March 15, 2014

MacArthur Associated Consultants, LLC
2420 Springer Drive, Suite 120
Norman, OK 73069

Attn: Mr. Gregory L. Fitter, Ph.D., P.E.

Re: Subsurface Exploration & Geotechnical Engineering Report
Proposed Three-Span Bridge on US-59 over Big Brushy Creek
State Job No. 29563(04)
Le Flore County, Oklahoma
HGE Project No. MAC-13-01

Dear Mr. Fitter:

The Subsurface Exploration & Geotechnical Engineering Report has been completed for the proposed three-span bridge widening on US-59 over Big Brushy Creek in Le Flore County, Oklahoma. Our scope of services and fee schedule were agreed via email correspondence.

The purpose of the attached report is to provide a summary of the field investigation methods used and to provide recommendations for the design and construction of foundations. Logs of the borings and test results are provided in the appendices of this report.

Mr. Fitter, please do not hesitate to contact HGE at (405) 942-4090 should you have questions regarding this report.

Respectfully:

Mark H. Hinderliter, P.E.
Oklahoma No. 21327


P:\HGE\Reports\2014 Geo\March\MAC-13-01
Copies: Client (3 + pdf & Invoice)
March 15, 2014

MacArthur Associated Consultants, LLC
2420 Springer Drive, Suite 120
Norman, OK 73069

Attn: Mr. Gregory L. Fitter, Ph.D., P.E.

Re: Subsurface Exploration & Geotechnical Engineering Report
Proposed Three-Span Bridge on US-59 over Big Brushy Creek
State Job No. 29563(04)
Le Flore County, Oklahoma
HGE Project No. MAC-13-01

Dear Mr. Fitter:

The Subsurface Exploration & Geotechnical Engineering Report has been completed for the proposed three-span bridge widening on US-59 over Big Brushy Creek in Le Flore County, Oklahoma. Our scope of services and fee schedule were agreed via email correspondence.

The purpose of the attached report is to provide a summary of the field investigation methods used and to provide recommendations for the design and construction of foundations. Logs of the borings and test results are provided in the appendices of this report.

Mr. Fitter, please do not hesitate to contact HGE at (405) 942-4090 should you have questions regarding this report.

Respectfully:

Mark H. Hinderliter, P.E.
Oklahoma No. 21327


P:\HGE\Reports\2014 Geo\March\MAC-13-01

Copies: Client (3 + pdf & Invoice)
# TABLE OF CONTENTS

1.0 Executive Summary ................................................................. 1

2.0 Project Description ........................................................................ 2

3.0 Site Exploration ............................................................................ 2
   3.1 Boring Layout & Elevations .................................................... 2
   3.2 Subsurface Investigation ......................................................... 2

4.0 Laboratory Evaluation .................................................................. 4
   4.1 In-Situ Moisture Content ....................................................... 4
   4.2 Liquid & Plastic Limits .......................................................... 4
   4.3 Sieve Analysis .................................................................... 5

5.0 Findings & Recommendations .................................................... 6
   5.1 Site Conditions .................................................................... 6
   5.2 Subsurface Geology & Conditions ......................................... 6
   5.3 Groundwater Conditions ..................................................... 7
   5.4 Driven Pile Foundations ....................................................... 7
   5.5 Drilled Shaft Foundations .................................................... 8

6.0 Concluding Remarks .................................................................... 9

Appendix A
   Boring Location Diagram
   Subsurface Fence Diagram
   Boring Logs

Appendix B
   Grain Size Distribution Results

Appendix C
   General Notes on Soil Classification
   Plasticity Classification – General Examples
   Granular Material Classification – General Examples
1.0 EXECUTIVE SUMMARY

The subsurface exploration is complete for the proposed three-span bridge widening project on US-59 over Big Brushy Creek in Le Flore County, Oklahoma near the Town of Page. The project is referred to as State Job No. 29563(04).

It is understood the project will include widening the existing bridge approximately 7 feet on each side and resurfacing the deck. Based on the General Plan & Elevation sheet provided to us, the abutments will be supported on driven piles while the interior columns will be supported on drilled shafts.

Exploration of the subsurface materials at the project site consisted of four soil test borings. The borings were advanced as close as practical to the existing piers and abutments. However, a water well drilling rig was used to advance casing through the cobbled overburden soils. Water well drilling rigs are quite large and heavy; some offsets were necessary due to embankment slopes and soft ground. Borings were advanced approximately 20 feet to 30 feet below the top of the sedimentary rock. Samples obtained from the borings were returned to the laboratory for further evaluation and laboratory testing. Groundwater levels were estimated while drilling or sampling at the abutment locations.

