Tier III Permit Application

Southern Oklahoma Regional Disposal Landfill

Presented to:
Southern Oklahoma Regional Disposal, Inc.

Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented by:

SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00

Offices Nationwide
www.scsengineers.com
December 10, 2018
File No. 27215136.00

Ms. Hillary Young
Land Protection Division
Oklahoma Department of Environmental Quality
707 North Robinson
Oklahoma City, Oklahoma 73101

Subject: NOD Response - Tier III Permit Modification
Southern Oklahoma Regional Disposal Landfill

Dear Ms. Young:

On behalf of our client, Southern Oklahoma Regional Disposal, Inc., SCS Engineers is submitting this response to the Notice of Deficiency dated November 5, 2018 from the Oklahoma Department of Environmental Quality (ODEQ) associated with the Southern Oklahoma Regional Disposal Landfill Tier III Permit Application dated April 30, 2018. SCS Engineers has addressed the deficiencies noted in the Notice of Deficiency and those responses are shown below. Please note this submittal only includes sections of the Tier III Permit Modification which have been revised from previous submittal.

1. OAC 252:515-3-55(c) specifies the existing contour map should include" ... the locations of all boreholes ... ". The existing contour map submitted with the Application does not include all currently active piezometers at the facility.

Response: The existing contour map has been revised by adding PZ-2, PZ-3, PZ-4, and PZ-5 located in the SE/4 of the facility.

2. OAC 252:515-3-56 specifies the site map should include "(b)(4) ... the locations of...each bore hole, monitoring well, test well, monitoring site, test pit, sampling site and permanent benchmarks." It should also include "(b)(10) ... on- and off-site borrow areas." The site map submitted with the Application does not include all currently active piezometers or the location of the borrow area.

Response: The site map has been revised by adding PZ-2, PZ-3, PZ-4, and PZ-5 located in the SE/4 of the facility and the location of the borrow area.

3. OAC 252:515-3-74 requires the groundwater contours to be set at 2 foot intervals and show the location of all proposed monitoring wells, boreholes, and piezometers. The highest groundwater contour map does not include all active piezometers and the contour lines are set to 5 foot intervals.
Response: The highest groundwater contour map site map has been revised by including the location of PZ-2, PZ-3, PZ-4, and PZ-5 located in the SE/4 of the facility and the groundwater contour lines set to 2 foot intervals. Groundwater measurements were not obtained from PZ-2, PZ-3, PZ-4, and PZ-5 located in the SE/4 of the facility as permitted base grades exist in this area and only PZ-1, PZ-6, and PZ-7 were evaluated for the purpose of revising the permitted base grades in this area.

4. OAC 252:515-3-75 requires the groundwater contours to be set at 2 foot intervals. The potentiometric surface map has contour lines set at 5 foot intervals.

Response: The ground water contours have been revised and set at 2 foot intervals on the potentiometric surface map.

5. OAC 252:515-5-52(e) requires the submittal of a demonstration that the facility will not pose a bird hazard to aircraft. The Application did not include this demonstration.

Response: OAC 252:515-5-52(e) requires the submittal of a demonstration that the facility will not pose a bird hazard to aircraft if any waste management or disposal area of a new land disposal facility, or expansion of waste management or disposal areas of an existing land disposal facility, is to be located within 10,000 feet of any airport runway end used by turbojet aircraft or within 5,000 feet of any airport runway end used by only piston-type aircraft.

The Bass Aero Airport located northwest of SORD is used by only piston-type aircraft. The General Location Map (Figure 1) demonstrates that the SORD is not located within the 5,000 foot requirement for piston-type aircraft and therefore satisfies the location restriction for airports.

6. OAC 252:515-7-71(a) requires all bore holes, not to be converted to piezometers, to be plugged within thirty days of drilling. The Application contains no records of surface plugging of bore holes that were not converted to piezometers.

Response: Borings that were not converted to piezometers were decommissioned by utilizing 2-inch tremmie pipe to fill the annulus from the total depth to ground surface with a bentonite/Portland grout. Text in Section 3.0 Page 6 of Appendix B has been revised to reflect same. Multi-Purpose Well Completion and Plugging Reports are also included as Appendix F of the Hydrogeologic and Geotechnical Investigation Report.

7. OAC 252:515-9-31(d) specifies the minimum required parameters to be tested for in each monitoring well. The list of groundwater background quality parameters provided in the Application is missing the following constituents: 1,2-dichloropropane, cis 1,3-dichloropropene, trans 1,3-dichloropropene, and methyl iodide.

Response: Table 4 of the Groundwater Monitoring Plan has been revised to include the additional constituents.

8. OAC 252:515-13-34 requires the leachate header pipes be cleaned out after placement of the protective layer, again after the placement of the first lift of waste, and once per year thereafter. Review of the Application showed no information on the initial cleanouts and
annual maintenance of the leachate collection system. Please include this language in the leachate management plan.

Response: This requirement has been included in Section 11.2 of the Application and Section 6.0 of the Operations Plan.

9. OAC 252.515-1 3-52(c) specifics how a leachate surface impoundment shall be constructed. The Application contains no specifications as to the construction of the impoundment or justification to prove its proposed size would be sufficient to hold all leachate from the expansion.

Response: Section 11.5 of the Application has been revised to include the construction specifications and capacity of the proposed leachate storage impoundment as well as the estimated annual drainage collected.

10. Drawings #6 of 17: the highest groundwater contour line in the northeast portion of the expansion area is mislabeled as 775 feet. It should be 770 feet. Please check all other contour labels.

Response: The highest groundwater contour line in the northeast portion of the expansion area has been corrected and others confirmed on the Permit Drawings.

11. The existing contour map does not include all of the expansion area north of the existing permit boundary. Please update the map to include the entire expansion area.

Response: The existing contour map has been revised to include the entire expansion area.

12. Maps presented in the Application refer to the "permit boundary" when they should state "proposed permit boundary" and "current permit boundary".

Response: The maps and drawings have been revised and boundaries identified as requested.

13. On page 26 of the Application it states, "Intermediate side slopes will not exceed a slope of 3:1..." OAC 252:515 rules do not have a requirement for intermediate cover slopes; however, there are requirements for internal and external slopes. Please clarify the slope requirements in the Application.

Response: The reference of intermediate side slopes has been removed and clarified to state the slope requirements of 3:1 for internal slopes and 4:1 for external slopes.

14. Appendix A, one notice to an adjacent land owner was unclaimed. A second attempt is requested.

Response: A second notification letter was submitted and delivered on December 5, 2018. Delivery confirmation is included in Appendix A.
15. Appendix B, page 13, paragraph 5 states, "The deepest placement of waste would therefore be 2 feet above this elevation which would be the top of the liner." OAC 252:515-11-3(a) requires a minimum 5 foot vertical separation between the highest groundwater elevation and the lowermost surface on which waste, including leachate, will be placed. Please update the Application to reflect this rule.

Response: The separation requirement has been corrected and now reads 5 feet instead of 2 feet.

16. Appendix B, Drawing 2.2, the site is located in the wrong location. Please correct.

Response: The location of the site depicted in Drawing 2.2 of Appendix B has been corrected.

17. Appendix B, Table 3.1 is titled "SORO Landfill Precipitation"; however, the actual table contains the details of borings drilled.

Response: Appendix B, Table 3.1 title has been corrected.

18. Appendix B, Table 4.2 is titled "Paul's Valley Precipitation"; however, the station information is provided from Ardmore.

Response: Appendix B, Table 4.2 title has been corrected.

19. Appendix B, Table 4.3 "Slug Test Results", PZ-5 was recorded "IN" twice, and PZ-13 was recorded "IN" but there is no "OUT" record. Please correct.

Response: Field equipment malfunctioned during the PZ-13 raising head test and therefore no results are presented for PZ-13. Table 4.3 and Section 4.3 of Appendix B have been revised.

20. Appendix G, Section 3.2.5, page 12, specifies "the protective cover layer shall consist of either a 5 foot layer of compacted select waste or...". If a 5 foot layer of select waste is to be used in place of one foot of sand, the waste layer should be uncompacted select waste.

Response: This section has been corrected. The word compacted has been removed and replaced with uncompacted.

21. Appendix G, Table 5, page 34, the minimum lift thickness has no units specified.

Response: The minimum lift thickness unit has been corrected. Inches is the specified unit.

22. Appendix I, page 7, states "during wet weather, the landfill will have two options available. An alternative daily cover. ... and soil." Please specify what type of ADC is approved for use before, during and/or after rain events.

Response: SORD is currently approved to utilize foundry sand, tire chips, and posi-shell plus extreme rain shield during and/or after rain events. Section 4.0 of the Operations Plan has been revised accordingly.
23. Appendix K, Tables H.1 and H.2 have two different disposal costs listed. Please update both tables to reflect the correct cost.

Response: The disposal cost has been corrected to reflect the correct costs of $25.75/ton.

24. Appendix K, Table 1.1 the multiplier for 4.b Repair Erosion, Settlement, and Subsidence for On-Site Soils is incorrect. The correct multiplier should be 60.

Response: The multiplier has been corrected to 60.

This response has been prepared to address the Notice of Deficiency dated November 5, 2018 in reference to the Tier III Permit Modification dated April 30, 2018. We trust that the attached documents include all of the information sufficient for your approval. Should you have any questions or require additional information, please feel free to contact us at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade J. Miller
Project Director

Floyd Cotter, P.E.
Vice President

cc: Mr. Troy Duke – Southern Oklahoma Regional Disposal, Inc.
Mr. Terry Lewis – Southern Oklahoma Regional Disposal, Inc.
APPLICATION TO MODIFY A SOLID WASTE DISPOSAL FACILITY PERMIT

Date: December 10, 2018

County: Carter

Send to:
Solid Waste Permitting Unit
Waste Management Division
Dept. of Environmental Quality
707 N. Robinson (PO Box 1677)
Oklahoma City, OK 73101-1677

FOR DEQ USE

DEQ Log No. __________________
No. Copies __________________
Date Received: _____________

Southern Oklahoma Regional Disposal, Inc. proposes to modify the permit of

(Applicant's Name)

the Southern Oklahoma Regional Disposal Landfill, located at N84°4 of Section 34 and the S1/2 of the S1/2 of the SE1/4 of Section 13

(Facility Name)

(Exact legal description:

Township 4 South, Range 2 East of the Indian Meridian, containing 20 acres more or less, Carter County, Oklahoma.

metes & bounds, platted lot, or land survey. Append extra sheets if necessary)

in Carter County, Oklahoma. We hereby make application for a modification of existing permit number 3510097 as required by the Oklahoma Solid Waste Management Act and the Rules pursuant thereto.

Remarks & brief description of proposed modification:
Expand the permit boundary to 200 acres to include the 80 acres adjacent to the north and east of the existing landfill.

Applicant or Authorized Agent:

Signature

Typed Name

Address: PO Box 1088
City: Ardmore State: OK

Date signed: 12/10/2018
Phone: 580.226.1276

Preparring Engineer:

Signature

Typed Name

Address: 8575 West 110th Street, Suite 100
City: Overland Park State: OK

Date signed: 12/10/2018
Phone: 913.302.1428

July 2016
DEQ Form #515-020

DEQ USE ONLY
VERIFICATION

STATE OF OKLAHOMA
COUNTY OF Carter

Troy Duke, of lawful age, being first duly sworn, upon oath state that I have read the foregoing APPLICATION TO MODIFY A SOLID WASTE DISPOSAL FACILITY PERMIT, that I am familiar with the matters set forth therein, and that the same are true to the best of my information and belief.

Troy Duke
Applicant

Subscribed and sworn to before me this 10th day of December, 2018.

Troy Duke
(Applicant or legal representative)

K. Lynn
Notary Public

My commission expires:

6-8-2020

1 This Verification is required for a Tier III modification application.

July 2016
DEQ Form #515-020
Tier III Permit Application

Southern Oklahoma Regional Disposal Landfill

Presented to:
Southern Oklahoma Regional Disposal, Inc.

Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented by:

SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00

Offices Nationwide
www.scsengineers.com
Tier III Permit Application

Presented To:

Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented From:

SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00
INDEX AND CERTIFICATION PAGE

REPORT INDEX

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Number of Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0</td>
<td>Filing of Application &amp; Public Participation</td>
<td>2</td>
</tr>
<tr>
<td>3.0</td>
<td>General Information</td>
<td>2</td>
</tr>
<tr>
<td>4.0</td>
<td>Location Restrictions</td>
<td>5</td>
</tr>
<tr>
<td>5.0</td>
<td>Subsurface Investigation</td>
<td>1</td>
</tr>
<tr>
<td>6.0</td>
<td>Landfill Development</td>
<td>2</td>
</tr>
<tr>
<td>7.0</td>
<td>Groundwater Monitoring</td>
<td>2</td>
</tr>
<tr>
<td>8.0</td>
<td>Explosive Gas Monitoring</td>
<td>1</td>
</tr>
<tr>
<td>9.0</td>
<td>Storm Water Management</td>
<td>2</td>
</tr>
<tr>
<td>10.0</td>
<td>Liner Construction</td>
<td>2</td>
</tr>
<tr>
<td>11.0</td>
<td>Leachate Collection and Management</td>
<td>4</td>
</tr>
<tr>
<td>12.0</td>
<td>Site Operations</td>
<td>1</td>
</tr>
<tr>
<td>13.0</td>
<td>Cover and Soil Borrow Requirements</td>
<td>2</td>
</tr>
<tr>
<td>14.0</td>
<td>Closure and Post-Closure</td>
<td>1</td>
</tr>
<tr>
<td>15.0</td>
<td>General Comments</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Figures</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Permit Drawings</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Appendices</td>
<td>1274</td>
</tr>
</tbody>
</table>

Certification

This Tier III Permit Application has been prepared in accordance with good engineering practice including consideration of industry standards and the requirements of the Oklahoma Department of Environmental Quality.

Prepared by:

Floyd Cotter, P.E.
Vice President
SCS Engineers
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0 Filing of Application &amp; Public Participation</td>
<td>2</td>
</tr>
<tr>
<td>3.0 General Information</td>
<td>4</td>
</tr>
<tr>
<td>3.1 Oath 4</td>
<td>4</td>
</tr>
<tr>
<td>3.2 Legal Description</td>
<td>4</td>
</tr>
<tr>
<td>3.3 Legal Right to Property</td>
<td>4</td>
</tr>
<tr>
<td>3.4 Adjacent Property Owner Notification</td>
<td>5</td>
</tr>
<tr>
<td>3.5 Aesthetic Enhancement</td>
<td>5</td>
</tr>
<tr>
<td>3.6 Air Quality</td>
<td>5</td>
</tr>
<tr>
<td>4.0 Location Restrictions</td>
<td>6</td>
</tr>
<tr>
<td>4.1 Scenic Rivers</td>
<td>6</td>
</tr>
<tr>
<td>4.2 Recreation and Preservation Areas</td>
<td>6</td>
</tr>
<tr>
<td>4.3 Endangered or Threatened Species</td>
<td>6</td>
</tr>
<tr>
<td>4.4 100-Year Floodplain</td>
<td>6</td>
</tr>
<tr>
<td>4.5 Public Water Supply</td>
<td>7</td>
</tr>
<tr>
<td>4.6 Wellhead Protection Area</td>
<td>7</td>
</tr>
<tr>
<td>4.7 Wetlands</td>
<td>7</td>
</tr>
<tr>
<td>4.8 Terrace Deposits</td>
<td>8</td>
</tr>
<tr>
<td>4.9 Karst Terrain</td>
<td>8</td>
</tr>
<tr>
<td>4.10 Earthquake Epicenter Area</td>
<td>8</td>
</tr>
<tr>
<td>4.11 Utility/Transmission Lines</td>
<td>8</td>
</tr>
<tr>
<td>4.12 Fault Areas</td>
<td>9</td>
</tr>
<tr>
<td>4.13 Seismic Impact Zones</td>
<td>9</td>
</tr>
<tr>
<td>4.14 Unstable Areas</td>
<td>9</td>
</tr>
<tr>
<td>4.15 Airports</td>
<td>9</td>
</tr>
<tr>
<td>4.16 Buffer Zones</td>
<td>10</td>
</tr>
<tr>
<td>5.0 Subsurface Investigation</td>
<td>11</td>
</tr>
<tr>
<td>6.0 Landfill Development</td>
<td>12</td>
</tr>
<tr>
<td>6.1 Design Criteria</td>
<td>12</td>
</tr>
<tr>
<td>6.2 Landfill Development</td>
<td>12</td>
</tr>
<tr>
<td>6.2.1 Capacity Increase</td>
<td>13</td>
</tr>
<tr>
<td>6.2.2 Sequence of Development</td>
<td>13</td>
</tr>
<tr>
<td>7.0 Groundwater Monitoring</td>
<td>14</td>
</tr>
<tr>
<td>8.0 Explosive Gas Monitoring</td>
<td>16</td>
</tr>
<tr>
<td>9.0 Storm Water Management</td>
<td>17</td>
</tr>
<tr>
<td>9.1 OKR05 Permit Requirements</td>
<td>17</td>
</tr>
<tr>
<td>9.2 Run-on Control Systems</td>
<td>17</td>
</tr>
</tbody>
</table>
9.3 Run-off Control Systems ................................................................. 17
  9.3.1 Drainage Swales ................................................................. 18
  9.3.2 Leidown Channels ............................................................... 18
  9.3.3 Perimeter Drainage Channels ............................................... 18
10.0 Liner Construction ................................................................. 19
11.0 Leachate Collection and Management ........................................ 21
  11.1 Leachate Drainage Layer ........................................................ 22
  11.2 Leachate Collection Pipe Network ........................................... 23
  11.3 Leachate Collection Sumps ..................................................... 23
  11.4 Leachate Pumping System ...................................................... 23
  11.5 Leachate Storage and Disposal ................................................. 24
12.0 Site Operations ........................................................................ 25
13.0 Cover and Soil Borrow Requirements ...................................... 26
  13.1 Daily and Intermediate Cover .................................................. 26
  13.2 Final Cover System ............................................................... 26
  13.3 Borrow Sources .................................................................... 27
  13.4 Borrow Area Reclamation ....................................................... 27
14.0 Closure and Post-Closure ....................................................... 28
15.0 General Comments .................................................................. 29
List of Figures

No.
1 General Location Map
2 Floodplain Map
3 Topographic Map

Permit Drawings

No.
1 Coversheet
2 Existing Contour Map
3 Site Map
4 Highest Groundwater Contour Map
5 Top of Subgrade Grading Plan
6 Top of Clay Liner Grading Plan
7 Top of Final Cover Grading Plan
8 Cross Sections Locations
9 Cross Section A-A'
10 Cross Section B-B'
11 Cross Section C-C'
12 Cross Section D-D'
13 Cross Section E-E'
14 Stormwater Control Plan
15 Details Sheet 1
16 Details Sheet 2
17 Details Sheet 3

Appendices

Appendix A Adjacent Property Owner Notification and Location Restriction
Correspondence Letters
Appendix B Subsurface Investigation
Appendix C Liner and Final Cover System Stability Analysis
Appendix D Groundwater Monitoring Plan
Appendix E Explosive Gas Monitoring Plan
Appendix F Surface Water System Design Report
Appendix G Quality Assurance/Quality Control Plan for Liner and Leachate Collection System Installation and Testing
Appendix H Leachate Collection System Design Report
Appendix I Operations Plan
Appendix J Approved Waste Exclusion Plan
Appendix K Closure and Post-Closure Plan
Appendix L Quality Assurance/Quality Control Plan for Approved Evapotranspiration Alternative Earthen Final Cover Construction
1.0 INTRODUCTION

SCS Engineers, on behalf of Southern Oklahoma Regional Disposal, Inc., is submitting the necessary documents to revise the permitted base grades for the previously permitted Cells 3-6, expand the permit boundary, establish permit base grades for such area, reconfigure the cell alignment, and permit a leachate storage impoundment at the Southern Oklahoma Regional Disposal Landfill (SORD). The SORD is located in the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma, approximately 4 miles east of Ardmore, Oklahoma (Figure 1).

The SORD permit boundary contains approximately 120 acres. Approximately 65.84 acres have been developed for municipal solid waste disposal, of which 43.20 acres have been developed with a Pre-Subtitle D liner, and the remaining 22.64 acres have been developed with a Subtitle D composite liner system. This horizontal expansion proposes to increase the permit boundary to 200 acres.

The SORD was issued Permit No. 3510007 on March 20, 1979 by the Oklahoma Department of Environmental Quality (ODEQ) and operates as a Subtitle D facility.

A subsurface investigation of approximately 80 acres was completed between January 2016 and October 2017. The hydrogeological report documenting the investigation is included in this application as Appendix B.
2.0 FILING OF APPLICATION & PUBLIC PARTICIPATION

In accordance with the Uniform Environmental Permitting Act and the Oklahoma Administrative Code (OAC) 252:4-7-13(g)(1), the SORD will publish notice of the filing of this application in The Daily Ardmoreite newspaper. The published notice will serve as the legal notice to the public. The publication will identify locations where the application may be reviewed by the public, including a location in Carter County, where the site is located. The publication will include notice of a 30 day opportunity to request a process meeting. If the ODEQ receives timely requests and determines that a significant degree of public interest in the application exists, the ODEQ shall schedule and hold a process meeting. In addition, notices will be provided by certified mail and return receipt request to adjacent landowners whose property may be affected by the horizontal expansion of the SORD.

Upon conclusion and approval of the technical review for this Tier III application, the ODEQ will prepare a draft permit. Notice of the draft permit shall be given by the SORD by publishing a legal notice in The Daily Ardmoreite newspaper. The notice shall identify locations where the draft permit and the application may be reviewed by the public, including a location in Carter County, where the site is located. The publication will include notice of a 30 day opportunity to request a public meeting on the permitting process. If the ODEQ receives timely requests and determines that a significant degree of public interest in the application exists, the ODEQ shall schedule and hold a public meeting. In addition, notices of the draft permit will be provided by certified mail and return receipt request to adjacent landowners whose property may be affected by the horizontal expansion of the SORD.

Should the ODEQ determine the need for a public meeting, the ODEQ shall expeditiously schedule and hold a formal public meeting no more than 120 days after the date the notice was published. The public meeting shall be held at a location convenient to and near the SORD. At the meeting, any person may submit oral or written statements and data concerning the draft permit or permit application. The public comment period shall automatically be extended at the close of the public meeting. A representative of the SORD shall be present at the meeting to respond to questions.

After the public comment period, the ODEQ shall prepare a response to comments and issue a final denial or a proposed permit. If a proposed permit is prepared, the SORD shall provide notice of the proposed permit by publishing a legal notice in The Daily Ardmoreite newspaper. The notice shall identify locations where the proposed permit and the ODEQ response to comments may be reviewed by the public, including a location in Carter County, where the site is located. The publication will include notice of a 20 day opportunity to request an administrative hearing. In addition, notices will be provided by certified mail and return receipt request to adjacent landowners whose property may be affected by the horizontal expansion of the SORD.

The opportunity to request an administrative hearing shall be available to the SORD and any person or qualified interest group who claims that the construction or operation of the landfill would directly and adversely affect their interests. If no written administrative hearing request is received by the ODEQ by the end of the 20 day opportunity, the final permit shall be issued.
If an administrative hearing is timely requested on the proposed permit, the ODEQ shall schedule a hearing. All timely requests shall be combined in a single hearing, and the hearing shall be conducted by an Administrative Law Judge. A representative of the SORD shall attend the hearing, which shall be scheduled within 60 days of the end of the 20 day hearing request opportunity. Upon final issuance or denial of a permit for this Tier III application, the ODEQ shall provide public notice of the final permit decision and availability of the response to comments, if any. A written affidavit of all notice publications by the SORD should be submitted to ODEQ within 20 days of the publication.
3.0 GENERAL INFORMATION

The SORD is a municipal solid waste landfill, which accepts municipal and industrial sludge, non-hazardous industrial waste (NHIW), non-friable asbestos, municipal waste, residential waste, construction and demolition waste, and commercial waste. The following is general information for the facility:

Facility Name: Southern Oklahoma Regional Disposal Landfill
Mailing Address: P.O. Box 1088, Ardmore, Oklahoma 73402
Physical Location: 31 Sord Dr, Ardmore, OK 73401
Facility Owner/Operator: Southern Oklahoma Regional Disposal, Inc.
Facility Phone Number: (580) 226-1276
Hours of Operation: Monday-Friday 8:00am-5:00pm, Saturday 8:00am-12:00pm
Primary Contact: Troy Duke

3.1 OATH

OAC 252:515-3-33 requires the applicant to sign the permit application under oath on forms provided by the ODEQ. The signed oath is attached to the cover letter of this application.

