GEOTECHNICAL ENGINEERING REPORT
COWAN ESTATES SUBDIVISION STREETS
ROLAND, OKLAHOMA

PROJECT NO. G2014038

July 30, 2014

July 30, 2014
Project No.: G2014038

Scott and Associates, Inc.
Attention: Mr. Scott
901 Callahan Street
Muskogee, Oklahoma 74403

Subject: **Geotechnical Engineering Report**
Cowan Estates Subdivision Streets
Roland, Oklahoma

Dear Mr. Scott:

GFAC Engineering Inc. has completed the authorized subsurface exploration and geotechnical engineering evaluation for the above-referenced project in general accordance with our Proposal for Geotechnical Engineering Services and Terms and Conditions dated July 14, 2014. The purpose of the geotechnical study was to explore and evaluate the subsurface conditions at various locations on the site and develop geotechnical design and construction recommendations for the project. The attached GFAC Engineering Inc. report contains a description of the findings of our field exploration and laboratory testing program, our engineering interpretation of the results with respect to the project characteristics, and our geotechnical recommendations for the proposed subdivision streets recommendations as well as construction guidelines for the planned project.

Recommendations provided herein are contingent on the provisions outlined in the ADDITIONAL SERVICES and LIMITATIONS sections of this report. The project Owner should become familiar with these provisions in order to assess further involvement by GFAC Engineering Inc. and other potential impacts to the proposed project.

We appreciate the opportunity to be of service and are prepared to provide the recommended additional services. Please call us if you have any questions concerning this report.

Respectfully submitted,
GFAC ENGINEERING INC.
Certificate of Authorization #6389, Exp. 6/30/2016

REGISTERED PROFESSIONAL ENGINEER
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GEOTECHNICAL ENGINEERING REPORT
COWAN ESTATES SUBDIVISION STREETS
ROLAND, OKLAHOMA
GFAC ENGINEERING INC. PROJECT NO. G2014038
EXECUTIVE SUMMARY

Site:

- It is our understanding the project will consist of the construction of two new residential streets (Kennedy Circle and Jackson Circle) in the Cowan Estates subdivision in Roland, Oklahoma. The roadways will have a total length on the order of 1,275 feet. It is our understanding that cuts and fills along the alignment are anticipated to be less than 1 foot.
- Groundwater observations were made both during and after completion of drilling operations. Except for Boring B-5, the borings remained dry during the drilling and sampling operations. Groundwater was encountered in Boring B-5 at an approximate depth of 2.4 feet both during and following completion of the drilling operations. It appears that the groundwater encountered in Boring B-5 is "perched"
- In a "perched' groundwater condition, precipitation will infiltrate the upper lower plasticity more permeable soils and sit (perch) on the underlying less permeable bedrock or higher plasticity clay soils.
- A portion of the soils encountered at the site have a high sand and/or silt content. These types of soils are highly moisture sensitive and may become unstable with minor variations in moisture content or when subjected to repeated construction traffic. Close moisture control during compaction operations will be required to reduce the potential for pumping of these soils.

Site Development:

- Initial site preparation for the proposed project may require demolition of the existing pavements/curbs. All debris resulting from the demolition of these pavements/curbs should be removed from the site. Areas disturbed during demolition should be thoroughly evaluated by the geotechnical engineer prior to placement of structural fill. All disturbed soils should be undercut prior to placement of structural fill.
- Site development should include stripping of any vegetation, organic soils, and associated root systems from planned construction areas. Any required tree removal should also be performed at this time. Care shall be taken to thoroughly remove all root systems from the construction areas. Materials disturbed during stripping operations and stump removal should be undercut and replaced with structural fill.
- Prior to placement of any required structural fill, the moisture content of the exposed subgrade should be evaluated. The moisture content of the exposed grade should be adjusted to within the range recommended for structural fill. Extremely wet or unstable areas that hamper compaction of the subgrade may require undercutting and replacement with structural fill or other stabilization techniques.
- Following moisture conditioning, it is recommended that the exposed grade be Test Rolled. Test Rolling should be performed in accordance with Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 203.

- Excavation and embankment construction procedures should be performed in accordance with Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 202
- It is anticipated that excavations will generally be in existing fill, newly placed structural fill and native soils above the groundwater level. Excavations within these materials should be possible with conventional excavation equipment. Deeper excavations may extend into the highly weathered to weathered shale bedrock. The soil materials and the soft, highly weathered to weathered shale with a Standard Penetration Resistance (N) value of less than 25 blows per foot can generally be excavated with conventional heavy equipment such as backhoes, scrapers, loaders, etc.
- Excavation of harder, less weathered bedrock will most likely be difficult and may require the use of single-tooth rippers mounted on large tractors such as a Caterpillar D-8 or larger, pneumatic breakers mounted on backhoes/trackhoes, or other rock excavating techniques to complete the excavations. Excavation of these materials in confined excavations may be difficult.

Pavement Subgrade:

- Pavement subgrade preparation procedures should be performed as specified by the Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 310.
- The pavement subgrade will consist of evaluated and approved existing fill, newly placed structural fill, or native soils.
- The pavement subgrade shall be scarified, moisture conditioned and recompacted to a minimum depth of 8 inches.

Pavements:

- It is our understanding that the City of Roland does not have standard pavement sections for residential streets. In addition, information concerning the City of Roland standards regarding the construction of city streets was not provided prior to completion of this report. If this information becomes available, it should be provided to GFAC Engineering, Inc. to determine if modification of the recommendations provided in this report would be warranted.
- GFAC Engineering has assumed that 200,000 Equivalent Single Axle Loads (ESALs) would be appropriate for a residential street in Roland. If traffic is in excess of what has been assumed, a reduced pavement life would occur.
- Alternative pavement sections for 300,000 and 400,000 ESALs are also included in Section 4.4.
- A minimum of 8 inches of aggregate base material, such as ODOT Aggregate Base Type "A", should be placed below the pavement.

The information stated above is a brief summary of the recommendations presented within this report. The report should be reviewed in its entirety for proper implementation of the recommendations.

GEOTECHNICAL ENGINEERING REPORT
COWAN ESTATES SUBDIVISION STREETS
ROLAND, OKLAHOMA

1. INTRODUCTION

1.1 GENERAL

GFAC Engineering Inc. has completed the authorized subsurface exploration and geotechnical engineering evaluation for the proposed Cowan Estates Subdivision Streets in Roland, Oklahoma. The services provided were in general accordance with our Proposal for Geotechnical Engineering Services and Terms and Conditions dated July 14, 2014. This report includes our recommendations related to the geotechnical aspects of the project design and construction. Conclusions and recommendations presented in the report are based on the subsurface information encountered at the location of our exploration and the provisions and requirements outlined in the ADDITIONAL SERVICES and LIMITATIONS sections of this report.