In general, the borings encountered gravel, cobble and boulder sized particles interbedded with mixtures of sand, silt and clay. These overburden materials tended to be very dense. At depths of approximately 11 feet to 12 feet, the subsurface materials transitioned to hard, very dense, cobbly weathered sandstone and/or cobbly weathered shale. Gray, weathered shale was encountered at depths ranging from approximately 11 feet to 25 feet. The weathered shale was bedded at an angle resulting in poor recovery and RQD's. The weathered shale persisted to the boring termination depths of approximately 33 feet to 55 feet. Site geology appears best described as the Stanley Unit (PMs) and appears to cross the Honess Fault.

Based on the subsurface conditions encountered at the time of our investigation, driven pile foundations can be used to support the proposed abutments and drilled shafts can be used to support the interior bents. Specific geotechnical recommendations concerning foundations are presented subsequently in this report.
2.0 PROJECT DESCRIPTION

The proposed bridge widening project is located on US-59 over Big Brushy Creek in Le Flore County, Oklahoma near the Town of Page. The project is referred to as State Job No. 29563(04).

It is understood the existing bridge will be widened approximately 7 feet on each side and that the existing deck will be resurfaced. We understand abutments are to be supported on driven piles and interior bents will be supported on drilled shafts.

3.0 SITE EXPLORATION

3.1 Boring Layout & Elevations

Four borings were included in the subsurface exploration for the proposed bridge; one as close as practical to the location of each existing abutment and pier line. The approximate locations of the borings are displayed on the boring location diagram included in Appendix A of this report. Borings were located using a measuring wheel. Due to existing embankment slopes and soft ground, the borings were offset to relatively flat places that were accessible to the water well drill rig used to advance casing through the overburden cobbly soils.

Elevations at the boring locations were determined using a common surveyor's level and grade rod. Elevations were referenced to the cut "X" in the wing wall at Station 894+97.38 at 17.93 feet right. The benchmark had a reported elevation of 917.48. Based on this benchmark, ground surface elevations at the boring locations ranged from approximately 910 feet to 914 feet.

Boring locations and elevations should be considered only roughly accurate and not survey quality.

3.2 Subsurface Investigation

A four-wheel drive, rotary drill rig outfitted with hollow-stem augers was used to advance the boreholes to auger refusal. A water well drilling rig was used to hammer drill through the cobbly overburden soils to, or near to, bedrock. The water well rig then set steel casing, generally to depths of about 13 feet. Afterward, the rotary drill rig returned to advance the boring into bedrock using rotary drilling and/or coring. A bulldozer was used to assist the drill rigs with site access.

Representative soil and rock samples of less than cobble size were obtained down to the auger refusal depth using the split-barrel sampling procedure generally as detailed in ASTM D 1586. This method is commonly referred to as the Standard Penetration Test (SPT). The split-barrel sampling...
The process requires a split-barrel (two-piece) sampling tube be used to obtain soil samples. A two-inch outside diameter sampling tube is hammered into the bottom of the boring with a 140-pound weight falling 30 inches. The number of blows required to drive the sampling tube the last 12 inches, or less, of an 18-inch sampling interval is recorded as the SPT resistance value, N. The in-situ relative density of granular soils, consistency of cohesive soils, and the hardness of weathered bedrock can be estimated from the N value. The N values recorded for each test are displayed on the attached boring logs adjacent to their relative sampling depths.

Bedrock was cored within borings B-1, B-2 and B-3 using an NQ size, double-walled core barrel. Within boring B-2, rotary drilling methods were used after the boring experienced excessive caving while coring. Within boring B-2 and B-4, a Texas Department of Transportation (TxDOT) cone penetrometer was used to evaluate the sedimentary rock proposed to be the bearing strata. The TxDOT cone penetrometer test is a standard test developed by the Texas Department of Transportation to determine the strength and hardness of foundation materials in bridge foundation exploration work. The test is performed by attaching a 3-inch diameter penetrometer cone to the drill pipe and lowering it to the bottom of the borehole. The cone is seated and driven with a 140 pound drive hammer falling 30 inches. The penetration after 50 hammer blows into the bearing material is measured to the nearest 1/16th-inch. The process is repeated for another 50 blows. The total penetration for 100 blows is used to determine the strength of the bearing materials.

An automatic drive hammer was used to advance the split-barrel sampler and the cone penetrometer. A greater mechanical efficiency is achieved using an automatic drive hammer when compared to a conventional safety drive hammer operated with a cathead and rope. The effect of this higher efficiency on the N values has been considered in our interpretation and analysis of the subsurface information provided with this report.

The drill crew prepared field boring logs as part of the drilling operations. The samples were packaged in plastic bags to reduce moisture loss, labeled for identification and transported to our laboratory for further evaluation. Rock core was stored in waxed, cardboard boxes. Appendix A of this report contains the final boring logs that represent modifications based on the engineer's observations.