3.2 LEGAL DESCRIPTION

The legal description of the SORD permit boundary is as follows: The NE/4 of the NE/4, the SE/4 of the NE/4, the SW/4 of the NE/4, and the NW/4 of the NE/4 of Section 24, Township 4 South, Range 2 East, Carter County, Oklahoma and the S/2 of the S/2 of the SE/4 of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

3.3 LEGAL RIGHT TO PROPERTY

OAC 252:515-3-34(a)(1) requires that the SORD have a true and correct copy of a legal document filed in Carter County, demonstrating that the applicant possesses a legal right to access and use the property in the manner outlined in this application. Documentation showing that Southern Oklahoma Regional Disposal, Inc. owns the property containing the SORD and its proposed expansion area is included as part of the Closure and Post-Closure Plan found in Appendix K of this application.
3.4 ADJACENT PROPERTY OWNER NOTIFICATION

Notification of the proposed landfill expansion was provided to adjacent properties owners and copies of the notification letters and delivery confirmations are included in Appendix A. The notification letter provided to Ms. Kelly Kendrick was unclaimed. A second notification letter was submitted and delivered on December 5, 2018. Delivery confirmation is included in Appendix A.

3.5 AESTHETIC ENHANCEMENT

Due to the site's rural location and the dense vegetation surrounding the site, it is anticipated that the horizontal expansion of the SORD will have a minimal effect on aesthetics. The guidelines outlined in the facility’s Operations Plan, included in Appendix I, should control vectors at the site and keep the SORD aesthetically pleasing.

3.6 AIR QUALITY

The SORD will conform to applicable ambient air quality and source control regulations. The SORD's current permitted capacity is greater than 2.5 million cubic yards as detailed in Section 6.2.1 and is subject to 40 CFR 70 permitting. SORD operates under Operating Permit No. 2012-311-TVR2. Odors will be controlled at the site through proper operations and, more specifically, through proper application of daily, intermediate, and final cover. Cover requirements are further discussed in Section 13. Dust control is discussed in the site's Operations Plan included in Appendix I.
4.0 LOCATION RESTRICTIONS

All active solid waste disposal facilities are subject to the location restrictions set forth by the ODEQ in OAC 252:515-5. The subchapters of this section show compliance with the location restrictions for solid waste disposal facilities.

4.1 SCENIC RIVERS

No area within the permit boundary of the horizontal expansion shall be located within the drainage basin of any river designated by the Oklahoma Scenic Rivers Commission Act. Appendix A contains correspondence from the Oklahoma Scenic Rivers Commission, dated June 27, 2015, stating that the expansion of the SORD will have no adverse impact on any of Oklahoma's Scenic River Areas.

4.2 RECREATION AND PRESERVATION AREAS

No area within the permit boundary of the horizontal expansion shall be located within one-half mile of any area formally dedicated and managed for public recreation or natural preservation by a federal, state, or local government agency. Appendix A contains correspondences from the Oklahoma Archeological Survey dated July 9, 2015, the US Department of the Interior – Bureau of Reclamation dated June 29, 2015, and the Oklahoma Tourism and Recreation Department dated July 30, 2015. The letters indicate that the expansion of the SORD will not be within one-half mile of any area formally dedicated and managed for public recreation or national preservation.

4.3 ENDANGERED OR THREATENED SPECIES

For the SORD horizontal expansion area, statements from the Oklahoma Department of Wildlife Conservation (ODWC), the United States Fish and Wildlife Service (USFWS), and the Oklahoma Biological Survey (OBS) shall be submitted regarding current information about endangered or threatened wildlife or plant species listed in state and federal laws that exist within one mile of the expansion area. Appendix A contains correspondences from the ODWC and OBS dated August 5, 2015, and June 25, 2015, respectively, stating that it is unlikely for endangered or threatened wildlife or plant species listed in state and federal laws to be located within one mile of the expansion area and/or stating that the SORD horizontal expansion is not likely to adversely affect any threatened or endangered species in the area. On August 5, 2015, the USFWS requested further information on the presence of American Burying Beetle (ABB) habitat within the expansion area. From July 30, 2017, to August 4, 2017, SCS conducted a survey of the ABB on the proposed expansion area. No ABBs were collected during the study. The ABB Survey was submitted in September 2017, and a copy is included in Appendix A.

4.4 100-YEAR FLOODPLAIN

No solid waste disposal facilities shall be located within the 100-year floodplain. Carter County, Oklahoma does participate in the National Flood Insurance Program (NFIP) under the Federal
Emergency Management Agency (FEMA). Figure 2 of this application shows the Flood Insurance Rate Map for Carter County, published by the NFIP and effective on April 19, 2010. According to the map, the northwest corner of the proposed permit boundary is located near the edge of the floodplain. However, no landfill development is planned for that area. The remaining area of the proposed expansion is not in or near the floodplain.

4.5 PUBLIC WATER SUPPLY

The SORD horizontal expansion area shall not be located within one mile upgradient of an existing public water supply surface intake, including those permitted for construction, or within a one year time of travel of a public water supply well. Appendix A contains a note to file dated March 9, 2018, explaining correspondence between SCS Engineers, the Oklahoma Water Resources Board, and the Oklahoma Department of Environmental Quality to determine that there are no public water supply surface intakes within one mile or any public water supply wells within a one year travel time of the horizontal expansion area.

4.6 WELLHEAD PROTECTION AREA

Under OAC 252:515-5-32(c), if the horizontal expansion area is located within two miles of a public water supply well, a wellhead protection area shall be identified and submitted to the ODEQ, as specified by the State Wellhead Protection Plan. Based on correspondence with the Oklahoma Water Resources Board dated March 9, 2018, and located in Appendix A of this application, there are no public water supply wells located within two miles of the horizontal expansion area.

4.7 WETLANDS

No solid waste disposal facility shall be located within wetland areas as designated by the Oklahoma Conservation Commission (OCC) or other appropriate agency. Appendix A contains a correspondence letter from the OCC, dated June 25, 2015, stating that the expansion area most likely does not contain wetland ecosystems and the proposed expansion should not significantly impact wetland resources in the area.

Appendix A also includes additional correspondence that was submitted to the U.S. Army Corps of Engineers and response dated April 15, 2016 stating that no jurisdictional wetlands were located within the reviewed area. However, the unnamed tributary of Sand Branch and on-channel pond were determined to be regulated waterways. SCS submitted an additional correspondence letters on October 4, 2016 and February 7, 2017 to the U.S. Army Corps of Engineers regarding this item. No placement of dredged or fill material, permanently or temporarily, into the unnamed tributary of Sand Branch and on-channel pond is proposed and therefore no Section 401/404 permits are required for the proposed expansion.
4.8 TERRACE DEPOSITS

The SORD horizontal expansion area shall not be located within an area designated as alluvium or terrace deposits and their recharge areas, as shown on the Map of Aquifers and Recharge Areas in Oklahoma, compiled by Kenneth S. Johnson of the Oklahoma Geologic Survey (OGS) dated 1991. Appendix A contains a correspondence email from the OGS, dated July 6, 2015, stating that a part of the proposed site contains alluvium deposits.

Further correspondence with the OGS indicated that the map consulted was actually publication OGQ-86, Preliminary Geologic Map of the Ardmore 30' X 60' Quadrangle and the Oklahoma Part of the Gainesville 30' X 60' Quadrangle, Carter, Jefferson, Love, Murray, and Stephens Counties, Oklahoma. However, OAC 252:515-5-51(a)(1) states, “no area within the permit boundary of a new land disposal facility, or expansion of the permit boundary of an existing land disposal facility, shall be located within an area designated as alluvium or terrace deposits and their recharge areas, as shown on "Map of Aquifers and Recharge Areas in Oklahoma" compiled by Kenneth S. Johnson, Oklahoma Geological Survey (1991).” Review of the Map of Aquifers and Recharge Areas in Oklahoma indicates that there are no areas designated as alluvium or terrace deposits and their recharge areas in the proposed landfill expansion area. The map and correspondence are contained in Appendix A.

4.9 KARST TERRAIN

Appendix A contains correspondence documentation between SCS and the Oklahoma Geologic Survey. Review of Figure 24 of Geologic Hazards in Oklahoma and the ODEQ online map system confirmed that no karst terrain exists in the vicinity of the proposed expansion area.

4.10 EARTHQUAKE EPICENTER AREA

The SORD horizontal expansion area shall not be located within five miles of a known epicenter of an earthquake of more than 4.0 on the Richter Scale, or a number V on the modified Mercalli (MM) scale, as recorded by the Oklahoma Geological Survey. Appendix A contains a correspondence letter from the Oklahoma Geologic Survey, dated July 6, 2015, stating that no magnitude 4.0 and/or MM V earthquakes are within five miles of the expansion area.

4.11 UTILITY/TRANSMISSION LINES

A minimum horizontal separation of 25 feet shall be maintained between disposal areas of land disposal facilities and any aboveground or underground pipeline or transmission line. Information on the locations and owners of all such lines and easements shall be provided to the ODEQ. Appendix A contains a certified mail receipt from a submittal to the Oklahoma Corporation Commission, dated June 19, 2015, but no response was received from the agency.

No utility or transmission line is located within 25 feet of the proposed waste boundary.
4.12 FAULT AREAS

The SORD horizontal expansion area shall not be located within 200 feet of a fault that has had displacement in Holocene time. Appendix A contains correspondence from the Oklahoma Geologic Survey, dated July 6, 2015, stating that no known Holocene faults have occurred within 200 feet of the horizontal expansion area. A topographic map of the area is included as Figure 3.

4.13 SEISMIC IMPACT ZONES

The SORD horizontal expansion area shall not be located in a seismic impact zone. This restriction may be waived upon successful demonstration that all containment structures, including liners, leachate collection system, and surface water control systems, are designed to resist the maximum horizontal and vertical displacement in lithified earth material for the site. Appendix A contains a correspondence letter from the Oklahoma Geologic Survey, dated July 6, 2015, stating that the site is not located in a seismic impact zone, an area in which it is probable that the maximum horizontal acceleration will exceed .10-.11g in 250 years. Regardless, the Liner and Final Cover System Stability Analysis in Appendix C of this application demonstrate that the containment structures are designed to resist the potential maximum horizontal and vertical displacement.

4.14 UNSTABLE AREAS

The SORD horizontal expansion area shall not be located over a subsurface mining area or any other unstable area. Appendix A contains a certified mail receipt from a submittal to the Oklahoma Department of Mines, dated June 22, 2015, but no response was received from the agency.

4.15 AIRPORTS

The SORD horizontal expansion area shall not be located within 10,000 feet of any airport runway end used by turbojet aircraft or within 5,000 feet of any airport runway end used by only piston-type aircraft. The Bass Aero Airport is located northwest of SORD and is used by only piston-type aircraft. The General Location Map (Figure 1) demonstrates that the SORD is not located within the 5,000 foot requirement for piston-type aircraft and therefore satisfies the location restriction for airports.

Since the SORD horizontal expansion area is located within a 5 mile radius of the Bass Aero Airport, the airport and the Federal Aviation Administration (FAA) have been notified in writing of the planned expansion in accordance with OAC 252:515-5-52(e)(1). No responses were received. Copies of the certified mail receipts and the letters mailed to the FAA and the Bass Aero Airport are included in Appendix A.
4.16 BUFFER ZONES

In accordance with OAC 252:515-19-38(b)(2), municipal solid waste landfills incorporating land not permitted for disposal prior to July 1, 1994 shall have a waste-free buffer zone of at least 100 feet in width from the site's property boundary. As shown in the Permit Drawings of this application, the waste boundary of the proposed expansion area is 100 feet away from the property boundary of the SORD.
5.0 SUBSURFACE INVESTIGATION

A geotechnical and hydrogeological investigation has been conducted at the SORD over the proposed expansion area of the landfill. The field investigation for determining subsurface soil and groundwater characteristics consisted of drilling 20 exploratory borings, 11 of which were completed as piezometers. The results of the investigation are detailed in the report *Hydrogeologic and Geotechnical Investigation* prepared by SCS Engineers, dated April 2018 included in this application as Appendix B. Results of the subsurface investigation were considered while designing the horizontal expansion area for the SORD.
6.0 LANDFILL DEVELOPMENT

This section, in conjunction with the accompanying drawings and appendices, addresses the various design and operational elements of the SORD horizontal expansion.

6.1 DESIGN CRITERIA

The development of the SORD horizontal expansion was based on the following design criteria:

- Compliance with Subtitle D requirements.
- Final sideslopes will be created at a maximum 4:1. The slope of the top of the landfill (crown) will be no less than 4 percent.
- Drainage swales and letdowns will be developed to improve surface water drainage.
- Surface water diversionary structures will be capable of handling at a minimum the 25-year 24-hour storm event.
- Seismic and stability design criteria established in the Liner and Final Cover Stability Analysis (Appendix C) are to be incorporated into the design.

The applicable regulations followed in part or entirely are as follows:

- OAC 252:515
- 40 CFR Part 257 and 258 (Subtitle D)

6.2 LANDFILL DEVELOPMENT

The existing permit boundary contains approximately 120 acres. Approximately 65.84 acres have been developed for municipal solid waste disposal, of which 43.20 acres have been developed with a Pre-Subtitle D liner, and the remaining 22.64 acres have been developed with a Subtitle D composite liner system.

The horizontal expansion proposes to increase the permit boundary by 80 acres for a total of 200 acres. The site will be developed in phases with Cell 3 consisting of approximately 16.9 acres, Cell 4 and Cell 5 consisting of approximately 15.6 acres each, and Cell 6 consisting of approximately 15.9 acres.
6.2.1 Capacity Increase

A summary of the capacity increase is listed below.

<table>
<thead>
<tr>
<th>Item</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Design Capacity</td>
<td>8,034,959 Cubic Yards</td>
</tr>
<tr>
<td>Base Grade Modification and Expansion Increase</td>
<td>15,261,128 Cubic Yards</td>
</tr>
<tr>
<td>Proposed Capacity</td>
<td>23,296,087 Cubic Yards</td>
</tr>
</tbody>
</table>

6.2.2 Sequence of Development

The landfill will be developed through the construction of phases. The first phase of the horizontal expansion to be constructed will be the western portions of Cells 5 and 6. The remaining portions of Cells 5 and 6 as well as the remaining phases will be developed as needed from north to south.

Filling should begin at the lowest elevations of each phase and work toward higher elevations to prevent excess leachate generation. Temporary drainage swales and channels should be constructed, as needed, on intermediate contours to control surface water and minimize leachate generation. It should be recognized that the phasing plans are conceptual in nature and may require revision during the operation of the facility.

The daily cells will be operated using the area fill method with lifts generally not exceeding 10 feet high. Under this method, the working cell is built next to the previous day's working daily cell until an established row length is reached. Then another row is started parallel to the previously constructed row. After a number of rows have been constructed, a second lift is constructed over the first lift. Daily cell row construction will alternate between various lifts of refuse and will allow landfill traffic to discharge waste at various levels.

The main two criteria used when establishing the sequence of fill are as follows:

1. Areas should be small enough to allow organized, controlled development, and;
2. Development should be sequenced such that surface water runoff does not flow into the working area.

A layer of 6 inches of daily cover or approved alternative daily cover will be placed on the top of waste each day.

The landfill will be developed to provide for long-term stability of the entire landfill. Included in Appendix C is a Liner and Final Cover Stability Analysis for the SORD. This analysis confirms the landfill is stable under active, intermediate, and final development of the landfill. The design of the expansion area, particularly the base grades and cap components, are based on meeting factor of safety requirements and site specific conditions.
7.0 GROUNDWATER MONITORING

A detailed hydrogeologic and geotechnical investigation has been conducted at this site. The report for this investigation entitled, *Hydrogeologic and Geotechnical Investigation*, is included in Appendix B. Results of this subsurface investigation were used in selecting locations for groundwater monitoring detection wells. A Groundwater Monitoring Plan has been included with this application in Appendix D. The Groundwater Monitoring Plan is intended to be used as a standalone document, a copy of which will be maintained within the facility’s operating record. The Groundwater Monitoring Plan contains pertinent information for existing and proposed detection wells and piezometers, as well as schedules and proper sampling and statistical analysis procedures to complete groundwater monitoring events.

The groundwater monitoring wells have been and will be installed to yield groundwater samples from the uppermost aquifer that represent the quality of background groundwater that has not been affected by the SORD and that represent the quality of groundwater that has passed underneath the SORD. Background groundwater quality was established during the subsurface investigation for existing wells. The results of the background levels for existing groundwater monitoring wells are summarized in the *Statistical Analysis for Groundwater Monitoring* report prepared by Enivro Clean Cardinal, dated January 2018, which is not included as part of the application.

Groundwater monitoring wells were installed on land owned by the SORD and at a distance of no more than 150 meters from the permitted waste boundary of the disposal area. One monitoring well is located upgradient of the landfill (MW-1), and four monitoring wells are downgradient (MW-2R, MW-3, MW-4, and MW-5). Because the horizontal expansion will be contiguous with the existing landfill, three monitoring wells (MW-2R, MW-4 and MW-5) are proposed to be removed from the groundwater monitoring network and will be plugged and abandoned in accordance with the OWRB, as stated in the OAC 785:35. Also, six new detection wells (MW-6, MW-7, MW-8, MW-9, MW-10, and MW-11) are proposed. Existing piezometer PZ-9 will become MW-9 and existing piezometer PZ-5 will become MW-11. Figure 2 of Appendix D shows the location of all abandoned, existing, and proposed borings, piezometers, and detection wells. Detailed information regarding the proposed monitoring network is included in Appendix D of this application.

The SORD will provide the ODEQ with two weeks written notice prior to any drilling. The monitoring wells will be installed in accordance with OAC 785:35 and registered online or by mail with the Oklahoma Water Resources Board (OWRB) by a licensed monitoring well installation contractor within 60 days after installation.

Background groundwater quality establishment is required at each new monitoring well in accordance with OAC 252:515-9-31. Four quarters of statistically independent data are required to be collected for each parameter or constituent. At a minimum, wells should monitor for constituents listed in OAC 252:515-9-31(d)(1). Background groundwater data should contain the natural variations in groundwater chemistry. Ideally, the background data should contain enough data points to conduct the selected statistical analysis and exhibit any seasonal, temporal, or
spatial variability. The background groundwater quality data should be representative of the groundwater quality near the landfill and not impacted by the landfill.

Groundwater samples for detection monitoring should be collected following the same sampling procedures used to collect the background groundwater quality samples. Samples are to be collected from the monitoring wells semi-annually. A report of the sampling results and results of the statistical analysis will be submitted to the ODEQ within 60 days of the sampling date. Sampling procedures for groundwater sampling are detailed in the Groundwater Monitoring Plan in Appendix D.
8.0 EXPLOSIVE GAS MONITORING

The decomposition of encapsulated solid waste within a landfill is known to produce landfill gas, typically consisting of approximately 50% methane (CH₄) and 50% carbon dioxide (CO₂). Trace amounts of non-methane organic compounds (NMOCs), oxygen, hydrogen sulfide, and reactive organic gases are also present (Engineering and Design Landfill Off-Gas Collection and Treatment Systems, U.S. Army Corps of Engineers, 1995).

Per OAC 252:515-15-2, the concentration of methane gas generated by the facility shall not exceed twenty-five percent (25%) of the lower explosive limit (LEL) for methane in all structures within the permit boundary or exceed the LEL for methane at the permit boundary. The LEL is defined as the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25°C and atmospheric pressure. The LEL for methane is 5% by volume in air.

OAC 252:515-15-3(a) requires an Explosive Gas Monitoring Plan to be submitted and approved by the ODEQ to demonstrate how compliance with the LEL listed in OAC 252:515-15-2 will be achieved. A copy of the Explosive Gas Monitoring Plan is included with this application as Appendix E. The Explosive Gas Monitoring Plan is intended to be used as a standalone document, a copy of which will be maintained within the facility's operating record.

Upon approval of the proposed horizontal expansion, fourteen existing gas monitoring probes (GMW-1, GMW-2, GMW-3, GMW-4, GMW-5, GMW-6, GMW-7, GMW-8, GMW-9, GMW-10, GMW-11, GMW-15, GMW-16, and GMW-17) will remain in place, three existing gas probes will be decommissioned (GMW-12, GMW-13, and GMW-14), and ten additional gas probes (GMW-18, GMW-19, GMW-20, GMW-21, GMW-22, GMW-23, GMW-24, GMW-25, GMW-26, and GMW-27) will be installed according to OAC 252:515-15-4 as well as the Oklahoma Water Resources Board (OWRB) requirements detailed in OAC 785:35.
9.0 STORM WATER MANAGEMENT

9.1 OKR05 PERMIT REQUIREMENTS

State law requires an Oklahoma Pollutant Discharge Elimination System (OPDES) Permit be obtained to allow storm water to discharge from this facility. Under state regulations, the SORD is subject to requirements of the ODEQ Department of Water Quality Division Sector L Industrial General Permit OKR05 (OKR05). Under the requirements of OKR05, the facility is to prepare and maintain a Storm Water Pollution Prevention Plan (SWP3). The SWP3 describes the SORD and its operations, identifies potential sources of storm water pollution at the facility, recommends appropriate Best Management Practices (BMPs) or pollution control measures to reduce the discharge of pollutants in storm water runoff, and provides procedures for regular inspections, storm water monitoring, recordkeeping and reporting, and periodic review of the SWP3.

The SWP3 for the facility is maintained at the SORD. As shown in the Permit Drawings, the proposed permit modification will alter surface water drainage and outfall locations from their present locations. As storm water confluence is altered at the facility, the site's SWP3 shall be amended accordingly.

9.2 RUN-ON CONTROL SYSTEMS

In accordance with OAC 252:515-17-2(1), the SORD has been designed to have a run-on control system to prevent flow onto active portions of the facility during the peak discharge from a 24-hour, 25-year storm event. Detail C of the Permit Drawings shows the design for a temporary separation berm. The temporary separation berms will be constructed, as needed, between phases as the landfill is expanded. Additional run-on control features such as diversion berms will be constructed upgradient of the construction areas and active portions of the landfill.

9.3 RUN-OFF CONTROL SYSTEMS

The peak volume and flow were calculated using the SCS TR-55 Hydrology Method and the SCS TR-55 Time of Concentration Method associated with Hydraflow Hydrographs Extension for AutoCAD Civil 3D 2016. The flows for each surface water structure were determined to show that the run-off controls are adequately sized to handle a 24-hour, 25-year single storm event. Surface water model results and calculations are included in the Surface Water Drainage System Design Report in Appendix F.

The existing storm water impoundment located in the northwest corner of the facility has a storage capacity of 1,489,874 cubic feet of water. The calculated combined discharge from the current waste footprint is 1,218,176 cubic feet. As the landfill waste footprint is expanded, the storm water impoundment will be expanded accordingly to handle the 24-hour, 25-year single storm event.
The following surface water management structures will be constructed to control surface water flow:

- Drainage swales,
- Letdown channels, and
- Perimeter channels.

9.3.1 Drainage Swales

The drainage swales are V-shaped, with 4:1 uphill sideslopes and 3:1 downhill sideslopes. The drainage swales have a height of 3.0 feet and will be sloped at approximately 1.0 percent towards the letdown channels on side slopes, as shown in the Permit Drawings. Design calculations for drainage swales can be found in Appendix F.

9.3.2 Letdown Channels

The drainage area for the letdown channel was determined based on channel and sheet flow from each sub-basin draining to the letdown channel. A peak flow was determined by utilizing a time of concentration for the worst-case point (i.e., the point within the drainage area located furthest away from the letdown) and applying that time of concentration to the entire area. Thus, a conservative design is achieved. Calculations for the letdown channel are shown in the Surface Water System Design Report located in Appendix F.

The letdown is trapezoidal shaped with 3:1 side slopes, a bottom width of 8 feet, and a depth of 2.0 feet. The letdown channels are sloped at approximately 25 percent towards the perimeter drainage channels. Alternate materials may be used to line the letdown channel such as HDPE, manufactured erosion, etc., but must be approved by ODEQ prior to installation.

