and N>15
Moderately	Reacts strongly with HCl, and filaments continuous throughout, and nodules present, and sample is white/gray, and considerable finger pressure required to break soil into chunks, and blowcount for 3rd interval >30
Strongly	Reacts strongly with HCl, filaments continuous and almost indistinguishable, nodules are larger, and sample is white, and will not crumble with firm finger pressure, and refusal blowcounts (blowcount >50 for 6-inch interval)

EXPLANATION OF CORE LOG PRESENTATION
AND TERMINOLOGY FOR THE DESCRIPTION OF ROCK

I. **ROCK QUALITY DESIGNATION (RQD).** Percentage of rock core per core run which is relatively sound and unfractured and which is longer than 0.33 feet in length. Rock which is soft or weathered, closely jointed, or rock from which the core recovery is low, will have poor to fair RQD.

II. **DISCONTINUITIES**

A. **Spacing of Joints**

Code	Spacing of Joints	Descriptive Term
1	Greater than 10 ft.	Very wide
2	3 ft. - 10 ft.	Wide
3	1 ft. - 3 ft.	Moderately close
4	0.2 ft. - 1 ft.	Close
5	Less than 0.2 ft.	Very close

B. **Orientation of Joints**

Measurements presented represent dip angles from horizontal.

Symbol	Description
Rdm	Random - preferred orientation cannot be determined.

C. **Condition of Joints**

1. Roughness

Symbol	Descriptive Term	Properties
Smth	Smooth	Appears smooth and is essentially smooth to the touch. May be slickensided.
Srgh	Slightly rough	Asperities on the fracture surfaces are visible and can be distinctly felt.
Mrgh	Medium rough	Asperities are clearly visible and fracture surface feels abrasive.
Rgh	Rough	Large angular asperities can be seen. Some ridge and high side angle steps evident.
VRgh	Very rough	Near-vertical steps and ridges occur on the fracture surface.

EXPLANATION OF CORE LOG PRESENTATION
AND TERMINOLOGY FOR THE DESCRIPTION OF ROCK

C. Condition of Joints (cont.)

2. Presence or Absence of Fracture Filling Material

Symbol	Descriptive Term	Definition
Cln	Clean	No fracture filling material.
Stn	Stained	Coloration of rock only. No recognizable filling material.
Fld	Filled	Fracture filled with recognizable filling material.

III. BEDDING

Symbol	Descriptive Term	Definition
TL	Thinly laminated	Less than 0.01 ft.
L	Laminated	0.01 ft. to 0.04 ft.
ThB	Thinly bedded	0.04 ft. to 0.20 ft.
MB	Medium bedded	0.20 ft. to 2.00 ft.
TkB	Thickly bedded	More than 2.00 ft.

IV. DEGREE OF WEATHERING

Symbol	Descriptive Term	Properties
Dec	Decomposed, generally soil-like, can be crumbled by hand pressure.	
HiW	Highly weathered, generally rock-like, can be broken easily, but crumbles with difficulty by hand.	
MdW	Moderately weathered, fabric stained rusty brown, can be indented by steel nail, breaks only with difficulty.	
SlW	Slightly weathered, open discontinuities are weathered, coated, but only slight weathering of rock mass, generally not indented by steel nail.	
UnW Ex Jts	Unweathered except joints, weathering limited to the surface of discontinuities; fabric is fresh throughout but most joints show rusty stain and/or soil filling material.	
UnW Inc Jts	Unweathered including joints, rock mass and discontinuities are unweathered; only occasional joints show rusty stain, practically no soil filling.	
UnW	Unweathered, rock mass unweathered; no staining or infilling.	

EXPLANATION OF CORE LOG PRESENTATION
AND TERMINOLOGY FOR THE DESCRIPTION OF ROCK

V. HARDNESS

Descriptive Term	Properties
Very hard	Cannot be scratched with knife or sharp pick. Breaking of hand specimens requires several hard blows of geologist's pick.
Hard	Can be scratched with knife or pick only with difficulty. Hard blow of hammer required to detach hand specimen.
Moderately hard	Can be scratched with knife or pick. Gouges or grooves to 3 inch deep can be excavated by hard blow of point of a geologist's pick. Hand specimens can be detached by moderate blow.
Moderately soft	Can be grooved or gouged 1/16 inch deep by firm pressure on knife or pick point. Can be excavated in small chips to pieces about 1 inch maximum size by hard blows of the point of a geologist's pick.
Soft	Can be gouged or grooved readily with knife or pick point. Can be excavated in chips to pieces several inches in size by moderate blows of a pick point. Small thin pieces can be broken by finger pressure.
Very soft	Can be carved with knife. Can be excavated readily with point of pick. Pieces 1 inch or more in thickness can be broken with finger pressure. Can be scratched readily by fingernail.

VI. MISCELLANEOUS ABBREVIATIONS

Symbol	Description	Symbol	Description
Bkn	Broken	Incl	Inclusions
Brc	Brecciated	Mgd	Medium-Grained
Band	Banded	Mod	Moderately
Qtz	Quartz	Wkly	Weakly
Calc	Calcite	Slicks	Slickensides
Cem	Cemented	Strong	Strongly
Frct	Fractured	SZ	Shear Zone
Fgd	Fine-Grained	Gog	Gouge

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4600 East Washington Street, Suite 600
Phoenix, Arizona 85034

BORING LOG I.D.: B-1

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes	**PROJECT FEATURE:**	GRS-IBS - West Abutment
DRILLER:	Guy Midkiff	**AFW PROJECT #:**	17-2017-4057
DRILLER FIRM:	Resilient	**STATION/OFFSET:**	Station 7+181
RIG I.D.:	103	**REFERENCE:**	N5001(1)1,2&4 Project Plans
RIG TYPE:	CME-75	**COORDINATES:**	N4011810.5, E695594.9
BORING TYPE:	HSA/HQ **BORING DIA.:** 168mm	**COORDINATE SYS:**	NAD83 UTM ZONE 12N (meters)
ORIENTATION:	90°	**SURFACE ELEV. (m):**	1832.4 ±
HAMMER TYPE:	Automatic	**VERTICAL DATUM:**	NAVD88
HAMMER CALIBRATION-ENERGY TRANSFER RATIO:	96	**COMPLETION DATE:**	10/9/2017 **COMPLETION TIME:** 14:00
START DATE:	10/9/2017 **START TIME:** 10:20		

Depth (m)	Drill Rate Min/m	Graphical Log	Sample	Sample Type	Blow Count	Dry Density Kg per Cubic meter.	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				S	3-4-6		4.6	SM	slightly moist	**SILTY SAND,** occasional predominantly fine grained, subangular to subrounded gravel, predominantly fine grained sand, nonplastic, light brown
				A					moderately firm	note: some gravel & cobbles on the ground surface
1.5				S	5-6-7					
3.0				S	50/ 125mm				hard	
										MESA VERDE GROUP **POINT LOOKOUT SANDSTONE - SANDSTONE,** fine grained texture, slightly weathered, moderately soft to moderately hard, gray
4.5										Stopped Auger at 4.35m Began HQ Coring at 4.35m * note: groundwater not encountered within auger portion of borehole
6.0										

GROUNDWATER

DEPTH(ft)	HOUR	DATE
	* see note	

METHOD N/A

SAMPLE TYPE
A - Drill cuttings
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
NR - No Recovery

(Continued Next Page)

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4600 East Washington Street, Suite 600
Phoenix, Arizona 85034

BORING LOG I.D.: B-1

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes	**PROJECT FEATURE:**	GRS-IBS - West Abutment
DRILLER:	Guy Midkiff	**AFW PROJECT #:**	17-2017-4057
DRILLER FIRM:	Resilient	**STATION/OFFSET:**	Station 7+181
RIG I.D.:	103	**REFERENCE:**	N5001(1)1,2&4 Project Plans
RIG TYPE:	CME-75	**COORDINATES:**	N4011810.5, E695594.9
BORING TYPE:	HQ Casing **BORING DIA.:** 168mm	**COORDINATE SYS:**	NAD83 UTM ZONE 12N (meters)
ORIENTATION:	90°	**SURFACE ELEV. (m):**	1832.4 ±
HAMMER TYPE	Automatic	**VERTICAL DATUM:**	NAVD88
HAMMER CALIBRATION-ENERGY TRANSFER RATIO:	96	**COMPLETION DATE:**	10/9/2017 **COMPLETION TIME:** 14:00
START DATE:	10/9/2017 **START TIME:** 10:20		

Boring Operation and Drill Rate (Min/m)	Depth (m)	Sample	Sample Type	Unconfined Compression or Point Load IndexTest (kPa)	% Core Recovery	% Drilling Fluid Rec.	Rock Quality Designation (RQD)	DISCONTINUITIES: Spacing (Wide - Close 1 2 3 4 5)	DISCONTINUITIES: Orientation (Horiz - 45 - Vert H 45 V)	Condition	Bedding and/or Fabric	Weathering or USCS (Soils)	Rock Type & Remarks
													Began HQ Coring at 4.35m
10/9 HQ 3.0	4.5		HQ		20	80	20	N/A	BROKEN	N/A	Fgn	SlW	**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE - SANDSTONE,** medium to thickly bedded, moderately soft to moderately hard, yellowish-gray (5Y 8/1)
				14807							MB to TkB		
	6.0		HQ		100		50				Mass-ive Fgn		
								N/A	N/A			HiW to Dec	note: some mechanical breaks from 6.0m to 7.35m, not actual discontinuities
1.4	7.5		HQ		100		90					SlW	
				13578									note: moderately hard, massive sandstone below 7.35m, light olive gray (5Y 6/1) below 7.35m
1.0	9.0		HQ		100		100						

(Continued Next Page)

GROUNDWATER

DEPTH(ft)	HOUR	DATE
	* see note	

METHOD N/A

BORING OPERATION

HQ - Wireline Rock Coring
HSA - Hollow Stem Auger
S - 51mm O.D., 35mm I.D.Tube Sample

amec foster wheeler

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Phoenix, Arizona 85034

BORING LOG I.D.: B-1

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes	**PROJECT FEATURE:**	GRS-IBS - West Abutment

Boring Operation and Drill Rate (Min/m)	Depth (m)	Elevation (m)	Sample	Sample Type	Unconfined Compression or Point Load IndexTest (kPa)	% Core Recovery	% Drilling Fluid 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
10/9 HQ 1.0							80			NONE	N/A	Mass-ive Fgn	SlW	**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE -** **SANDSTONE,** continued, moderately hard, light olive gray
1.2	10.5			HQ		100		100						
	12.0			HQ		100		100						
	13.5													Stopped HQ Coring at 13.35m * note: water used during coring did not allow for identification of groundwater
	15.0													
	16.5													