The borings were backfilled or grouted per OWRB requirements after the drilling operations were completed. Groundwater level measurements obtained prior to rotary drilling or coring are included in Section 5.3 of this report.
4.0 LABORATORY EVALUATION

As part of the geotechnical investigation, soil and rock samples obtained from the borings were evaluated for in-situ moisture content. Where enough recovery was obtained, representative samples were classified according to the Unified Soil Classification System (USCS). These tests help the engineer determine the soils engineering properties. Classification tests included Liquid and Plastic Limit (commonly referred to as Atterberg Limits) tests and Washed Sieve Analysis tests. The engineer reviewed all soil descriptions and made modifications based on the materials plasticity, texture, and color along with the laboratory test results.

Rock core samples were measured for percentage of recovery per 5-foot run of core, and Rock Quality (RQD). Due to the poor RQD results of the rock core, unconfined compressive strength was estimated rather than determined directly.

The laboratory test results and an estimated group symbol from the Unified Soil Classification System, percentage of core recovery and RQD are provided next to their representative sample locations in the appropriate column of the boring logs. The following sections provide brief information about the tests performed.

4.1 In-Situ Moisture Content

The in-situ moisture content of soil and rock samples was determined in the laboratory in general accordance with specification AASHTO T 265. The results of these tests have been provided in the appropriate column of the boring logs. Used appropriately with the SPT N-values, these results give indication of subsurface features such as groundwater levels and material consistency.

The moisture content is expressed as a percentage and is the ratio of the weight of water in a given amount of soil to the weight of solid particles. This ratio is obtained by weighing a sample of the soil and oven drying until all of the moisture has evaporated. Once a stable dry weight is obtained it is recorded and used for calculations.

4.2 Liquid & Plastic Limits

The Liquid Limit (LL) and Plastic Limit (PL) of selected soil samples were determined in the laboratory in general accordance with AASHTO T 89 and T 90. The results of these tests have been provided in the appropriate column of the boring logs and on the laboratory report sheets located in
Appendix B. The Plasticity Index (PI) is the difference between the Liquid Limit and the Plastic Limit (\( PI = LL - PL \)). There is a correlation between these limits and experimental shrink/swell data.

The Liquid Limit (LL) of a soil is the water content at which the soil passes from a liquid state to a plastic state and is essentially a flow test. The determination of the LL in the laboratory involves the incremental addition of water to a soil sample comprised of material that passes a No. 40 Standard Sieve until a uniform mass of semi-liquid consistency is achieved. This sample is placed in a brass cup where the soil is divided into two pieces with a grooving tool. The cup is lifted a required height and dropped a number of times to close the gap between the split sample. If the two sides of the sample come in contact before the required number of drops, then the sample is dried and the procedure is repeated. If the two sides of the sample do not come in contact before the required number of drops, then the sample is moistened and the procedure is repeated. After the sample has undergone the required number of drops needed to close the gap and is verified to within two blows, the sample is oven-dried to determine the moisture content. The moisture content is normalized to 25 drops and is considered the Liquid Limit.

The Plastic Limit (PL) of a soil is the water content at which the soil passes from a plastic state to a semi-solid state and is, in many ways, a toughness test. The determination of the PL in the laboratory involves the incremental removal of water from a hydrated soil sample until a uniform mass of semi-stiff consistency is achieved. This sample is hand rolled into a 1/8-inch diameter thread. After the sample has reached the moisture content at which it crumbles at a 1/8-inch diameter, it is oven-dried to determine the moisture content. This moisture content is the Plastic Limit.

4.3 Sieve Analysis Test

The amount of material passing the 3/4", 1/2", 3/8", No. 4, No. 10, No. 40 and No. 200 U.S. Standard Sieves was determined in the laboratory in general accordance with AASHTO T 11 and T 88. Determination of the material grading, combined with the LL, PL and PI provide the information needed to classify the soil according to the Unified Soil Classification System (USCS). The resultant percentage of material passing each sieve has been provided in the appropriate column of the boring logs and on the laboratory report sheets located in Appendix B.

A U.S. Standard Sieve is a weave of wire with specified gaps between the cross weave. The sieve number, such as those referred to above, designates the number of openings per inch. In the case of larger sieves such as a 1/2-inch or 3/8-inch sieve, the size refers to the aperture opening. Typically, soil samples are washed over a No. 200 U.S. Standard Sieve prior to grading over larger sieves to prevent clogging. The percentage of material passing through the No. 200 sieve
determines whether a soil is made of mostly coarse or fine-grained particles. The amount of coarse or fined-grained particles in a soil along with the LL and PI determine whether a soil is classified as a gravel, sand, clay, or silt. The amount passing any sieve expressed as a percentage is the ratio of the accumulated mass retained on the sieve divided by the total sample weight and multiplied by 100. This percent retained is subtracted from 100 to determine the percent passing.