1.2 PROPOSED CONSTRUCTION

It is our understanding the project will consist of construction of two new residential streets (Kennedy Circle and Jackson Circle) in the Cowan Estates subdivision in Roland, Oklahoma. The existing east-west roadway (Adysen Avenue) was previously paved with asphaltic concrete pavement during the development of Phase I, however; portions of the roadway have deteriorated. The total length of the roadway to be constructed/reconstructed is anticipated to be on the order of 1,275 linear feet.

Curbs associated with Kennedy Circle and Jackson Circle are currently present at the site. We have assumed that these curbs were constructed at the same time that Adysen Avenue was constructed. Partial construction/reconstruction of Adysen Avenue is anticipated at/near the intersections with Kennedy Circle and Jackson Circle. It is not known if demolition of the existing curbs along Kennedy Circle and Jackson Circle will be required as part of the construction at the project site.

It is our understanding that the City of Roland does not have standard pavement sections for residential streets. In addition, information concerning the City of Roland standards regarding the construction of city streets was not provided prior to completion of this report. If this information becomes available, it should be provided to GFAC Engineering, Inc. to determine if modification of the recommendations provided in this report would be warranted.

Recommendations related to pavement subgrade preparation and pavement thickness/type were requested. Due to the lack of information available, i.e., traffic data, a pavement design was not performed. Typical pavement sections for residential streets are provided in this report.

A grading plan for the project was not reviewed by GFAC Engineering, however, we anticipate that cuts and fills along the roadway alignment to achieve the finish subgrade elevation will be less than 1 foot.

Recommendations related to adjacent building lots, stability of cut or fill slopes, embankment construction, resilient modulus testing, or California Bearing Ratio (CBR) testing were beyond the scope of work of this study.

The scope of the exploration and engineering evaluation for this study, as well as the conclusions and recommendations in this report, were based on our understanding of the project as described above. If pertinent details of the project have changed or otherwise differ from our descriptions, we must be notified and engaged to review the changes and modify our recommendations, if needed.

2. SITE CONDITIONS

2.1 SITE DESCRIPTION

The project site is located northwest of the intersection of Highland Road and Mayfield Road in Roland, Oklahoma. Adysen Avenue extends in an east to west direction across the northern end of the subdivision. Kennedy Circle and Jackson Circle will extend southward from Adysen Avenue. The curbs associated with Kennedy Circle and Jackson Circle are currently present at the site. We have assumed that these curbs were constructed at the same time that Adysen Avenue was constructed. The curbs are not present at the proposed cul-de-sac portion of Kennedy Circle and Jackson Circle. The approximate project location is indicated on Plate 1 included in APPENDIX A. The proposed alignment of the access road is indicated on Plate 2 included in APPENDIX A.

The ground surface along the proposed alignment is generally covered with asphaltic concrete, gravel, or grass. A few trees are located in the general vicinity of the proposed roadway alignment/cul-de-sac areas. It is not known if removal of these trees will be required as part of the site development. The project location is bounded by residential development on the north and east, a baseball/softball complex on the west, and by railroad tracks on the south. No information regarding the existing grades at the site was available.

Existing utilities in the vicinity of the proposed alignment include, but most likely are not limited to, overhead electric lines. Additional utilities servicing the residential structures to the east and to the northwest and also within the right-of-way of Adysen Avenue, Kennedy Circle and Jackson Circle may be present.

2.2 SUBSURFACE CONDITIONS

The following presents a general summary of the major strata encountered at the boring locations drilled for the proposed street construction during our subsurface exploration and includes a discussion of the results of field and laboratory tests conducted. Specific subsurface conditions encountered at the boring locations are presented on the respective logs in APPENDIX A. The stratification lines shown on the logs represent the approximate boundaries between material types; in situ, the transitions may vary or be gradual.

Surficial Materials: Asphaltic concrete pavement with a thickness of 3-1/2 inches underlain by 6 inches of aggregate base was encountered at the location of Boring B-4. A 2 to 4 inch thick layer of topsoil was encountered at the ground surface at the remaining boring locations.

Existing/Possible Fill Materials: With the exception of Boring B-3, existing/possible fill materials were encountered in the borings. The existing/possible fill materials were encountered below the pavement materials in Boring B-4 and below the topsoil in Borings B-1, B-2, B-5, and B-6 and continued to approximate depths ranging from 2.2 to 3.3 feet. The existing/possible fill materials consisted of mixtures of lean clay with varying amounts of sand, broken shale, and broken sandstone.

Native Soils: Native soils generally consisting of combinations of sandy silt, sandy silty clay, sandy lean clay, silty sand, and lean to fat clay was encountered below the topsoil and the existing/possible fill and continued to the bottom of Borings B-1 through B-5 at an approximate depth of 5 feet and to an approximate depth of 4.5 feet in Boring B-6.

Bedrock: Sandstone gravel and highly weathered to weathered shale bedrock was encountered in Boring B-6 at an approximate depth of 4.5 feet and continued to the bottom of the boring at an approximate depth of 5 feet.

Table 2.2.1 presents the boring designation, type of pavement and thickness, Atterberg Limits test and Percent passing the No. 200 sieve test results, and classification of the soils:

TABLE 2.2.1 – GENERALIZED BOREHOLE INFORMATION

Boring	Sample	Depth	USCS	AASHTO	Moisture Content	Percent Passing No. 200 Sieve	Liquid Limit	Plastic Limit	Plasticity Index
B-1	SS-2	3.5-5.0	CL-ML	A-4(2)	16.1	63.5	23	16	7
B-2	SS-1	0.5-2.0	CL	A-6(5)	11.6	62.6	28	16	12
B-3	SS-1	0.5-2.0	SM	A-4(0)	11.6	46.0	NV	NP	NP
B-4	SS-1	0.8-2.3	CL	A-6(4)	14.2	56.7	28	15	13
B-5	SS-1	0.5-2.0	CL	A-6(7)	16.9	60.5	35	19	16
B-6	SS-1	0.5-2.0	CL	A-6(8)	17.6	83.5	28	17	11

2.3 GENERAL SITE GEOLOGY

According to the "Engineering Classification of Geologic Materials – Division One" from the Oklahoma Highway Department, 1970, the project site appears to be located within area designated as the Savanna Unit (Psv).