GROUNDWATER

	DEPTH(ft)	HOUR	DATE
▽		* see note	
▼			
▼			
▼			

METHOD N/A

BORING OPERATION

HQ - Wireline Rock Coring
HSA - Hollow Stem Auger
S - 51mm O.D., 35mm I.D.Tube Sample

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Phoenix, Arizona 85034

BORING LOG I.D.: B-2

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes	**PROJECT FEATURE:**	GRS-IBS - East Abutment
DRILLER:	Guy Midkiff	**AFW PROJECT #:**	17-2017-4057
DRILLER FIRM:	Resilient	**STATION/OFFSET:**	Station 7+200
RIG I.D.:	103	**REFERENCE:**	N5001(1)1,2&4 Project Plans
RIG TYPE:	CME-75	**COORDINATES:**	N4011815.4, E695613.0
BORING TYPE:	HSA/HQ **BORING DIA.:** 168mm	**COORDINATE SYS:**	NAD83 UTM ZONE 12N (meters)
ORIENTATION:	90°	**SURFACE ELEV. (m):**	1832.7 ±
HAMMER TYPE:	Automatic	**VERTICAL DATUM:**	NAVD88
HAMMER CALIBRATION-ENERGY TRANSFER RATIO:	96	**COMPLETION DATE:**	10/10/2017 **COMPLETION TIME:** 10:30
START DATE:	10/10/2017 **START TIME:** 08:00		

Depth (m)	Drill Rate Min/m	Graphical Log	Sample	Sample Type	Blow Count	Dry Density Kg per Cubic meter.	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				A				SM	slightly moist	**SILTY SAND WITH GRAVEL & COBBLES,** trace to some cobbles up to 152mm in diameter, some well graded, subangular to subrounded gravel, predominantly fine grained sand, nonplastic, light brown note: well graded gravel in zones with depth
1.5				S	5-4-34		6.8	SC-SM	slightly moist very firm to hard	**SILTY CLAYEY SAND WITH GRAVEL,** trace to some predominantly fine grained, subangular to subrounded gravel, predominantly fine grained sand, low plasticity, light brown
3.0				S	11-50/ 125mm					**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE - SANDSTONE,** fine grained texture, slightly weathered, moderately hard, gray
4.5										Auger refused at 4.35m Began HQ Coring at 4.35m * note: groundwater not encountered within auger portion of borehole
6.0										

GROUNDWATER

	DEPTH(ft)	HOUR	DATE
▽		* see note	
▼			
▼			
▼			

METHOD N/A

SAMPLE TYPE
A - Drill cuttings
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
NR - No Recovery

(Continued Next Page)

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BORING LOG I.D.: B-2

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes	**PROJECT FEATURE:**	GRS-IBS - East Abutment
DRILLER:	Guy Midkiff	**AFW PROJECT #:**	17-2017-4057
DRILLER FIRM:	Resilient	**STATION/OFFSET:**	Station 7+200
RIG I.D.:	103	**REFERENCE:**	N5001(1)1,2&4 Project Plans
RIG TYPE:	CME-75	**COORDINATES:**	N4011815.4, E695613.0
BORING TYPE:	HQ Casing **BORING DIA.:** 168mm	**COORDINATE SYS:**	NAD83 UTM ZONE 12N (meters)
ORIENTATION:	90°	**SURFACE ELEV. (m):**	1832.7 ±
HAMMER TYPE	Automatic	**VERTICAL DATUM:**	NAVD88
HAMMER CALIBRATION-ENERGY TRANSFER RATIO:	96	**COMPLETION DATE:**	10/10/2017 **COMPLETION TIME:** 10:30
START DATE:	10/10/2017 **START TIME:** 08:00		

Boring Operation and Drill Rate (Min/m)	Depth (m)	Sample	Sample Type	Unconfined Compression or Point Load IndexTest (kPa)	% Core Recovery	% Drilling Fluid Rec.	Rock Quality Designation (RQD)	DISCONTINUITIES Spacing (Wide - Close)	DISCONTINUITIES Orientation (Horiz - Vert)	Condition	Bedding and/ or Fabric	Weathering or USCS (Soils)	Rock Type & Remarks
								1 2 3 4 5	H 45 V				Began HQ Coring at 4.35m
10/10 HQ 1.2	4.5		HQ		95	90	50	N/A	BROKEN	N/A	Fgn Mass-ive	SlW	**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE -** **SANDSTONE,** moderately hard, yellowish-gray (5Y 7/2)
				15088									note: medium light gray (N6) below 5.55m
	6.0		HQ		100		100						
	7.5		HQ		100		100						
	9.0		HQ		100		80						note: speckled gray rock fabric at 8.84m

(Continued Next Page)

GROUNDWATER

DEPTH(ft)	HOUR	DATE
	* see note	

METHOD N/A

BORING OPERATION

HQ - Wireline Rock Coring
HSA - Hollow Stem Auger
S - 51mm O.D., 35mm I.D.Tube Sample

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BORING LOG I.D.: B-2

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes	**PROJECT FEATURE:**	GRS-IBS - East Abutment

Boring Operation and Drill Rate (Min/m)	Depth (m)	Elevation (m)	Sample	Sample Type	Unconfined Compression or Point Load IndexTest (kPa)	% Core Recovery	% Drilling Fluid 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
10/10 HQ 1.2							90			NONE	N/A	Fgn Mass-ive	SlW	**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE - SANDSTONE,** continued note: some mechanical breaks from 9.6m to 10.5m, not actual discontinuities
	10.5			HQ	15621	100		90						
	12.0													Stopped HQ Coring at 11.85m * note: water used during coring did not allow for identification of groundwater
	13.5													
	15.0													
	16.5													

GROUNDWATER

	DEPTH(ft)	HOUR	DATE
▽		* see note	
▼			
▼			
▼			

METHOD N/A

BORING OPERATION

HQ - Wireline Rock Coring
HSA - Hollow Stem Auger
S - 51mm O.D., 35mm I.D.Tube Sample

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BORING LOG I.D.: B-3

PROJECT:	BIA Project N5001(1)1,2&4			**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes			**PROJECT FEATURE:**	Two-Span Bridge - North Abutment
DRILLER:	Guy Midkiff			**AFW PROJECT #:**	17-2017-4057
DRILLER FIRM:	Resilient			**STATION/OFFSET:**	Station 7+912
RIG I.D.:	103			**REFERENCE:**	N5001(1)1,2&4 Project Plans
RIG TYPE:	CME-75			**COORDINATES:**	N4011987.4, E696294.9
BORING TYPE:	HSA/HQ	**BORING DIA.:**	168mm	**COORDINATE SYS:**	NAD83 UTM ZONE 12N (meters)
ORIENTATION:	90°			**SURFACE ELEV. (m):**	1813.4 ±
HAMMER TYPE:	Automatic			**VERTICAL DATUM:**	NAVD88
HAMMER CALIBRATION-ENERGY TRANSFER RATIO:			96	**COMPLETION DATE:**	10/12/17 **COMPLETION TIME:** 11:45
START DATE:	10/12/2017	**START TIME:**	09:15		

Depth (m)	Drill Rate Min/m	Graphical Log	Sample	Sample Type	Blow Count	Dry Density Kg per Cubic meter.	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				A				SM	slightly moist firm	**SILTY SAND WITH GRAVEL,** occasional boulder up to 450mm in diameter, some well graded, subrounded to subangular gravel, predominantly fine grained sand, nonplastic, light brown
				S	11-14-10		2.6			
1.5										note: increase in well graded gravel & decrease in silt below 1.5m
				S	50/50mm					**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE - SHALE WITH SILTSTONE INTERBEDS,** fine grained texture, moderately weathered, thinly bedded, soft, gray
3.0										
4.5										Stopped Auger at 3.9m Began HQ Coring at 3.9m * note: groundwater not encountered within auger portion of borehole
6.0										

GROUNDWATER

	DEPTH(ft)	HOUR	DATE
▽		* see note	
▼			
▼			
▼			

METHOD N/A

SAMPLE TYPE
A - Drill cuttings
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
NR - No Recovery

(Continued Next Page)

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BORING LOG I.D.: B-3

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes	**PROJECT FEATURE:**	Two-Span Bridge - North Abutment
DRILLER:	Guy Midkiff	**AFW PROJECT #:**	17-2017-4057
DRILLER FIRM:	Resilient	**STATION/OFFSET:**	Station 7+912
RIG I.D.:	103	**REFERENCE:**	N5001(1)1,2&4 Project Plans
RIG TYPE:	CME-75	**COORDINATES:**	N4011987.4, E696294.9
BORING TYPE:	HSA/HQ **BORING DIA.:** 168mm	**COORDINATE SYS:**	NAD83 UTM ZONE 12N (meters)
ORIENTATION:	90°	**SURFACE ELEV. (m):**	1813.4 ±
HAMMER TYPE	Automatic	**VERTICAL DATUM:**	NAVD88
HAMMER CALIBRATION-ENERGY TRANSFER RATIO:	96	**COMPLETION DATE:**	10/12/17 **COMPLETION TIME:** 11:45
START DATE:	10/12/2017 **START TIME:** 09:15		

Boring Operation and Drill Rate (Min/m)	Depth (m)	Sample	Sample Type	Unconfined Compression or Point Load IndexTest (kPa)	% Core Recovery	% Drilling Fluid 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 3.9m
10/12 HQ 1.8	4.5		HQ	20782	100	100	95		]	N/A	L to ThB	SlW	**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE -** **SANDSTONE WITH SILTSTONE INTERBEDS,** thin coal laminae throughout from 3.9m to 5.4m, moderately hard, very light gray (N8) to light gray (N7) with black laminae note: some low-angle, machine breaks along coal laminae
	6.0		HQ		100		100		]		Fgn Mass-ive with coal L		
	7.5		HQ		100		90		]		Coal & Silt-stone L in zones		note: breaks along bedding planes not actual discontinuities
1.4	9.0		HQ		100		100		]				

(Continued Next Page)

GROUNDWATER

DEPTH(ft)	HOUR	DATE
	* see note	

METHOD N/A

BORING OPERATION

HQ - Wireline Rock Coring
HSA - Hollow Stem Auger
S - 51mm O.D., 35mm I.D.Tube Sample

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Phoenix, Arizona 85034

BORING LOG I.D.: B-3

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes	**PROJECT FEATURE:**	Two-Span Bridge - North Abutment