5.0 FINDINGS & RECOMMENDATIONS

5.1 Site Conditions

US-59 near the Town of Page, Oklahoma was open to traffic at the time of this investigation. Frequent truck traffic uses the roadway and because the bridge is at the bottom of a valley, traffic speeds are relatively high. At the time of our investigation, the existing bridge had an excessively worn and patched concrete deck and a low concrete traffic rail with a steel rail extending above. The bridge was supported by steel beams, concrete piers and concrete abutments. Big Brushy Creek split into two separate channels at the bridge location. Boulders and cobbles were easily visible along the creek channel. Drill rig access around the site was assisted by use of a bulldozer due to areas of shallow, soft soil.

5.2 Subsurface Conditions

Based on published information¹, the dominant geologic features appear to be the Stanley Unit (PMs). Further, the project site crosses a fault line referred to as the Honess Fault. The Stanley Unit is predominantly composed of shale, but sandstone makes up about 25 percent of the total thickness, while siltstone occurs in subordinate amounts. The shales are typically thin-bedded, laminated, dark gray to green-gray and weathers to olive-green and tan. Topographically, the Stanley Unit is known as the “great valley maker” of the Ouachitas.

In general, the borings encountered gravel, cobble and boulder sized particles interbedded with mixtures of sand, silt and clay. These overburden materials tended to be very dense. At depths of approximately 11 feet to 12 feet, the subsurface materials transitioned to hard, very dense, cobbly weathered sandstone and/or cobbly weathered shale. Gray, weathered shale was encountered at depths ranging from approximately 11 feet to 25 feet. The weathered shale was bedded at an angle resulting in poor recovery and RQD’s. The weathered shale persisted to the boring termination depths of approximately 33 feet to 55 feet.

¹ 1966; Engineering Classification of Geologic Materials, Division 2; Research & Development Division, Oklahoma Department of Transportation.
A graphic log of each boring is included in Appendix A of this report. Every attempt is made to accurately reflect the depths of material change; however, stratification boundaries should be considered approximate. Specific recommendations concerning the design of driven pile foundations are included in Section 5.4 of this report. Recommendations concerning drilled shaft foundations are found in Section 5.5.

5.3 Groundwater Conditions

The groundwater levels were estimated within the borings while auger drilling. Once rotary or core drilling methods were conducted, no further water levels were obtained due to the injection of drilling fluid into the borings. However, given the amount of boulder, cobble and gravel sized soils, groundwater can be assumed to generally be at the creek flow line. The borings were plugged per OWRB requirements immediately after completion.

Groundwater was observed within boring B-1 at a depth of approximately 7-1/2 feet below the existing ground surface and within boring B-3 at approximately 6-1/2 feet bgs. To obtain more accurate groundwater level information, long-term observations in a well or piezometer that is sealed from the influence of surface water would be needed. Groundwater level fluctuations and/or perched water conditions may occur due to seasonal variations in the amount of rainfall and other factors such as drainage characteristics. The possibility of groundwater level fluctuations should be considered during the preparation of construction plans.

5.4 Driven Pile Foundations

Dense, very hard, gravelly cobbles were encountered from the ground surface to bedrock at the boring locations. Difficulty driving piles through this material should be anticipated. To prevent kick-out or bending of the piles during driving operations, it is expected that pilot holes and casings will be required through the overlying cobbles down to weathered shale. We do not expect that pilot holes can be advanced using auger techniques but will require hammer drilling methods. Once casings are set and cleared, piles can be driven into bedrock.

The weathered sandstone and weathered shale encountered within the borings is bedded at an angle along a fault line resulting in relatively poor RQD values; the average being approximately 14. However, the bedrock is hard and discontinuities appear densely spaced; the bedrock is expected to provide relatively high pile-driving stresses. Therefore, the use of low displacement piles such as steel H-piles is appropriate. Driven piles will develop their capacity from a combination of end-bearing and side resistance in the weathered sandstone and/or weathered shale. An allowable load capacity of 50 tons can be used for HP10x42 driven piles while 70 tons can be used for HP12x53.
piles. The table included on the next page provides estimates of the required penetrations for HP10x42 and HP12x53 piles to carry the allowable load. End bearing has been calculated using a safety factor of 3 and side resistance has a safety factor of 2. However, all piles should be driven until satisfactory resistance is developed in accordance with an appropriate formula or wave equation analysis.