9.3.3 Perimeter Drainage Channels

The perimeter channels will vary in dimension but generally will be vegetated channels, 3 feet deep with a bottom width of 4 to 14 feet and 3:1 side slopes. The channels will be sloped toward a discharge point at an approximate average slope of 1.0 percent. Design calculations for perimeter ditches can be found in the Surface Water System Design Report in Appendix F.
10.0 LINER CONSTRUCTION

A composite liner system will be constructed to protect groundwater quality. The composite liner system will conform to specifications included in OAC 252:515-11 and consist of the following layers from bottom to top:

- Compacted subgrade
- 24 inches of compacted soil liner (less than or equal to 1x10^-7 centimeters per second (cm/sec) hydraulic conductivity),
- 60-mil high density polyethylene (HDPE) smooth or double-sided textured geomembrane liner,
- 8 oz/sq yd non-woven geotextile fabric cushion layer, and
- 24" of granular drainage/protective cover material (greater than or equal to 1x10^-3 cm/sec hydraulic conductivity).

Where fill is necessary to achieve subgrade elevations, the subgrade component of the liner will be placed in uniform lifts that do not exceed 9 inches in loose thickness and are compacted to at least 95 percent of standard Proctor (ASTM D 698) at a moisture content ranging from one percentage point below optimum to three percentage points above optimum. The top 6 inches of compacted fill material underlying the soil liner will have a maximum particle size of 2-inch diameter. Where excavation is necessary to achieve subgrade elevations the upper 6 inches of soil subgrade will be recompacted, and graded to provide a relatively smooth workable surface on which to construct the compacted soil liner component.

The compacted soil liner will be constructed by placing uniform lifts not exceeding 9 inches in loose thickness to produce compacted lifts of approximately 6 inches. The soil liner will be compacted to a moisture content and density condition consistent with that necessary to produce a competent liner with a hydraulic conductivity less than or equal to 1 x 10^-7 cm/sec. The appropriate moisture content and density condition will be determined prior to construction for each type of material to be used.

Generally, densities greater than 95 percent of Standard Proctor maximum dry density and moisture contents exceeding the optimum moisture content are necessary to achieve a hydraulic conductivity of less than or equal to 1 x 10^-7 cm/sec. Compaction will be completed utilizing an appropriately heavy, properly ballasted, penetrating-foot compactor (such as a CAT 815 or equivalent). Dozer or scraper equipment will not be used for primary compaction efforts. One of the goals of compaction is to allow thorough remolding of the clay by kneading action. Following construction, the compacted soil liner will be protected from desiccation or freeze/thaw cycles by geosynthetics and protective cover materials as necessary.

The soils used in the construction of the compacted soil liner will meet the following minimum specifications:

- Contain less than or equal to 20 percent gravel (dry-weight percentage retained on the No. 4 sieve);
- Allow more than 30 percent passage through a Number 200 Sieve;
- Have a liquid limit greater than or equal to 24 percent;
- Have a plasticity index greater than or equal to 10 percent;
- Particle size shall be less than 1 inch diameter;
- After the soil is compacted, the water content of the soil shall be equal to or greater than optimum;
- After the soil is compacted, the minimum density of the soil shall be greater than or equal to 95 percent of the standard proctor density (ASTM D698) or 90 percent of the modified proctor density (ASTM D1557).

Specific information pertaining to quality assurance and quality control during construction of the liner system is included in the Quality Assurance / Quality Control (QA/QC) Plan for Liner and Leachate Collection System Installation and Testing, which is included with this application in Appendix G. The QA/QC Plan is intended to be used as a standalone document, a copy of which will be maintained within the facility’s operating record.

Appendix C includes liner stability calculations. These calculations confirm the stability of the liner system for the proposed design.

The geomembrane will be installed in accordance with the manufacturer’s recommendation for a facility of this type. A geotextile cushion layer will then be placed in accordance with manufacturer’s recommendations to protect the geomembrane from the overlying granular leachate collection layer. Quality assurance and quality control procedures to be followed during construction of this liner system can be found in the QA/QC Plan.
11.0 LEACHATE COLLECTION AND MANAGEMENT

The design of the leachate collection system (LCS) was based on the following criteria:

- Minimum slope along the leachate pipe is 0.5 percent.
- Minimum slope to the leachate pipe is 0.5 percent.
- Twelve inches or less of head must be maintained on the liner during all phases (active, interim, and closed). To accomplish this, a drainage media will be used and will have a minimum hydraulic conductivity of $1.0 \times 10^{-3}$ cm/sec.

The LCS, designed to collect and remove leachate from the landfill and reduce the potential leachate head on the liner system, has been included in the design of the expansion. This system has been designed in accordance with OAC 252:515-13 to effectively manage leachate for both the operating life of the landfill and the 30-year post closure period. Specifically, the system has been designed to function without clogging through the scheduled operating life, closure, and post-closure of the landfill. In general, the LCS will use gravity drainage from the existing landfill as well as in the expansion area to drain to the sumps at the perimeter of the landfill.

The existing subtitle D landfill (Cells 7-9) and LCS currently employs leachate collection piping draining to the existing leachate storage impoundment located north of Cells 7 and 8. The expansion will not require a transition between the existing LCS and the expansion LCS as they will remain separate.

The LCS will consist of the following:

- Collection pipe network
- 8-oz/sqy non-woven geotextile
- 24 inches of granular material
- Leachate collection sumps
- Associated leachate pumping systems
- 2-acre Leachate Evaporation Pond

An 8-oz/sqy non-woven geotextile will be placed directly on top of the 60-mil HDPE geomembrane liner prior to placement of the granular material for cushioning purposes. The effectiveness of the LCS has been evaluated using the Hydrologic Evaluation of Landfill Performance (HELP) model, Version 3.07. Design details of the landfill and weather data for the Ardmore, Oklahoma area were used to determine leachate volumes produced during the life of the landfill as well as the maximum hydraulic head created on the liner system.

The HELP model was run for three operating scenarios to model the landfill at various stages of its development (active, interim, and closed). The table below summarizes the modeling scenarios.
HELP MODEL SCENARIO

ACTIVE – 20 FEET OF MSW IN PLACE
INTERIM – 120 FEET OF MSW IN PLACE
CLOSED – 220 FEET OF MSW IN PLACE

Modeling indicated that the design will not result in a leachate head greater than 12 inches on the liner system for each scenario as required by OAC 252:515-13-31(b)(1). HELP model results are located in Appendix H.

HELP modeling was completed on a "1 acre" basis to allow for leachate generation quantities to be applied to various operating stages of the landfill. Specifically, active, interim, and closed leachate generation quantities were applied to the estimated acreage of active, interim, and closed conditions, respectively, to estimate leachate volumes at different stages of landfill development. A summary of leachate generation quantities is included in Appendix H.

11.1 LEACHATE DRAINAGE LAYER

A leachate drainage layer is necessary above the liner to drain leachate away from the waste to the leachate collection sumps. The leachate drainage layer will consist of a minimum of 12 inches of granular material placed on top of the bottom liner system. Prior to placement of the granular material, an 8-oz/sq yd non-woven geotextile cushion will be placed directly on top of the geomembrane liner to cushion and protect the geomembrane liner from the overlying granular leachate collection material. The granular material should be clean, with a minimum hydraulic conductivity of $1 \times 10^{-3}$ cm/sec.

Aggregate placement/spreading techniques that minimize the potential for damage to the underlying geomembrane liner shall be used. Specifically, the granular material will be placed by advancing the aggregate in fingers across the underlying geotextile and geomembrane liner. Low ground pressure equipment, such as a light-weight, wide-tracked dozer, will be used for spreading the aggregate. During granular drainage layer installation, periodic visits to the site will be made by the CQA Inspector to observe and document installation procedures. A 12 inch granular protective cover layer will be placed on top of the 12 inch leachate collection layer. The 12 inch granular leachate collection layer and 12 inch protective layer will likely consist of the same material and be installed in conjunction.

The drainage material, in combination with positive slopes of a minimum of 0.5 percent will induce gravity flow of leachate toward a leachate collection pipe network. The HELP model results indicate that this design maintains less than 12 inches of head on the liner at all times.
11.2 LEACHATE COLLECTION PIPE NETWORK

In the expansion area, perforated, 6 inch leachate collection pipes will be strategically placed on top of the geosynthetic liner and geotextile within the granular drainage material to direct leachate flow to the collection sump. The collection pipes are located to minimize the distance that leachate will flow through the drainage layer prior to intercepting a collection pipe. The collection pipes are sloped at a minimum of 0.5 percent toward leachate impoundments located north and east of the landfill.

The 6 inch collection pipes will be constructed of HDPE material with a Standard Dimension Ratio (SDR) of 11 or equivalent. Pipe perforations will consist of three rows of 0.5 inch diameter holes drilled at a 60-degree angle from vertical on the bottom of each side of the pipe. Holes will be spaced in 4-inch increments. The collection pipes will be bedded in granular material and protected by a geotextile to serve as a filtering mechanism to keep silt and other fines from clogging the pipes. Per OAC 252:515-13-14, the leachate collection pipes shall be cleaned out after placement of protective cover layer, again after the placement of the first lift of waste, and once per year thereafter.

Design calculations were completed to evaluate the structural strength imposed by the overlying waste and potential equipment loads (see Appendix H for calculations). Typical details for collection pipes, pipe perforations, and surrounding granular material are shown in the Permit Drawings.

11.3 LEACHATE COLLECTION SUMPS

Four leachate collection sumps are proposed. The sumps will provide collection points from which leachate can be removed from the landfill. Leachate will drain into the sumps through collection pipes directly from the drainage layer. The sumps will be located on the east side of the expansion area and will have dimensions of approximately 24 feet by 24 feet by 2 feet deep. The sumps will be filled with clean, non-carbonate drainage stone to an elevation even with the surrounding granular material layer.

11.4 LEACHATE PUMPING SYSTEM

Leachate will be removed from the sumps using submersible pumps or aboveground pumps. One 18 inch diameter perforated PVC or HDPE pipe, holding submersible pumps, will be buried in the sump to access the leachate. The 18-inch HDPE SDR 11 or PVC Schedule 80 perforated pipes will exit the sump as a solid pipe and follow the 3:1 side slope to the top of the landfill composite liner system, where it can be accessed outside of the landfill footprint. This access point will allow pumps and associated hoses and cables to be lowered into the sump and removed, as needed for maintenance or replacement. The leachate collection system will be equipped with a system for automatic and continuous removal of leachate not requiring intervention by the owner/operator. Leachate levels will be monitored with a pressure transducer and level readout at the surface. The system will also be equipped with a high level alarm to inform site personnel when the leachate head on the liner exceeds 12 inches.
11.5 LEACHATE STORAGE AND DISPOSAL

Leachate generated within existing Cells 7-9 collects and gravity drains to the existing leachate storage impoundment located north of Cells 7 and 8.

Leachate collected in Cells 3-6 will be pumped up the side slope to a dual contained force main and transported via the dual contained force main to the proposed leachate storage impoundment. The proposed leachate storage impoundment will be constructed in accordance with the Quality Assurance/Quality Control Plan for Liner and Leachate Collection System Installation and Testing. A composite liner system will be constructed to protect groundwater quality. The composite liner system will conform to specifications included in OAC 252:515-11 and consist of the following layers from bottom to top:

- Compacted subgrade
- 24 inches of compacted soil liner (less than or equal to $1 \times 10^{-7}$ centimeters per second (cm/sec) hydraulic conductivity)
- 60-mil high density polyethylene (HDPE) smooth on floor and double-sided textured geomembrane liner on slope

The proposed leachate storage impoundment will maintain a minimum 3 feet of freeboard with a capacity of 3,327,118 gallons. The HELP model calculated the highest daily leachate drainage collected rate which occurred during peak closed condition and is equal to 4.6065 gallons/acre/day. Based upon the approximate 64 acres of proposed cell development within Cells 3-6 the estimated annual drainage collected is 107,608 gallons/year.

Leachate stored in the leachate storage impoundments will be recirculated and/or irrigated in accordance with their approved plans.
12.0 SITE OPERATIONS

In accordance with OAC 252:515-19, an Operations Plan has been prepared and is included with this application in Appendix I. The Operations Plan is intended to be used as a standalone document, a copy of which will be maintained within the facility’s operating record. The Operations Plan provides pertinent operational methods and procedures to provide public access control, control litter, control emissions, control disease vectors, place waste, and measure and report incoming waste. The Operations Plan outlines acceptable waste streams as well as limitations on incoming waste streams, as well as recordkeeping and reporting requirements for the SORD.

Acceptable and prohibited wastes for the SORD are outlined in depth in the Waste Exclusion Plan, included with this application in Appendix J. The Waste Exclusion Plan is intended to be used as a standalone document, a copy of which is maintained within the facility’s operating record. The Waste Exclusion Plan also provides information on restrictions for the disposal of bulk liquids, restrictions on the disposal of municipal sewages, as well as recordkeeping and reporting requirements for incoming waste streams.

The SORD is currently conducting a recycling/salvage operation. The recycling/salvage operation at the SORD will be conducted as outlined in the Operations Plan.
13.0 COVER AND SOIL BORROW REQUIREMENTS

Cover will be applied to reduce fire hazards, infiltration, odors, and blowing litter; to control gas venting and vectors; to discourage scavenging; and to provide a pleasing appearance.

13.1 DAILY AND INTERMEDIATE COVER

Daily soil cover or an alternative daily cover will be applied at the end of each operating day, regardless of weather, as required by ODEQ, to deter disease vectors, fires, odors, and blowing litter. The daily soil cover material should consist of nominally compacted earthen material free of garbage, trash, or other unsuitable material. The minimum thickness of the daily soil cover will be six inches.

Intermediate cover will consist of at least one foot of nominally compacted soil over refuse. Proper surface grades and sideslopes will be maintained to promote runoff and minimize infiltration without excessive erosion. Internal sideslopes will not exceed a slope of 3:1 and external side slopes will not exceed a slope of 4:1 (25 percent) with the final top slope graded to a minimum of 4 percent.

13.2 FINAL COVER SYSTEM

The final cover system will be constructed once the landfill reaches final grade. The SORD is permitted to use an alternate evapotranspiration final cover system. The cover system conforms to ODEQ specifications and includes the following components from bottom to top:

- 12 inches of intermediate cover soil
- 24 inches of vegetation support soil
- 12 inches of vegetation top soil

Once the cover system and surface water control structures are constructed as prescribed, the vegetative soil layer will be fertilized, seeded, and mulched to develop a thick stand of vegetation.

Each layer of this final cover system will be supportive of vegetative growth. The soils that make up the vegetative topsoil layer will be tested for proper application of lime, fertilizer, or other soil conditioning amendments. Once the proper amendments have been disked into the soil, seeding of a hardy grass mixture such as fescue and clover will take place. At the conclusion of seeding, the vegetative layer will be mulched to prevent soil erosion and assist with soil moisture retention and seed germination. The vegetative crop will be cared for (e.g., irrigated, reseeded, etc.) to establish a healthy stand of grass as quickly as possible. Both the crown and sideslopes of the completed portions of the landfill will be seeded in the fall or early spring. The vegetative soil cover will be tested to determine the lime and fertilizer rates needed.
13.3 BORROW SOURCES

The active borrow area for the site is located east of the existing landfill in the proposed expansion area. Based on proposed base and final grades for that area it is estimated that approximately 2,500,000 CY of soil will need to be excavated to achieve top of subgrade elevations in the expansion area.

The SORD owns additional property east and south of the landfill that can be utilized as a borrow area when deemed necessary.

13.4 BORROW AREA RECLAMATION

The borrow areas should have a gently sloping topography which provides wet weather drainage. The borrow areas will be excavated in a manner which results in final contours similar to those present before disturbance, except the area will have a lower elevation. A minimum of approximately 12 inches of unconsolidated material will be left in place. The area will be excavated in a manner to provide positive drainage and to possibly create one or more impoundments. In the case that impoundments are proposed or constructed, all applicable permits will be obtained and copies provided to the ODEQ. Activities will be scheduled to minimize erosion and sedimentation. Disturbance of vegetation will be limited to the extent possible. Attempts will be made to save trees where practicable. The borrow areas will be regraded in a manner to provide sufficient soil material for the re-establishment of vegetation. Revegetation activities should be scheduled for spring and fall.
14.0 CLOSURE AND POST-CLOSURE

A Closure and Post-Closure (CPC) Plan is included in Appendix K. The CPC Plan is in general
cordance with OAC 252:515-25. The CPC Plan is intended to be used as a standalone
document, a copy of which will be maintained within the facility’s operating record. The CPC
Plan includes the necessary actions to be completed at the site before the facility can be certified
closed and sets forth the maintenance and monitoring requirements during the post-closure
period. The post-closure period will be in effect for 30 years to ensure that the closed landfill
facility will continue to retain its integrity and will not pose a threat to human health or the
environment. The CPC Plan also addresses cost estimates and financial assurance requirements
for the SORD.
15.0 GENERAL COMMENTS

This permit application is based on the available information as provided to SCS Engineers. If, upon further evaluation or during construction, inconsistencies become apparent, re-evaluation of this report will be necessary.

This report has been prepared for the exclusive use of the SORD and Southern Oklahoma Regional Disposal, Inc. for the specific application to the project discussed and has been prepared in accordance with generally accepted engineering practices. No warranties, expressed or implied, are intended or made. In the event of any changes in the nature, design, or location of the project as outlined in this report, this report shall not be considered valid, unless the changes are reviewed and this report modified or verified in writing by the engineer.
NOTES:

1. BACKGROUND IMAGERY RETRIEVED FROM GOOGLE MAPS.
CURRENTLY PERMITTED DISPOSAL BOUNDARY
Permit Drawings
NOTES:
1. AERIAL TOPOGRAPHY FLOWN BY AERIAL, LLC ON JANUARY 28, 2019.
2. EXISTING SITE FEATURES INCLUDING EXISTING PERIMETERS, MONITORING Wells, AND GAS PROBES BASED ON DRAWING PREPARED BY CARRERA ENGINEERING.
CROSS SECTION D-D'

LEGEND
- HIGHEST GROUNDWATER
- PREPARED TOP OF CLAY LINER
- PROPOSED TOP OF FINAL COVER
- AS-BUILT TOP OF CLAY LINER (SUBTLE D CELL)
- EXISTING GROUND SURFACE

NOTES:
1. EXISTING GROUND SURFACE BASED ON THE AERIAL TOPOGRAPHY
   FURNISHED BY ACS ARBITRAL, LLC ON JANUARY 24, 2015.
2. GROUNDWATER LEVELS BASED UPON THE HIGHEST RECORDED
   ELEVATION DURING THE EARTHWORK INVESTIGATION.
3. AS-BUILT TOP OF CLAY LINER BASED ON SURVEY INFORMATION
   PROVIDED BY OTHERS.

Elevation

Station

PRE-SUBTLE D CELL
CROSS SECTION B-B'

LINES:
- HIGHEST GROUNDWATER
- PROPOSED TOP OF CLAY LINER
- PROPOSED TOP OF FINAL COVER
- AS-BUILT TOP OF CLAY LINER (SUBTILE D CELL)
- EXISTING GROUND SURFACE

NOTES:
1. EXISTING GROUND SURFACE BASED ON THE AERIAL TOPOGRAPHY PHOTO BY NCI AERIAL LLC ON JANUARY 29, 2016.
2. GROUNDWATER ELEVATIONS BASED UPON THE HIGHEST RECORDED MEASUREMENT DURING THE SKRUGHT INVESTIGATION.
3. AS-BUILT TOP OF CLAY ELEVATIONS BASED ON SURVEY INFORMATION PROVIDED BY OTHERS.
SOUTHERN OKLAHOMA REGIONAL DISPOSAL LANDFILL LANDFILL EXPANSION PERMIT DRAWINGS

ODEQ Land Protection Permit No. 3510007
December 2018

PREPARED FOR

SOUTHERN OKLAHOMA REGIONAL DISPOSAL, INC.
31 SORD DRIVE
ARDMORE, OKLAHOMA 73401

DRAWING INDEX

<table>
<thead>
<tr>
<th>DRAWING NO.</th>
<th>TITLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>COVERSHEET</td>
</tr>
<tr>
<td>2</td>
<td>EXISTING CONTOUR MAP</td>
</tr>
<tr>
<td>3</td>
<td>SITE MAP</td>
</tr>
<tr>
<td>4</td>
<td>HIGHEST GROUNDWATER CONTOUR MAP</td>
</tr>
<tr>
<td>5</td>
<td>TOP OF SUBGRADE GRADING PLAN</td>
</tr>
<tr>
<td>6</td>
<td>TOP OF CLAY LINER GRADING PLAN</td>
</tr>
<tr>
<td>7</td>
<td>TOP OF FINAL COVER GRADING PLAN</td>
</tr>
<tr>
<td>8</td>
<td>CROSS SECTIONS LOCATIONS</td>
</tr>
<tr>
<td>9</td>
<td>CROSS SECTION A-A'</td>
</tr>
<tr>
<td>10</td>
<td>CROSS SECTION B-B'</td>
</tr>
<tr>
<td>11</td>
<td>CROSS SECTION C-C'</td>
</tr>
<tr>
<td>12</td>
<td>CROSS SECTION D-D'</td>
</tr>
<tr>
<td>13</td>
<td>CROSS SECTION E-E'</td>
</tr>
<tr>
<td>14</td>
<td>STORMWATER CONTROL PLAN</td>
</tr>
<tr>
<td>15</td>
<td>DETAILS SHEET 1</td>
</tr>
<tr>
<td>16</td>
<td>DETAILS SHEET 2</td>
</tr>
<tr>
<td>17</td>
<td>DETAILS SHEET 3</td>
</tr>
</tbody>
</table>

PREPARED BY

SCS ENGINEERS
8575 WEST 110th STREET, SUITE 100
OVERLAND PARK, KANSAS 66210
(913) 681-0030 FAX (913) 681-0012
PROJECT NO. 27215136.00
IN WITNESS WHEREOF, the said party of the first part has hereunto set its hand
the day and year first above written.

ARDMORE PUBLIC WORKS AUTHORITY

By: Bob Geurin

CHAIRMAN BOB GEURIN

ATTEST:

Kenneth L. Campbell
CITY CLERK
KEN CAMPBELL

STATE OF OKLAHOMA  )  ss.
COUNTY OF CARTER   )

Before me the undersigned, a Notary Public, in and for said County and State, on
this 17th day of September 2007, personally appeared Chairman Bob Geurin, to me
known to be the identical person who executed the within and foregoing instrument and
acknowledged to me that he executed the same as his free and voluntary act and deed for
the uses and purposes therein set forth.

Given under my hand and seal of office the day and year last above written.

Notary Public

(seal)
QUIT CLAIM DEED

THIS INDENTURE, made this 17th day of September, 2007, between the Ardmore Public Works Authority, A Municipal Trust Authority, party of the first part, and Southern Oklahoma Regional Disposal Inc., An Oklahoma Non-Profit Corporation, party of the second part.

WITNESSETH, that said party of the first part, in consideration of the sum of Ten Dollars ($10.00) and other good and valuable consideration to them duly paid, the receipt of which is hereby acknowledged, does hereby quit-claim, grant, bargain, sell and convey unto said party of the second part, and to its successors and assigns forever, all its right, title, interest and estate, both at law and in equity, of, in and to the following described real estate, situated in the County of Carter, State of Oklahoma, to-wit:

Tract 1: That Ten-acre industrial waste site commonly known as the "Uniroyal Site" described as the W/2 of the W/2 of the NW/4 of the NE/4 (W/2 W/2 NW NE) of Section 24, Township 4 South, Range 2 East, Carter County, Oklahoma;

Tract 2: That Five-acre parcel of land described as the W/2 of the SW/4 of the SW/4 of the SE/4 (W/2 SW SW SE) of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

Including, on both Tract 1 and 2, the right to use or utilize any limestone deposits or other non-organic minerals lying on the surface of the ground and to a depth not to exceed 50 feet below the surface of the ground, but accepting and reserving to the Grantor all of the oil, gas, coal, asphalt, or other organic minerals lying in, on or under the property from the surface to the center of the earth, together with all other deposits, including limestone and other non-organic minerals for 50 feet below the surface to the center of the earth.

TO HAVE AND TO HOLD the above granted premises unto the said party of the second part its successors and assigns forever.
acknowledged to me that he executed the same in the above capacity on behalf of the corporation for the uses and purposes therein set forth.

GIVEN under my hand and seal the day and year last above written.

[Signature]

Notary Public
State of Oklahoma

My Commission Expires: 5-19-04
further excepting the potential claims of third parties (to include the heirs of Wilson Jones) recited in the specific title requirement set forth in paragraph five of the Title Opinion rendered by Ted J. Pasley on October 8, 1993, pertaining to portions of the hereinbefore-described real property, and that Party Grantor will warrant and forever defend the same unto said Party of the Second Part, its successors and assigns, against said Party of the First Part, its successors and assigns, and all and every person or persons whomsoever lawfully claiming, or to claim the same.