Boring Operation and Drill Rate (Min/m)	Depth (m)	Elevation (m)	Sample	Sample Type	Unconfined Compression or Point Load IndexTest (kPa)	% Core Recovery	% Drilling Fluid 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
10/12 HQ 1.4				HQ	25447	75	100	85			N/A	Mass-ive with L	SlW	**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE -** **SANDSTONE WITH SILTSTONE INTERBEDS,** continued, moderately hard to hard, very light gray (N8) to light gray (N7) with black laminae
	10.5													
	12.0													Stopped HQ Coring at 11.4m * note: water used during coring did not allow for identification of groundwater
	13.5													
	15.0													
	16.5													

GROUNDWATER

	DEPTH(ft)	HOUR	DATE
▽		* see note	
▼			
▼			
▼			

METHOD N/A

BORING OPERATION

HQ - Wireline Rock Coring
HSA - Hollow Stem Auger
S - 51mm O.D., 35mm I.D.Tube Sample

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BORING LOG I.D.: B-5

PROJECT:	BIA Project N5001(1)1,2&4			**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes			**PROJECT FEATURE:**	Two-Span Bridge - South Abutment
DRILLER:	Guy Midkiff			**AFW PROJECT #:**	17-2017-4057
DRILLER FIRM:	Resilient			**STATION/OFFSET:**	Station 7+948
RIG I.D.:	103			**REFERENCE:**	N5001(1)1,2&4 Project Plans
RIG TYPE:	CME-75			**COORDINATES:**	N4011985.1, E696331.8
BORING TYPE:	HSA/HQ	**BORING DIA.:**	168mm	**COORDINATE SYS:**	NAD83 UTM ZONE 12N (meters)
ORIENTATION:	90°			**SURFACE ELEV. (m):**	1815.7 ±
HAMMER TYPE:	Automatic			**VERTICAL DATUM:**	NAVD88
HAMMER CALIBRATION-ENERGY TRANSFER RATIO:			96	**COMPLETION DATE:**	10/10/2017 **COMPLETION TIME:** 15:00
START DATE:	10/10/2017	**START TIME:**	12:00		

Depth (m)	Drill Rate Min/m	Graphical Log	Sample	Sample Type	Blow Count	Dry Density Kg per Cubic meter.	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
0.0				A				SM	slightly moist hard	**SILTY SAND WITH GRAVEL,** trace cobbles up to 152mm in diameter, predominantly fine grained sand, nonplastic, light brown note: boulders up to 600mm in diameter on the ground surface note: predominantly fine grained gravel zones with depth
				S	18-27-38		2.5			
1.5										
								SC/GC		**CLAYEY SAND TO CLAYEY GRAVEL,** predominantly fine grained, subangular gravel, predominantly fine grained sand, medium plasticity, light brown with black zones
				S	9-13-16		8.4		slightly moist firm	note: trace coal inclusions
3.0										
				S	50/125mm					**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE - SHALE WITH COAL ZONES,** thinly bedded to laminated, moderately weathered, soft, dark gray to black
4.5										
				S	27-50/50mm					
6.0										

GROUNDWATER

DEPTH(ft)	HOUR	DATE
	* see note	

METHOD N/A

SAMPLE TYPE
A - Drill cuttings
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
NR - No Recovery

(Continued Next Page)

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BORING LOG I.D.: B-5

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
		PROJECT FEATURE:	Two-Span Bridge - South Abutment

Elevation (m)	Depth (m)	Drill Rate Min/m.	Graphical Log	Sample	Sample Type	Blow Count	Dry Density Kg per Cubic Meter	Moisture Content Percent of Dry Weight	Unified Soil Classification	REMARKS	VISUAL CLASSIFICATION
											MESA VERDE GROUP **POINT LOOKOUT SANDSTONE -** **SHALE WITH COAL ZONES,** continued
	7.5										Auger refused at 7.2m Began HQ Coring at 7.2m * note: groundwater not encountered within auger portion of borehole
	9.0										
	10.5										
	12.0										
	13.5										

GROUNDWATER

	DEPTH(ft)	HOUR	DATE
▽		* see note	
▼			
▼			
▼			

METHOD N/A

SAMPLE TYPE
A - Drill cuttings
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
NR - No Recovery

(Continued Next Page)

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BORING LOG I.D.: B-5

PROJECT:	BIA Project N5001(1)1,2&4		**PROJECT LOCATION:**	Toadlena, New Mexico	
LOGGED BY:	Mark Keyes		**PROJECT FEATURE:**	Two-Span Bridge - South Abutment	
DRILLER:	Guy Midkiff		**AFW PROJECT #:**	17-2017-4057	
DRILLER FIRM:	Resilient		**STATION/OFFSET:**	Station 7+948	
RIG I.D.:	103		**REFERENCE:**	N5001(1)1,2&4 Project Plans	
RIG TYPE:	CME-75		**COORDINATES:**	N4011985.1, E696331.8	
BORING TYPE:	HSA/HQ	**BORING DIA.:** 168mm	**COORDINATE SYS:**	NAD83 UTM ZONE 12N (meters)	
ORIENTATION:	90°		**SURFACE ELEV. (m):**	1815.7 ±	
HAMMER TYPE	Automatic		**VERTICAL DATUM:**	NAVD88	
HAMMER CALIBRATION-ENERGY TRANSFER RATIO:	96		**COMPLETION DATE:**	10/10/2017	**COMPLETION TIME:** 15:00
START DATE:	10/10/2017	**START TIME:** 12:00			

Boring Operation and Drill Rate (Min/m)	Depth (m)	Sample	Sample Type	Unconfined Compression or Point Load IndexTest (kPa)	% Core Recovery	% Drilling Fluid 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 7.2m
10/10 HQ 2.0	7.5		HQ	18212	85	100	60		BROKEN	None	Fgn & ThB to L zones & MB zones	SlW to MdW	**MESA VERDE GROUP POINT LOOKOUT SANDSTONE - SANDSTONE Interbedded with SILTSTONE & COAL ZONES,** moderately hard to hard sandstone with thin soft coal zones, very light gray (N8) to light gray (N7) with black zones note: some mechanical breaks along low-angle bedding planes
	9.0		HQ		100		100				Mass-ive to TkB	SlW	note: some irregularly-shaped inclusions from 8.7m to 9.0m note: predominantly moderately hard sandstone from 8.7m to 10.2m
1.9	10.5		HQ		100		100						
	12.0		HQ	23556	100		100				L zones		note: thin low-angle laminae zones below 12.0m with coal zones
			HQ	.	100		90						

(Continued Next Page)

GROUNDWATER

	DEPTH(ft)	HOUR	DATE
▽		* see note	
▼			
▼			
▼			

METHOD N/A

BORING OPERATION

HQ - Wireline Rock Coring
HSA - Hollow Stem Auger
S - 51mm O.D., 35mm I.D.Tube Sample

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Phoenix, Arizona 85034

BORING LOG I.D.: B-5

PROJECT:	BIA Project N5001(1)1,2&4	**PROJECT LOCATION:**	Toadlena, New Mexico
LOGGED BY:	Mark Keyes	**PROJECT FEATURE:**	Two-Span Bridge - South Abutment

Boring Operation and Drill Rate (Min/m)	Depth (m)	Elevation (m)	Sample	Sample Type	Unconfined Compression or Point Load IndexTest (kPa)	% Core Recovery	% Drilling Fluid Rec.	Rock Quality Designation (RQD)	DISCONTINUITIES Spacing (Wide - Close: 1 2 3 4 5)	DISCONTINUITIES Orientation (Horiz - 45 - Vert: H 45 V)	Condition	Bedding and/ or Fabric	Weathering or USCS (Soils)	Rock Type & Remarks
10/10 HQ 1.9	13.5			HQ		90	100	90			None	L zones	SlW	**MESA VERDE GROUP** **POINT LOOKOUT SANDSTONE -** **SANDSTONE Interbedded with SILTSTONE & COAL ZONES,** continued note: predominantly massive bedding with occasional thin low-angle, wavy coal zones
	15.0													Stopped HQ Coring at 14.7m * note: water used during coring did not allow for identification of groundwater
	16.5													
	18.0													
	19.5													

GROUNDWATER

	DEPTH(ft)	HOUR	DATE
▽		* see note	
▼			
▼			
▼			

METHOD N/A

BORING OPERATION

HQ - Wireline Rock Coring
HSA - Hollow Stem Auger
S - 51mm O.D., 35mm I.D.Tube Sample

Note: All depths in photos are in feet.

Note: All depths in photos are in feet.

Note: All depths in photos are in feet.

Note: All depths in photos are in feet.

Note: All depths in photos are in feet.

Note: All depths in photos are in feet.

APPENDIX B

LABORATORY TEST RESULTS

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 (%)	Unconfined Compressive Strength of Rock Core Samples (kPa)[1] (ASTM D7012)
		meter			Begin	End						
Proposed BIA Route N5001(1)1,2&4 CL	7+181	3	L	B-1	0.00	0.45	SM	NV	NP	24	4.6	
Proposed BIA Route N5001(1)1,2&4 CL	7+181	3	L	B-1	1.35	1.80	SM	NV	NP	26		
Proposed BIA Route N5001(1)1,2&4 CL	7+181	3	L	B-1	5.55	5.73						14,807
Proposed BIA Route N5001(1)1,2&4 CL	7+181	3	L	B-1	7.65	7.98						13,578
Proposed BIA Route N5001(1)1,2&4 CL	7+200	1	L	B-2	0.00	1.35	SM	NV	NP	14		
Proposed BIA Route N5001(1)1,2&4 CL	7+200	1	L	B-2	1.35	1.80	SC-SM	22	4	32	6.8	
Proposed BIA Route N5001(1)1,2&4 CL	7+200	1	L	B-2	5.25	5.55						15,088
Proposed BIA Route N5001(1)1,2&4 CL	7+200	1	L	B-2	10.93	11.25						15,621
Proposed BIA Route N5001(1)1,2&4 CL	7+912	5	R	B-3	0.00	1.20	SM	NV	NP	17		
Proposed BIA Route N5001(1)1,2&4 CL	7+912	5	R	B-3	1.20	1.65	SM	NV	NP	12	2.6	
Proposed BIA Route N5001(1)1,2&4 CL	7+912	5	R	B-3	3.90	4.17						20,782
Proposed BIA Route N5001(1)1,2&4 CL	7+912	5	R	B-3	10.92	11.10						25,447
Proposed BIA Route N5001(1)1,2&4 CL	7+948	7	R	B-5	0.00	1.20	SM	NV	NP	23		
Proposed BIA Route N5001(1)1,2&4 CL	7+948	7	R	B-5	1.20	1.65	SM	NV	NP	15	2.5	
Proposed BIA Route N5001(1)1,2&4 CL	7+948	7	R	B-5	2.70	3.15	SC	39	18	47	8.4	
Proposed BIA Route N5001(1)1,2&4 CL	7+948	7	R	B-5	7.95	8.19						18,212
Proposed BIA Route N5001(1)1,2&4 CL	7+948	7	R	B-5	12.30	12.57						23,556
							MEAN	**---**	**---**	**23**	**5.0**	**18,386**
							STDEV	**---**	**---**	**11**	**2.6**	**4,421**
							MAXIMUM	**39**	**18**	**47**	**8.4**	**25,447**
							MINIMUM	**NV**	**NP**	**12**	**2.5**	**13,578**
							COUNT	**9**	**9**	**9**	**5**	**8**

Note:
[1](kPa) = kilopascal

LABORATORY TESTING PROCEDURES

Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates (ASTM C136) or Standard Test Method for Particle-Size Analysis of Soils (ASTM D422) or Sieving of Coarse and Fine Graded Soils and Aggregates (AZ 201)

A particle-size analysis indicates the range of soil particle diameters included in a particular sample. The distribution of particle sizes larger than 75 µm (retained on the No. 200 sieve) is determined by sieving, while the distribution of particle sizes smaller than 75 µm is determined by a sedimentation process, using a hydrometer to secure the necessary data. Unless otherwise stated the sedimentation process using a hydrometer was not performed. The particle-size analysis is utilized to aid in soil classification.