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Surface Elevation (ft)</th>
<th>Pile Type</th>
<th>Allowable Design Capacity (ton)</th>
<th>Estimated Top of Rock Elevation (ft)</th>
<th>Estimated Penetration into rock (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>910</td>
<td>HP10x42</td>
<td>50</td>
<td>893</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HP12x53</td>
<td>70</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>B-4</td>
<td>912</td>
<td>HP10x42</td>
<td>50</td>
<td>900</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>HP12x53</td>
<td>70</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>

Piles should be appropriately spaced using a minimum center-to-center distance of 3 times the maximum pile cross-section dimension. Long term settlement of driven pile foundations, designed and constructed as recommended, is expected to be negligible.

5.5 Drilled Shaft Foundations

Similar difficulties to driving pile foundations are expected when advancing drilled shafts. The overburden gravelly cobbles are densely arranged and very hard. We do not expect that casings for the drilled shafts can be placed using auger techniques. It is expected that hammer drilling methods will be required to set casings for the drilled shafts.

Drilled shafts should extend through the cobbly overburden soils and penetrate the weathered sandstone and/or weathered shale. The table included in this section provides allowable design criteria for drilled piers at increasing penetrations into the rock. The net allowable bearing pressure has been calculated using an LRFD resistance factor of 0.55 and the allowable side resistance has an LRFD resistance factor of 0.55. The allowable side resistance value should not be used until the pier has penetrated the weathered shale at least one pier diameter or 4 feet, whichever is greater.

(see Table on next page)
Temporary casing will be required to construct the drilled shafts. A sufficient head of concrete having a slump of at least 6 inches should be maintained in the casing while it is being pulled to prevent the infiltration of soil and water into the shaft. Concrete should be directed down the center of the shaft using a concrete pump. At no time should concrete be allowed to free-fall into water or slough but should be pumped from the bottom of the shaft. If concrete is placed into a dry shaft, the bottom of the shaft should be sufficiently clean of loose materials and water deeper than 2 inches.

Estimated long-term settlement is expected to be less than 1/2-inch for piers constructed as recommended.

6.0 CONCLUDING REMARKS

Recommendations provided in this report are based on information from discrete borings (generally 4 to 8 inches in diameter) and, in some cases, from an engineer's general surficial observations. All site conditions cannot be detailed based on a limited number of borings and increasing the number of borings so that all site conditions can be defined is generally not practical. Variations in site conditions between boring locations should be expected and, on occasion, revised recommendations will be required. Hinderliter Geotechnical Engineering (HGE) should be retained to review final plans and specifications so that comments can be provided regarding the implementation of recommendations provided in this report. HGE should also be retained to provide monitoring of site construction.

This report provides recommendations concerning site construction and, while it may or may not provide limited analysis of soil corrosiveness and / or contaminant content, is not an Environmental Site Assessment (ESA). If the Owner is concerned about environmental and / or biological assessment, a separate study specifically focused on environmental issues should be undertaken.
This report has been prepared specifically for the referenced project and for the exclusive use of our Client. Third-party reliance may be granted upon specific written request of the Client. This report has been prepared using locally specific and generally accepted geotechnical engineering practices based on structural information provided by the Client and information gained from the site. No warranties are implied or granted regarding site recommendations not specifically discussed in this report.
APPENDIX A

BORING LOCATION DIAGRAM
SUBSURFACE FENCE DIAGRAM
BORING LOGS
### Field Data

<table>
<thead>
<tr>
<th>Soil Symbol</th>
<th>Depth (ft)</th>
<th>Samples</th>
<th>Physical Property</th>
<th>Atterberg Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Moisture Content (%)</td>
<td>Liquid Limit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N=21</td>
<td>8</td>
<td>NP</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N=41</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N=50/1.5</td>
<td>11</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>R=28.3</td>
<td>RQD = 0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R=75</td>
<td>RQD = 8.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R=71.7</td>
<td>RQD = 11.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>R=41.7</td>
<td>RQD = 10</td>
<td></td>
</tr>
</tbody>
</table>

### Laboratory Data

- **Vegetation Cover**
- **Silty Gravel with Sand and Cobbles**
  - Brown and gray
  - Medium dense to dense
- **Gravely Lean Clay with Sand (CL)**
  - Brown, hard
- **Cobbly Sandstone and Shale**
  - Brown and gray
- **Weathered Shale**
  - Gray
  - Moderately hard to hard
  - Massive in diagonal bed
  - High jointing
- **Bottom of boring approximately 33 feet**