IN WITNESS WHEREOF, the Party of the First Part has executed or caused to be executed, this instrument the day and year first above written.

SOUTHERN OKLAHOMA DEVELOPMENT ASSOCIATION, an Oklahoma non-profit corporation

By: [Signature]
BOB STICK, President

STATE OF OKLAHOMA )
 ) ss
COUNTY OF CARTER )

Before me, the undersigned, a Notary Public, in and for said County and State on this 23rd day of September, 2003, personally appeared BOB STICK, President of SOUTHERN OKLAHOMA DEVELOPMENT ASSOCIATION, an Oklahoma non-profit corporation, to me known to be the identical person who executed the within and foregoing instrument and
The South Half (S/2) of the South Half (S/2) of the Southeast Quarter (SE/4) of Section Thirteen (13), Township Four (4) South, Range Two (2) East, LESS AND EXCEPT that five (5) acre parcel of land described as the West Half (W/2) of the Southwest Quarter (SW/4) of the Southwest Quarter (SW/4) of the Southeast Quarter (SE/4) of Section Thirteen (13), Township Four (4) South, Range Two (2) East, Carter County, Oklahoma, wherein the City of Ardmore has previously in a prior conveyance reserved a total of 15 acres above stated and known herein as the "Uniroyal Site";

- and -

SURFACE RIGHTS ONLY: The North Half (N/2) of the Southeast Quarter (SE/4) and the North Half (N/2) of the Southwest Quarter (SW/4) of the Southeast Quarter (SE/4) and the Northwest Quarter (NW/4) of the Southeast Quarter (SE/4) of the Southeast Quarter (SE/4) and the North Half (N/2) of the Southeast Quarter (SE/4) of the Southwest Quarter (SW/4) of Section Twenty Four (24), Township Four (4) South, Range Two (2) East, Carter County, Oklahoma;

TO HAVE AND TO HOLD the same, together with all and singular the tenements hereditaments and appurtenances thereunto belonging or in any wise appertaining forever; and

Said Party of the First Part, its successors and assigns, does hereby covenant and agree to and with said Party of the Second Part that, at the delivery of these presents, it is lawfully seized of an absolute and indefeasible estate of inheritance in fee simple, of and in, all and singular, the hereinbefore-granted and -described premises, with appurtenances; that the same is free, clear and discharged and unencumbered of and from all former and other grants, titles, charges, judgments, estates, taxes, assessments and encumbrances of whatsoever nature and kind, EXCEPT easements and building restrictions of record and special assessments not yet due, and
GENERAL WARRANTY DEED

THIS INDENTURE, made this 23rd day of September, 2003, between SOUTHERN OKLAHOMA DEVELOPMENT ASSOCIATION, an Oklahoma non-profit corporation (hereinafter "Party of the First Part"), and SOUTHERN OKLAHOMA REGIONAL DISPOSAL, INC., an Oklahoma non-profit corporation, having a mailing address of P.O. Box 1088, Ardmore, Oklahoma, 73402, (hereinafter "Party of the Second Part").

WITNESSETH:

That in consideration of the sum of Ten Dollars ($10.00) and other good and valuable consideration, receipt whereof is hereby acknowledged, said Party of the First Part does by these presents grant, bargain, sell and convey unto SOUTHERN OKLAHOMA REGIONAL DISPOSAL, INC., an Oklahoma non-profit corporation, Party of the Second Part, its successors and assigns, the following-described real estate situated in Carter County, State of Oklahoma, to-wit:

The Northeast Quarter (NE/4) of the Northeast Quarter (NE/4), the Southwest Quarter (SW/4) of the Northeast Quarter (NE/4) and the Northwest Quarter (NW/4) of the Northeast Quarter (NE/4) of Section Twenty Four (24), Township Four (4) South, Range Two (2) East,

LESS AND EXCEPT that 10-acre industrial waste site commonly known as the "Unroyal Site" described as the West Half (W/2) of the West Half (W/2) of the Northwest Quarter (NW/4) of the Northeast Quarter (NE/4) of Section Twenty Four (24), Township Four (4) South, Range Two (2) East, Carter County, Oklahoma;
Appendix B

Right of Access Documentation
<table>
<thead>
<tr>
<th>Task/Service</th>
<th>Quantity</th>
<th>Units</th>
<th>Multiplier</th>
<th>Unit Cost</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Leachate Management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a Clean Leachate Line(s)</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>30</td>
<td>$1,678.80</td>
<td>$50,364.00</td>
</tr>
<tr>
<td>b Maintain Leachate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collection System and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>30</td>
<td>$2,608.08</td>
<td>$78,242.40</td>
</tr>
<tr>
<td>c Collect, Treat, Transport,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>and Dispose Leachate</td>
<td>23,500.0</td>
<td>Gallons/Year</td>
<td>30</td>
<td>$0.33</td>
<td>$232,650.00</td>
</tr>
<tr>
<td><strong>TOTAL NOT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SUBTOTAL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,789,736.20</td>
</tr>
<tr>
<td><strong>Administrative Services</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 TECHNICAL and</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>0.06</td>
<td>$1,789,736.20</td>
<td>$107,384.17</td>
</tr>
<tr>
<td>PROFESSIONAL SERVICES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 POST-CLOSURE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONTINGENCY</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>0.10</td>
<td>$1,789,736.20</td>
<td>$178,973.62</td>
</tr>
<tr>
<td><strong>TOTAL POST CLOSURE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$2,201,375.53</td>
</tr>
</tbody>
</table>
## Table 1.1 2018 Post-Closure Cost Estimate

<table>
<thead>
<tr>
<th>Task/Service</th>
<th>Quantity</th>
<th>Units</th>
<th>Multiplier</th>
<th>Unit Cost</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 SITE MAINTENANCE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a Site Inspections</td>
<td>4.0</td>
<td>Per Year</td>
<td>30</td>
<td>$654.68</td>
<td>$78,561.60</td>
</tr>
<tr>
<td>b General Maintenance</td>
<td>1.0</td>
<td>Per Year</td>
<td>30</td>
<td>$1,962.79</td>
<td>$58,883.70</td>
</tr>
<tr>
<td>c Remediation and/or Gas Control Equipment</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>0.3</td>
<td>$1,287,190.00</td>
<td>$386,157.00</td>
</tr>
<tr>
<td><strong>2 MONITORING</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a Rework/Replace Monitoring Well(s)</td>
<td>290.0</td>
<td>VLF</td>
<td>0.25</td>
<td>$75.68</td>
<td>$5,486.80</td>
</tr>
<tr>
<td>b Plug Abandoned Monitoring Well(s)</td>
<td>290.0</td>
<td>VLF</td>
<td>0.25</td>
<td>$30.30</td>
<td>$2,196.75</td>
</tr>
<tr>
<td>c Final Plugging of Monitoring Well(s)</td>
<td>290.0</td>
<td>VLF</td>
<td>1</td>
<td>$30.30</td>
<td>$8,787.00</td>
</tr>
<tr>
<td>d Rework/Replace Methane Probe(s)</td>
<td>425.0</td>
<td>VLF</td>
<td>0.25</td>
<td>$65.36</td>
<td>$6,944.50</td>
</tr>
<tr>
<td>e Plug Abandoned Methane Probe(s)</td>
<td>425.0</td>
<td>VLF</td>
<td>0.25</td>
<td>$23.88</td>
<td>$2,537.25</td>
</tr>
<tr>
<td>f Final Plugging of Methane Probe(s)</td>
<td>425.0</td>
<td>VLF</td>
<td>1</td>
<td>$23.88</td>
<td>$10,149.00</td>
</tr>
<tr>
<td>g Final Plugging of Piezometer(s)</td>
<td>0.0</td>
<td>VLF</td>
<td>1</td>
<td>$23.88</td>
<td>$0.00</td>
</tr>
<tr>
<td><strong>3 SAMPLING and ANALYSIS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a Groundwater Monitoring Wells</td>
<td>8.0</td>
<td>Wells</td>
<td>60</td>
<td>$705.94</td>
<td>$338,851.20</td>
</tr>
<tr>
<td>b Methane Gas Probes</td>
<td>24.0</td>
<td>Probes</td>
<td>60</td>
<td>$45.80</td>
<td>$65,952.00</td>
</tr>
<tr>
<td>c Surface Water Monitoring Points</td>
<td>1.0</td>
<td>Points</td>
<td>60</td>
<td>$85.08</td>
<td>$5,104.80</td>
</tr>
<tr>
<td>d Leachate</td>
<td>1.0</td>
<td>Sample</td>
<td>60</td>
<td>$137.09</td>
<td>$8,225.40</td>
</tr>
<tr>
<td><strong>4 FINAL COVER MAINTENANCE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a Mow and Fertilize Vegetative Cover</td>
<td>65.84</td>
<td>Acres</td>
<td>30</td>
<td>$216.58</td>
<td>$427,788.82</td>
</tr>
<tr>
<td>b Repair Erosion, Settlement, and Subsidence for On-Site Soils</td>
<td>65.84</td>
<td>Acres</td>
<td>60</td>
<td>$3.14</td>
<td>$12,404.26</td>
</tr>
<tr>
<td>c Repair Erosion, Settlement, and Subsidence for Off-Site Soils</td>
<td>0.0</td>
<td>Acres</td>
<td>30</td>
<td>$18.78</td>
<td>$0.00</td>
</tr>
<tr>
<td>e Re-Seed Vegetative Cover</td>
<td>65.84</td>
<td>Acres</td>
<td>0.2</td>
<td>$793.57</td>
<td>$10,449.73</td>
</tr>
<tr>
<td>Task/Service</td>
<td>Quantity</td>
<td>Units</td>
<td>Multiplier</td>
<td>Unit Cost</td>
<td>Subtotal</td>
</tr>
<tr>
<td>-------------</td>
<td>----------</td>
<td>-----------</td>
<td>------------</td>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>Install Flexible Membrane e</td>
<td></td>
<td>Square Feet</td>
<td>1</td>
<td>$0.41</td>
<td>$0.00</td>
</tr>
<tr>
<td>Drainage layer f</td>
<td></td>
<td>Acres</td>
<td>1</td>
<td>$38,153.48</td>
<td>$0.00</td>
</tr>
<tr>
<td>Place Sand or Install Net and Geonet</td>
<td></td>
<td>Square Feet</td>
<td>1</td>
<td>$0.37</td>
<td>$0.00</td>
</tr>
<tr>
<td>Place On-Site Topsoil g</td>
<td>106,921.7</td>
<td>Cubic Yards</td>
<td>1</td>
<td>$2.20</td>
<td>$233,688.11</td>
</tr>
<tr>
<td>Place Off-Site Topsoil</td>
<td></td>
<td>Cubic Yards</td>
<td>1</td>
<td>$17.63</td>
<td>$0.00</td>
</tr>
<tr>
<td>Establish Vegetative Cover, Including On- and Off-Site Borrow Areas h</td>
<td>106.00</td>
<td>Acres</td>
<td>1</td>
<td>$793.57</td>
<td>$84,118.42</td>
</tr>
<tr>
<td>DRAINAGE/EROSION CONTROL 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construct Terraces a</td>
<td>15,000.0</td>
<td>Linear Feet</td>
<td>1</td>
<td>$9.23</td>
<td>$138,450.00</td>
</tr>
<tr>
<td>Construct Letdown b</td>
<td>785.0</td>
<td>Linear Feet</td>
<td>1</td>
<td>$101.02</td>
<td>$79,300.70</td>
</tr>
<tr>
<td>Clean Perimeter Drainage Channel e Ditches</td>
<td>7,200.0</td>
<td>Linear Feet</td>
<td>0.5</td>
<td>$7.03</td>
<td>$25,308.00</td>
</tr>
<tr>
<td>TASK NOT 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUBTOTAL 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$1,986,755.79</td>
</tr>
<tr>
<td>ADMINISTRATIVE SERVICES 7</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>0.10</td>
<td>$1,986,755.79</td>
<td>$198,675.58</td>
</tr>
<tr>
<td>TECHNICAL and PROFESSIONAL SERVICES 8</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>0.12</td>
<td>$1,986,755.79</td>
<td>$238,410.69</td>
</tr>
<tr>
<td>CLOSURE 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONTINGENCY</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>0.10</td>
<td>$1,986,755.79</td>
<td>$198,675.58</td>
</tr>
<tr>
<td>TOTAL FINAL CLOSURE 10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$2,622,517.64</td>
</tr>
</tbody>
</table>
### Table H.2 2018 Closure Cost Estimate
**Facility Name: Southern Oklahoma Regional Disposal Landfill**
**Permit Number: 3510007**

<table>
<thead>
<tr>
<th>Task/Service</th>
<th>Quantity</th>
<th>Units</th>
<th>Multiplier</th>
<th>Unit Cost</th>
<th>Subtotal</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRELIMINARY SITE WORK</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a Conduct Site Evaluation</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>1</td>
<td>$3,598.94</td>
<td>$3,598.94</td>
</tr>
<tr>
<td>b Dispose Final Waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c Average Daily Flow</td>
<td>608.9</td>
<td>tons/day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d Disposal Cost</td>
<td>608.9</td>
<td>tons/day</td>
<td>5</td>
<td>$25.75</td>
<td>$78,401.13</td>
</tr>
<tr>
<td>e Remove Temporary Building(s)</td>
<td>2.0</td>
<td>Lump Sum</td>
<td>1</td>
<td>$3,300.24</td>
<td>$6,600.48</td>
</tr>
<tr>
<td>f Remove Equipment</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>1</td>
<td>$2,693.96</td>
<td>$2,693.96</td>
</tr>
<tr>
<td>g Repair/Replace Perimeter Fencing</td>
<td>11,700.0</td>
<td>Linear Feet</td>
<td>0.25</td>
<td>$3.54</td>
<td>$10,354.50</td>
</tr>
<tr>
<td>h Clean Leachate Line(s)</td>
<td>1.0</td>
<td>Lump Sum</td>
<td>1</td>
<td>$1,630.06</td>
<td>$1,630.06</td>
</tr>
</tbody>
</table>

| **MONITORING EQUIPMENT** |          |           |            |            |            |
| a Rework/Replace Monitoring Well(s) | 290.0 | VLF       | 0.25       | $75.68     | $5,486.80  |
| b Plug Abandoned Monitoring Well(s) | 290.0 | VLF       | 0.25       | $30.30     | $2,196.75  |
| c Rework/Replace Methane Probe(s) | 425.0 | VLF       | 0.25       | $65.36     | $6,944.50  |
| d Plug Abandoned Methane Probe(s) | 425.0 | VLF       | 0.25       | $23.88     | $2,537.25  |

| **CONSTRUCTION** |          |           |            |            |            |
| a Complete Site Grading, Including Borrow Area | 106.00 | Acres     | 1          | $1,426.89  | $151,250.34 |
| b Construct Final Cap |        |           |            |            |            |
| c Compacted On-Site Clay Cap or | 212,443.7 | Cubic Yards | 1          | $5.13      | $1,089,836.35 |
| d Compacted Off-Site Clay Cap or |        |           |            |            |            |
| e Install Geosynthetic Clay Liner Cap |        |           |            |            |            |
| f Construct Landfill Gas Venting Layer |        |           |            |            |            |
| g Place Sand or |        |           |            |            |            |
| h Install Net and Geotextile |        |           |            |            |            |
| i Install Passive Landfill Gas Vents |        |           |            |            |            |


Table H.1 2018 Site Data
Facility Name: Southern Oklahoma Regional Disposal Landfill
Permit Number: 3510007

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Permitted Area</td>
<td>200.00</td>
<td>acres</td>
</tr>
<tr>
<td><strong>Active Portion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite Lined</td>
<td>22.64</td>
<td>acres</td>
</tr>
<tr>
<td>Soil Lined</td>
<td>43.20</td>
<td>acres</td>
</tr>
<tr>
<td><strong>Area of Largest Cell/Phase Requiring Final Cap</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Composite Lined</td>
<td>22.64</td>
<td>acres</td>
</tr>
<tr>
<td>Soil Lined</td>
<td>43.20</td>
<td>acres</td>
</tr>
<tr>
<td>Perimeter Fencing</td>
<td>11,700.0</td>
<td>linear feet</td>
</tr>
<tr>
<td>Groundwater Monitoring Wells</td>
<td>290.0</td>
<td>VLF</td>
</tr>
<tr>
<td>Methane Gas Probes</td>
<td>425.0</td>
<td>VLF</td>
</tr>
<tr>
<td>Terraces</td>
<td>15,000.0</td>
<td>linear feet</td>
</tr>
<tr>
<td>Letdown Channels</td>
<td>785.0</td>
<td>linear feet</td>
</tr>
<tr>
<td>Perimeter Drainage Ditches</td>
<td>7,200.0</td>
<td>linear feet</td>
</tr>
<tr>
<td>Average Daily Waste Flow</td>
<td>608.9</td>
<td>tons/day</td>
</tr>
<tr>
<td>Landfill Disposal Cost</td>
<td>$25.75</td>
<td>$/ton</td>
</tr>
</tbody>
</table>

VLF = Vertical Linear Feet. The sum of the depths of all monitoring wells.
Average Daily Waste Flow based on 2017 waste receipts.
Appendix A

Closure and Post-Closure Cost Estimates
12.0 POST-CLOSURE REPORTING REQUIREMENTS

12.1 ANNUAL POST-CLOSURE REPORT

Beginning one year after the ODEQ’s approval of the certification of final closure, SORD will submit an annual post-closure maintenance and monitoring report to the ODEQ until the post-closure period ends. This report will document the maintenance performed at the site and summarize all monitoring data for the previous year. The report shall be submitted by April 1st of each year after ODEQ’s certification of final closure.

12.2 CERTIFICATION OF POST-CLOSURE PERFORMANCE

At the conclusion of the post-closure period, SORD will submit, in lieu of the annual post-closure report, a certification prepared and sealed by a professional engineer registered in the State of Oklahoma certification, indicating that the MSWLF was maintained and monitored in accordance with the approved post-closure plan, the permit, and applicable regulations. This certification will also indicate whether monitoring throughout the post-closure period has shown the presence of elevated levels of any constituent or if any evidence of contamination related to site operations has been found and, if so, what corrective measures were taken. The certification will be maintained in the site operating record.
11.0 POST-CLOSURE LAND USE

There are no current planned uses for SORD after closure. Should use of the closed landfill not associated with solid waste activities be considered, plans will be prepared and submitted to the ODEQ for review and approval per OAC 252:515-25-55.
10.0 FINANCIAL ASSURANCE INSTRUMENT

At a minimum, the financial assurance instrument (FAI) shall be updated no later than April 9th of each year. Updates will address modifications to the landfill's closure and post-closure requirements, if any, and the associated cost estimates. If there are no significant changes to the post-closure plan, the cost estimate may be adjusted by use of an inflation factor. The inflation factor can be derived from the most recent annual Implicit Price Deflator for Gross National Product or the Implicit Price Deflator for Gross Domestic Product published by the U.S. Department of Commerce in its Survey of Current Business in a year for which the adjustment is made. The current FAI shall be placed in the operating record.
9.0 POST-CLOSURE COST ESTIMATE

A cost estimate for post-closure care of the landfill, including costs for the activities described above, is provided in Appendix A. This estimate includes the following costs:

- Quarterly site inspection,
- Site security and access control,
- Final cover erosion and seeding repair,
- Semi-annual groundwater monitoring,
- Surface water control structure maintenance,
- Semi-annual explosive gas monitoring,
- Leachate collection, disposal, and system maintenance,
- Annual reporting, and
- Certification and recordkeeping.

Post-closure estimates and the amount of financial assurance provided must be increased if, at any time during the active life, changes to the closure plan of the facility increase the maximum cost of post-closure. Proposals for reduction of post-closure cost estimates and the amount of financial assurance required must be submitted to the ODEQ for approval. To qualify for a reduction, the cost estimate must be demonstrated to exceed the minimum cost of post-closure during the remaining post-closure care period, the amount of security remaining after the reduction must adequately cover the estimated post-closure cost yet to be performed, and financial assurance shall not be reduced until ODEQ approval has been granted.

At a minimum, cost estimates for post-closure shall be adjusted no later than April 9th of each year; the adjustment must be submitted to the ODEQ for approval. In the adjustment, maximum costs of post-closure may be recalculated, in current dollars, in accordance with OAC 252:515-27-51. If there are no significant changes to the post-closure plan, the cost estimate may be adjusted by use of an inflation factor. The inflation factor can be derived from the most recent annual Implicit Price Deflator for Gross National Product or the Implicit Price Deflator for Gross Domestic Product published by the U.S. Department of Commerce in its Survey of Current Business in a year for which the adjustment is made. The approved adjusted cost estimate shall be placed in the operating record.

If corrective action is required at SORD, cost estimates for corrective action shall be submitted to the ODEQ for approval. The cost estimates shall be a detailed written estimate, in current dollars, of the cost of hiring a third party to perform the corrective action in accordance with an approved corrective action plan. The corrective action cost estimate shall be set by the ODEQ and account for the total costs of corrective action activities as described in an approved corrective action plan for the entire corrective action period. The amount of financial assurance provided must be increased to account for corrective action costs.
8.1.8  Site Security and Access Control

Post-closure care of the security system is necessary to control unauthorized access and prevent illegal dumping of wastes. Inspection of the security system at the site should be performed during the post-closure inspections. Signs shall be posted on the outer perimeter indicating the site is a closed MSWLF, as required by OAC 252:515-25-54(a)(1). The closed facility will be maintained as necessary to provide access to the closed areas throughout the post-closure period.
Maintenance and repairs should be conducted as soon as practical, and may consist of the following activities:

- Replacement of riprap, gabions, or other structural lining installed for erosion protection;
- Removal of obstructions to permit conveyance of surface water;
- Placement of fill and re-grading;
- Removal of silt and sediment;
- Repairs to berms; and
- Repair or replacement of stacked hay bales or silt fencing.

8.1.4 Leachate Collection System

Post-closure care of the leachate collection system consists of operation and maintenance of the leachate collection system, as well as any storage, pumping, or conveyance systems. As required per OAC 252:515-25-54(b)(2)(B), the leachate collection system will be equipped with a system for automatic and continuous leachate removal not requiring intervention by the owner/operator.

The leachate collection system will be observed during each scheduled inspection event throughout the post-closure period. Based on the results of the inspections, more frequent or less frequent monitoring may be required due to problems with the system or changes in the rate of production of leachate. During these inspections, leachate collection sumps and/or piping, cleanouts, or inspection points will be observed to determine the effectiveness of the system in removing leachate and minimizing the head on the liner system.

Maintenance, on an annual or otherwise as-needed basis, may include flushing and pressure cleaning of the leachate collection and removal pipes.

8.1.5 Groundwater Monitoring System

Semi-annual groundwater monitoring of the monitoring network wells will be completed in accordance with the most recently approved groundwater monitoring plan.

8.1.6 Surface Water Monitoring Program

During site inspections, surface water control structures (drainage swales, letdown channels, perimeter channels, culverts, and detention ponds) will be inspected to ensure they are functioning properly. Any problems noted during the inspection will be addressed as soon as reasonably possible.

8.1.7 Landfill Gas Monitoring System

Monitoring of explosive gas monitoring wells located along the site boundary will be conducted on a semi-annual basis during the post-closure period as outlined in the most recently approved explosive gas monitoring plan.
Included as part of the final cover system inspection, the integrity of the vegetation and its ability to minimize infiltration and erosion will be determined. The following conditions should be examined during the inspection:

- Erosion;
- Overgrowth of shrubs, trees, and other deep-rooted vegetation; and
- Patches of dead vegetation.

Maintenance and repairs of the vegetative cover may consist of the following activities:

- Reseeding, fertilizing, liming, and mulching of washed out areas;
- Brush removal; and
- Mowing.

Reseeding should be conducted as necessary to assure proper vegetative growth over all areas of the final cover. Mowing and removal of deep-rooted brush and vegetation should be performed as necessary during the growing season.

8.1.2 Borrow Area Reclamation

The borrow areas will have a gently sloping topography to provide wet weather drainage. The borrow area will be excavated in a manner which results in final contours similar to those present before disturbance, except the area will have a lower elevation. The areas will be excavated in a manner to provide positive drainage and to possibly create one or more impoundments. In the case that impoundments are proposed/constructed, all applicable permits will be obtained and copies provided to the ODEQ.

Activities will be scheduled to minimize erosion and sedimentation. The borrow area will be re-graded in a manner to provide sufficient soil material for the re-establishment of vegetation. Re-vegetation activities will be completed as needed during the spring or fall growing seasons.