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils (ASTM D4318) or Determining the Plastic Limit and Plasticity Index of Soils (AASHTO T 90)

The liquid limit, plastic limit and plasticity index (Atterberg Limits) are used to characterize the fine-grained fractions of soils. The liquid limit is the water content, in percent, of a soil at the arbitrarily defined boundary between the semi-liquid and plastic states. The plastic limit is the water content, in percent, of a soil at the boundary between the plastic and semi-solid states. Samples may be prepared as wet or dry, unless otherwise stated the dry preparation method was utilized. Additionally, the test may be conducted using Method A, which is a multipoint test, or Method B, which is a one-point test. Unless otherwise stated, Method B was utilized. The plasticity index and liquid limit are utilized to aid in soil classification. The liquid limit, plastic limit and plasticity index of soils are also used extensively, either individually or together, with other soil properties in establishing a correlation between soil behavior and its index properties.

Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass (ASTM D2216)

Water content determinations of soil, rock and similar materials by mass where the reduction in mass by drying is due to loss of water. For many materials, the water content is one of the most significant index properties used in establishing a correlation between soil behavior and its index properties.

Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures (ASTM D7012)

These test methods cover the determination of the strength of intact rock core specimens in uniaxial and triaxial compression. Rock core specimens are subjected to loads applied at a certain rate to obtain the uniaxial unconfined compressive strength. Additionally, the test may be conducted using Methods A and B to determine the triaxial compressive strength at different pressures and Methods C and D to determine the unconfined, uniaxial strength. Unless otherwise stated, Method C or D was utilized. The test method is primarily intended to determine rock strength parameters.

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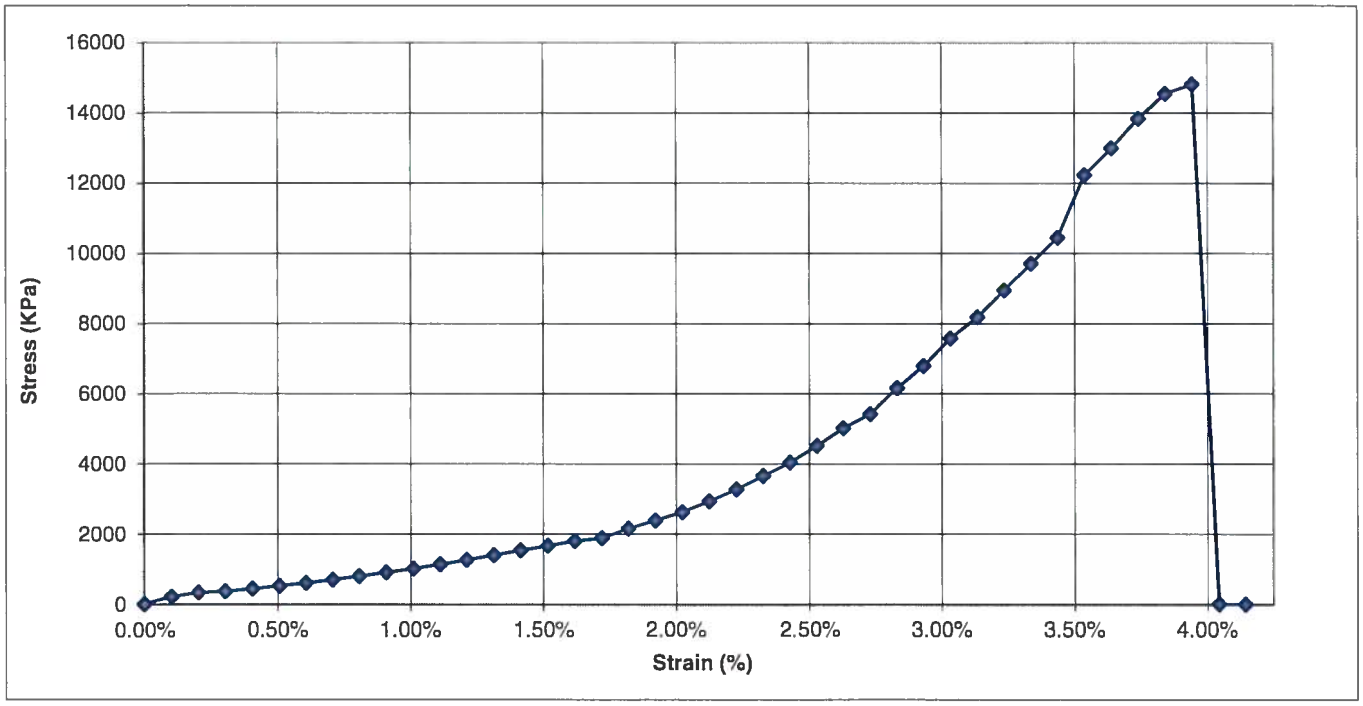
PROJECT: BIA N5001(1) 1,2 &4
LOCATION: Toadlena, New Mexico
MATERIAL: Rock Cores
SAMPLE SOURCE: B-1 (5.55-5.73m)
SAMPLE PREP: INSITU

JOB NO: 17-2017-4057
WORK ORDER NO: 1
LAB NO: 17-2657-01
DATE SAMPLED: 10/17/17

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS (ASTM D7012)

DIAMETER:	6.04 cm	MAXIMUM STRESS:	14,807 KPa
HEIGHT:	12.56 cm	AT STRAIN:	3.94%
STRAIN RATE:	0.05 cm/min.		
DRY DENSITY:	1,914.7 kg/cu.m		




Before


After

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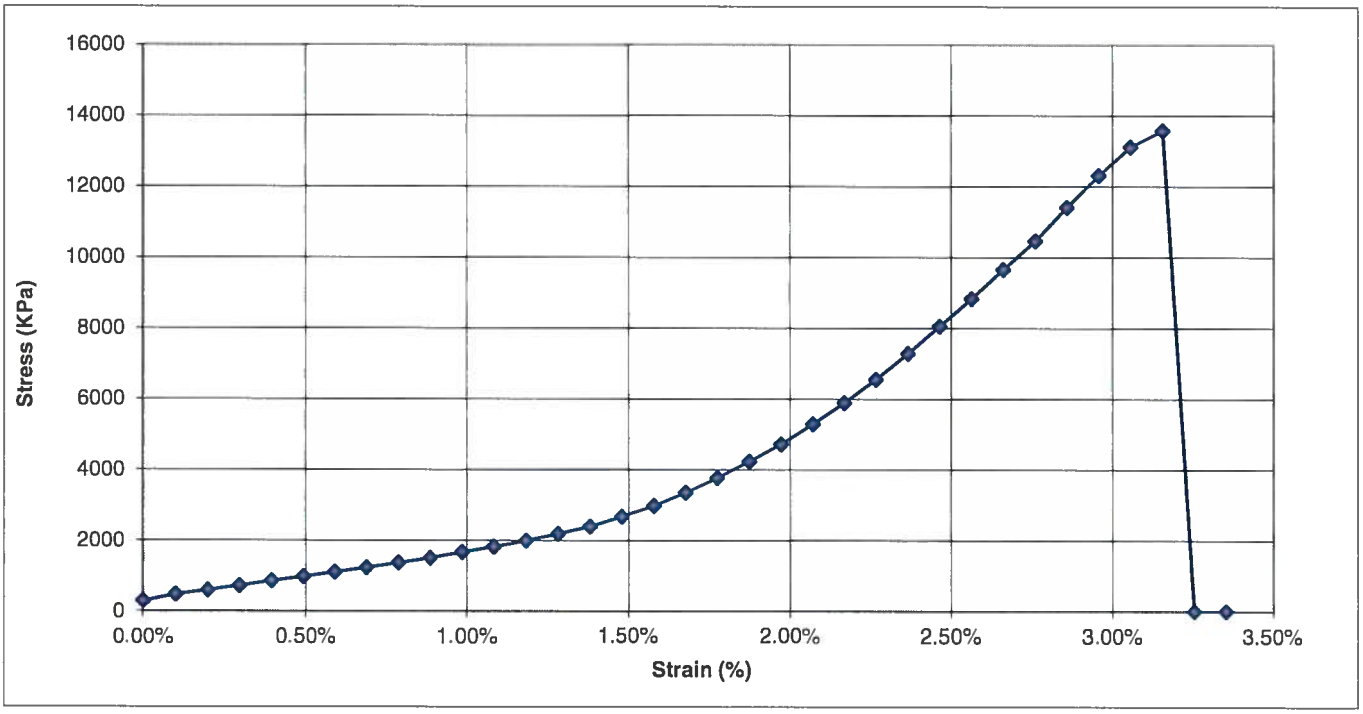
PROJECT: BIA N5001(1) 1,2 &4
LOCATION: Toadlena, New Mexico
MATERIAL: Rock Cores
SAMPLE SOURCE: B-1 (7.65-7.98m)
SAMPLE PREP: INSITU

JOB NO: 17-2017-4057
WORK ORDER NO: 1
LAB NO: 17-2657-02
DATE SAMPLED: 10/17/17

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS (ASTM D7012)

DIAMETER:	5.98 cm	MAXIMUM STRESS:	13,578 KPa
HEIGHT:	12.88 cm	AT STRAIN:	3.15%
STRAIN RATE:	0.05 cm/min.		
DRY DENSITY:	1,966.8 kg/cu.m		