This unit consists predominately of shale, a lesser amount of sandstone, and a few thin beds of limestone and siltstone. The shale is gray to black, fissile, locally clayey, and in intervals up to approximately 400 feet thick. The sandstone is moderately hard to hard, buff to gray, in beds a few inches to 10 feet thick and averaging 5 feet in thickness, in sequences up to 120 feet thick but normally averaging 25 feet thick. The beds of limestone and siltstone are less than one foot thick and are minor in this unit.

The topography of this unit is characterized by prominent ridges capped by the sandstone with shale valleys.

2.4 GROUNDWATER OBSERVATIONS

Groundwater observations were made both during and after completion of drilling operations. Except for Boring B-5, the borings remained dry during the drilling and sampling operations. Groundwater was encountered in Boring B-5 at an approximate depth of 2.4 feet both during and following completion of the drilling operations.

The materials encountered in the borings have a wide range of hydraulic conductivities and observations over an extended period of time may show the presence of groundwater. Use of piezometers would be required to better define current groundwater conditions and groundwater level fluctuations with time. Fluctuations of groundwater levels can occur due to seasonal variations in the amount of rainfall, runoff, and other factors not evident at the time the borings were performed. The possibility of groundwater level fluctuations should be considered when developing the design and construction plans for the project.

It appears that the groundwater encountered in Boring B-5 is "perched". In a "perched' groundwater condition, precipitation will infiltrate the upper lower plasticity/non plastic more permeable soils and sit (perch) on the underlying less permeable bedrock or the higher plasticity clay soils. Generally, perched water is of limited volume and can be controlled with typical dewatering methods. However, it should be noted, that depending upon site grades, the subsurface stratigraphy, and the volume of water, more sophisticated dewatering methods/equipment may be required if a perched ground water condition is encountered at the time of construction. During wet seasons, the perched groundwater can cause the upper layers of soils to become soft and unstable.

3. ANALYSIS AND DISCUSSION

3.1 GENERAL

Based on the results of our evaluation, it is our professional opinion that the proposed project site can be developed for the proposed roadway using conventional grading and construction techniques. Recommendations regarding geotechnical aspects of the project design and construction are presented below.

3.2 SITE DEVELOPMENT

3.2.1 Demolition

The following recommendations are provided in the instance that demolition of a portion of the existing pavement along Adysen Lane and the curbs that are currently in place along Kennedy Circle and Jackson Circle is required as part of this project. Initial site preparation for the proposed project should include with demolition of the existing pavements/curbs. All debris resulting from the demolition of these pavements/curbs should be removed from the site. Areas disturbed during demolition should be thoroughly evaluated by the geotechnical engineer prior to placement of structural fill. All disturbed soils should be undercut prior to placement of structural fill.

3.2.2 Stripping and Grubbing

Site development should include stripping of any vegetation, organic soils, and associated root systems from planned construction areas. Any required tree removal should also be performed at this time. Care shall be taken to thoroughly remove all root systems from the construction areas. Materials disturbed during stripping operations and stump removal should be undercut and replaced with structural fill.

3.2.3 Existing Utility Trenches

Existing below grade utilities may be present within the proposed roadway alignment. It is anticipated these existing utilities will remain in place. Following required cuts and prior to any fill placement the exposed subgrade shall be test tolled (proofrolled). Unstable soils may be present at the location of the existing utility trenches. Soft/unstable soils present within the existing utility trenches should be stabilized as outlined in Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 310.

3.2.4 Moisture Conditioning and Compaction

Following demolition, stripping, grubbing, any required undercutting, and prior to placement of any required structural fill, the moisture content of the exposed subgrade should be evaluated. Depending on the in-situ moisture content of the exposed subgrade, moisture conditioning may be required prior to test rolling and/or fill placement. The moisture content of the exposed grade in these fill areas should be adjusted to within the range recommended for structural fill, to allow the exposed material to be compacted to a minimum of 95 percent of the standard Proctor density. Extremely wet or unstable areas that hamper compaction of the subgrade may require undercutting and replacement with structural fill or other stabilization techniques.

3.2.5 Test Rolling (Proofrolling)

Following moisture conditioning, it is recommended that the exposed grade be Test Rolled. Test Rolling should be performed in accordance with Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 203.

3.2.6 Pavement Subgrade

In areas where soft and unstable subgrade conditions are encountered, pavement subgrade preparation procedures should be performed in accordance with Oklahoma

Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 310.

3.2.7 Construction Considerations

A portion of the soils encountered at the site have a high sand and/or silt content. These types of soils are highly moisture sensitive and may become unstable with minor variations in moisture content or when subjected to repeated construction traffic. If these soils are unstable at the time of construction, they will need to be undercut and replaced with structural fill, or be stabilized in place. Close moisture control during compaction operations will be required to reduce the potential for pumping of these soils.

3.2.8 Perched Groundwater

The site is favorable for development of "perched" groundwater in the near surface soils with a high sand and/or silt content. Depending upon the amount of precipitation that falls prior to and during the construction of the proposed roadways, a perched groundwater condition may develop. Depending upon the amount of perched groundwater present, the near surface soils could become soft and unstable with repetitive construction traffic. Typically, "perched" groundwater can be controlled with typical dewatering methods.

3.3 EXCAVATIONS

3.3.1 General

Excavation procedures should be performed in accordance with Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 202.

All excavations must comply with applicable local, state and federal safety regulations. ***The responsibility for excavation safety and stability of temporary construction***

slopes lies solely with the contractor. We are providing this information below solely as a service to our client. Under no circumstances should this information provided be interpreted to mean that GFAC Engineering Inc. is assuming responsibility for construction site safety or the contractors activities, such responsibility is not being implied and should not be inferred.

3.3.2 Excavations

It is anticipated that excavations will generally be in existing fill, newly placed structural fill and native soils above the groundwater level. Excavations within these materials should be possible with conventional excavation equipment. Deeper excavations may extend into the highly weathered to weathered shale bedrock. The soil materials and the soft, highly weathered to weathered shale with a Standard Penetration Resistance (N) value of less than 25 blows per foot can generally be excavated with conventional heavy equipment such as backhoes, scrapers, loaders, etc. Excavation of harder, less weathered bedrock will most likely be difficult and may require the use of single-tooth rippers mounted on large tractors such as a Caterpillar D-8 or larger, pneumatic breakers mounted on backhoes/trackhoes, or other rock excavating techniques to complete the excavations. Excavation of these materials in confined excavations may be difficult.