8.1.3 Drainage and Erosion Controls Structures

Drainage and erosion controls will be inspected throughout the post-closure period to assure that surface water is conveyed away from the landfill to the perimeter drainage system. Items or conditions to be examined include the following:

- Erosion;
- Settlement;
- Structural integrity of berms, letdown structures, and other drainage and erosion control structures; and
- Silt and sediment buildup.
8.0 POST-CLOSURE ACTIVITIES

8.1 MONITORING AND MAINTENANCE

In accordance with OAC 252:515-25-51(b), post-closure care maintenance will commence immediately upon ODEQ approval of final closure. Post-closure activities will continue for a period of 30 years, unless the ODEQ approves a post-closure period of a different duration. Documentation pursuant to OAC 252:515-3-34 is included in Appendix B of this plan showing that SORD has legal right to access all property subject to post-closure care requirements.

Post-closure inspections shall be performed on a quarterly basis. Additional inspections may be conducted to observe repairs or evaluate problem areas discovered during prior inspections.

The quarterly post-closure inspections will consist of the inspection and evaluation of the final cover system and vegetative cover, the drainage and erosion control structures, the leachate collection system, and the security system. The frequency and specific inspections associated with the groundwater monitoring and gas monitoring programs are addressed in SORD’s Groundwater Monitoring Plan and Explosive Gas Control Plan.

8.1.1 Final Cover

Post-closure care will verify the integrity of the final cover system and its ability to minimize infiltration and erosion. The following conditions should be examined during the inspection:

- Settlement;
- Cracking;
- Erosion;
- Animal burrows; and
- Other disturbances affecting either the thickness or configuration of the final cover.

Maintenance and repairs should be conducted as soon as practical and may consist of filling in areas of settlement, re-grading, and slope restabilization. In areas of substantial settlement or displacement of the final cover, the integrity of the cap should be re-evaluated and any necessary repairs made. The final cover should be maintained to provide the proper slope to promote surface water runoff and to assure continuity of the soil components to minimize infiltration and leachate production. Settlement that occurs on side slopes of the landfill will generally not require re-grading or placement of additional cover to maintain surface drainage. Side slopes are designed no greater than 4:1 (horizontal: vertical) slope, and the crown of the landfill area slopes at a minimum of four percent to minimize the effect of settlement. With these slope conditions, it is anticipated that minimal soil will be required during the post-closure care period for maintenance of this site.
7.0 CLOSURE COST ESTIMATE

A closure cost estimate including costs for the activities described above, is provided in Appendix A. Closure estimates and the amount of financial assurance provided must be increased if, at any time during the active life, changes to the closure plan of the facility increase the maximum cost of closure. Proposals for reduction of closure cost estimates and the amount of financial assurance required must be submitted to the ODEQ for approval. To qualify for a reduction, the cost estimate must be demonstrated to exceed the minimum cost of closure during the remaining life of the facility, the amount of security remaining after the reduction must adequately cover the estimated closure cost yet to be performed, and financial assurance shall not be reduced until ODEQ approval has been granted.

At a minimum, cost estimates for closure shall be adjusted no later than April 9th of each year; the adjustment must be submitted to the ODEQ for approval. In the adjustment, maximum costs of closure may be recalculated, in current dollars, in accordance with OAC 252:515-27-51. If there are no significant changes to the closure plan, the cost estimate may be adjusted by use of an inflation factor derived from the most recent annual Implicit Price Deflator for Gross National Product or the Implicit Price Deflator for Gross Domestic Product published by the U.S. Department of Commerce in its Survey of Current Business in a year for which the adjustment is made. The approved adjusted cost estimate shall be placed in the operating record.
6.2 COUNTY LAND RECORDS NOTICE

The ODEQ shall approve the final closure of the facility before the post-closure period can begin. Upon approval of the final closure of the facility, a notice shall be recorded in the land records of the property for Carter County giving notice in perpetuity that the site was used for the disposal of municipal solid waste and is now closed. The notice shall specify the type, location, and quantity of wastes disposed. The notice shall also identify the required post-closure monitoring period and state that the facility will be monitored for at least 30-years; that a survey plat and record of the disposal area's locations and elevations have been filed with the ODEQ and with an identified city or county; and that future uses may be restricted in accordance with OAC 252:515-25-57. SORD is responsible for providing a file-stamped copy of the notice to the ODEQ.
6.0 CLOSURE SCHEDULE

The site will be closed in an orderly fashion, consistent with OAC 252:515-25-33. The final closure schedule is as follows:

- The ODEQ shall be notified in writing prior to beginning final closure of SORD or closure of a disposal cell at SORD;
- Closure activities shall begin no later than 90 days after final receipt of wastes at SORD or final receipt of wastes into a disposal cell;
- Closure activities shall be completed according to the approved Closure Plan within 180 days after closure activities are initiated; and
- Extensions of the closure period may be granted by the ODEQ if SORD demonstrates that closure will, of necessity, take longer than 180 days, and that all steps have been taken, and will continue to be taken, to prevent threats to human health or the environment from the unclosed cell or facility.

6.1 CERTIFICATION OF FINAL CLOSURE

Upon completion of closure activities, a professional engineer registered in the State of Oklahoma will submit a certification of final closure to the ODEQ, certifying that the facility or disposal cell was closed in accordance with approved permit documents and this closure plan. The certification of final closure shall:

- Be signed by the owner/operator;
- State the facility was closed according to the approved closure plan, the permit documents, and applicable rules;
- Contain a closure report with related drawings, plans, or specifications describing how closure was performed;
- Indicate whether inspection of gas, groundwater, or surface water monitoring has shown the presence of elevated levels of any constituent or if any evidence of contamination related to site operations has been found and, if so, what corrective measures were taken; and
- Include a final closure map. The final closure map shall show as-built conditions at the time of closure including but not limited to:
  - Final contours of the entire site;
  - The final permit boundary and boundaries of disposal areas;
  - The location of gas monitoring probes;
  - The location of groundwater monitoring wells;
  - The location of leachate management systems or surface impoundments;
  - The location of permanent surface drainage structures;
maintenance building are not located on the permit boundary. All equipment used during the operation and closure of the landfill will be removed from the site after final closure has been certified as complete.

The access roads will be maintained throughout the active life and post-closure period of the landfill. Facilities at the site, including the perimeter fencing, will be maintained throughout the post-closure period.

Prior to initiating closure, the existing conditions and applicable regulations will be re-evaluated to ensure that this Closure Plan is still applicable.
5.0 CLOSURE PROCEDURES

5.1 CLOSURE SEQUENCE

SORD will conduct ongoing closure of the landfill throughout its active life. This procedure allows for successive closures of fill areas by placement of final cover, construction of drainage and erosion control features, and establishment of vegetative cover. It is anticipated that, where possible, portions of the landfill will be closed as additional phases are constructed. If the site is to undergo premature closure, closure activities would be required only on those areas of the site that had been constructed and received waste. SORD will submit a permit modification to the ODEQ showing redesigned final contours and permanent storm water structures in accordance with the Oklahoma Administrative Code (OAC) Rules and Regulations prior to premature closure of SORD.

5.2 CLOSURE DURING ACTIVE LIFE

As described above, the final cover will be constructed as fill areas achieve the design grades. Should complete closure of the landfill become necessary at any time during the active life of the landfill, the following steps will be taken:

- Engineering plans will be developed to address site closure at the time of discontinued waste filling;
- The final waste received will be placed and properly compacted;
- Excavations will be filled with suitable material, and the site will be graded to promote runoff and prevent ponding;
- The final cover system will be constructed according to specifications;
- The top of the landfill will be re-graded and re-shaped as needed to provide the proper slope for positive drainage;
- During the first growing season, following application of final cover, the site will be vegetated with permanent vegetation;
- Additional soil will be added to the side slopes, as needed, and processed using a disc to prepare the soil for seeding;
- A surface water management system will be constructed to minimize erosion;
- A closure certification report will be prepared by an independent registered professional engineer in the State of Oklahoma and submitted to ODEQ for approval; and
- All proper notices and documentation will be filed with the appropriate agencies.

5.3 ADDITIONAL CLOSURE INFORMATION

There are currently two onsite structures. These structures along with all other structures that are on site at the time of final closure will be removed or decommissioned. The office and
4.0 BORROW AREAS

Onsite and offsite soil borrow areas will be re-shaped and vegetated to blend in with the surrounding terrain within 180 days of the time that they are no longer utilized. After vegetation is established in the borrow areas, these areas will be routinely inspected throughout the life of the site and the Closure/Post-Closure periods. The vegetation cover will be capable of self-regeneration and will require no maintenance. If bare spots develop, then the area will be re-seeded and maintained (e.g., watered and fertilized) until the vegetation is re-established. Also during these inspections, the slopes will be inspected and if necessary re-shaped to maintain their grades.
3.0 FINAL COVER SYSTEM

3.1 COVER SYSTEM DESIGN

The final cover system for SORD consists of an Evapotranspiration (ET) alternative earthen final cover system. The components of the ET final cover system from top to bottom are listed below.

- A minimum 12-inch vegetation layer of earthen material capable of sustaining plant growth.
- A minimum 24-inch vegetation support layer of earthen material.
- A minimum 12-inch intermediate cover layer of earthen material.

3.2 COVER SYSTEM INSTALLATION

The final cover should be constructed in accordance with the approved permit documents, design plans, and the Construction Quality Assurance / Construction Quality Control Plan (QA/QC) for Evapotranspiration Alternative Earthen Final Cover, dated April 2018, prepared by SCS Engineers, or more recently approved plan. The intermediate cover soils will be placed by the owner over the completed waste fill prior to installing the final cover system. The material used for the vegetation support layer shall classify as CL, CH, ML, SM, or SC according to the Unified Soil Classification System. The vegetation support layer material should be placed in one 24-inch lift. The material will be compacted by tracking in the material with low pressure earth moving equipment.

The vegetation layer will be placed over the vegetation support layer. This layer will consist of soil suitable for sustaining vegetative growth. The soil will be placed in one lift (12-inch minimum thickness) over the entire surface of the final cover and compacted in place with low pressure earth moving equipment.

Individual areas of the SORD may be closed in phases. For construction of each final cover phase, project specific design plans will be prepared and sealed by an independent professional engineer licensed in the State of Oklahoma, in accordance with the site's current permit documents and QA/QC plan. At this time it is anticipated the final cover will be constructed in one phase at the time of closure. To reduce financial assurance for the disposal area closed in a phased closure scenario, a certification prepared and sealed by an independent professional engineer licensed in the State of Oklahoma shall be submitted to the ODEQ. The ODEQ must approve closure of the disposal area before financial assurance may be reduced. The certification shall:

- Certify that the area was closed according to the approved permit documents, design plans, QA/QC plan, and applicable rules and regulations; and
- Contain a closure report with related drawings, plans, or specifications describing how closure was performed.
2.2 POST-CLOSURE REQUIREMENTS

For current active landfills, OAC 252:515-25-51 requires a 30-year post-closure maintenance period including maintenance of the integrity and effectiveness of the final cover, maintaining and operating the leachate collection system, monitoring groundwater, and maintaining any gas venting, collection, or monitoring systems.

The ODEQ requires that a Certification of Post-Closure Performance be prepared and sealed by an independent professional engineer licensed in the State of Oklahoma.
2.0 REGULATIONS

This Closure and Post-Closure Plan has been prepared pursuant to OAC 252:515, as promulgated by the Oklahoma Department of Environmental Quality (ODEQ).

2.1 CLOSURE REQUIREMENTS

OAC 252:515 requires that all Municipal Solid Waste Landfills (MSWLFs) install a final cover system that is designed to minimize infiltration and erosion. The final cover system will consist of an erosion layer/vegetation layer underlain by an infiltration/vegetation support layer. The facility will be closed in accordance with the provisions included in this Closure Plan and in a manner that minimizes the need for further maintenance and controls and minimizes post-closure escape of waste and waste constituents into the environment.

Prior to beginning final closure of the landfill, the owner/operator is required to give notice of intent to close the site. ODEQ regulations require closure to begin a minimum of 90 days after final receipt of waste at the facility or for the disposal area, as applicable. ODEQ requires completion of all closure activities within 180 days following the beginning of closure unless otherwise approved.

ODEQ requires a Certification of Final Closure be prepared and sealed by an independent professional engineer licensed in the State of Oklahoma and signed by the site owner/operator.

ODEQ requires that upon approval of final closure, a notice shall be recorded in the property deed stating that the land has been used as a solid waste disposal facility. The notice shall specify the type, location, and quantity of wastes disposed of at the facility. In addition, the notice shall state that a survey plat and a record of disposal area locations and elevations has been filed with the ODEQ and with an identified city or county, and future uses may be restricted per OAC 252:515-25-57. A file stamped copy of the notice shall be provided to the ODEQ.

ODEQ also requires Closure/Post-Closure cost estimates to be updated if additional active areas are constructed, if final cover is constructed, or the landfill gas collection and control system (GCCS) is expanded. The cost estimates will be updated annually consistent with OAC 252:515-27-34.
1.0 INTRODUCTION

This Closure and Post-Closure Plan provides the criteria necessary to properly close and maintain the entire disposal area of the Southern Oklahoma Regional Disposal Landfill (SORD).

The Closure Plan includes the necessary actions to be completed at the site before the facility can be certified closed and sets forth the maintenance and monitoring during the post-closure period.

The Post-Closure Plan will be in effect for a minimum 30-year period to ensure that the closed landfill facility will retain its integrity and will not pose a threat to human health or the environment.
# Table of Contents

1.0 Introduction ...................................................................................................................... 1  
2.0 Regulations ...................................................................................................................... 2  
  2.1 Closure Requirements .................................................................................................. 2  
  2.2 Post-Closure Requirements ....................................................................................... 3  
3.0 Final Cover System ........................................................................................................ 4  
  3.1 Cover System Design ................................................................................................. 4  
  3.2 Cover System Installation ......................................................................................... 4  
4.0 Borrow Areas .................................................................................................................. 5  
5.0 Closure Procedures ........................................................................................................ 6  
  5.1 Closure Sequence ....................................................................................................... 6  
  5.2 Closure During Active Life ....................................................................................... 6  
  5.3 Additional Closure Information .............................................................................. 6  
6.0 Closure Schedule ............................................................................................................ 8  
  6.1 Certification of Final Closure .................................................................................. 8  
  6.2 County Land Records Notice .................................................................................. 9  
7.0 Closure Cost Estimate ................................................................................................... 10  
8.0 Post-Closure Activities ................................................................................................ 11  
  8.1 Monitoring and Maintenance .................................................................................... 11  
    8.1.1 Final Cover .......................................................................................................... 11  
    8.1.2 Borrow Area Reclamation ................................................................................ 12  
    8.1.3 Drainage and Erosion Controls Structures ....................................................... 12  
    8.1.4 Leachate Collection System ............................................................................. 13  
    8.1.5 Groundwater Monitoring System .................................................................... 13  
    8.1.6 Surface Water Monitoring Program ................................................................ 13  
    8.1.7 Landfill Gas Monitoring System ..................................................................... 13  
    8.1.8 Site Security and Access Control ................................................................... 14  
9.0 Post-Closure Cost Estimate ........................................................................................... 15  
10.0 Financial Assurance Instrument ................................................................................ 16  
11.0 Post-Closure Land Use ............................................................................................... 17  
12.0 Post-Closure Reporting Requirements ........................................................................ 18  
  12.1 Annual Post-Closure Report .................................................................................... 18  
  12.2 Certification of Post-Closure Performance ............................................................ 18  

### Appendices

- **Appendix A** Closure and Post-Closure Cost Estimates  
- **Appendix B** Right of Access Documentation
INDEX AND CERTIFICATION PAGE

REPORT INDEX

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Number of Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0</td>
<td>Regulations</td>
<td>2</td>
</tr>
<tr>
<td>3.0</td>
<td>Final Cover System</td>
<td>1</td>
</tr>
<tr>
<td>4.0</td>
<td>Borrow Areas</td>
<td>1</td>
</tr>
<tr>
<td>5.0</td>
<td>Closure Procedures</td>
<td>2</td>
</tr>
<tr>
<td>6.0</td>
<td>Closure Schedule</td>
<td>2</td>
</tr>
<tr>
<td>7.0</td>
<td>Closure Cost Estimate</td>
<td>1</td>
</tr>
<tr>
<td>8.0</td>
<td>Post-Closure Activities</td>
<td>4</td>
</tr>
<tr>
<td>9.0</td>
<td>Post-Closure Cost Estimate</td>
<td>1</td>
</tr>
<tr>
<td>10.0</td>
<td>Financial Assurance Instrument</td>
<td>1</td>
</tr>
<tr>
<td>11.0</td>
<td>Post-Closure Land Use</td>
<td>1</td>
</tr>
<tr>
<td>12.0</td>
<td>Post-Closure Reporting Requirements</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Appendices</td>
<td>14</td>
</tr>
</tbody>
</table>

Certification

This Closure and Post-Closure Plan has been prepared in accordance with good engineering practice including consideration of industry standards and the requirements of the Oklahoma Department of Environmental Quality.

Prepared by:

Floyd Cotter, P.E.
Vice President
SCS Engineers
Closure and Post-Closure Plan

Prepared for:
Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402

Prepared by:
SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas

April 2018
Revised December 2018
File No. 27215136.00
Closure and Post-Closure Plan

Southern Oklahoma Regional Disposal Landfill

Prepared for:

Southern Oklahoma Regional Disposal, Inc.

Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Prepared by:

SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas

April 2018
Revised December 2018
File No. 27215136.00

Offices Nationwide
www.scsengineers.com
Appendix K

Closure and Post-Closure Plan
FIGURE 1
SITE MAP
9) Material recycled by the facility will be weighed prior to transportation offsite or reuse. Amounts of recycled or reused material will be recorded in the landfill operating record.

10) On the Monthly Report to Oklahoma Department of Environmental Quality (ODEQ), SORD Landfill will submit the amount of material recycled and date sent or used.

A copy of this Salvage and Recycling Plan will be maintained at the SORD Landfill. Additions or changes to this Plan will be maintained onsite and able for review by request from ODEQ.
4) Once sorted and placed in the recycling area, there are no other anticipated sorting or handling operations other than those necessary to remove the material for shipping and transporting. The exceptions would be for Freon removal and for wood material. This Plan includes the removal of Freon from recycled metal products by a licensed individual. Additionally, this Plan includes a provision to allow chipping, shredding, or grinding wood material to produce a useable product. Wood material will be processed when sufficient volumes exist to constitute economic feasibility.

5) The recycling area will be open for operation during normal operating hours of the landfill disposal facility. Traffic will follow patterns identified at the facility.

6) The collected materials will be transported to the following applicable facilities, or suitable equivalent:
   a. Miscellaneous metal products will be recycled by a metal recycling facility
   b. Freon will be transported to a recycling facility
   c. Tires will be transported to a tire recycling facility
   d. Wooden cross-ties will be used by SORD Landfill in the construction of site improvements
   e. Wood materials will be chipped and used in the construction of site improvements
   f. Uncontaminated rock, dirt, concrete, bricks, and solidified asphalt will be used by SORD Landfill in the construction of site improvements.

7) Recyclable materials will not be accumulated speculatively. However, SORD proposes the following storage times for material:
   a. Miscellaneous metal products - six (6) months (due to the low volume of material generated at the site it is not economically feasible to ship the material more frequently)
   b. Freon - six (6) months (due to the low volume of material generated at the site it is not economically feasible to ship the material more frequently)
   c. Tires - approximately every three (3) months
   d. Wooden cross-ties - less than three (3) months
   e. Processed wood material - less than three (3) months
   f. Uncontaminated rock, dirt, concrete, bricks, and solidified asphalt - less than three (3) months.

8) This Salvage and Recycling Plan does not include any processing of wastes at locations away from the facility. The landfill will accept source separated recyclable materials, if they pay the appropriate landfill fees.
SOUTHERN OKLAHOMA REGIONAL DISPOSAL LANDFILL
SALVAGE AND RECYCLING PLAN

In accordance with Oklahoma Administrative Code 252:515-19-39, the Southern Oklahoma Regional Disposal (SORD) Landfill presents the following Salvage and Recycling Plan detailing operations for conducting salvage and recycling activities at the permitted facility.

1) Figure 1 identifies the recycling operation areas and the permitted areas of the landfill. Salvage and recycling activities will be conducted in an area away from the working face.

2) The following work plan details methods of collection and transportation of recyclable materials both to and from the disposal site. Recyclable materials will be collected by and transported to the disposal site by patrons of the facility. Upon arriving at the site, the recyclable material will be weighed and then directed to the recycling area. If suitable and as practicable, if recycling material is identified at the working face of the landfill, the recyclable materials will be removed by facility staff and taken to the recycling area. When SORD Landfill has collected enough material for market and there appears to be a financial benefit, the recyclable material will be weighed and transported to the appropriate vendor(s).

3) This Salvage and Recycling Plan includes salvaging and recycling the following materials of which volumes will vary based on daily landfill volumes:

- Miscellaneous metal products, e.g., refrigerators, stoves, dryers, sheet metal, etc.
- Freon removed from the above recycled miscellaneous metal products, e.g., refrigerators, etc.
- Tires
- Wooden cross-ties
- Wood, e.g., tree limbs, stumps, branches, brush, lumber, pallets
- Uncontaminated rock, dirt, concrete, bricks and solidified asphalt
- Other materials found appropriate to recycle and/or beneficial reuse.

These materials will be stored in the area identified in Figure 1. The materials will be stored in separate piles. The storage piles will be spaced at least twelve (12) feet apart to act as a fire lane and allow vehicle access. This Plan does not include any putrescible wastes that would attract vectors. The operation of this recycling area should not significantly add to the population of insects or animals not already present at the disposal facility. These recyclable materials are innocuous and will not negatively impact the environment. Freon removal from recycled metal products will be conducted by a SORD employee or third-party licensed to remove Freon.
APPLICATION TO MODIFY A SOLID WASTE DISPOSAL FACILITY PERMIT

Date: October 30, 2017
County: Carter

Send to:
Solid Waste Permitting Unit
Waste Management Division
Dept. of Environmental Quality
707 N. Robinson (PO Box 1677)
Oklahoma City, OK 73101-1677

FOR DEQ USE

DEQ Log No. 
No. Copies 
Date Received: 

Southern Oklahoma Regional Disposal proposes to modify the permit of
(Applicant's Name)

the Southern Oklahoma Regional Disposal Landfill, located at SE/4 of NE/4; SW/4 of NE/4; NW/4 of NE/4
(Facility Name)

of Section 24, Township 4 South, Range 2 East
(Exact legal description: 
moves & bounds, platted lot, or land survey. Append extra sheets if necessary)

in Carter County, Oklahoma. We hereby make application for a modification of existing permit number 3570001 as required by the Oklahoma Solid Waste Management Act and the Rules pursuant thereto.

Remarks & brief description of proposed modification:
In accordance with OAC 252:515-19-39, submitting a Salvage and Recycling Plan to conduct salvage and recycling operations at the landfill.

Applicant or Authorized Agent:

Signature

Troy Duke
Typed Name

Address: P.O. Box 1088
City: Ardmore State: OK

Date signed: 10-30-17
Phone: 580.226.1276

Facility Address (if any):
33 SORD Drive
Ardmore, OK 73401

Preparing Engineer:

Signature
Melissa Vaught, P.E.
Typed Name

Address: 525 Central Park
City: Oklahoma City State: OK

Date signed: 10/30/17
Phone: 405.842.1066

July 2016
DEQ Form #515-020
October 31, 2017

Ms. Hillary Young, P.E.
Chief Engineer, Land Protection Division
Oklahoma Department of Environmental Quality
707 N. Robinson
Oklahoma City, OK 73101-1677
Via: Hand Delivery

RE: Tier I Permit Modification — Salvage and Recycling Plan
Southern Oklahoma Regional Disposal (SORD) Landfill
Carter County, Oklahoma
Permit No. 3510007

Dear Ms. Young:

On behalf of the Southern Oklahoma Regional Disposal (SORD) Landfill, Enviro Clean Cardinal, LLC (ECC) is providing the attached Tier I permit modification to submit and implement a Salvage and Recycling Plan.

Two copies of the permit modification are being submitted. Should you have questions regarding this submittal or need additional information, please contact me at 405-842-1066 or melissa.vaught@eccgrp.com.