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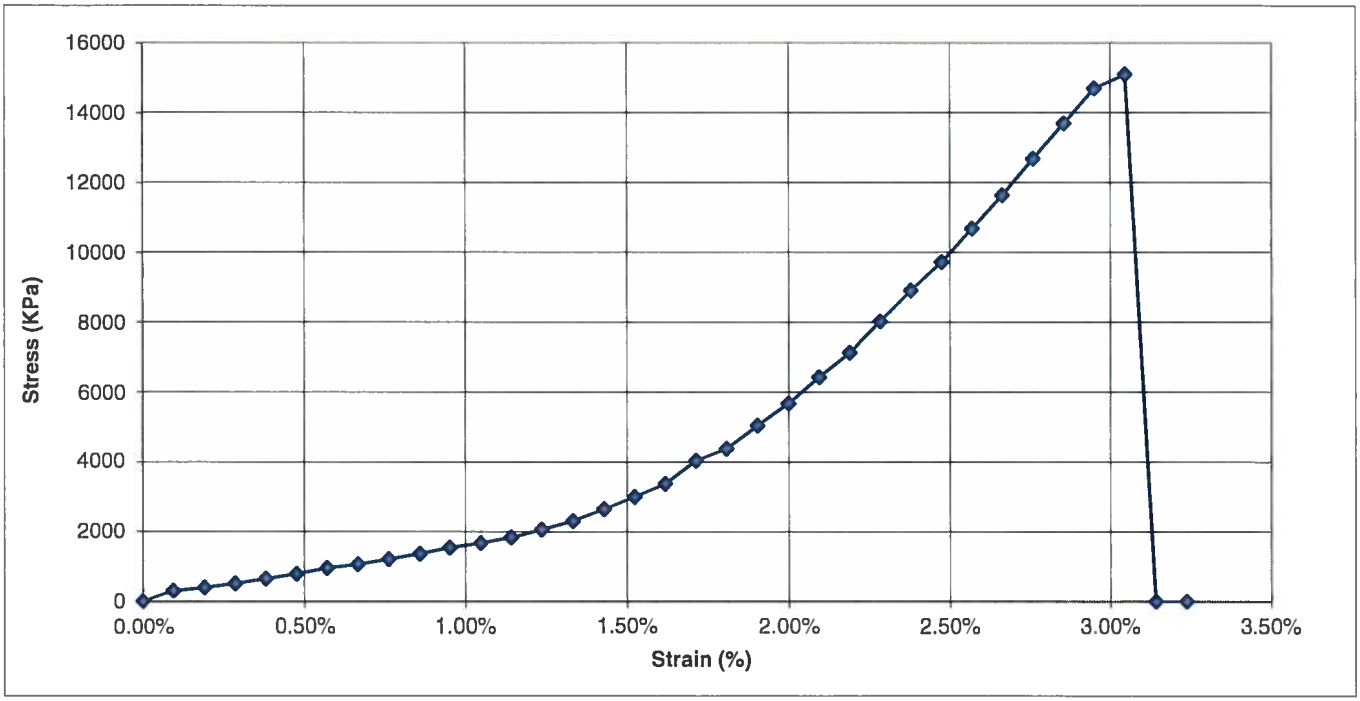
PROJECT: BIA N5001(1) 1,2 &4
LOCATION: Toadlena, New Mexico
MATERIAL: Rock Cores
SAMPLE SOURCE: B-2 (5.25-5.55m)
SAMPLE PREP: INSITU

JOB NO: 17-2017-4057
WORK ORDER NO: 1
LAB NO: 17-2657-03
DATE SAMPLED: 10/17/17

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS (ASTM D7012)

DIAMETER:	5.95 cm	MAXIMUM STRESS:	15,088 KPa
HEIGHT:	13.35 cm	AT STRAIN:	3.05%
STRAIN RATE:	0.05 cm/min.		
DRY DENSITY:	1,915.0 kg/cu.m		

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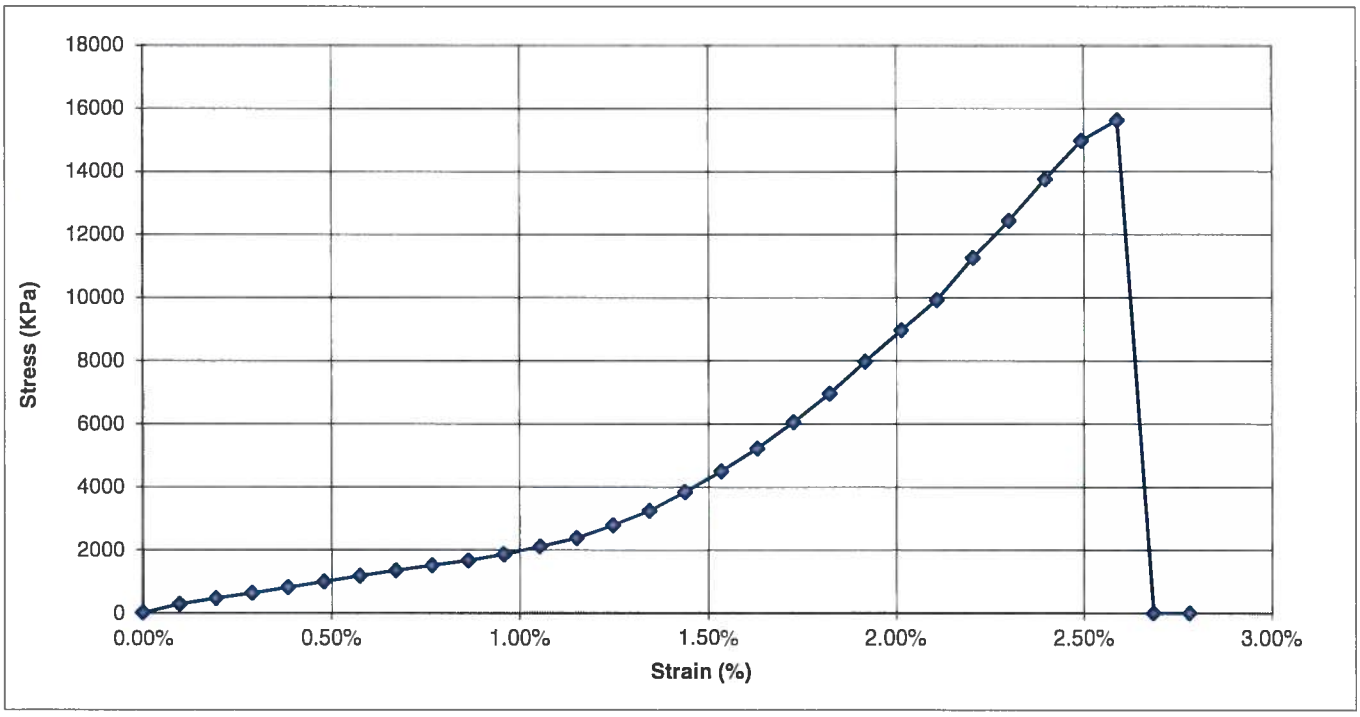
PROJECT: BIA N5001(1) 1,2 &4
LOCATION: Toadlena, New Mexico
MATERIAL: Rock Cores
SAMPLE SOURCE: B-2 (10.93-11.25m)
SAMPLE PREP: INSITU

JOB NO: 17-2017-4057
WORK ORDER NO: 1
LAB NO: 17-2657-04
DATE SAMPLED: 10/17/17

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS (ASTM D7012)

DIAMETER:	6.01 cm	MAXIMUM STRESS:	15,621 KPa
HEIGHT:	13.25 cm	AT STRAIN:	2.59%
STRAIN RATE:	0.05 cm/min.		
DRY DENSITY:	2,049.7 kg/cu.m		

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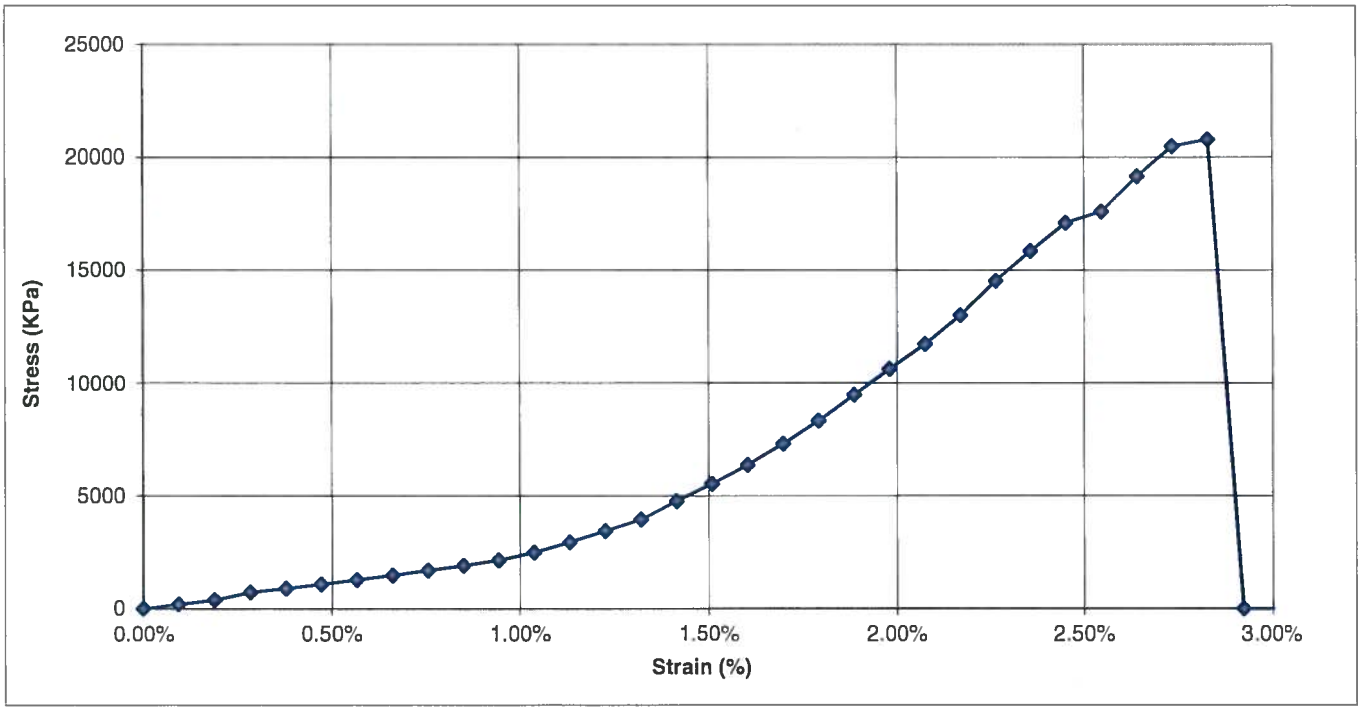
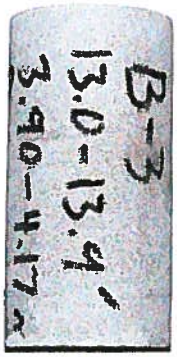
PROJECT: BIA N5001(1) 1,2 &4
LOCATION: Toadlena, New Mexico
MATERIAL: Rock Cores
SAMPLE SOURCE: B-3 (3.90-4.17m)
SAMPLE PREP: INSITU