### Remarks

Approximate Boring Location: 893+43 @ 28' LT
### LOG OF BORING B-2

#### CLIENT: MacArthur Associated Consultants

#### PROJECT: State Job No. 29563(04)

#### LOCATION: US 59 at Big Brushy Creek; Le Flore County

#### NUMBER: MAC-13-01

#### DATE(S) DRILLED: 1/14/14

#### FIELD DATA

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLES</th>
<th>SOIL SYMBOL</th>
<th>LABORATORY DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>N = 18/6</td>
<td>5</td>
<td>S.I. LIMITS</td>
</tr>
<tr>
<td>5</td>
<td>NP</td>
<td>LL, PL, PI</td>
<td>MOISTURE CONTENT (%)</td>
</tr>
<tr>
<td>5</td>
<td>NP</td>
<td></td>
<td>LIQUID LIMIT</td>
</tr>
<tr>
<td>5</td>
<td>NP</td>
<td></td>
<td>DRY DENSITY</td>
</tr>
<tr>
<td>N</td>
<td>53</td>
<td>MINUS NO. 4 SIEVE (%)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>43</td>
<td>MINUS NO. 10 SIEVE (%)</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>37</td>
<td>MINUS NO. 20 SIEVE (%)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### LABORATORY DATA

- **MOISTURE CONTENT (%)**: 5
- **LIQUID LIMIT**: LL
- **PLASTIC LIMIT**: PL
- **DENSITY**: PI
- **MINUS NO. 4 SIEVE (%)**: 53
- **MINUS NO. 10 SIEVE (%)**: 43
- **MINUS NO. 20 SIEVE (%)**: 37

#### DESCRIPTION OF STRATUM

- **Vegetation Cover**: Silty Gravel with Sand and Cobbles
- **Silty Gravel**: Brown
- **Weathered Cobbly Sandstone**: Brownish-gray, thick bedded, high to very high jointing
- **Weathered Shale**: Gray
- **Bottom of Boring**: Approximately 42 feet

#### REMARKS:

Approximate Boring Location: 893+61 @ 32' RT
**LOG OF BORING B-3**

**CLIENT:** MacArthur Associated Consultants  
**PROJECT:** State Job No. 29563(04)  
**LOCATION:** US 59 at Big Brushy Creek; Le Flore County  
**NUMBER:** MAC-13-01  
**DATE(S) DRILLED:** 1/14/14

**FIELD DATA**

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLES</th>
<th>MOISTURE CONTENT (%)</th>
<th>ATTERBERG LIMITS</th>
<th>SUBSOIL</th>
<th>PLASTIC DENSITY</th>
<th>DESCRIPTION OF STRATUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>N = 22</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>64</td>
<td>VEGETATION COVER</td>
</tr>
<tr>
<td>10</td>
<td>N = 41</td>
<td>9</td>
<td>NP</td>
<td>NP</td>
<td>61</td>
<td>SILTY SAND with GRAVEL and COBBLES (SM)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>57</td>
<td>brown medium dense to very dense</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SANDY, CLAYEY GRAVEL with COBBLES</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>26</td>
<td>brown very dense</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>WEATHERED SHALE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>gray</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>hard with soft clay seams</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>massive bedding</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>medium to very high jointing</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bottom of boring approximately 55 feet</td>
</tr>
</tbody>
</table>

**LABORATORY DATA**

- **MOISTURE CONTENT (%)**
- **PLASTIC DENSITY**
- **DESCRIPTION OF STRATUM**
- **VEGETATION COVER**
- **SILTY SAND with GRAVEL and COBBLES (SM)**
- **SANDY, CLAYEY GRAVEL with COBBLES**
- **WEATHERED SHALE**

**REMARKS:**

- Approximate Boring Location: 894+69 @ 42' LT
## LOG OF BORING B-4

### FIELD DATA

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>SAMPLE</th>
<th>N: T BLOWS</th>
<th>PLASTICITY LIMIT</th>
<th>ATTERBERG LIMITS</th>
<th>LABORATORY DATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>N = 50/2</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>T = 50/0.6</td>
<td>50/0.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>T = 50/2.0</td>
<td>50/1.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>T = 50/0.3</td>
<td>50/0.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>T = 50/0.4</td>
<td>50/0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>T = 50/0.5</td>
<td>50/0.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### LABORATORY DATA

- **MOISTURE CONTENT (%)**
- **LIQUID LIMIT**
- **PLASTIC LIMIT**
- **PLASTICITY INDEX**
- **DENSITY**
- **SIEVE PASS (%)**
- **SIEVE retained (%)**

### DESCRIPTION OF STRATUM

- **Vegetation Cover**
- **CLAYEY GRAVEL with COBBLES**
  - brown
  - very dense

- **WEATHERED SHALE**
  - gray
  - moderately hard to hard with some soft clay seams

- **Bottom of boring approximately 33 feet**

### DRILLING METHOD(S):

- Augers & SPT sampling in cobbly overburden. Casing set with hammer drill. Tx Cone below casing.