Sincerely,

Melissa M. Vaught, P.E.
Project Engineer

cc: Troy Duke, SORD Landfill

Enclosure: Permit Modification Application Page
Salvage and Recycling Plan

2301 E Lamar Boulevard, Suite 200
Arlington, TX 76006
(817) 617-2675

3700 West Robinson, Suite 200
Norman, OK 73072
(405) 701-5058

525 Central Park Drive, Suite 402
Oklahoma City, OK 73105
(405) 842-1066

7050 South Yale, Suite 603
Tulsa, OK 74136
(918) 794-7828

WWW.ECCGRP.COM
Appendix D

SORD Salvage and Recycling Plan
METHOD 9095B
PAINT FILTER LIQUIDS TEST

Start

7.1 Assemble test apparatus.

7.2 Place sample in filter.

7.3 Allow sample to drain into graduated cylinder.

7.4 Did any test material collect in graduated cylinder?

No → Stop

Yes

7.4 Material is deemed to contain free liquids; see 40 CFR 264.314 or 265.314.

Stop
6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

A 100-mL or 100-g representative sample is required for the test. If it is not possible to obtain a sample of 100 mL or 100 g that is sufficiently representative of the waste, the analyst may use larger size samples in multiples of 100 mL or 100 g, i.e., 200, 300, 400 mL or g. However, when larger samples are used, analysts shall divide the sample into 100-mL or 100-g portions and test each portion separately. If any portion contains free liquids, the entire sample is considered to have free liquids. If the sample is measured volumetrically, then it should lack major air spaces or voids.

7.0 PROCEDURE

7.1 Assemble test apparatus as shown in Figure 1.

7.2 Place sample in the filter. A funnel may be used to provide support for the paint filter. If the sample is of such light bulk density that it overflows the filter, then the sides of the filter can be extended upward by taping filter paper to the inside of the filter and above the mesh. Settling the sample into the paint filter may be facilitated by lightly tapping the side of the filter as it is being filled.

7.3 In order to assure uniformity and standardization of the test, material such as sorbent pads or pillows which do not conform to the shape of the paint filter should be cut into small pieces and poured into the filter. Sample size reduction may be accomplished by cutting the sorbent material with scissors, shears, a knife, or other such device so as to preserve as much of the original integrity of the sorbent fabric as possible. Sorbents enclosed in a fabric should be mixed with the resultant fabric pieces. The particles to be tested should be reduced smaller than 1 cm (i.e., should be capable of passing through a 9.5 mm (0.375 inch) standard sieve). Grinding sorbent materials should be avoided as this may destroy the integrity of the sorbent and produce many "fine particles" which would normally not be present.

7.4 For brittle materials larger than 1 cm that do not conform to the filter, light crushing to reduce oversize particles is acceptable if it is not practical to cut the material. Materials such as clay, silica gel, and some polymers may fall into this category.

7.5 Allow sample to drain for 5 min into the graduated cylinder.

7.6 If any portion of the test material collects in the graduated cylinder in the 5-min period, then the material is deemed to contain free liquids for purposes of 40 CFR 264.314 and 265.314.

8.0 QUALITY CONTROL

8.1 Duplicate samples should be analyzed on a routine basis.

9.0 METHOD PERFORMANCE

9.1 No data provided.

10.0 REFERENCES

10.1 None provided.
METHOD 9095B

PAINT FILTER LIQUIDS TEST

1.0 SCOPE AND APPLICATION

1.1 This method is used to determine the presence of free liquids in a representative sample of waste.

1.2 The method is used to determine compliance with 40 CFR 264.314 and 265.314.

2.0 SUMMARY OF METHOD

2.1 A predetermined amount of material is placed in a paint filter. If any portion of the material passes through and drops from the filter within the 5-min test period, the material is deemed to contain free liquids.

3.0 INTERFERENCES

3.1 Filter media were observed to separate from the filter cone on exposure to alkaline materials. This development causes no problem if the sample is not disturbed.

3.2 Temperature can affect the test results if the test is performed below the freezing point of any liquid in the sample. Tests must be performed above the freezing point and can, but are not required to, exceed room temperature of 25 °C.

4.0 APPARATUS AND MATERIALS

4.1 Conical paint filter -- Mesh number 60 +/- 5% (fine meshed size). Available at local paint stores such as Sherwin-Williams and Glidden.

4.2 Glass funnel -- If the paint filter, with the waste, cannot sustain its weight on the ring stand, then a fluted glass funnel or glass funnel with a mouth large enough to allow at least 1 in. of the filter mesh to protrude should be used to support the filter. The funnel should be fluted or have a large open mouth in order to support the paint filter yet not interfere with the movement, to the graduated cylinder, of the liquid that passes through the filter mesh.

4.3 Ring stand and ring, or tripod.

4.4 Graduated cylinder or beaker -- 100-mL.

5.0 REAGENTS

5.1 None.
Appendix C

Paint Filter Liquids Test Procedure
XYZ LANDFILL
RANDOM WEP INSPECTION CHECKLIST [EXAMPLE]

Use checklist for all suspicious loads and for 5% of all incoming loads of solid waste.

Date: ________________ Time: ________________ am/pm

Customer Name: ____________________________________________________________

Vehicle License Plate # and State: ________________________________

Type of Waste (check all that apply):
☐ Household ☐ Commercial
☐ Construction / Demolition ☐ Industrial
☐ Other __________________________

Identify All Unauthorized Wastes Present

☐ Hazardous (corrosive, ignitable, reactive, TCLP toxic, or listed hazardous waste)
☐ Radioactive ☐ Untreated Regulated Medical
☐ PCB ☐ Automobile Batteries
☐ Unauthorized Liquid ☐ Non-conforming NHIW
☐ Other __________________________

Waste accepted?

☐ Yes ☐ No

If no, what was done with the waste?

Additional Comments

_______________________________________________________________________

_______________________________________________________________________

Inspector's Name (Print) ____________________________ Driver's Name (Print) ____________________________

Inspector's Signature ____________________________ Driver's Signature ____________________________

Notification of unauthorized waste:

☐ DEQ Land Protection Division (405.702.5100)
   Name / Date

☐ Waste Hauler
   Name / Date

☐ Waste Generator
   Name / Date
• No later than April 1st of each year, cost estimates must be recalculated or adjusted for inflation, and the new figures submitted to the DEQ. The calculations must also be placed in the operating record. This includes all correspondence to/from DEQ related to this calculation.
• For all financial assurance mechanisms except the corporate test/guarantee and local government test/guarantee, no later than April 9th of each year, documentation must be submitted to the DEQ to demonstrate financial assurance mechanisms were updated and/or payments made based on the revised cost estimates. The documentation must also be placed in the operating record.
• If the corporate test/guarantee is used as a financial assurance mechanism, no later than 90 days after the end of the corporate fiscal year, the records identified in OAC 252:515-27-81(c) must be submitted to the DEQ and placed in the operating record.
• If the local government test/guarantee is used as a financial assurance mechanism, no later than 180 days after the end of the local government fiscal year, the records identified in OAC 252:515-27-82(h) must be submitted to the DEQ and placed in the operating record.

Subchapter 29 - Exclusion of Prohibited Wastes

• A copy of the Waste Exclusion Plan must be maintained in the operating record and submitted to the DEQ. This includes all correspondence to/from the DEQ related to the plan.
• Copies of all random inspections must be maintained in the operating record. Such records must include the date and time of the inspection, the name of the person conducting the inspection, and the results of the inspection.9
• No later than the next working day, the DEQ must be notified of any rejected loads.10 The notification must include: (1) the date of rejection; (2) the name, address, and phone number of the waste generator; (3) the name of the driver; (4) transporter tag number and (5) transporter name, address, contact name, and phone number. This information must also be maintained in the operating record.
• When necessary, documentation to verify proper disposal of rejected wastes must be maintained in the operating record.
• Copies of personnel training must be maintained in the operating record.11

Subchapter 31 - NHIW Management

• Generators disposing of more than 10 cubic yards of NHIW per calendar month off site in an Oklahoma landfill must submit an NHIW Notification/Certification to the DEQ for each NHIW to be disposed.
• No later than the last day of the month, commercial landfills accepting NHIW must submit a report to the DEQ itemizing the type, quantity, and source of NHIW received from persons disposing of more than 10 cubic yards of NHIW the previous month. This report must also be maintained in the operating record.

---

9 Attachment 1 is an example of a random inspection sheet that will meet the requirements of the rule.
10 Telephone notification will suffice.
11 This includes the training dates, curriculum, and attendees.
Subchapter 23 - Regulated Medical Waste Facilities

- A copy of the approved certificate of need must be in the operating record.
- Copies of emergency response agreements must be maintained in the operating record.
- The operating record must include records of when waste was placed into and removed from storage.
- Records of any tests done on a regulated medical waste incinerator must be maintained in the operating record.
- Incinerator monitoring data must be maintained for at least 2 years. Such data includes waste feed rates, fuel and combustion gas flows, oxygen and carbon monoxide, and temperature.
- Testing and disposal records for incinerator ash must be maintained in the operating record.
- For regulated medical waste incinerators, an NHIW notification/certification form and associated documentation showing the ash is non-hazardous must be submitted to the DEQ.

Subchapter 25 - Closure and Post-Closure Care

- Copies of closure and post-closure plans, all amendments, maps, drawings, construction plans, QA/QC reports, legal access documents, etc. required by the plans must be submitted to the DEQ and maintained in the operating record. All correspondence to/from the DEQ related to the permit application must also be maintained in the operating record.
- Documentation of all activities performed for closure must be submitted to the DEQ with the final closure report and placed in the operating record.
- A copy of the land records notice as recorded must be submitted to the DEQ at the conclusion of closure activities.
- All correspondence to/from the DEQ related to closure and/or post-closure activities must be maintained in the operating record.
- No later than April 1st of each year, a post-closure maintenance and monitoring report must be submitted to the DEQ, and a copy placed in the operating record.
- At the conclusion of post-closure, a Certification of Post-closure Performance must be submitted to the DEQ.

Subchapter 27 - Cost Estimates and Financial Assurance

- Copies of all cost estimates and financial assurance documents must be submitted to the DEQ and maintained in the operating record. This includes all correspondence to/from DEQ related to these documents.
- When a surety bond, letter of credit, certificate of deposit, or insurance is used as the financial assurance mechanism, an original and one copy of the instrument must be submitted to the DEQ.
- No later than April 1st of each year, life of site calculations must be submitted to the DEQ, identifying the life of the site as of December 31st of the previous year. The calculations must also be placed in the operating record. This includes all correspondence to/from DEQ related to this calculation.

8 The actual policy, not a certificate, must be submitted to DEQ.
• Landfills accepting asbestos must maintain the records identified in the Management of Friable Asbestos guidance document.
• Composting facilities must maintain records documenting when windrows were turned, windrow temperatures, and the amount of waste received, processed, and distributed.

Subchapter 21 - Waste Tire Processing, Certification, Permits, and Compensation

Waste tire facilities
• Records of gross and tare weights of each vehicle must be maintained in the operating record.
• A daily log for each load of tires received must be maintained in the operating record. The daily log must include the name and address of the hauler, the number of tires from each tire source, the name and address of each tire source, the number of tires processed each day, and the use and destination of each daily outbound load of processed tire material.
• No later than the 10th of each month, a monthly report must be submitted to the DEQ identifying the following for the previous month: the number of tires received, the number of tires from community-wide clean up events, the number of tires from PCL dumps, a summary of destinations and intended uses of processed tire material, the number of tons of processed tire material provided for each market category, and the number of tires provided to waste tire incinerators that were not useable by the incinerator. The monthly report must also be maintained in the operating record.
• No later than the 10th of the month following the end of each calendar quarter, a quarterly report must be submitted to the DEQ identifying the following for the previous quarter: statewide collection efforts and documentation the scales were certified in accordance with Department of Agriculture requirements. The quarterly report must also be maintained in the operating record.
• All copies of waste tire manifests must be maintained in the operating record.
• All records required by the Oklahoma Tax Commission for reimbursement purposes must be maintained in the operating record.

Entities installing river bank stabilization or other conservation projects
• A copy of the permit or other authorization for the project must be maintained.
• A copy of the project completion report must be submitted to the DEQ and retained by the installer.
• Copies of any letters to/from the DEQ related to the project must be retained by the installer.

Waste tire baling entities
• A copy of a waste tire baling plan must be submitted to the DEQ and maintained in the operating record.
• A copy of the project completion report must be submitted to the DEQ and retained by the entity.
• Copies of any letters to/from the DEQ related to the plan must be maintained in the operating record.

---

6 Records must be maintained by the entity for at least 3 years after completion of the project.
7 Records must be maintained by the entity for at least 3 years after completion of the project.
• Within 7 days of detection of an exceedance, submit a written notice to the DEQ of the exceedance and the steps taken to protect human health. A copy of this notice must also be placed in the operating record.
• Within 30 days of detection of an exceedance, a remediation plan must be submitted to the DEQ and a copy placed in the operating record.
• Written notification must be provided to the DEQ when the remediation plan is implemented, and a copy of that notice placed in the operating record.

**Subchapter 17 - Stormwater Management**

• A copy of the Stormwater Pollution Prevention Plan and OPDES Sector L permit must be maintained in the operating record.
• A copy of the OPDES stormwater permit for construction sites must be maintained in the operating record for any on- or off-site soil borrow areas of 5 acres or more in size.
• OPDES Sector L visual monitoring and Numeric Effluent Limitation Monitoring results must be maintained in the operating record.
• The Annual Comprehensive Site Compliance Evaluation Report must be submitted to the DEQ’s WQD no later than December 15th of each year.
• All NELM monitoring results must be submitted to the DEQ no later than October 29th of each year for the period October 2nd of the previous year to October 1st of the current year.

**Subchapter 19 - Operational Requirements**

• Copies of random waste screening inspections must be maintained in the operating record. ³
• Monthly waste receipt reports must be submitted to the DEQ and a copy placed in the operating record no later than the 15th of the month following the reporting month. ⁴
• To avoid penalties, quarterly returns and fees for landfills must be submitted to the DEQ within 30 days of the end of the quarter. ⁵ A copy of the quarterly return must be maintained in the operating record.
• Copies of approved out-of-state waste disposal plans must be on file with the DEQ and maintained in the operating record, as well as all correspondence to/from DEQ related to the development of the approved plan.
• The DEQ must be notified at least 5 working days in advance of any proposed changes to an approved out-of-state waste disposal plan.
• Copies of initial design capacity reports required by the New Source Performance Standards (NSPS), as well as required updates to the design capacity, must be submitted to the DEQ and placed in the operating record.
• Copies of all test results required by NSPS must be submitted to DEQ and maintained in the operating record.

---

³ An example of a waste screening checklist is included with this guidance.
⁴ Monthly reports are not required to be submitted to the DEQ for large NHIW generator landfills, generator owned and operated NHIW monofills, transfer stations, and processing facilities (including incinerators and regulated medical waste facilities). However, records identifying the amount of waste received must be maintained in the operating record and made available to DEQ upon request.
⁵ Returns and fees submitted later than this are subject to penalties and are not eligible for the handling waiver.
• Within 14 days of receiving the results from an assessment monitoring event, the DEQ must be notified of the constituents that were detected.
• Prior to a public meeting to discuss an assessment of corrective measures, the DEQ must be provided with:
  > an affidavit (with a copy of the published notice) showing that public notice of the meeting was published in a local newspaper;
  > copies of certified mail receipts showing that the entities identified in OAC 252:515-9-113(b) were notified of the public meeting; and
  > property and mineral ownership maps covering the area within a 2 mile radius of the facility.
• Within 60 days of the public meeting to discuss an assessment of corrective measures, a proposed remedy must be submitted to DEQ for approval and a copy placed in the operating record.
• When the remedy is complete, a certification signed by the owner/operator and a qualified groundwater scientist must be submitted to the DEQ for approval and the approved certification placed in the operating record.

Subchapter 13 - Leachate Collection and Management

• Documentation must be submitted to the DEQ and maintained in the operating record showing any underground storage tanks used to store leachate meet the requirements of the Oklahoma Corporation Commission at OAC 165:25, Subchapter 1, Part 8.
• Plans for leachate recirculation and/or irrigation must be submitted to the DEQ and maintained in the operating record, as well as all correspondence to/from DEQ related to those plans.
• Any testing results required by leachate recirculation/irrigation plans must be submitted to DEQ and maintained in the operating record.
• If leachate is discharged to a POTW, a copy of a letter from the POTW stating it will accept the leachate must be placed in the operating record and submitted to the DEQ.
• The results of any testing required by the POTW must be maintained in the operating record.
• If leachate is discharged under an OPDES permit, a copy of the permit must be maintained in the operating record.
• Any testing required by the OPDES permit must be submitted to DEQ and maintained in the operating record.

NOTE: Quarterly leachate reports are no longer required to be maintained or submitted.

Subchapter 15 - Methane Gas Monitoring and Control

• Within 30 days of monitoring, gas-monitoring results should be submitted to the DEQ and placed in the operating record.\(^2\)

---
\(^2\) While the rules don’t give a specific time to submit the gas monitoring results, the rules require a remediation plan to be submitted within 30 days of detecting an exceedance. Therefore, it would make sense that the gas monitoring results would be submitted at the same time.
DEQ Guidance on Recordkeeping and Reporting


Applicability. All solid waste disposal facilities.

Purpose. To provide guidance on the records to be maintained in the facility operating record and submitted to the DEQ.

Technical Discussion. All solid waste disposal facilities are required to maintain an operating record containing all records concerning the planning, construction, operation, closing and, if applicable, post-closure monitoring of the facility.\(^1\) Preferably, the operating record should be maintained at the disposal facility; however, an off-site location near the facility which is under the direct control of the owner/operator and accessible during DEQ inspections can be used. For the purposes of this rule, facility records maintained by consultants cannot be considered part of the operating record.

Various Subchapters of OAC 252:515 identify records that must be maintained and/or submitted to the DEQ. This guidance will identify those records so that owner/operators can ensure all required records are being maintained and submitted in a timely manner.

**Subchapters 3 through 31 - Permit Applications and Related Documents**

- All applications for new and modified permits must be submitted to the DEQ and maintained in the operating record. The permit application includes all text related to the application as well as all maps, drawings, construction plans, QA/QC reports, legal access documents, public notices, etc. required by other Subchapters.
- All correspondence to/from the DEQ related to the permit application must be maintained in the operating record.
- A copy of the approved permit and all associated modifications must be maintained in the operating record.

**Subchapter 9 - Groundwater Monitoring and Corrective Action**

- Within 60 days of groundwater sampling, a copy of groundwater monitoring results and associated statistical analysis (or cumulative analysis data for C/D landfills) must be placed in the operating record and submitted to the DEQ.
- Within 14 days of determining there is a statistically significant increase (SSI) in one or more monitoring constituents, the DEQ must be notified of the SSI in writing and a copy of the notice placed in the operating record.
- Within 90 days of determining there is a statistically significant increase, either an assessment monitoring program, or a demonstration that the increase was not caused by the facility, must be submitted to the DEQ and placed in the operating record.

\(^1\) This includes all correspondence to/from the DEQ.
Appendix B

ODEQ Guidance on Recordkeeping and Reporting
INSTRUCTIONS FOR COMPLETING THE QUARTERLY RETURN FOR SOLID WASTE LANDFILLS

GENERAL INSTRUCTIONS

All solid waste landfills, except generator owned and operated non-hazardous industrial waste monofills, are required by 27A O.S. §2-10-802 to collect fees on solid waste received at the landfill.

This return should be completed and returned to the Financial and Human Resources Division of the Department of Environmental Quality no later than 30 days after the end of each calendar quarter. Calendar quarters are: 1st quarter--January 1 through March 31, 2nd quarter--April 1 through June 30, 3rd quarter--July 1 through September 30, 4th quarter--October 1 through December 31.

If the return and fees cannot be submitted within 30 days of the end of the quarter, an extension for up to 30 days may be granted by the Department. A request for an extension must be submitted no later than the due date of the return and must include a detailed description of why the extension is needed. The Department will notify you if the extension is granted or not. Please note that extensions cannot be granted which will result in a due date of more than 60 days after the end of the quarter.

SPECIFIC LINE INSTRUCTIONS

Line 1: Enter the number of days during the quarter the landfill was open to receive waste.

Line 2a & 4a: The activities must be included in, and conducted in accordance with, the landfill’s permit. Records pertaining to this fee exemption must be included with the quarterly return. Exemption documentation is to include: 1) waste types and 2) weight/volume recycled and method of recycling for each waste type. If this information is not included, the claim may be disallowed.

Line 2b & 4b: A copy of the DEQ’s written approval waiving the fee must be included with the quarterly return. If a copy is not included, the claim may be disallowed.

Line 2c & 4c: Enter the amount of waste received from large industrial waste generators which was accompanied by a large industrial waste generator fee exemption certificate issued by the DEQ.

Line 12: If line 13 of last quarter’s return is $40,000, enter $0.00, otherwise:
- If line 9 is less than 100 tons/day, multiply line 8 by $0.50.
- If line 9 is equal to or more than 100 tons/day, multiply line 8 by $0.25.

NOTE: Records documenting the capital investment and the use of the funds must be included with the quarterly return.

Line 13: If line 13 of last quarter’s return is less than $40,000, add line 13 of last quarter’s return and line 12 of this quarter’s return. If line 13 of last quarter’s return is $40,000, enter $40,000.00.

Line 14: If line 13 of last quarter’s return is less than $40,000.00, enter $0.00. If line 13 of last quarter’s return is $40,000 AND this return in filed on time, multiply line 11 by 0.10. Otherwise, enter $0.00.

PENALTIES

There is a 5% penalty for returns postmarked more than 30 days after the due date (or filed after the extension date). Your penalty is determined by multiplying line 11 of the return by 0.05 and including this figure on line 16.

There is a 15% penalty per month for returns postmarked more than 60 days after the due date of the return. Your penalty is determined by multiplying line 11 of the return by 0.15, then by the number of months which have elapsed after the due date (or the extension date if applicable) and including this figure on line 16.

If you have any questions, please contact Amber Edwards, Land Protection Division Solid Waste Unit (405) 702-5133.

DEQ Form #515-030 Jan-18
QUARTERLY RETURN FOR SOLID WASTE LANDFILLS
Due no later than 30 days after the end of each calendar quarter

Facility Name: _____________________________________________
Mailing Address: ___________________________________________

1. Number of operating days this quarter (see instructions) __________________________ days
2. Total weight, in tons, of waste received during this quarter
   2a. Weight received, in tons, which was productively reused or recovered and sold (see instructions) __________________________ tons
   2b. Weight received, in tons, from a DEQ approved emergency or special event (see instructions) __________________________ tons
   2c. Weight received, in tons, from large industrial waste generators under the large industrial waste generator exemption (see instructions) __________________________ tons
3. Weight subject to state disposal fees (line 2 minus sum of lines 2a, 2b, and 2c) __________________________ tons
4. Total volume, in cubic yards, of waste received during this quarter
   4a. Weight received, in cubic yards, which was productively reused or recovered and sold (see instructions) __________________________ yd³
   4b. Weight received, in cubic yards, from a DEQ approved emergency or special event (see instructions) __________________________ yd³
   4c. Weight received, in cubic yards, from large industrial waste generators under the large industrial waste generator exemption (see instructions) __________________________ yd³
5. Volume subject to state disposal fee (line 4 minus sum of lines 4a, 4b, and 4c) __________________________ yd³
6. Volume weight subject to state disposal fee (multiply line 5 by 0.33) __________________________ tons
7. Determine volume weight from total volume (multiply line 4 by 0.33) __________________________ tons
8. Total weight received (add line 2 and line 7) __________________________ tons
9. Average weight received per operating day (divide line 8 by line 1) __________________________ tons/day
10. Weight received subject to state disposal fee (add line 3 and line 6)
    10a. Line 13 from previous quarter __________________________
11. Enter state disposal fee (If line 10a < $40,000, line 10 x $1.50, otherwise, line 10 x $1.25) __________________________
12. Enter capital investment waiver (see instructions) __________________________
13. Determine total capital investment waiver to date (see instructions) __________________________
14. Enter handling waiver (see instructions) __________________________
15. Enter total allowable waivers (add line 12 and line 14) __________________________
16. Penalties (see instructions) __________________________
17. TOTAL STATE DISPOSAL FEE DUE (line 11 plus line 16 minus line 15) __________________________

Typed/Printed Name of Authorized Agent: ___________________________________________ Date: __________________________
Signature of Authorized agent: __________________________ Phone No.: __________________________
Email Address: __________________________________________

Remit report with payment to:
Oklahoma Department of Environmental Quality
Administrative Service - Accounts Receivable
P.O. Box 2036
Oklahoma City, OK 73101-2036

Remit copy of report to:
Oklahoma Department of Environmental Quality
Land Protection Division
P.O. Box 1677
Oklahoma City, OK 73101-1677

Electronic submissions should be submitted to: solidwastereports@deo.ok.gov bernice.green@deo.ok.gov

DEQ Form #515-030 Jan-18
INSTRUCTIONS FOR COMPLETING THE MONTHLY REPORT FOR SOLID WASTE DISPOSAL FACILITIES

The monthly report for solid waste disposal facilities should be submitted to DEQ no later than the 15th of the month following the reporting month and should include all solid waste received during the month. **If no solid waste is received in a given month, a monthly report is still required. Please include a notation that no solid waste was received during the month. If submitting report electronically, please send to solidwastereports@deq.ok.gov and bernice.green@deq.ok.gov.**

1. In the spaces provided, enter the month and year covered by the report, the facility name, permit number, mailing address, and phone number.