JOB NO: 17-2017-4057
WORK ORDER NO: 1
LAB NO: 17-2657-05
DATE SAMPLED: 10/17/17

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS (ASTM D7012)

DIAMETER:	5.99 cm	MAXIMUM STRESS:	20,782 KPa
HEIGHT:	13.47 cm	AT STRAIN:	2.83%
STRAIN RATE:	0.05 cm/min.		
DRY DENSITY:	2,262.9 kg/cu.m		





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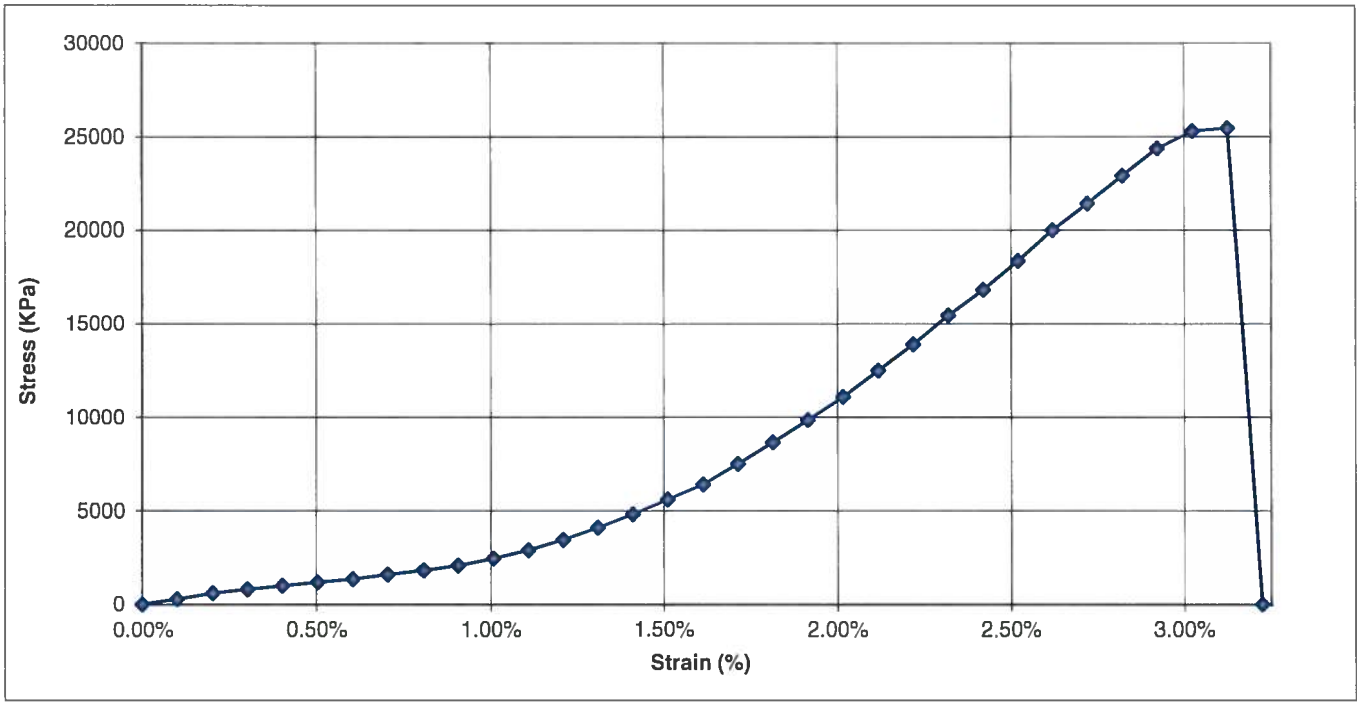
PROJECT: BIA N5001(1) 1,2 &4
LOCATION: Toadlena, New Mexico
MATERIAL: Rock Cores
SAMPLE SOURCE: B-3 (10.92-11.10m)
SAMPLE PREP: INSITU

JOB NO: 17-2017-4057
WORK ORDER NO: 1
LAB NO: 17-2657-06
DATE SAMPLED: 10/17/17

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS (ASTM D7012)

DIAMETER:	6.04 cm	MAXIMUM STRESS:	25,447 KPa
HEIGHT:	12.60 cm	AT STRAIN:	3.12%
STRAIN RATE:	0.05 cm/min.		
DRY DENSITY:	2,229.7 kg/cu.m		



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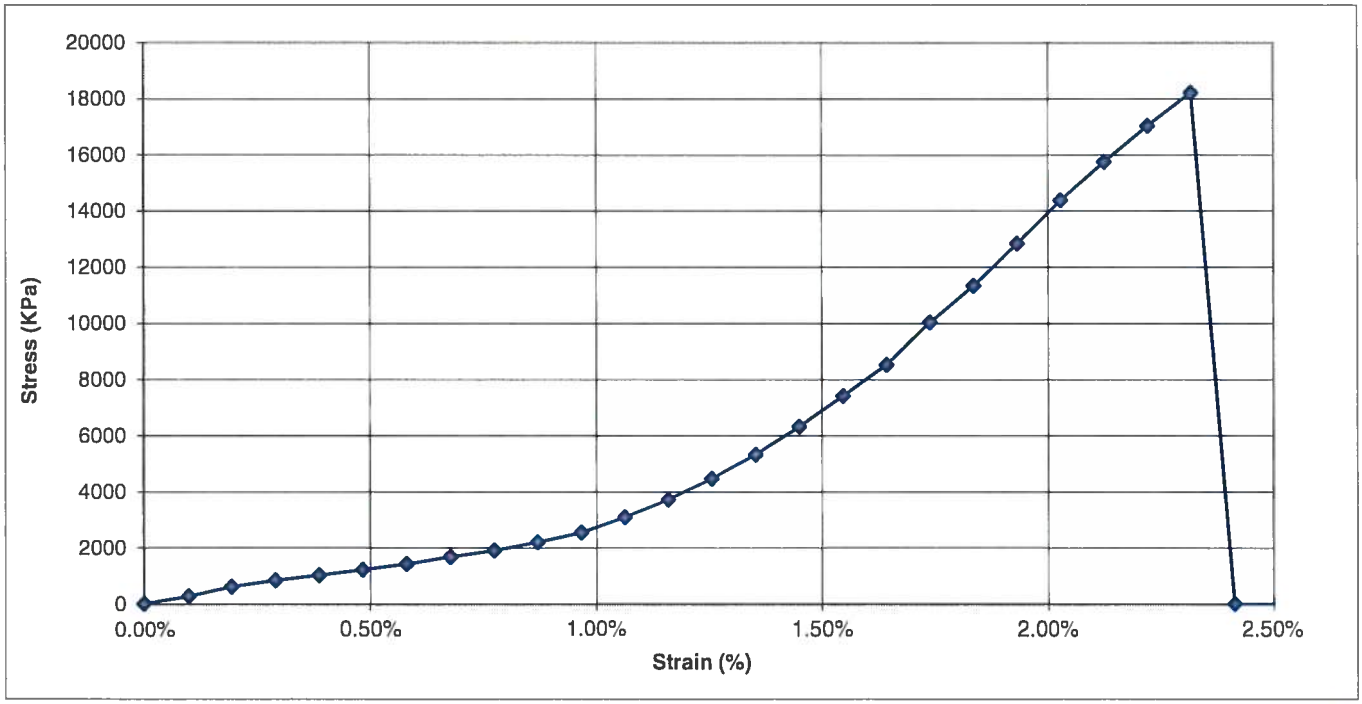
PROJECT: BIA N5001(1) 1,2 &4
LOCATION: Toadlena, New Mexico
MATERIAL: Rock Cores
SAMPLE SOURCE: B-5 (7.95-8.19m)
SAMPLE PREP: INSITU

JOB NO: 17-2017-4057
WORK ORDER NO: 1
LAB NO: 17-2657-07
DATE SAMPLED: 10/17/17

UNCONFINED COMPRESSIVE STRENGTH OF INTACT ROCK CORE SPECIMENS (ASTM D7012)

DIAMETER:	6.00 cm	MAXIMUM STRESS:	18,212 KPa
HEIGHT:	13.15 cm	AT STRAIN:	2.32%
STRAIN RATE:	0.05 cm/min.		
DRY DENSITY:	2,157.0 kg/cu.m		

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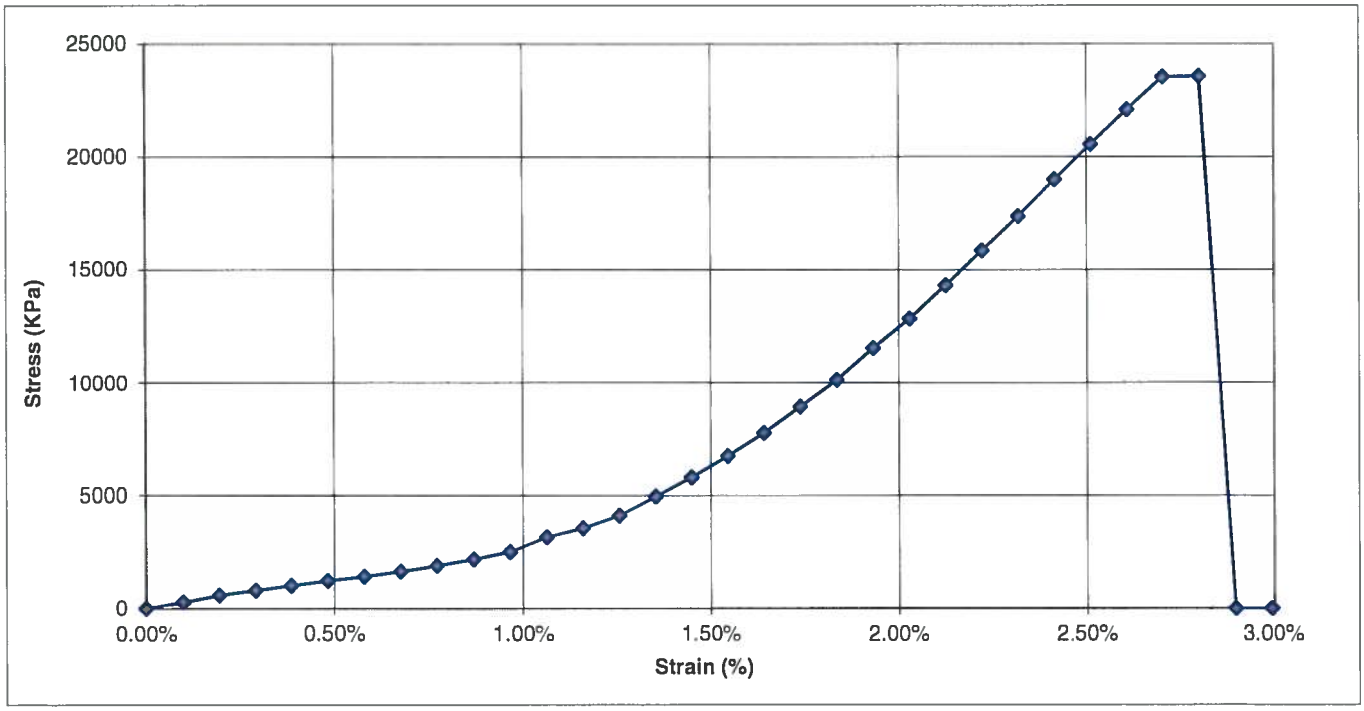
PROJECT: BIA N5001(1) 1,2 &4
LOCATION: Toadlena, New Mexico
MATERIAL: Rock Cores
SAMPLE SOURCE: B-5 (12.3-12.57m)
SAMPLE PREP: INSITU