3.3.3 Excavation Slopes and Construction Considerations

Excavations should be cut to a stable slope or be temporarily braced, depending upon the excavation depths and the subsurface conditions encountered. ***Temporary construction slopes should be designed in strict compliance with the most recent governing regulations.*** Stockpiles should be placed well away from the edge of the excavation and their heights should be controlled so they do not surcharge the sides of the excavation. Surface drainage should be carefully controlled to prevent flow of water into the excavations. Construction slopes should be closely observed for signs of mass movement: tension cracks near the crest, bulging at the toe, etc. If potential stability problems are observed, a geotechnical engineer should be immediately contacted.

3.4 STRUCTURAL FILL

Based on the conditions encountered in the borings and the results of the laboratory testing, the on-site soils are suitable for use as structural fill within the roadway alignment. Additional testing and observation at the time of construction is recommended to further evaluate these materials prior to use as structural fill. All imported material shall meet the requirements as outlined in Section 4.3.

3.5 CLIMATIC CONDITIONS AND CONSTRUCTION CONSIDERATION

Weather conditions will influence the site preparation required. In spring and late fall, following periods of rainfall, the moisture content of the near-surface soils may be significantly above the optimum moisture content. Excessive moisture could seriously impede grading by causing an unstable subgrade condition. Typical remedial measures include aerating the wet subgrade, removal of the wet materials and replacing them with dry materials, reinforcing the subgrade with geotextiles/geogrid or applying lime, cement kiln dust (CKD), or Class "C" fly ash as a drying agent.

If construction of the project is to be performed during winter months, appropriate steps should be taken to prevent the soils from freezing. In no case should the fill or other flat work be placed on or against frozen or partially frozen materials. Frozen materials shall be removed and replaced with a suitable material. Frozen materials shall not be included in any compacted fills.

3.6 LANDSCAPING AND SITE GRADING CONSIDERATIONS

Provisions should be made to reduce the potential for large moisture changes within pavement subgrade soils located adjacent to landscape areas, to reduce the potential for subgrade movement. Positive drainage away from the pavements should be incorporated into the design plans. Ponding of water adjacent to the pavements could contribute to significant moisture increases in the subgrade soils and subsequent loss of pavement support.

Consideration should also be given to limiting landscaping and irrigation adjacent to the pavements. Trees and large bushes can develop intricate root systems that can draw moisture from the subgrade soils, causing them to shrink during dry periods of the year. Desiccation of soils below pavements can result in settlement of pavements.

3.7 PAVEMENT SUBGRADE PREPARATION

It is anticipated that the pavement subgrade will consist of a combination of evaluated and approved existing fill, native soils, and newly placed structural fill. In areas that are to receive fill, the existing fill and native soils should be scarified, moisture conditioned, and recompacted to a minimum depth of 8 inches.

The pavement subgrade should be sloped to provide rapid drainage. This includes the underlying subgrade soils since the granular base material readily transmits water. The granular section should be graded to pipe underdrains, adjacent storm sewer inlets, or drainage ditches to provide drainage from the granular section. Water allowed to pond on or adjacent to the pavement could saturate the subgrade and cause premature pavement deterioration.

Pavement subgrades should be prepared in accordance with the recommendations presented in Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 310.

3.8 PAVEMENTS

3.8.1 General

Traffic data for this roadway was not available at the time this report was prepared. It is our understanding that the City of Roland does not have standard pavement sections for residential streets. GFAC Engineering has assumed that 200,000 Equivalent Single Axle Loads (ESALs) would be appropriate for a residential street in Roland, Oklahoma.

3.8.2 Pavement Analysis

The pavement analysis was performed in general accordance with the AASHTO Guide for Design of Pavement Structures (1993). The pavement analysis is based on the following variables:

Resilient Modulus of Subgrade	4,000 psi
Drainage Factor	1.0
Initial Serviceability	4.2
Terminal Serviceability	2.0
Standard Deviation	0.45
Reliability	80%
Structural Coefficient of ACC Surface Course	0.42
Structural Coefficient of ACC Base Course	0.42
Structural Coefficient of Dense Graded Aggregate Base	0.14

The pavement design assumes that at least fair drainage will be provided with the planned drainage system improvements. The pavement thickness indicated in Section 4.4 is based on the assumed pavement capacity of 200,000 Equivalent Single Axle Loads (ESALs) and the design variables previously listed in this section. Alternative pavement sections for 300,000 and 400,000 ESALs are also included in Section 4.4.

GFAC Engineering analyzed the pavement section using Windows Pavement Analysis Software (WinPAS 12) obtained from the American Concrete Pavement Association (ACPA).

3.8.3 General Asphaltic Pavement Performance

Asphaltic concrete pavements are susceptible to shoving under heavy truck traffic loads in sections of the pavement where truck turning and braking take place. Examples of these areas include at the bottom of grade changes, intersections, and moderate to tight

turn radii. The asphaltic concrete pavements are also more susceptible to shoving during high surficial temperatures.

Handling and placement of the pavement materials should be performed in accordance with Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction" (2009). All materials utilized in the construction of the pavements should be in accordance with the ODOT "Standard Specifications for Highway Construction" (2009).

3.8.4 Pavement Construction Considerations

Construction traffic on the pavements has not been considered in the design. If construction scheduling dictates the pavements will be subject to traffic by construction equipment/vehicles, the designs should be reconsidered to include the effects of the additional traffic loading.

Construction scheduling, involving paving and grading by separate contractors, typically results in a time lapse between the end of grading operations and the commencement of paving. Disturbance, desiccation, and/or wetting of the subgrade between grading and paving can result in deterioration of the previously completed subgrade. A non-uniform subgrade can result in poor pavement performance and local failures relatively soon after pavements are constructed.

We recommend that the pavement subgrades be test rolled and the moisture content and density of the top 12 inches of subgrade be checked within two days prior to commencement of actual paving operations. If any significant event, such as precipitation, occurs after test rolling, the subgrade should be reviewed by qualified geotechnical engineering personnel immediately prior to placing the pavement. The subgrade should be in its finished form at the time of the final review.

4. RECOMMENDATIONS

4.1 GENERAL

Based on the results of our evaluation, it is our professional opinion that the proposed roadway construction can be accomplished using standard earthwork and pavement construction operations.

The recommendations submitted herein are based, in part, upon data obtained from our subsurface exploration. The nature and extent of subsurface variations that may exist at the proposed project site will not become evident until construction. If variations appear evident, then the recommendations presented in this report should be evaluated. In the event that any changes in the nature, design, alignment, or grades of the proposed street reconstruction, the conclusions and recommendations contained in this report will not be considered valid unless the changes are reviewed and our recommendations modified in writing.

4.2 SITE PREPARATION

We recommend the following for site preparation:

1. All debris resulting from the demolition of these pavements/curbs should be removed from the site. Areas disturbed during demolition should be thoroughly evaluated by the geotechnical engineer prior to placement of structural fill. All disturbed soils should be undercut prior to placement of structural fill.