2. For each operating day of the month, provide the following and identify which days during the month the facility was closed.

   Column 1: **Total weight accepted:** Enter the total weight, in tons, of all waste accepted at the facility for each day. The total must include weights to be reported in columns 2, 3, and 4.

   Column 2: (Only applicable to landfill disposal facilities) **Weight which is reused or recycled in accordance with facility permit:** Enter the weight, in tons, of waste accepted at the facility which was productively reused at the facility in accordance with the facility’s permit OR was recovered and sold in accordance with the facility’s permit.

   Column 3: (Only applicable to landfill disposal facilities) **Weight accepted from a DEQ approved emergency or special event:** Enter the weight, in tons, of waste accepted at the facility from an emergency or special event for which the facility received prior approval from the DEQ to waive the state disposal fee.

   Column 4: (Only applicable to landfill disposal facilities) **Weight accepted from large industrial waste generators with DEQ exemption certificate:** Enter the weight, in tons, of waste received from large industrial waste generators which was accompanied by a large industrial waste generator fee exemption certificate issued by the DEQ.

   Column 5: (Only applicable to landfill disposal facilities) **Time scales placed out-of-service:** Enter the approximate time (hour:minute) the scales became inoperative.

   Column 6: (Only applicable to landfill disposal facilities) **Time scales placed into service:** Enter the approximate time (hour:minute) the scales were placed into service.

*Note: Section 2-10-802 of the Oklahoma Solid Waste Management Act requires operators of certain landfill disposal facilities to weigh all solid waste received at the landfill. Only when the scales are inoperative may a landfill record the volume of waste received.*

   Column 7: **Total volume accepted:** Enter the total volume in cubic yards of all waste accepted at the facility. The total must include volumes to be reported in columns 8, 9, and 10.

   Column 8: (Only applicable to landfill disposal facilities) **Volume which is reused or recycled in accordance with facility permit:** Enter the volume, in cubic yards, of waste accepted at the facility which was productively reused at the facility in accordance with the facility’s permit OR was recovered and sold in accordance with the facility’s permit.

   Column 9: (Only applicable to landfill disposal facilities) **Volume accepted from a DEQ approved emergency or special event:** Enter the volume, in cubic yards, of waste accepted at the facility from an emergency or special event for which the facility received prior approval from the DEQ to waive the state disposal fee.

   Column 10: (Only applicable to landfill disposal facilities) **Volume accepted from large industrial waste generators with DEQ exemption certificate:** Enter the volume, in cubic yards, of waste received from large industrial waste generators which was accompanied by a large industrial waste generator fee exemption certificate issued by the DEQ.

3. At the end of the month, calculate the total down time for the scales (hours:minutes) and include in the space provided. Sum each column and include in the appropriate column.
MONTHLY REPORT FOR SOLID WASTE DISPOSAL FACILITIES

(Please see instructions prior to completing this form)

Please Remit Original Report to:
Solid Waste Compliance and Enforcement
Land Protection Division
P. O. Box 1677
Oklahoma City, OK 73101-1677
Solidwastereports@deq.ok.gov

And

Please Remit Copy of Report to:
Revenue Management Section
Administrative Services Division
P. O. Box 2036
Oklahoma City, OK 73101-2036
Bernice.Green@deq.ok.gov

Facility Physical Address: ________________________________________________________________

Facility Name: ____________________________________________________

Mailing Address: ____________________________________________________________

Report month/year: ____________________________

Permit No.: ____________________________

Phone No.: ( ) ____________________________

Number of Operating days: ______

<table>
<thead>
<tr>
<th>Day</th>
<th>(1) Total weight accepted (tons)</th>
<th>(2) Weight which is reused or recycled in accordance with facility permit (tons)</th>
<th>(3) Weight accepted from a DEQ approved emergency or special event (tons)</th>
<th>(4) Weight accepted from large industrial waste generators with DEQ exemption certificate (tons)</th>
<th>(5) Time scales placed out-of-service</th>
<th>(6) Time scales placed into service</th>
<th>(7) Total volume accepted (yd³)</th>
<th>(8) Volume which is reused or recycled in accordance with facility permit (yd³)</th>
<th>(9) Volume accepted from a DEQ approved emergency or special event (yd³)</th>
<th>(10) Volume accepted from large industrial waste generators with DEQ exemption certificate (yd³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

I hereby certify that the information reported above is accurate and correct to the best of my knowledge and includes all solid waste received at this facility.

Signature of authorized agent: ____________________________ Date: ____________________________

April 2017: DEQ Form # 515-031
Appendix A

Monthly and Quarterly Reporting Forms
13.0 RECORDKEEPING AND REPORTING

The SORD shall maintain operating records at the facility containing records concerning the planning, construction, operation, monitoring, closing, and post-closure monitoring of the facility. Such records shall be maintained until the post-closure monitoring period is terminated. A list of recordkeeping and reporting that should be completed by the SORD is included in the ODEQ Guidance on Recordkeeping and Reporting attached in Appendix B of this plan.
12.0 SAFETY

12.1 FIRES

Protection against fires shall include providing fire extinguishers on all landfill equipment and proper maintenance and cleaning of the equipment to remove trash that may be ignited by equipment exhaust.

Landfill personnel will be on alert for indication that an arriving load of solid waste may be smoldering or have the potential to ignite. If a smoking or smoldering load is observed, the solid waste will immediately be pushed or directed away from the active working face and spread out as much as possible. A thick layer of soil will then be spread over the solid waste and compacted to effectively smother the fire. The sealed solid waste will be observed for several days, and if signs of smoke appear, more soil will be spread and compacted over the solid waste. It may be necessary to leave the "hot" solid waste sealed for an extended period of time before incorporating it into the active working face.

If an area of the daily cell should ignite or show signs of smoldering, the area will be excavated to ensure that all of the hot material is segregated from the active face. The excavated solid waste will be pushed as far as possible from the working face and sealed as described above.

12.2 EMERGENCY CONTACTS

In the event of an emergency at the SORD, personnel will dial 911 in order to direct the appropriate assistance to the site. Fire, police, and ambulance assistance is available to the site by dialing 911.

12.3 COMMUNICATION EQUIPMENT

All vehicles, including the compactor, will have a two-way radio capable of communicating with the landfill office. Telephone service is available at the landfill office and can be used for calling emergency equipment (fire, police, or ambulance) in the event of an accident or other emergency. Additional emergency telephone numbers will be clearly posted near the telephone.

12.4 TRAFFIC SIGNS

In addition to the entrance sign described in Section 1.3 of this report, additional signs will be posted as necessary. These signs may include:

- Directions to active face of landfill,
- Speed limits, and
- Cautionary signs.
11.0 AIR QUALITY

11.1 DUST CONTROL

The SORD shall be operated to prevent the discharge of visible fugitive dust emissions beyond the property boundaries. Fugitive dust emissions shall not damage or interfere with the use of adjacent properties or cause air quality standards to be exceeded. The SORD should spray haul roads using a water truck, as needed, when the facility is in operation. Additionally, open burning of solid waste at the SORD is prohibited.
10.0 ENVIRONMENTAL MONITORING

10.1 SURFACE WATER MONITORING

Surface water will be monitored in accordance with the site's current SWP3. A copy of the SWP3 should be maintained within the site's operating record.

10.2 STORM WATER STRUCTURE MAINTENANCE

Numerous storm water drainage control structures will be constructed at the landfill. These structures include perimeter channels, letdown channels, and terraces. Routine maintenance must be conducted on these structures to ensure proper operation. These drainage structures will be inspected in accordance with the facility's SWP3. If erosion damage has occurred to a drainage structure, it will be repaired as soon as possible.

Temporary surface run-on and run-off control will be implemented as operationally necessary to reduce the amount of run-on and run-off coming into contact with the active refuse face of the landfill or to reduce erosion from disturbed areas of the site.

10.3 GROUNDWATER MONITORING

Groundwater will be monitored in accordance with the approved Groundwater Monitoring Plan for the site, which is maintained in the facility's operating record.

10.4 GAS MONITORING

Landfill gas will be monitored in accordance with the approved Explosive Gas Monitoring Plan for the site, which is maintained in the facility's operating record.

10.5 LEACHATE MONITORING

Leachate monitoring will be conducted as required for recirculation, irrigation, or by the receiving facility when leachate is hauled offsite for disposal. Results of leachate monitoring will be retained in the operating records of the facility.
9.0 VECTORS AND AESTHETICS

9.1 VECTORS

In general, vectors will not find suitable harborage in the landfill due to the compaction and covering of the waste. However, if a vector problem should arise, an assessment of the operating conditions will be made and necessary corrective actions will be taken. If the vector problem persists after initial corrective action, a professional exterminator will be hired to mitigate the problem.

9.2 LITTER CONTROL

The SORD is surrounded by dense vegetation consisting of tall trees that minimizes wind speeds and air-blown litter from leaving the site. Portable litter fences are used around the active disposal area. Additionally, a litter vacuum is available on site and temporary labor used to pick up litter as needed. Utilizing a sweeper, the site and approach roadways of the SORD shall be cleaned of litter.

9.3 SPECIAL COVERING

Waste that is received at the site that may cause a nuisance with blowing litter, dust, or odors will be covered immediately rather than waiting for cover at the end of the day.
8.4 BORROW SOURCE

Borrow areas for the SORD are located in the expansion area and south of the permitted waste boundary on property owned by Southern Oklahoma Regional Disposal, Inc. Borrow areas which are no longer active shall be reshaped and re-vegetated or otherwise reclaimed to blend with surrounding terrain within 180 days of the date the area ceased being used. Borrow areas shall be maintained as outlined in the site's current Storm Water Pollution Prevention Plan (SWP3).
After disking the seeded area, hay will be mulched at a rate of approximately 3 bales (700 to 1,000 lbs each) per acre. To further minimize erosion potential and facilitate moisture retention, the hay will then be "crimped" using a roller to integrate the hay into the soil.

For future areas that will receive final cover, the initial seeding event will occur as follows:

- For final cover that is constructed in the winter, the initial seeding event will consist of a Fall/Winter seed mix, followed by permanent vegetation using a Spring/Summer seeding mixture.
- For final cover that is constructed in the spring, the initial seeding event will consist of a Spring/Summer seed mix, followed by permanent vegetation using a Fall/Winter seeding mixture.

Vegetation will be established during the first possible growing season. Maintenance of the permanent vegetation will typically consist of protection, replanting, maintaining existing grades, repair of erosion damage, and mowing. After the seeds have sprouted, the site will inspect the slopes for areas with no grass or with thin grass. These areas will be reseeded, watered, and fertilized to establish an acceptable permanent vegetation layer. If there are areas where establishing vegetation is unsuccessful, an alternative plan will be developed.

To prevent ponding, the final cover gradient on top of the fill (as measured from the center of the fill area to the break in slope between the top and sides of the fill) shall be four (4) percent, unless otherwise approved by the ODEQ. The final side slope gradient shall not exceed twenty-five (25) percent. Final cover surface contours shall prevent ponding water and erosion of fill areas.

The ODEQ shall be notified in writing prior to the beginning of final closure of the facility or closure of a disposal cell. Closure activities shall begin no later than 90 days after final receipt of wastes at the facility or final receipt of wastes into a disposal cell, as applicable. Closure activities shall be completed within 180 days after closure activities are initiated. Extensions of the closure period may be granted by the ODEQ if the SORD demonstrates that closure will, of necessity, take longer than 180 days and that all steps have been taken, and will continue to be taken, to prevent threats to human health or the environment from the cell or facility.

Upon closing the facility, the SORD shall have a licensed surveyor's plat of the site prepared. The survey plat and detailed description will show, at a minimum, the final contours of the entire site; the permit boundary and boundaries of the disposal areas; the location of gas monitoring wells and extraction systems; the location of groundwater monitoring wells; the location of leachate management systems or surface impoundments; the location of permanent surface drainage structures; aesthetic enhancements; and other relevant information. The site's approved Closure and Post-Closure Plan should be referenced for additional information required for a Certification of Final Closure submittal.
during each season of the year. Permanent or interim vegetation shall be established in areas that have been undisturbed for 90 days or more.

Typical Seeding Mixtures

Spring/Summer Planting Season
(Optimal Time for Planting – April 1 through May 30)

<table>
<thead>
<tr>
<th>Seed Mixture</th>
<th>Minimum Percent Live Seed Required</th>
<th>Pure</th>
<th>Pounds Per Live Seeds Required Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Bermuda Grass</td>
<td>85</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Blue Stem</td>
<td>65</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Side Oats Grama</td>
<td>65</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Rye</td>
<td>85</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td>26</td>
<td></td>
</tr>
</tbody>
</table>

Fall/Winter Planting Season
(Optimal Time for Planting – September 1 through February 15)

<table>
<thead>
<tr>
<th>Seed Mixture</th>
<th>Minimum Percent Live Seed Required</th>
<th>Pure</th>
<th>Pounds Per Live Seeds Required Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter Wheat</td>
<td>75</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Fescue or Rye</td>
<td>85</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Total:</td>
<td></td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

The Typical Seeding Mixtures table shown above lists typical seeding mixtures that will be used for the site during each season and is only provided as a reference. It is understood that a variety of application rates and types of seed mixtures will produce adequate vegetative cover. The seed may be applied to the landfill slopes by various typical application methods such as hydro mulch or seed drilling.

Fertilizer will be applied to the seeded area as needed. The following typical application method should be used:

- Additional soil will be added to the side slopes, as needed, and the soil will be processed using a disk to prepare the soil for seeding.
- Fertilizer will be applied using a commercial spreader at a rate of approximately 150 pounds per acre (lb/acre), and the soil will be simultaneously disked using a disk-harrow. The fertilizer rate may vary. However, an initial rate of 10 (nitrogen) - 20 (phosphate) -10 (potassium) may be used.
- The seed mixture will then be applied using a commercial spreader and the area simultaneously disked using a disk harrow.

1 The mixtures shown in the tables are for reference only. Other mixtures may also be applied.
8.0 COVER AND BORROW SOIL

8.1 DAILY COVER

Daily soil cover or an alternative daily cover (ADC) will be applied at the end of each operating day, regardless of weather, as required by ODEQ, to deter disease vectors, fires, odors, and blowing litter. The daily soil cover material should consist of nominally compacted earthen material free of garbage, trash, or other unsuitable material. The minimum thickness of the daily soil cover will be six inches. The frequency of daily cover application may need to be increased in order to provide adequate control of disease vectors, fires, odors, blowing litter, or scavenging.

As an alternative to daily soil cover, the SORD is permitted to use tarps, tire chips, foundry sand, posi-shell, and posi-shell plus extreme rain shield. The ADC shall not be used for more than six consecutive days without placing six inches of earthen cover on the seventh day. Six inches of earthen material must be used instead of any ADC if the working face fill remain unused for more than 24 hours. ODEQ approval for the ADC should be maintained in the site's operating record.

8.2 INTERMEDIATE COVER

Intermediate cover shall be applied to inactive areas of the landfill that are not protected by final cover. The intermediate cover shall consist of 12-inches of nominally compacted earthen material free of garbage, trash, or other unsuitable materials.

The SORD may submit a permit modification to the ODEQ to approve the use of an alternative intermediate cover, demonstrating the alternative is capable of controlling disease vectors, fires, odors, and blowing litter without presenting a threat to human health or the environment. If an alternative intermediate cover is approved by the ODEQ for use at the SORD, this Plan should be revised to discuss the use of the approved alternate intermediate cover.

8.3 FINAL COVER

When the landfill has been filled to final waste elevations, the final landfill cap will be constructed. Terraces and storm water management structures will be constructed at the same time that the landfill cap is installed. The final cover at SORD will be constructed in accordance with the approved Closure and Post-Closure Plan and QA/QC Plan. Cover system material conformance testing, general construction procedures, and testing requirements are presented in the QA/QC Plan.

The final cover will be an evapotranspiration cover system. The cover system will consist of a 12-inch thickness of intermediate cover, a 24-inch vegetation support layer, and a 12-inch vegetation layer (topsoil). Each layer will be constructed to support vegetative growth.

Final cover vegetation must be effective, long-lasting, and capable of self-regeneration and plant succession. Vegetation shall consist of species that are equal or superior to native vegetation.
7.1.3 Proper Disposal of Dead Animals

Dead animals accepted for disposal should be covered with solid waste or cover soil immediately upon placement at the open face.

7.1.4 Storm Water Management

Per OAC 252:515-19-38(a), solid waste shall not be placed or allowed to enter, accidentally or otherwise, waters that communicate with waters of the state located outside the permit boundary. Storm water that accumulates in or near the active landfill area will be managed to minimize contact with the working face or other exposed waste. Temporary berms will be constructed along the perimeter of each disposal cell to direct potential storm water run-on to the appropriate storm water ditches or structures and to prevent storm water run-off from the working face of the landfill from intermingling with “clean” storm water. In addition, temporary storm water diversion berms or “rain flaps” may be constructed to minimize storm water that enters the leachate collection system. The construction of such berms or “rain flaps” will be dependent on the rate and location of waste placement within each cell.

7.2 EQUIPMENT

The equipment to be used on the site will include but not necessarily be limited to the following (or equivalent):

- Dozer;
- Backhoe;
- Haul truck;
- Compactor; and
- Water truck

Available equipment will be modified as necessary to accommodate changes in operations or waste flows. All equipment will receive mechanical service on a routine basis. Fire extinguishers will be provided on all landfill equipment.

The manufacturer’s recommendations on equipment maintenance will be followed for each piece of landfill equipment. Regularly scheduled equipment maintenance is essential if the landfill equipment is to be dependable. In addition, at the end of each operating day, the equipment operator will remove trash that may be lodged in the operating portion of the equipment tracks or the compaction equipment.
7.0 LANDFILLING PROCEDURES

7.1 LANDFILL PROGRESSION AND SEQUENCE OF FILL

Refuse trucks will deposit waste in the area identified as the working face. The working face is a sloped surface upon which the waste is compacted in layers. The waste is compacted by the landfill compactor as it is spread. The slope of the working face will be no more than four feet horizontal to one foot vertical (4:1). The compactor will make multiple passes over the waste layer until the waste rebounds the same amount that it was depressed by the compactor. The height of waste will generally not exceed fifteen (15) feet in height and is referred to as a lift. The width of the working face will be kept as small as practical. The waste will be spread and compacted as it is received.

Under the area fill method, waste is placed next to the previous day’s waste until an established row length is reached. Another row is then started parallel to the previously constructed row. As the rows form lifts over each area, the top of each landfill lift should slope in such a manner to allow surface runoff to drain away from the working face. After a number of rows have been constructed (creating a lift), a second lift is constructed over the first lift. Waste placement will alternate between various lifts of waste and will allow landfill traffic to discharge waste at various levels. This method will allow the earthmoving equipment to stockpile daily cover at the top of the day’s waste, if necessary.

When the last load of refuse for the day has been spread and compacted, the application of 6-inches of daily cover soil or an alternative daily cover (ADC) will begin (see Section 8.1). Waste will not be placed in areas where the presence of water would prohibit proper spreading of the waste or promote a mosquito problem.

7.1.1 Placement of Initial Layer of Waste

Upon completion of cell construction and receipt of approval from the ODEQ, the landfill may begin placing waste in a new disposal cell. Filling should begin at the lowest elevations of each cell and work toward higher elevations to prevent excess leachate generation. The initial lift of waste placed in a cell should be comprised of “select” waste that will not damage the composite liner system and will provide an additional protective layer against freeze/thaw effects. This lift of select waste should be comprised of waste which does not contain long, sharp objects, or bulky material. When placing this select waste lift, a compactor should not be used until a minimum of five feet of waste has been placed over the drainage/protective cover layer. A track dozer can be used to spread waste into the cell while operating on already-placed waste.

7.1.2 Placement of Bulky Solid Wastes

Bulky waste should be crushed on the ground surface and then pushed onto the working face near the bottom of the fill area. Bulky waste that cannot be crushed should be placed near the bottom of the cell, though not in the first lift of waste.
6.0 LEACHATE COLLECTION AND STORAGE

The slope of the bottom of the landfill will allow leachate to be directed to leachate sumps located at the perimeter of the landfill. To ensure that the leachate drains toward the leachate sumps, the geomembrane liner will be covered with an 8-oz/sq yd non-woven geotextile cushion and a 24-inch thick leachate collection/protective cover. Leachate collection pipes will be placed in each drainage area to intercept leachate and transport it to a collection sump. The leachate collection system will be equipped with a pressure transducer, leachate level readout, and high level alarm to monitor leachate levels. The sump pump will be manually engaged on a daily basis, if needed, to ensure leachate levels do not exceed one foot above the top of the sump. As-builts for the sumps will be included in the Liner Installation and Testing (LIT) report, which will be submitted to the ODEQ upon construction.

Per OAC 252:515-13-14, the leachate collection pipes shall be cleaned out after placement of protective cover layer, again after the placement of the first lift of waste, and once per year thereafter.

Removal of leachate by a leachate collection system will eliminate the pressure head that would be necessary to force leachate through the composite liner. Prior to the placement of waste, traffic will be routed to minimize its detrimental impact on the constructed liner. Additionally, care will be taken when the initial lift of waste is placed in the landfill to avoid large or sharp objects that might damage the liner.

Leachate generated within existing Cells 7-9 collects and gravity drains to the existing leachate storage impoundment located north of Cells 7 and 8.

During the active life of the landfill, leachate collected in the sumps within the expansion area will be pumped up the side slope to the dual contained force main and transported via the dual contained force main to the proposed leachate storage impoundment. Leachate stored in the leachate storage impoundments will be recirculated, irrigated, and/or hauled offsite for disposal.
5.0 LINER SYSTEM

The liner system at the SORD will be constructed in accordance with the approved Quality Assurance/Quality Control (QA/QC) Plan for Liner and Leachate Collection System Installation and Testing. Liner system material conformance testing, general construction procedures and testing requirements are presented in the QA/QC Plan. Each portion of the liner must be constructed under the supervision of a professional engineer licensed in the state of Oklahoma. Before waste can be placed in any newly constructed cell, approval of a Liner Installation and Testing Report must be obtained from the ODEQ.
4.0 WET WEATHER MANAGEMENT

Wet weather should not adversely impact landfill operations due to all-weather access roads. Throughout the landfill operation, adequate temporary landfill roads will be constructed to ensure access to the working face of the landfill during all weather conditions.

Soil material from the borrow area or an approved ADC will be utilized to meet daily cover requirements during wet weather. SORD is currently approved to utilize foundry sand, tire chips, and posi-shell plus extreme rain shield during and/or after rain events.
3.0 SURVEY CONTROL

Horizontal and vertical control must be maintained at the landfill in order to construct the landfill according to the approved permit documents. All boundary markers, benchmarks, horizontal control stations, and construction stakes will be clearly marked and identified. Permanent monuments designating horizontal and vertical control are already in place at the landfill in the form of monuments with surveyed, permanently stamped information. Evidence of permanent monuments and boundary markers placed by a registered land surveyor are shown on the approved Permit Documents maintained in the facility’s operating record.

Permanent vertical control has been established by a registered surveyor on the property. In the event a control monument is damaged or destroyed, a registered land surveyor shall re-establish the monument. The permanent monuments at the property corners are established with markers embedded in concrete or other similar type permanent structures. Boundary markers have been established designating the entire permitted acreage.

Construction staking will be used to mark individual cells where waste is to be placed. Staking will be utilized during landfilling operations to maintain slopes and check filling elevations, as necessary. Stakes will generally be made of wood or some other suitable material for use on a landfill. Construction stakes and temporary benchmarks will be replaced during the landfill operations, as needed.