JOB NO: 17-2017-4057
WORK ORDER NO: 1
LAB NO: 17-2657-08
DATE SAMPLED: 10/17/17

UNCONFINED COMPRESSION STRENGTH OF COHESIVE SOIL
APPLICABLE PORTIONS OF (ASTM D2166)

DIAMETER:	6.00 cm	MAXIMUM STRESS:	23,556 KPa
HEIGHT:	13.15 cm	AT STRAIN:	2.80%
STRAIN RATE:	0.05 cm/min.		
DRY DENSITY:	2,157.0 kg/cu.m		



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PROJECT: BIA N5001 (1) 1,2&4
LOCATION: Toadlena, NM
MATERIAL: Native Soil
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2017-4057
WORK ORDER NO: 2
DATE ASSIGNED: 10/17/17

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

PERCENT PASSING BY WEIGHT

					SAND								GRAVEL									COBBLES	
				Silt or 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 #
B-1 (0.00-0.45m)	SM	NV	NP	24	68	87	89	90	92	93	93	95	96	97	97	97	100	100	100	100	100	100	17-2655-02
B-1 (1.35-1.80m)	SM	NV	NP	26	72	87	89	90	91	92	92	94	96	97	98	100	100	100	100	100	100	100	17-2655-03
B-2 (0.00-1.35m)	SM	NV	NP	14	31	59	62	64	66	67	68	71	73	77	81	87	91	95	97	99	100	100	17-2655-05
B-2 (1.35-1.80m)	SC-SM	22	4	32	51	75	80	82	83	84	84	85	86	89	94	97	100	100	100	100	100	100	17-2655-06
B-3 (0.00-1.20m)	SM	NV	NP	17	43	60	66	70	74	76	76	79	80	83	84	87	89	92	93	95	97	100	17-2655-08
B-3 (1.20-1.65m)	SM	NV	NP	12	20	33	39	43	47	50	52	60	64	69	72	80	89	100	100	100	100	100	17-2655-09
B-5 (0.00-1.20m)	SM	NV	NP	23	48	63	72	79	84	86	86	89	90	91	91	92	92	94	95	98	100	100	17-2655-11
B-5 (1.20-1.65m)	SM	NV	NP	15	29	43	49	52	55	57	58	65	69	75	81	89	98	100	100	100	100	100	17-2655-12
B-5 (2.70-3.15m)	SC	39	18	47	54	62	66	69	73	74	74	76	78	81	83	94	97	100	100	100	100	100	17-2655-13

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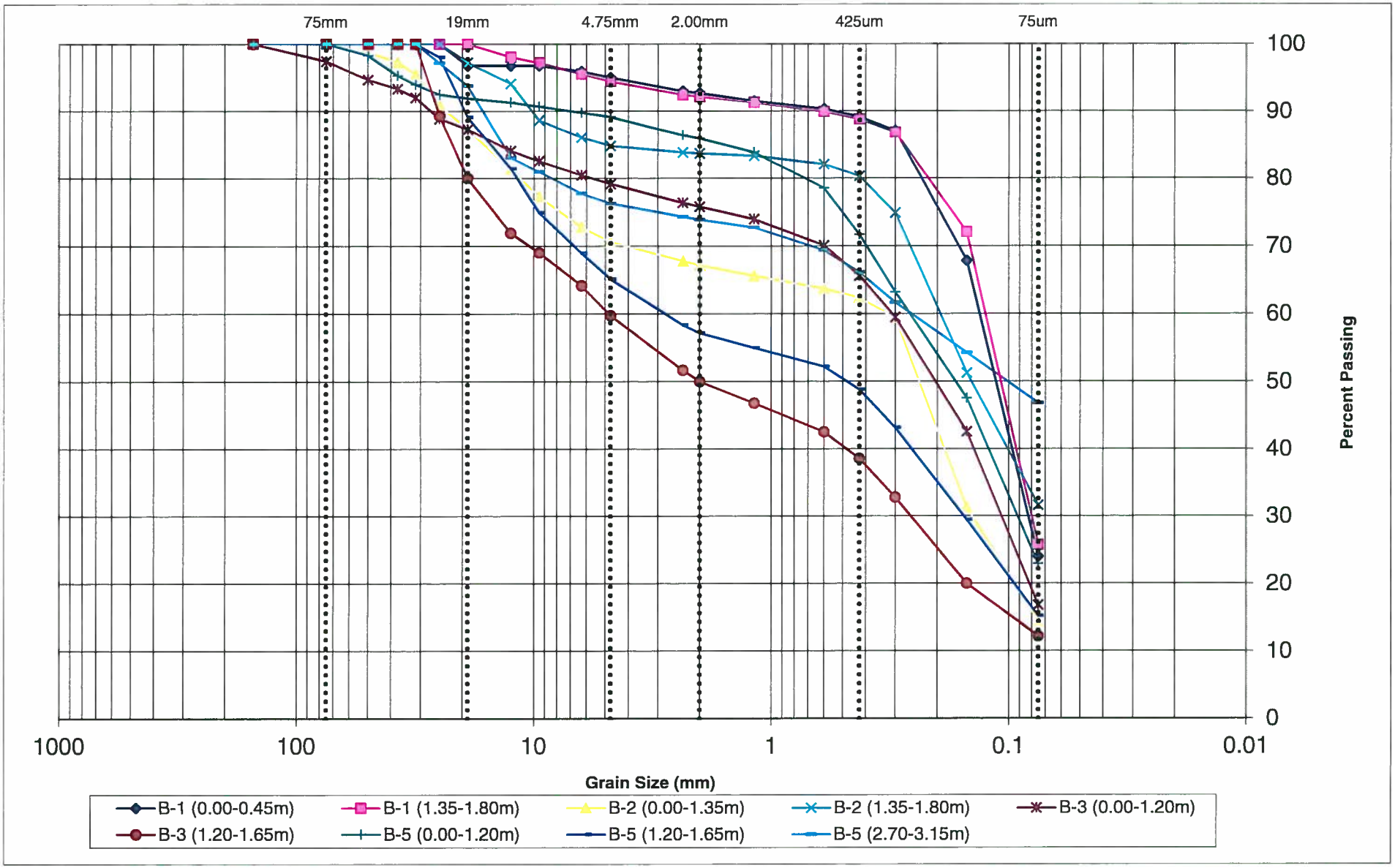
PROJECT: BIA N5001 (1) 1,2&4
LOCATION: Toadlena, NM
SAMPLE SOURCE: SEE BELOW

JOB NO: 17-2017-4057
WORK ORDER NO: 2
DATE ASSIGNED: 10/17/17

MECHANICAL SIEVE ANALYSIS



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PROJECT: BIA N5001 (1) 1,2&4
LOCATION: Toadlena, NM
MATERIAL: Native Soil
SAMPLE SOURCE: See Below

JOB NO: 17-2017-4057
WORK ORDER NO: 2
LAB NO: See Below
DATE ASSIGNED: 10/17/17

MOISTURE CONTENT OF SOIL (AASHTO T265)

LAB #	BORING & DEPTH	WET WT. (gram)	DRY WT. (gram)	MOISTURE CONTENT
17-2655-02	B-1 (0.00-0.45m)	341.9	327.0	4.6%
17-2655-06	B-2 (1.35-1.80m)	680.3	637.1	6.8%
17-2655-09	B-3 (1.20-1.65m)	676.8	659.7	2.6%
17-2655-12	B-5 (1.20-1.65m)	1106.6	1079.1	2.5%
17-2655-13	B-5 (2.70-3.15m)	821.1	757.4	8.4%