2. Stripping of any vegetation, organic soils, and associated root systems from planned construction areas should be performed. Any required tree removal should also be performed at this time. Materials disturbed during stripping operations and stump removal should be undercut and replaced with structural fill.

3. Following demolition, stripping, grubbing, cutting to final grades, undercutting unsuitable materials, and prior to fill placement, the exposed subgrade should be scarified, moisture conditioned, and compacted to the requirements of structural fill.

4. Following moisture conditioning and recompaction, it is recommended that the exposed subgrade be Test Rolled. Test Rolling should be performed in accordance with Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 203.

5. Excavation procedures should be performed in accordance with Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 202.

6. Pavement subgrade preparation should be performed in accordance with Oklahoma Department of Transportation (ODOT) "Standard Specifications for Highway Construction (2009)" Section 310.

4.3 STRUCTURAL FILL

1. **ON-SITE SOILS** – Based on the conditions encountered in the borings and the results of the laboratory testing, the on-site soils are suitable for use as fill within the roadway alignment. Additional testing and observation at the time of construction is recommended to further evaluate these materials prior to use as structural fill.

2. **OTHER IMPORTED MATERIAL** – We recommend the following criteria for imported materials to be used as fill within the roadway alignment:

    a. The material should consist of approved materials, free of organic matter (organic content less than 4 percent) and debris. Approved materials are defined as those soils classified by ASTM D 2487 as CL, GC, and SC.

b. A maximum Liquid Limit of 45 and a maximum Plasticity Index (PI) of less than 25.

3. All fill material placed with the roadway alignment should have a maximum particle size of 3 inches.

4. All fill should be placed in lifts having a maximum loose lift thickness of 9 inches.

5. All fill shall be compacted to a minimum of 95 percent of the material's maximum dry density as determined by ASTM D 698, standard Proctor compaction.

6. The moisture content of the clay fill (Plasticity Index > 10) at the time of compaction should be within a range of 0 to 4 percent above optimum moisture content as defined by the standard Proctor compaction procedure.

7. For clay fills having lower plasticities (Plasticity Index < 10) and sand, it may be necessary to use a moisture range of 2 percent below to 2 percent above optimum moisture content.

4.4 PAVEMENT THICKNESS

Table 4.4 indicates the recommended pavement sections based on the design criteria presented in Section 3.8.

Table 4.4: Pavement Sections

Pavement Section	18 kip Equivalent Single Axle Loads (ESALs)
2" Type "C" AC 2.5" Type "A" AC 8" Aggregate Base 8" Compacted Subgrade	200,000 SN = 3.03
Alternative 2" Type "C" AC 3" Type "A" AC 8" Aggregate Base 8" Compacted Subgrade	300,000 SN=3.22
Alternative 2" Type "C" AC 3.5" Type "A" AC 8" Aggregate Base 8" Compacted Subgrade	400,000 SN=3.37

1 ODOT "Standard Specifications for Highway Construction" Section 708, Type B Surface Course or Type S4 or S5, PG-64-22.
2 ODOT "Standard Specifications for Highway Construction" Section 708, Type A Base Course or Type S3, PG-64-22.
3 ODOT "Standard Specifications for Highway Construction" Section 703.01, Type A

The use of a geotextile separator fabric should be considered below the aggregate base material. The separator fabric helps to prevent loss of aggregate base support caused by the aggregate penetrating the subbase. The separator fabric should be installed in accordance with the manufactures recommendations. Proper care should be taken when placing the geotextile separator fabric to ensure the fabric is not punctured or torn. If utilized, the geotextile separator fabric should be in accordance with AASHTO M288 Class 2 and Appendices A1 and A3.

5. ADDITIONAL SERVICES

5.1 PLANS AND SPECIFICATIONS REVIEW

We recommend that GFAC Engineering, Inc. conduct a general review of the final plans and specifications to evaluate that our earthwork and pavement subgrade recommendations have been properly interpreted and implemented during design. In the event GFAC Engineering, Inc. is not retained to perform this recommended review, we will assume no responsibility for misinterpretation of our recommendations.

5.2 CONSTRUCTION OBSERVATION AND TESTING

We recommend that all site preparation, placement of all engineered fill, and pavement subgrade preparation be monitored by a representative of GFAC Engineering Inc. or other geotechnical engineering firm. The purpose of these services would be to provide GFAC Engineering, Inc. the opportunity to observe the subsurface conditions encountered during construction, evaluate the applicability of the recommendations presented in this report, and recommend appropriate changes in design or construction procedures if conditions differ from those described herein.

6. LIMITATIONS

Recommendations contained in this report are based on our field observations and subsurface explorations, limited laboratory tests, and our present knowledge of the proposed construction. It is possible that subsurface conditions could vary between or beyond the points explored. If subsurface conditions are encountered during construction that differ from those described herein, we should be notified immediately in order that a review may be made and any supplemental recommendations provided. If the scope of the proposed construction, including the proposed loads or structural locations, changes from that described in this report, our recommendations should also be reviewed.

We have prepared this report in substantial accordance with the generally accepted geotechnical engineering practice as it exists in the site area at the time of our study. No warranty is expressed or implied. The recommendations provided in this report are based on the assumption that an adequate program of tests and observations will be conducted by GFAC Engineering Inc. during the construction phase in order to evaluate compliance with our recommendations. The scope of our services did not include any environmental assessment or exploration for the presence of hazardous or toxic materials in the soil, surface water, groundwater or air, on, below or around this site.

This report may be used only by owner and only for the purposes stated, within a reasonable time from its issuance, but in no event later than three years from the date of report. Land use, site conditions (both on-site and off-site), regulations, or other factors may change over time, and additional work may be required with the passage of time. Any party other than the client who wishes to use this report shall notify GFAC Engineering Inc. of such intended use. Based on the intended use of the report, GFAC Engineering Inc. may require that additional work be performed and that an updated report be issued. Non-compliance with any of these requirements by the client or anyone else will release GFAC Engineering Inc. from any liability resulting from the use of this report by any unauthorized party and client agrees to defend, indemnify and hold harmless GFAC Engineering Inc. from any claim or liability associated with such unauthorized or non-compliance.