### GROUNDWATER INFORMATION:

- No groundwater encountered prior to coring

### SURFACE ELEVATION:

- 912

### REMARKS:

- Approximate Boring Location: 895+03 @ 30' RT
APPENDIX B

GRAIN SIZE DISTRIBUTION RESULTS
APPENDIX C

GENERAL NOTES ON SOIL CLASSIFICATION
PLASTICITY CLASSIFICATION – GENERAL EXAMPLES
GRANULAR MATERIAL CLASSIFICATION – GENERAL EXAMPLES
Hinderliter Geotechnical Engineering classifies soils in accordance with the Unified Soil Classification System (USCS). In some cases, the AASHTO Classification System is also used.

The following charts provide graphic representations of how USCS soil classifications are derived. Materials with more than 50 percent passing the No. 200 U.S. Sieve (aperture opening = 0.075 mm) are considered to be fine-grained soils (sils or clays). Materials with less than 50 percent passing the No. 200 sieve are considered to be coarse-grained soils (sands, gravels, etc.)

The following sheet, Plasticity Classification - General Examples, depicts a Plasticity Chart which plots soil Liquid Limit vs. Plasticity Index and is used to classify fine-grained soils. The circled letters located on the chart are the USCS classification acronyms for the soils that plot in that general area. Additionally, there are example specimen test results recorded on the table located below the chart with associated icons located in the appropriate region of the Plasticity Chart.

Coarse-grained soils are classified by the USCS System by plotting the Grain Size in Millimeters vs. Percent Finer by Weight as depicted on the sheet Granular Material Classification - General Examples. Depending on the grain size, the materials are classified as cobbles, gravel, sand, or silt / clay. Additional identifiers are included in the tables below the chart which define whether the materials are well-graded or poorly-graded.

Most naturally-occurring materials have some portion of fine-grained and coarse-grained materials. Modifiers are used to describe the relative percentage of minor-occurring materials in the following fashion:

<table>
<thead>
<tr>
<th>Fine-Grained Soil Modifiers</th>
<th>Coarse-Grained Soil Modifiers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modifier</td>
<td>Percentage of Dry Weight</td>
</tr>
<tr>
<td>Trace</td>
<td>With</td>
</tr>
<tr>
<td>Sandy, Gravelly, etc.</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>Trace &lt; 15</td>
<td>With 15 - 29</td>
</tr>
<tr>
<td>Trace &lt; 15</td>
<td>With 5-12</td>
</tr>
<tr>
<td>Trace &lt; 5</td>
<td>Silty, Clayey, etc.</td>
</tr>
<tr>
<td>Trace &lt; 5</td>
<td>&gt; 12</td>
</tr>
</tbody>
</table>

The consistency of fine-grained soils and the relative density of coarse-grained soils is generally included on the boring logs as part of the material description. Consistency and relative density are generally defined as follows:

<table>
<thead>
<tr>
<th>Unconfined Compressive Strength, Qu, psf</th>
<th>Consistency</th>
<th>Standard Penetration Test, N, blows / foot</th>
<th>Standard Penetration Test, N, blows / foot</th>
<th>Relative Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 500</td>
<td>Very Soft</td>
<td>&lt; 2</td>
<td>0 - 3</td>
<td>Very Loose</td>
</tr>
<tr>
<td>500 - 1000</td>
<td>Soft</td>
<td>2 - 4</td>
<td>4 - 9</td>
<td>Loose</td>
</tr>
<tr>
<td>1000 - 2000</td>
<td>Medium</td>
<td>5 - 7</td>
<td>10 - 29</td>
<td>Medium Dense</td>
</tr>
<tr>
<td>2000 - 4000</td>
<td>Stiff</td>
<td>8 - 15</td>
<td>30 - 49</td>
<td>Dense</td>
</tr>
<tr>
<td>4000 - 8000</td>
<td>Very Stiff</td>
<td>16 - 30</td>
<td>50+</td>
<td>Very Dense</td>
</tr>
<tr>
<td>8000+</td>
<td>Hard</td>
<td>30+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specimen Identification</td>
<td>LL</td>
<td>PL</td>
<td>PI</td>
<td>Fines</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-------</td>
</tr>
<tr>
<td>• A</td>
<td>1.0</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>△ A</td>
<td>2.0</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>▲ A</td>
<td>3.0</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
</tr>
<tr>
<td>★ A</td>
<td>4.0</td>
<td>30</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td>◆ A</td>
<td>5.0</td>
<td>65</td>
<td>22</td>
<td>43</td>
</tr>
<tr>
<td>★ A</td>
<td>6.0</td>
<td>65</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>◆ A</td>
<td>7.0</td>
<td>35</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td>▲ A</td>
<td>8.0</td>
<td>15</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>★ A</td>
<td>9.0</td>
<td>15</td>
<td>12</td>
<td>3</td>
</tr>
</tbody>
</table>