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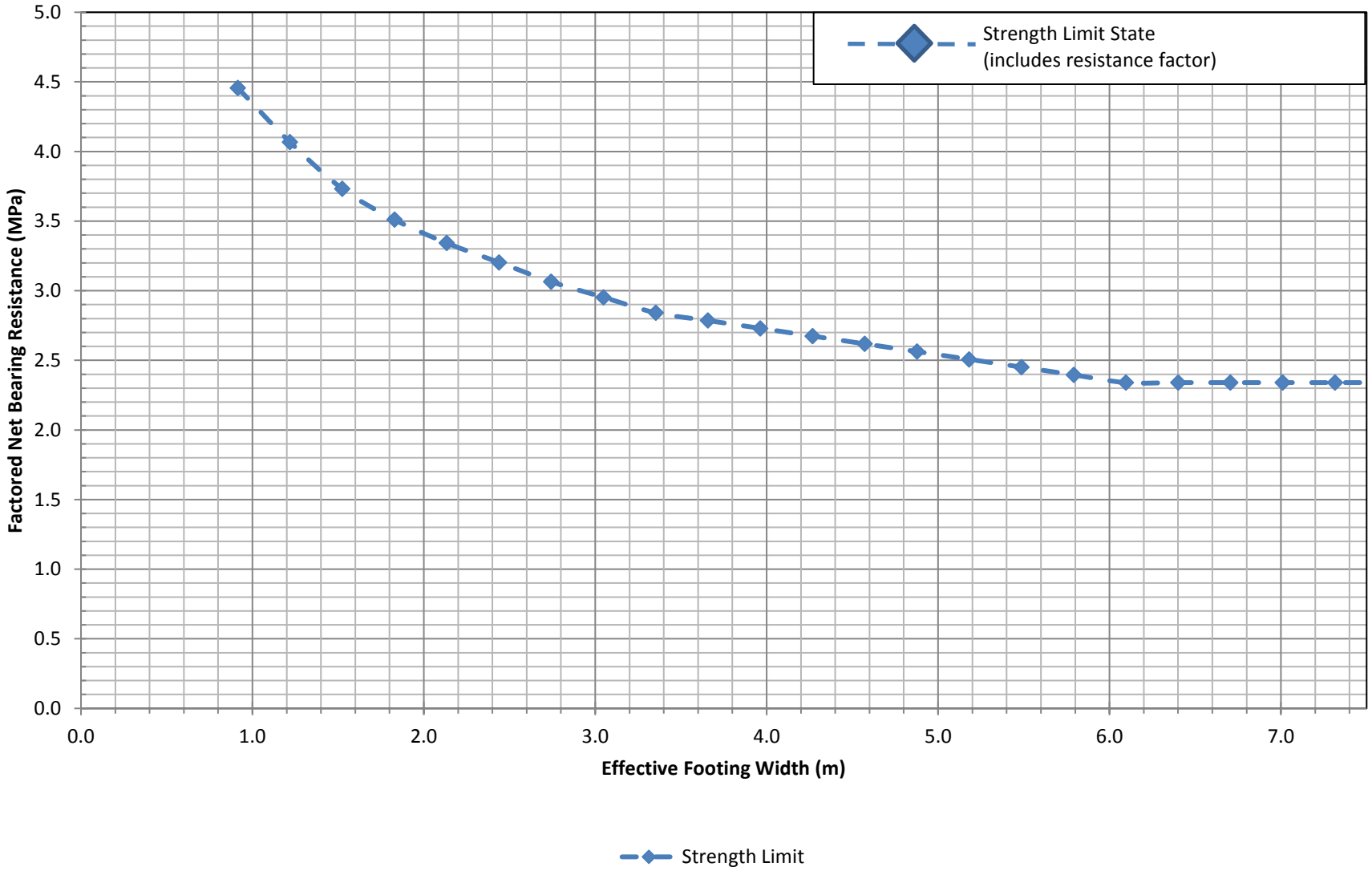
APPENDIX C

DESIGN CHARTS

Design Chart 1
GSR-IBS founded on Rock (STA 7+193)
Footing Length = 9 meters, Depth of Embedment = 0 meters



APPENDIX D

SLOPE STABILITY ANALYSIS

BIA Project N5001(1)1,2&4
Toadlena, NM (Navajo Nation)

Factor of Safety = 1.5

Traffic Load = 12 kPa

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Silty Sand	18.9	0	30
	Sandstone	18.9	120	58
	GSR-IBS	19.6	250	38
	Integrated Approach	19.6	0	38
	Concrete	23.6		
	GRS Backfill	19.6	0	38

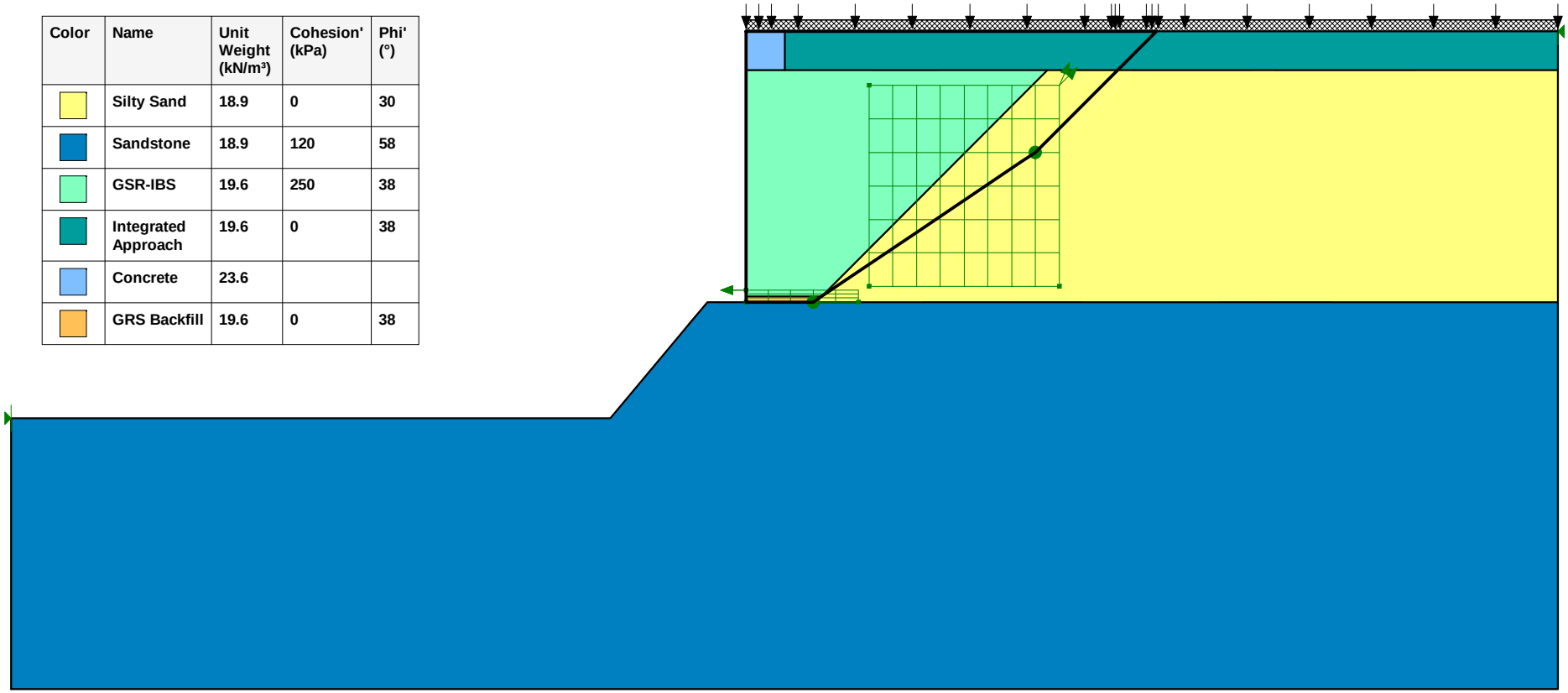


Figure D-1 (Block Failure)

BIA N5001(1)1,2&4 - GRS-IBS at STA 7+193

11/21/2017

BIA Project N5001(1)1,2&4
Toadlena, NM (Navajo Nation)

Factor of Safety = 1.8

Traffic Load = 12 kPa

Color	Name	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Silty Sand	18.9	0	30
	Sandstone	18.9	120	58
	GSR-IBS	19.6	250	38
	Integrated Approach	19.6	0	38
	Concrete	23.6		
	GRS Backfill	19.6	0	38

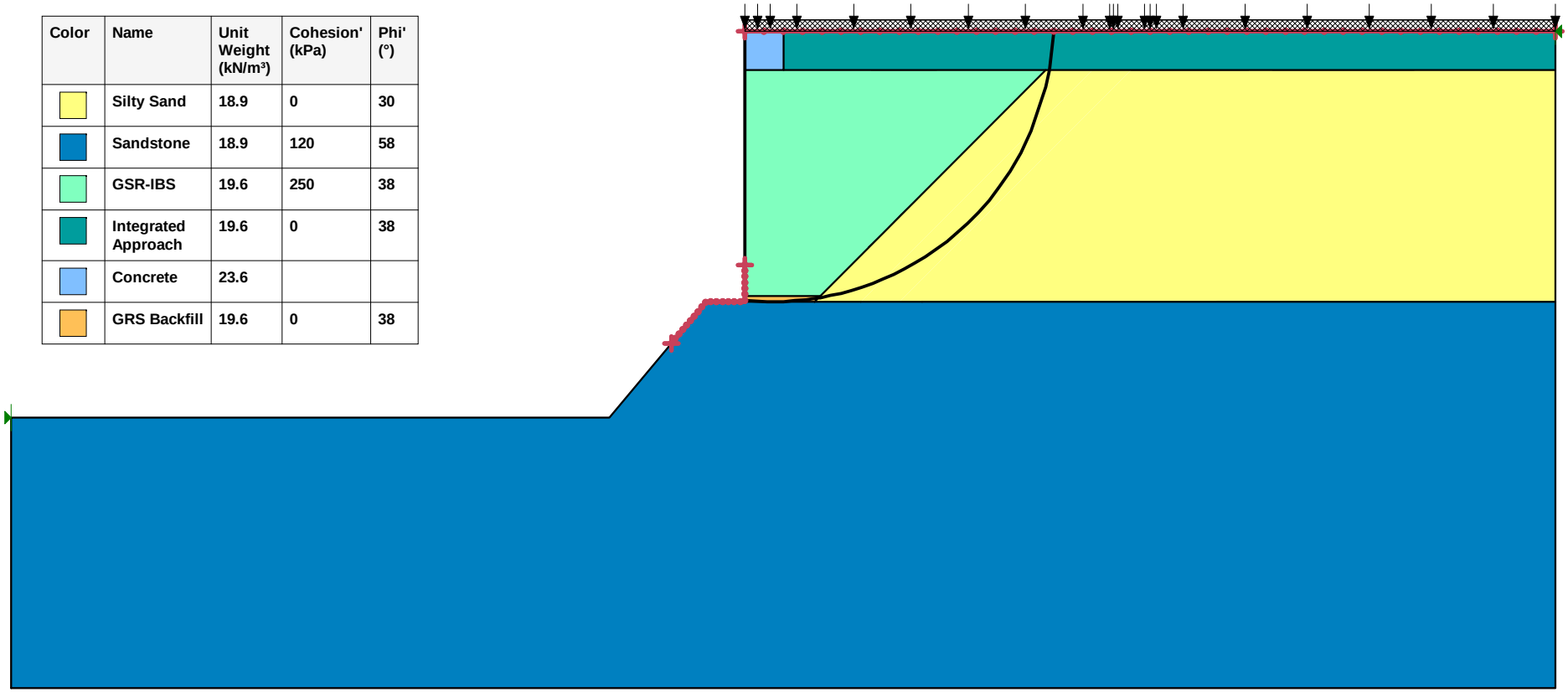


Figure D-2 (Circular Failure)

BIA N5001(1)1,2&4 - GRS-IBS at STA 7+193

11/21/2017