APPENDIX A

FIELD EXPLORATION PROGRAM
PLATE 1 – SITE VICINITY MAP
PLATE 2 – BORING LOCATION PLAN
BORING LOGS

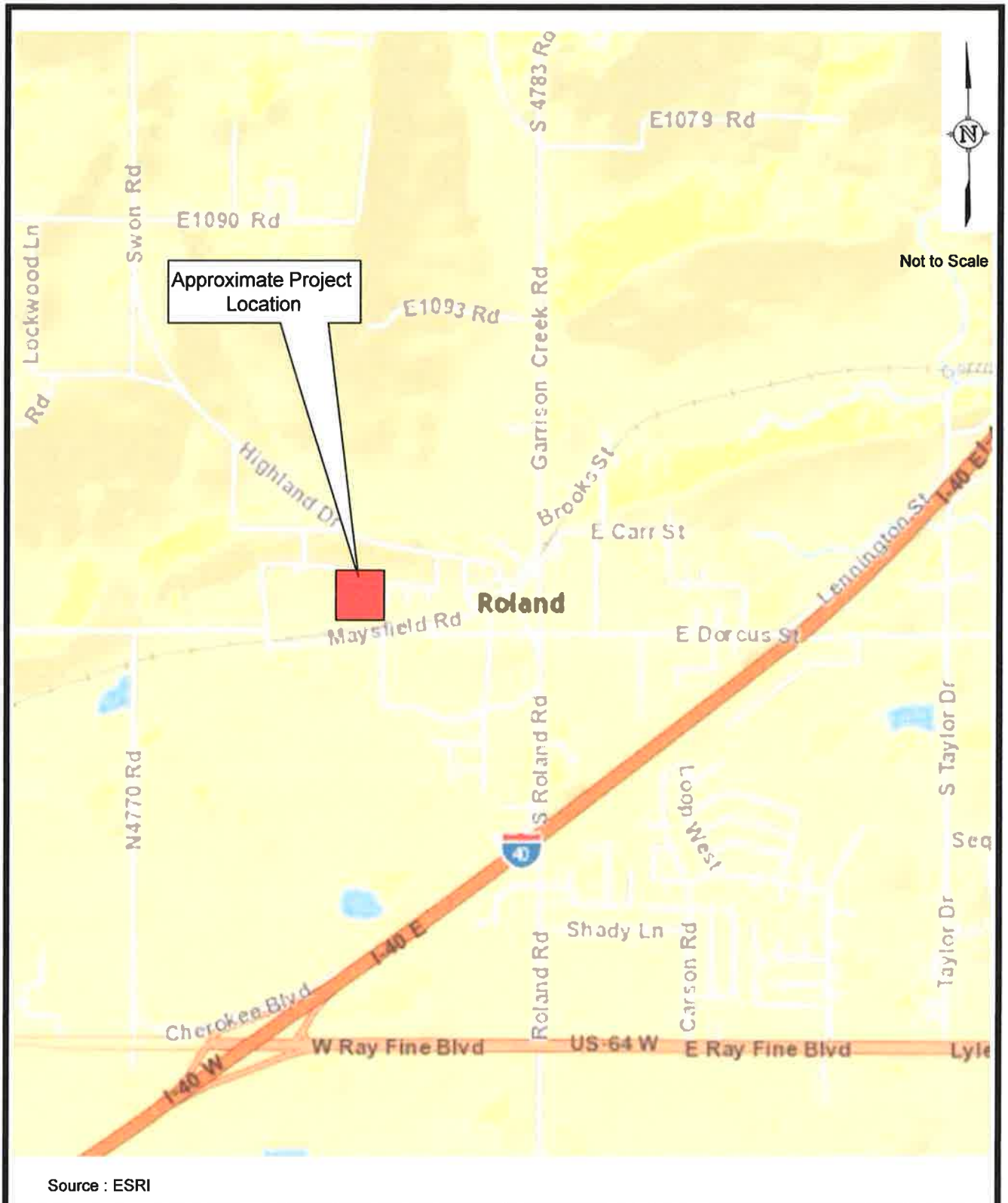
FIELD EXPLORATION PROGRAM

The fieldwork for this study was performed on July 15, 2014. The exploration consisted of six (6) borings extending to an approximate depth of 5 feet, each, below the existing ground surface elevations. Representatives of GFAC Engineering Inc. established the boring locations in the field near the locations indicated on the site plan provided to us. Boring locations were established by visual observation of the existing site features. Locations of the borings should be considered accurate only to the degree implied by the methods used to obtain them. Elevations at the boring locations were not determined.

The boring operations were performed by GFAC Engineering Inc. The borings were drilled using a truck-mounted (CME-55), rotary drill rig using solid flight augers to advance the boreholes. Representative samples were obtained by the split-barrel sampling procedure in general accordance with ASTM D 1586. The split-barrel sampling procedure utilizes a standard 2-inch O.D. split-barrel sampler that is driven into the bottom of the boring with a 140-pound auto-hammer falling a distance of 30 inches. The number of blows required to advance the sampler the last 12 inches of a normal 18 inch penetration is recorded as the Standard Penetration Resistance Value (N). These "N" values are indicated on the boring logs at their depth of occurrence and provide an indication of the relative density, consistency, and hardness of the material.

Boring logs included in this appendix, present such data as soil and bedrock descriptions, relative density, consistency, and bedrock hardness evaluations, depths, sampling intervals and observed groundwater conditions. Conditions encountered in each of the borings were monitored and recorded by the field engineer. Field logs included visual classification of the materials encountered during drilling, as well as drilling characteristics. Our final boring logs represent the engineer's interpretation of the field logs combined with laboratory observation and testing of the samples. Stratification boundaries indicated on the boring logs were based on observations during our fieldwork, an extrapolation of information obtained by examining samples

from the borings and comparisons of soils with similar engineering characteristics. Locations of these boundaries are approximate, and the transitions between soil and bedrock types may be gradual rather than clearly defined.