LIQUID & PLASTIC LIMITS RESULTS

Project: USCS Example Materials
Location:
Number:
### Specimen Identification

<table>
<thead>
<tr>
<th>Classification</th>
<th>LL</th>
<th>PL</th>
<th>PI</th>
<th>Cc</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>WELL-GRADED SAND (SW)</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>1.31</td>
<td>10.90</td>
</tr>
<tr>
<td>POORLY GRADED SAND (SP)</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>0.77</td>
<td>3.65</td>
</tr>
<tr>
<td>SILTY SAND (SM)</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td>30</td>
<td>13</td>
</tr>
<tr>
<td>CLAYEY SAND (SC)</td>
<td>65</td>
<td>22</td>
<td>43</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### GRAIN SIZE DISTRIBUTION RESULTS

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Identification</th>
<th>D100</th>
<th>D60</th>
<th>D30</th>
<th>D10</th>
<th>%Gravel</th>
<th>%Sand</th>
<th>%Silt</th>
<th>%Clay</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1.0</td>
<td>4.75</td>
<td>2.378</td>
<td>0.825</td>
<td>0.218</td>
<td>0.0</td>
<td>98.0</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>2.0</td>
<td>4.75</td>
<td>0.328</td>
<td>0.151</td>
<td>0.09</td>
<td>0.0</td>
<td>97.0</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>3.0</td>
<td>2</td>
<td>0.123</td>
<td></td>
<td></td>
<td>0.0</td>
<td>55.0</td>
<td>45.0</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>4.0</td>
<td>2</td>
<td>0.162</td>
<td></td>
<td></td>
<td>0.0</td>
<td>60.0</td>
<td>40.0</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>5.0</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>0.0</td>
<td>2.0</td>
<td>98.0</td>
<td></td>
</tr>
</tbody>
</table>
March 25, 2014

MacArthur Associated Consultants, LLC
2420 Springer Drive, Suite 120
Norman, OK 73069

Attn: Mr. Gregory L. Fitter, Ph.D., P.E.

Re: Addendum I – Subsurface Exploration & Geotechnical Engineering Report
Proposed Three-Span Bridge on US-59 over Big Brushy Creek
State Job No. 29563(04)
Le Flore County, Oklahoma
HGE Project No. MAC-13-01

Dear Mr. Fitter:

We understand the abutments of the bridge referenced above will be supported on drilled shaft foundations rather than driven piles. This letter provides design bearing values for borings B-1 and B-4 located adjacent to the existing abutment locations. This letter should be attached to, and considered a part of, Section 5.5 of the geotechnical report for this site, dated March 15, 2014.

Difficulties advancing drilled shafts should be anticipated. The overburden gravelly cobbles are densely arranged and very hard. We do not expect that casings for the drilled shafts can be placed using auger techniques. It is expected that hammer drilling methods will be required to set casings for the drilled shafts.

Drilled shafts should extend through the cobbly overburden soils and penetrate the weathered sandstone and/or weathered shale. The table included in this section provides allowable design criteria for drilled piers at increasing penetrations into the rock. The net allowable bearing pressure has been calculated using an LRFD resistance factor of 0.55 and the allowable side resistance has an LRFD resistance factor of 0.55. The allowable side resistance value should not be used until the pier has penetrated the weathered shale at least one pier diameter or 4 feet, whichever is greater.

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Surface Elevation (ft)</th>
<th>Estimated Top of Competent Rock Elevation (ft)</th>
<th>Bearing Elevation (ft)</th>
<th>Net Allowable End Bearing Pressure (tsf)</th>
<th>Allowable Side Resistance (tsf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-01</td>
<td>910</td>
<td>893</td>
<td>893 – 889 Above 889</td>
<td>28.5</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Below 889</td>
<td>28.5</td>
<td>1.9</td>
</tr>
<tr>
<td>B-04</td>
<td>912</td>
<td>900</td>
<td>900 – 896 Above 896</td>
<td>28.5</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Below 896</td>
<td>28.5</td>
<td>1.9</td>
</tr>
</tbody>
</table>
Temporary casing will be required to construct the drilled shafts. A sufficient head of concrete having a slump of at least 6 inches should be maintained in the casing while it is being pulled to prevent the infiltration of soil and water into the shaft. Concrete should be directed down the center of the shaft using a concrete pump. At no time should concrete be allowed to free-fall into water or slough but should be pumped from the bottom of the shaft. If concrete is placed into a dry shaft, the bottom of the shaft should be sufficiently clean of loose materials and water deeper than 2 inches.

Estimated long-term settlement is expected to be less than ½-inch for piers constructed as recommended.

Mr. Fitter, please do not hesitate to contact HGE at (405) 942-4090 should you have questions regarding this report.

Respectfully:

Mark H. Hinderliter, P.E.
Oklahoma No. 21327


P:\HGE\Reports\2014 Geo\MarchMAC-13-01 Addendum I

Copies: Client (pdf)