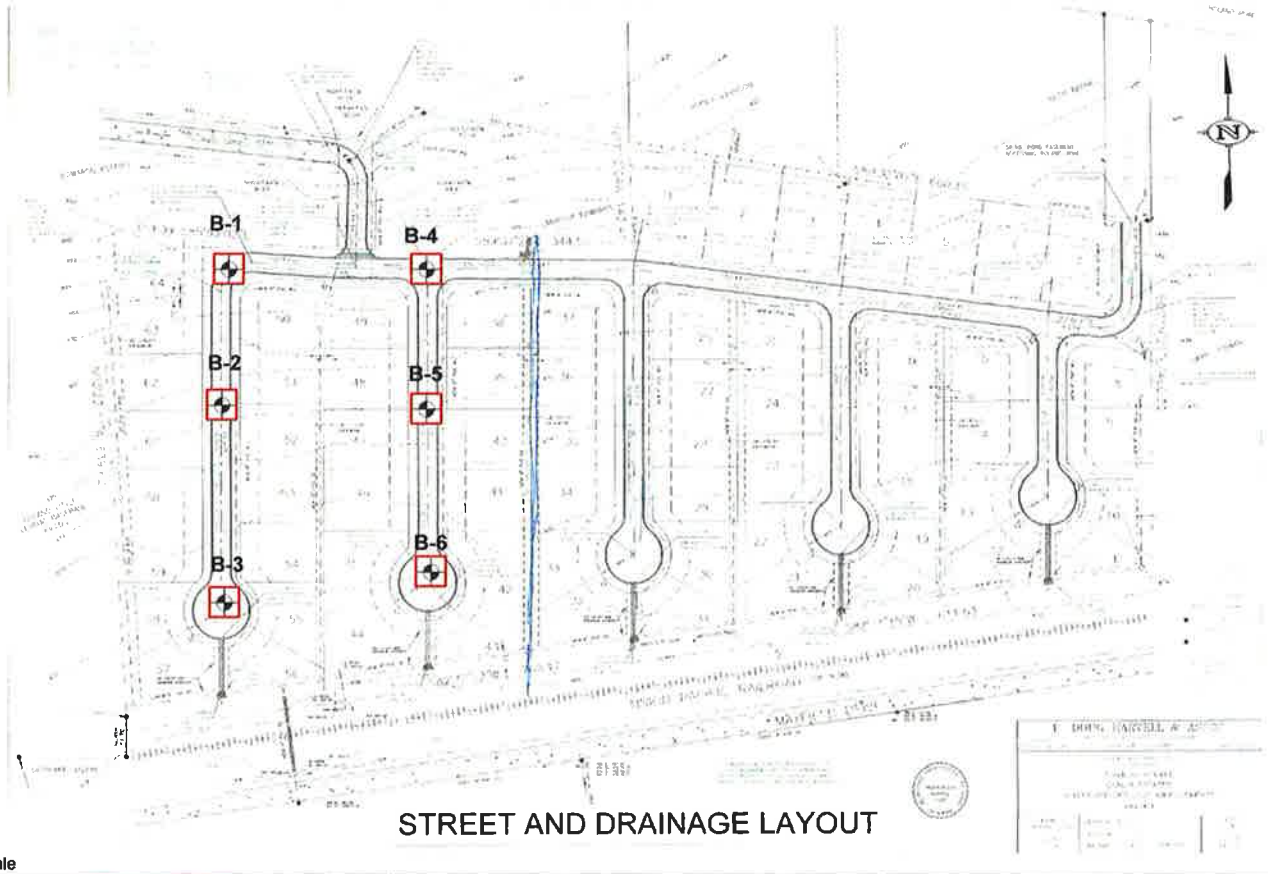


Source : ESRI

GFAC ENGINEERING

SITE VICINITY MAP
Cowan Estates Subdivision Streets
Roland, Oklahoma
Project G2014038 July 24, 2014

Plate 1



STREET AND DRAINAGE LAYOUT

Not to Scale

GFAC ENGINEERING

Boring locations are approximate.

Plan provided by Scott and Associates, modified by GFAC.

BORING LOCATION PLAN
Cowan Estates Subdivision Streets
Roland, Oklahoma
Project G2014038 July 28, 2014

Plate 2

GFAC Engineering Inc.
4150 South 100th E. Ave Ste. 200-K
Tulsa, Oklahoma 74146
Telephone: 9186227021

BORING NUMBER B-1

CLIENT Scott and Associates
PROJECT NAME Cowan Estates Subdivision Streets
PROJECT NUMBER G2014038
PROJECT LOCATION Roland, OK
DATE STARTED 7/15/14 **COMPLETED** 7/15/14
GROUND ELEVATION _____ **HOLE SIZE** 4 inches
DRILLING CONTRACTOR GFAC Engineering
GROUND WATER LEVELS:
DRILLING METHOD Continuous Flight Auger 4"
AT TIME OF DRILLING --- DRY
LOGGED BY PWV **CHECKED BY** DLK
AT END OF DRILLING --- DRY
NOTES _____
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	Texas Cone Penetrometer	BLOW COUNTS (N VALUE)	Uncon. Strength (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0.0		TOPSOIL											
		FILL - Lean Clay with Broken Shale, moist, brown	SS 1	33		3-4-5 (9)			15				
2.5		SANDY SILT, moist, stiff, tan, orange, and gray											
		SANDY SILTY CLAY, moist, stiff, light gray and tan											
		- very stiff below 4 feet	SS 2	83		5-11-15 (26)			16	23	16	7	64
5.0		- brown and orange with sandstone gravel below 4.7 feet											

Bottom of borehole at 5.0 feet.

GFAC Engineering Inc.
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Tulsa, Oklahoma 74146
Telephone: 9186227021

BORING NUMBER B-2

CLIENT Scott and Associates
PROJECT NAME Cowan Estates Subdivision Streets
PROJECT NUMBER G2014038
PROJECT LOCATION Roland, OK
DATE STARTED 7/15/14 **COMPLETED** 7/15/14
GROUND ELEVATION _____ **HOLE SIZE** 4 inches
DRILLING CONTRACTOR GFAC Engineering
GROUND WATER LEVELS:
DRILLING METHOD Continuous Flight Auger 4"
AT TIME OF DRILLING --- DRY
LOGGED BY PWV **CHECKED BY** DLK
AT END OF DRILLING --- DRY
NOTES _____
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	Texas Cone Penetrometer	BLOW COUNTS (N VALUE)	Uncon. Strength (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS			FINES CONTENT (%)
										LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	
0.0		TOPSOIL											
		FILL - Lean Clay with Broken Shale, moist, brown											
		SANDY LEAN CLAY, moist, stiff, brown and tan	SS 1	22		3-4-5 (9)			12	28	16	12	63
2.5		SANDY SILTY CLAY, moist, stiff, tan, brown, gray, and orange	SS 2	83		3-4-4 (8)			19				
5.0		Bottom of borehole at 5.0 feet.											

GFAC Engineering Inc.
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Tulsa, Oklahoma 74146
Telephone: 9186227021

BORING NUMBER B-3

CLIENT Scott and Associates
PROJECT NAME Cowan Estates Subdivision Streets
PROJECT NUMBER G2014038
PROJECT LOCATION Roland, OK
DATE STARTED 7/15/14 **COMPLETED** 7/15/14
GROUND ELEVATION _____ **HOLE SIZE** 4 inches
DRILLING CONTRACTOR GFAC Engineering
GROUND WATER LEVELS:
DRILLING METHOD Continuous Flight Auger 4"
AT TIME OF DRILLING --- DRY
LOGGED BY PWV **CHECKED BY** DLK
AT END OF DRILLING --- DRY
NOTES _____
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	Texas Cone Penetrometer	BLOW COUNTS (N VALUE)	Uncon. Strength (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0.0		TOPSOIL											
		SANDY SILT, moist, very soft, brown											
		SILTY SAND with sandstone gravel, fine grained, moist, loose, brown and orange	SS 1	78		1-2-2 (4)			12				46
2.5		SANDY SILTY CLAY, moist, medium stiff to stiff, brown and gray											
		LEAN TO FAT CLAY, moist, medium stiff to stiff, brown, gray, and orange	SS 2	56		3-3-4 (7)			20				
5.0		Bottom of borehole at 5.0 feet.											

GFAC Engineering Inc.
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Tulsa, Oklahoma 74146
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BORING NUMBER B-4

CLIENT Scott and Associates
PROJECT NAME Cowan Estates Subdivision Streets
PROJECT NUMBER G2014038
PROJECT LOCATION Roland, OK
DATE STARTED 7/15/14 **COMPLETED** 7/15/14
GROUND ELEVATION _____ **HOLE SIZE** 4 inches
DRILLING CONTRACTOR GFAC Engineering
GROUND WATER LEVELS:
DRILLING METHOD Continuous Flight Auger 4"
AT TIME OF DRILLING --- DRY
LOGGED BY PWV **CHECKED BY** DLK
AT END OF DRILLING --- DRY
NOTES _____
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	Texas Cone Penetrometer	BLOW COUNTS (N VALUE)	Uncon. Strength (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0.0		ASPHALTIC CONCRETE - 3.5 inches											
		AGGREGATE BASE - 6 inches											
		FILL - Sandy Lean Clay with Broken Shale, moist, brown	SS 1	44		3-3-4 (7)			14	28	15	13	57
2.5		SANDY SILT, moist, medium stiff to stiff, orange and brown											
		SANDY LEAN CLAY, moist, stiff, brown, amber, gray, and yellow with ferrous nodules	SS 2	78		3-5-9 (14)			17				
5.0		Bottom of borehole at 5.0 feet.											

GFAC Engineering Inc.
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Tulsa, Oklahoma 74146
Telephone: 9186227021

BORING NUMBER B-5

CLIENT Scott and Associates
PROJECT NAME Cowan Estates Subdivision Streets
PROJECT NUMBER G2014038
PROJECT LOCATION Roland, OK
DATE STARTED 7/15/14 **COMPLETED** 7/15/14
GROUND ELEVATION _____ **HOLE SIZE** 4 inches
DRILLING CONTRACTOR GFAC Engineering
GROUND WATER LEVELS:
DRILLING METHOD Continuous Flight Auger 4"
AT TIME OF DRILLING 2.40 ft
LOGGED BY PWV **CHECKED BY** DLK
AT END OF DRILLING 2.40 ft
NOTES _____
AFTER DRILLING --

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	Texas Cone Penetrometer	BLOW COUNTS (N VALUE)	Uncon. Strength (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0.0		TOPSOIL											
		FILL - Sandy Lean Clay with sandstone and shale fragments, moist, brown											
			SS 1	22		3-2-2 (4)			17	35	19	16	61
		SANDY SILTY CLAY, moist, soft to medium stiff, brown											
2.5		▼											
		LEAN TO FAT CLAY with sand and shale fragments, moist, stiff, brown with gray											
			SS 2	28		2-5-8 (13)			16				
5.0		Bottom of borehole at 5.0 feet.											

GFAC Engineering Inc.
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Tulsa, Oklahoma 74146
Telephone: 9186227021

BORING NUMBER B-6

CLIENT Scott and Associates
PROJECT NAME Cowan Estates Subdivision Streets
PROJECT NUMBER G2014038
PROJECT LOCATION Roland, OK
DATE STARTED 7/15/14 **COMPLETED** 7/15/14
GROUND ELEVATION _____ **HOLE SIZE** 4 inches
DRILLING CONTRACTOR GFAC Engineering
GROUND WATER LEVELS:
DRILLING METHOD Continuous Flight Auger 4"
AT TIME OF DRILLING --- Dry
LOGGED BY PWV **CHECKED BY** DLK
AT END OF DRILLING --- Dry
NOTES
AFTER DRILLING ---

DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	Texas Cone Penetrometer	BLOW COUNTS (N VALUE)	Uncon. Strength (psf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0.0		TOPSOIL											
		POSSIBLE FILL - Lean Clay with Sand, moist, soft to medium stiff, brown	SS 1	67		2-2-2 (4)			18	28	17	11	84
2.5		LEAN TO FAT CLAY with sand, moist, soft to medium stiff, brown, orange, and gray - brown, gray, and amber below 2.8 feet	SS 2	83		2-5-18 (23)			18				
5.0		SANDSTONE GRAVEL, orange and brown HIGHLY WEATHERED TO WEATHERED SHALE, moist, soft, brown and gray											

Bottom of borehole at 5.0 feet.

APPENDIX B

LABORATORY TESTING PROGRAM

LABORATORY TESTING PROGRAM

GENERAL

Laboratory tests were performed on select, representative samples to evaluate pertinent engineering properties of these materials. We directed our laboratory testing program primarily toward classifying the subsurface materials, and measuring index values of the on-site materials. Laboratory tests were performed in general accordance with applicable standards, and the results are presented on the respective boring logs. The laboratory testing program consisted of the following:

- **Moisture content tests** ASTM D 2216, Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
- **No. 200 sieve, ASTM D 1140,** Standard Test Methods for Amount of Material in Soils Finer Than the No. 200 Sieve
- **Atterberg limits tests** ASTM D 4318, Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
- **Visual classification** ASTM D 2488, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

MOISTURE CONTENTS

Moisture content tests were performed on samples obtained by the split-barrel sampler procedure.

NO. 200 SIEVE

No. 200 sieve tests were conducted on samples representative of the soils encountered in the borings. The test provides information on the amount of material finer than the No. 200 sieve, which is a basis for soil classification.

ATTERBERG LIMITS

Atterberg limits tests were conducted on representative samples of soils encountered across the site. These tests provide information on the plasticity of the soil, which is a basis for soil classification and for estimating the potential of subgrade soils to change volume with variations in moisture content.

CLASSIFICATION

All samples were examined in field by a geotechnical engineer using visual and manual procedures. The samples were classified in general accordance with the Unified Soil Classification System, and are shown on the boring logs.

Bedrock units encountered in the borings were described based on visual classification of disturbed auger cuttings and recovered samples, as well as drilling characteristics. Core samples may reveal other rock types.