If established benchmark or horizontal control monuments are disturbed over the life of the facility, these monuments shall be replaced or re-established by or under the supervision of a registered land surveyor.
2.4 LIMITATIONS ON WASTE RECEIVED

The SORD accepts approximately 550 tons per day of waste. Therefore, the facility is required to prepare a Vegetative Cover Plan under OAC 252:515-19-54. However, the SORD does not need to prepare a Disposal Plan as required under OAC 252-515-19-34(d) because the waste comes from locations less than 50 miles away from the facility.

2.5 RECYCLING OPERATIONS

The SORD is currently conducting a salvage/recycling operation in accordance with the ODEQ approved salvage and recycling plan provided in Appendix D.
• Review of paperwork included with incoming wastes by the scalehouse attendant
• Visually inspecting each load as it is pushed into the working face by operators trained to recognize regulated hazardous waste
• Notifying the ODEQ if unacceptable waste is discovered at the site by the end of the next working day. The site's current Waste Exclusion Plan should be referenced for information to include with the notification.

Random load inspections will consist of:

• Conducting random inspections of incoming loads for unacceptable wastes. Inspection of vehicles which contain uncompacted or open top loads will primarily occur at the scalehouse. Enclosed vehicles, such as commercial refuse vehicles, will be inspected at the working face. Loads will be visually observed for unacceptable waste when deposited at the toe of the working face by a landfill employee.

• Ensuring records are maintained on all random inspections which are performed. The information maintained in the records should include, at a minimum, the company or person delivering the waste, type of vehicle, rate and time, type of waste delivered, and person performing the inspection. These records shall be maintained in the operating record of the facility.

Should a particular hauler or refuse from a particular waste generator be suspected of being a source of prohibited waste, routine or planned inspections will be made of the suspected waste at a pull-off area near the truck scale. The facility's current Waste Exclusion Plan should be referenced for waste screening training requirements as well as additional information regarding the waste screening procedures at the SORD.

2.3 WASTE MEASURING

The scale at the SORD is located on the site's access road south of the active disposal area. All waste delivered to and disposed of at the SORD is weighed on a certified scale. The scale is tested and certified annually in accordance with the requirements of the Oklahoma Department of Agriculture, Food, and Forestry (ODAFF) per OAC 252:515-19-33(a)(2). The SORD should request the ODAFF to test the weighing and measuring of the scale on an annual basis.

If the scale is inoperative, tonnage shall be estimated on a volume basis where one cubic yard of waste shall be calculated to weigh one-third (1/3) ton. Solid waste disposal fees shall be collected and remitted to the ODEQ, except for solid waste received from emergencies or other special events, with prior approval from the ODEQ. Monthly reports shall be filed in the operating record and submitted to the ODEQ no later than the 15th of the month following the reporting period. A copy of the monthly and quarterly reporting forms to be submitted to the ODEQ are included in Appendix A of this Plan. Copies of submitted forms should be maintained in the site's operating record.
2.0 SOLID WASTE ACCEPTED/EXCLUDED

This section outlines accepted and excluded wastes, waste screening procedures, waste measuring requirements, and quantity limitation requirements which are applicable to the SORD under OAC 252:515.

2.1 WASTE ACCEPTANCE AND EXCLUSION

Under solid waste disposal permit number 3510007, the SORD is allowed to accept municipal solid waste for disposal, including household waste, commercial solid waste, non-hazardous sludge, and demolition waste. Municipal sewage sludge treated to Class B requirements, as described in 40 CFR 503.32(b), may be disposed at the SORD if the sludge passes the Paint Filter Liquids Test (PFLT). A procedure for the PFLT is included in Appendix C of this Plan. In addition, the SORD has received approval from the ODEQ to dispose of non-hazardous industrial waste in Subtitle D areas of the permit waste footprint. The disposal of any quantity of hazardous, radioactive, friable asbestos, regulated untreated infectious biomedical waste, or regulated polychlorinated biphenyl (PCB) waste is prohibited at the SORD.

Waste should be visually screened at the scale to determine if the shipment contains acceptable waste. Shipments received at the facility shall be rejected if the waste is not deemed acceptable. Shipments of waste entering the State of Oklahoma that are subsequently rejected shall be removed from the State by those persons who transported the waste into the State.

Additional information such as sources of waste, amount received, transporters used, and any special handling or management practices to be employed shall be recorded at the scalehouse and filed within the site’s operating record. Detailed information on acceptable and unacceptable wastes; screening procedures; recordkeeping and reporting requirements; and training requirements associated with waste acceptance at the site is detailed in the facility’s approved Waste Exclusion Plan, which is maintained in the site’s operating record and included as Appendix J of the permit application.

2.2 WASTE SCREENING

The scalehouse attendant will be responsible for screening incoming waste to ensure that prohibited wastes are identified and handled properly. If the scalehouse attendant or other landfill staff refuses such wastes, they will inform customers of the proper disposal alternatives, such as directing them to local facilities that would accept those wastes. This practice is intended to avoid illegal dumping of refused wastes.

Personnel at the site shall conduct routine procedures for the screening and removal of wastes which are not acceptable for receipt at the landfill for disposal. These procedures consist of both routine load screening procedures and random load inspections. Routine load screening procedures include:

- Identifying incoming vehicles by company and vehicle number. Any placards will be noted.
1.3 ACCESS CONTROL

The SORD is located approximately 4 miles east of Ardmore, Oklahoma on State Highway 199. The site is accessed from Red Cedar Road. The entrance to the landfill is on the east side of the property. Per OAC 252:515-19-32, artificial and/or natural barriers shall be used to discouraged unauthorized traffic and uncontrolled dumping. Access to the landfill is controlled by a lockable entrance gate. The SORD is also surrounded by dense vegetation. This provides a natural barrier around the site that discourages access to unauthorized traffic. Landfill personnel have appropriately placed signs directing waste hauling vehicles to the working face of the landfill. Scalehouse and operating personnel shall prohibit any unauthorized access and shall record all incidences of unauthorized access. At the conclusion of each operating day, the entrance gate shall be locked to prohibit vehicle access.
1.0 GENERAL INFORMATION

This Operations Plan (Plan) is intended to assist the operators of the Southern Oklahoma Regional Disposal Landfill (SORD) in operating the facility in accordance with the solid waste permit documents and Oklahoma Administrative Code (OAC) Rules and Regulations as promulgated by the Oklahoma Department of Environmental Quality (ODEQ). The SORD is located in the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma, approximately 4 miles east of Ardmore, Oklahoma. The SORD operates as a municipal solid waste landfill under solid waste permit number 3510007. Any reference to “operator” in this Plan shall mean the individual responsible for the facility on any given day or shift. The individual in responsible charge may assign operational tasks to various personnel. In addition, this Operations Plan shall be available to employees for reference to operations of the facility. It is the responsibility of the SORD to keep this information current. If changes to this Plan are to be made effecting the operations of the facility, then the SORD shall notify the DEQ within 5 working days prior to the change implementation.

1.1 OPERATING HOURS

It is anticipated that the SORD will be open from 8:00 a.m. to 5:00 p.m. Monday through Friday and Saturday from 8:00 a.m. to 12:00 p.m. The daily operation of equipment necessary for compaction and covering waste will normally cease within one hour after the daily closing time.

1.2 PERSONNEL

The operation of the SORD will be under the direction of a certified solid waste operator. The typical staffing level is listed below:

- Landfill Manager/Operator,
- Equipment Operator,
- Scalehouse Attendant,
- General Maintenance Person, and
- Truck Drivers.

Staff will be modified as necessary to accommodate changes to operations or to meet increased waste flows, as necessary. A properly trained equipment operator or other landfill employee will be present at the working face of the landfill to observe the unloading of waste and to perform and document random inspections of the waste.
12.0 Safety ................................................................. 19
  12.1 Fires ............................................................... 19
  12.2 Emergency Contacts ......................................... 19
  12.3 Communication Equipment ............................... 19
  12.4 Traffic Signs .................................................. 19
13.0 Recordkeeping And Reporting ............................... 20

Appendices

Appendix A  Monthly and Quarterly Reporting Forms
Appendix B  ODEQ Guidance on Recordkeeping and Reporting
Appendix C  Paint Filter Liquids Test Procedure
Appendix D  SORD Salvage and Recycling Plan
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 General Information</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Operating Hours</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Personnel</td>
<td>1</td>
</tr>
<tr>
<td>1.3 Access Control</td>
<td>2</td>
</tr>
<tr>
<td>2.0 Solid Waste Accepted/Excluded</td>
<td>3</td>
</tr>
<tr>
<td>2.1 Waste Acceptance and Exclusion</td>
<td>3</td>
</tr>
<tr>
<td>2.2 Waste Screening</td>
<td>3</td>
</tr>
<tr>
<td>2.3 Waste Measuring</td>
<td>4</td>
</tr>
<tr>
<td>2.4 Limitations on Waste Received</td>
<td>5</td>
</tr>
<tr>
<td>2.5 Recycling Operations</td>
<td>5</td>
</tr>
<tr>
<td>3.0 Survey Control</td>
<td>6</td>
</tr>
<tr>
<td>4.0 Wet Weather Management</td>
<td>7</td>
</tr>
<tr>
<td>5.0 Liner System</td>
<td>8</td>
</tr>
<tr>
<td>6.0 Leachate Collection And Storage</td>
<td>9</td>
</tr>
<tr>
<td>7.0 Landfilling Procedures</td>
<td>10</td>
</tr>
<tr>
<td>7.1 Landfill Progression and Sequence of Fill</td>
<td>10</td>
</tr>
<tr>
<td>7.1.1 Placement of Initial Layer of Waste</td>
<td>10</td>
</tr>
<tr>
<td>7.1.2 Placement of Bulky Solid Wastes</td>
<td>10</td>
</tr>
<tr>
<td>7.1.3 Proper Disposal of Dead Animals</td>
<td>11</td>
</tr>
<tr>
<td>7.1.4 Storm Water Management</td>
<td>11</td>
</tr>
<tr>
<td>7.2 Equipment</td>
<td>11</td>
</tr>
<tr>
<td>8.0 Cover And Borrow Soil</td>
<td>12</td>
</tr>
<tr>
<td>8.1 Daily Cover</td>
<td>12</td>
</tr>
<tr>
<td>8.2 Intermediate Cover</td>
<td>12</td>
</tr>
<tr>
<td>8.3 Final Cover</td>
<td>12</td>
</tr>
<tr>
<td>8.4 Borrow Source</td>
<td>15</td>
</tr>
<tr>
<td>9.0 Vectors And Aesthetics</td>
<td>16</td>
</tr>
<tr>
<td>9.1 Vectors</td>
<td>16</td>
</tr>
<tr>
<td>9.2 Litter Control</td>
<td>16</td>
</tr>
<tr>
<td>9.3 Special Covering</td>
<td>16</td>
</tr>
<tr>
<td>10.0 Environmental Monitoring</td>
<td>17</td>
</tr>
<tr>
<td>10.1 Surface Water Monitoring</td>
<td>17</td>
</tr>
<tr>
<td>10.2 Storm Water Structure Maintenance</td>
<td>17</td>
</tr>
<tr>
<td>10.3 Groundwater Monitoring</td>
<td>17</td>
</tr>
<tr>
<td>10.4 Gas Monitoring</td>
<td>17</td>
</tr>
<tr>
<td>10.5 Leachate Monitoring</td>
<td>17</td>
</tr>
<tr>
<td>11.0 Air Quality</td>
<td>18</td>
</tr>
<tr>
<td>11.1 Dust Control</td>
<td>18</td>
</tr>
</tbody>
</table>
# INDEX AND CERTIFICATION PAGE

**REPORT INDEX**

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Number of Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>General Information</td>
<td>2</td>
</tr>
<tr>
<td>2.0</td>
<td>Solid Waste Accepted/Excluded</td>
<td>3</td>
</tr>
<tr>
<td>3.0</td>
<td>Survey Control</td>
<td>1</td>
</tr>
<tr>
<td>4.0</td>
<td>Wet Weather Management</td>
<td>1</td>
</tr>
<tr>
<td>5.0</td>
<td>Liner System</td>
<td>1</td>
</tr>
<tr>
<td>6.0</td>
<td>Leachate Collection and Storage</td>
<td>1</td>
</tr>
<tr>
<td>7.0</td>
<td>Landfilling Procedures</td>
<td>2</td>
</tr>
<tr>
<td>8.0</td>
<td>Cover and Borrow Soil</td>
<td>4</td>
</tr>
<tr>
<td>9.0</td>
<td>Vectors and Aesthetics</td>
<td>1</td>
</tr>
<tr>
<td>10.0</td>
<td>Environmental Monitoring</td>
<td>1</td>
</tr>
<tr>
<td>11.0</td>
<td>Air Quality</td>
<td>1</td>
</tr>
<tr>
<td>12.0</td>
<td>Safety</td>
<td>1</td>
</tr>
<tr>
<td>13.0</td>
<td>Recordkeeping and Reporting</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Appendix A</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Appendix B</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Appendix C</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Appendix D</td>
<td>8</td>
</tr>
</tbody>
</table>

## Certification

This Operations Plan has been prepared in accordance with good engineering practice, including consideration of industry standards and the requirements of the Oklahoma Department of Environmental Quality.

Prepared by:

Floyd Cotter, P.E.
Vice President
SCS Engineers

---

**Table of Contents**
Operations Plan

Presented To:
Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented From:
SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00
Operations Plan

Southern Oklahoma Regional Disposal Landfill

Presented to:
Southern Oklahoma Regional Disposal, Inc.

Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented by:

SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 2721.5136.00

Offices Nationwide
www.scsengineers.com
Appendix I

Operations Plan
Adoption and Revision Schedule

GRI-GT13(a) – ASTM Version

"Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate"

Original: March 10, 2004

Revision 1: May 6, 2005: Editorial changes

Revision 2: August 29, 2008: Editorial changes

Revision 3: December 19, 2012: Changed ASTM D4355 to ASTM D7238 and editorial changes

Revision 4: June 20, 2017: Change UV stability from 50% retained to 80, 70, 60% retained (for high, moderate and low survivability, respectively) so as to be in agreement with the ISO version in GRI-GT13b.
Table 3 - Required Degree of Survivability as a Function of Subgrade Conditions, Construction Equipment and Lift Thickness
(Class 1, 2 and 3 Properties are Given in Table 1 and 2; Class 1 + Properties are Higher than Class 1 but Not Defined at this Time)

<table>
<thead>
<tr>
<th>Subgrade Condition</th>
<th>Low ground-pressure equipment (≤ 25 kPa (3.6 psi))</th>
<th>Medium ground-pressure equipment (25 to ≤ 50 kPa (&gt;3.6 to ≤ 7.3 psi))</th>
<th>High ground-pressure equipment (&gt; 50 kPa (&gt; 7.3 psi))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subgrade has been cleared of all obstacles except grass, weeds, leaves, and fine wood debris. Surface is smooth and level so that any shallow depressions and humps do not exceed 450 mm (18 in.) in depth or height. All larger depressions are filled. Alternatively, a smooth working table may be placed.</td>
<td>Low (Class 3)</td>
<td>Moderate (Class 2)</td>
<td>High (Class 1)</td>
</tr>
<tr>
<td>Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 450 mm (18 in.) in depth or height. Larger depressions should be filled.</td>
<td>Moderate (Class 2)</td>
<td>High (Class 1)</td>
<td>Very High (Class 1+)</td>
</tr>
<tr>
<td>Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than ± 150 mm (6 in.) above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.</td>
<td>High (Class 1)</td>
<td>Very high (Class 1+)</td>
<td>Not recommended</td>
</tr>
</tbody>
</table>

*Recommendations are for 150 to 300 mm (6 to 12 in.) initial lift thickness. For other initial lift thicknesses:
  - 300 to 450 mm (12 to 18 in.): reduce survivability requirement one level;
  - 450 to 600 mm (18 to 24 in.): reduce survivability requirement two levels;
  - > 600 mm (24 in.): reduce survivability requirement three levels

Note 1: While separation occurs in every geotextile application, this pavement-related specification focuses on subgrade soils being "firm" as indicated by CBR values higher than 3.0 (soaked) or 8.0 (unsoaked).

Source: Modified after Christopher, Holtz, and DiMaggio
### Table 2(a) – Geotextile Properties Class 1 (High Survivability)

<table>
<thead>
<tr>
<th>Property(1)</th>
<th>ASTM Test</th>
<th>Unit</th>
<th>Elongation &lt; 50%</th>
<th>Elongation ≥ 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grab Tensile Strength</td>
<td>D 4632</td>
<td>N</td>
<td>1400</td>
<td>900</td>
</tr>
<tr>
<td>Trapezoid Tear Strength</td>
<td>D 4533</td>
<td>N</td>
<td>500</td>
<td>350</td>
</tr>
<tr>
<td>CBR Puncture Strength</td>
<td>D 6241</td>
<td>N</td>
<td>2800</td>
<td>2000</td>
</tr>
<tr>
<td>Permittivity</td>
<td>D 4491</td>
<td>sec-1</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Apparent Opening Size</td>
<td>D 4751</td>
<td>mm</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>Ultraviolet Stability(2)</td>
<td>D 7238</td>
<td>% Str. Ret. @ 500 lt. hrs.</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

### Table 2(b) – Geotextile Properties Class 2 (Moderate Survivability)

<table>
<thead>
<tr>
<th>Property(1)</th>
<th>ASTM Test</th>
<th>Unit</th>
<th>Elongation &lt; 50%</th>
<th>Elongation ≥ 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grab Tensile Strength</td>
<td>D 4632</td>
<td>N</td>
<td>1100</td>
<td>700</td>
</tr>
<tr>
<td>Trapezoid Tear Strength</td>
<td>D 4533</td>
<td>N</td>
<td>400</td>
<td>250</td>
</tr>
<tr>
<td>CBR Puncture Strength</td>
<td>D 6241</td>
<td>N</td>
<td>2250</td>
<td>1400</td>
</tr>
<tr>
<td>Permittivity</td>
<td>D 4491</td>
<td>sec-1</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Apparent Opening Size</td>
<td>D 4751</td>
<td>mm</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>Ultraviolet Stability(2)</td>
<td>D 7238</td>
<td>% Str. Ret. @ 500 lt. hrs.</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>

### Table 2(c) – Geotextile Properties Class 3 (Low Survivability)

<table>
<thead>
<tr>
<th>Property(1)</th>
<th>ASTM Test</th>
<th>Unit</th>
<th>Elongation &lt; 50%</th>
<th>Elongation ≥ 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grab Tensile Strength</td>
<td>D 4632</td>
<td>N</td>
<td>800</td>
<td>500</td>
</tr>
<tr>
<td>Trapezoid Tear Strength</td>
<td>D 4533</td>
<td>N</td>
<td>300</td>
<td>180</td>
</tr>
<tr>
<td>CBR Puncture Strength</td>
<td>D 6241</td>
<td>N</td>
<td>1700</td>
<td>1000</td>
</tr>
<tr>
<td>Permittivity</td>
<td>D 4491</td>
<td>sec-1</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Apparent Opening Size</td>
<td>D 4751</td>
<td>mm</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>Ultraviolet Stability(2)</td>
<td>D 7238</td>
<td>% Str. Ret. @ 500 lt. hrs.</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

Notes:
1. All values are minimum average roll values (MARV) except AOS which is a maximum average roll value (MaxARV) and UV stability which is a minimum average value.
2. Evaluation to be on 50 mm strip tensile specimens after 500 hours exposure.
### English Units

#### Table 1(a) – Geotextile Properties Class 1 (High Survivability)

<table>
<thead>
<tr>
<th>Property(1)</th>
<th>ASTM Test</th>
<th>Unit</th>
<th>Elongation &lt; 50%</th>
<th>Elongation ≥ 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grab Tensile Strength</td>
<td>D 4632</td>
<td>lb</td>
<td>315</td>
<td>203</td>
</tr>
<tr>
<td>Trapezoid Tear Strength</td>
<td>D 4533</td>
<td>lb</td>
<td>112</td>
<td>79</td>
</tr>
<tr>
<td>CBR Puncture Strength</td>
<td>D 6241</td>
<td>lb</td>
<td>630</td>
<td>440</td>
</tr>
<tr>
<td>Permittivity</td>
<td>D 4491</td>
<td>sec-1</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Apparent Opening Size</td>
<td>D 4751</td>
<td>in.</td>
<td>0.024</td>
<td>0.024</td>
</tr>
<tr>
<td>Ultraviolet Stability(2)</td>
<td>D 7238</td>
<td>% Str. Ret. @ 500 lt. hrs.</td>
<td>80</td>
<td>80</td>
</tr>
</tbody>
</table>

#### Table 1(b) – Geotextile Properties Class 2 (Moderate Survivability)

<table>
<thead>
<tr>
<th>Property(1)</th>
<th>ASTM Test</th>
<th>Unit</th>
<th>Elongation &lt; 50%</th>
<th>Elongation ≥ 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grab Tensile Strength</td>
<td>D 4632</td>
<td>lb</td>
<td>248</td>
<td>158</td>
</tr>
<tr>
<td>Trapezoid Tear Strength</td>
<td>D 4533</td>
<td>lb</td>
<td>90</td>
<td>56</td>
</tr>
<tr>
<td>CBR Puncture Strength</td>
<td>D 6241</td>
<td>lb</td>
<td>500</td>
<td>320</td>
</tr>
<tr>
<td>Permittivity</td>
<td>D 4491</td>
<td>sec-1</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Apparent Opening Size</td>
<td>D 4751</td>
<td>in.</td>
<td>0.024</td>
<td>0.024</td>
</tr>
<tr>
<td>Ultraviolet Stability(2)</td>
<td>D 7238</td>
<td>% Str. Ret. @ 500 lt. hrs.</td>
<td>70</td>
<td>70</td>
</tr>
</tbody>
</table>

#### Table 1(c) – Geotextile Properties Class 3 (Low Survivability)

<table>
<thead>
<tr>
<th>Property(1)</th>
<th>ASTM Test</th>
<th>Unit</th>
<th>Elongation &lt; 50%</th>
<th>Elongation ≥ 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grab Tensile Strength</td>
<td>D 4632</td>
<td>lb</td>
<td>180</td>
<td>113</td>
</tr>
<tr>
<td>Trapezoid Tear Strength</td>
<td>D 4533</td>
<td>lb</td>
<td>68</td>
<td>41</td>
</tr>
<tr>
<td>CBR Puncture Strength</td>
<td>D 6241</td>
<td>lb</td>
<td>380</td>
<td>230</td>
</tr>
<tr>
<td>Permittivity</td>
<td>D 4491</td>
<td>sec-1</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Apparent Opening Size</td>
<td>D 4751</td>
<td>in.</td>
<td>0.024</td>
<td>0.024</td>
</tr>
<tr>
<td>Ultraviolet Stability(2)</td>
<td>D 7238</td>
<td>% Str. Ret. @ 500 lt. hrs.</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

**Notes:**

1. All values are minimum average roll values (MARV) except AOS which is a maximum average roll value (MaxARV) and UV stability which is a minimum average value.
2. Evaluation to be on 50 mm strip tensile specimens after 500 hours exposure.
Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.

9.2 Each geotextile roll shall be wrapped with a material that will protect the geotextile, including the ends of the roll, from damage due to shipment, water, sunlight and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

Note 5: The project specification shall be very explicit as to the maximum exposure time between the geotextile being removed from the wrapper and being backfilled with soil or covered with another geosynthetic.

9.3 During storage, geotextile rolls shall be elevated off the ground and adequately covered to protect them from the following: site construction damage, precipitation, extended ultraviolet radiation including sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temperatures in excess of 160°F (71°C), and any other environmental condition that may damage the property values of the geotextile.

10. Certification

10.1 The contractor shall provide to the engineer a certificate stating the name of the manufacturer, product name, style number, chemical composition of the filaments or yarns, and other pertinent information to fully describe the geotextile.

10.2 The manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.

10.3 The manufacturer's certificate shall state that the finished geotextile meets the requirements of the specification as evaluated under the manufacturer's quality control program. A person having legal authority to bind the manufacturer shall attest to the certificate.

10.4 Either mislabeling or misrepresentation of materials shall be reason to reject those geotextile products.
5.2 The required values for most properties in Tables 1 and 2 are to be minimum average roll values (MARV). The exceptions are AOS which is a maximum average roll value (MaxARV), and UV stability which is a minimum average value.

5.3 The required class is determined by the severity of installation conditions (i.e., size of equipment, condition of subgrade, thickness of covering lift, etc.). Table 3 gives guidance in this respect.

6. Workmanship and Appearance

6.1 The finished geotextile shall have good appearance qualities. It shall be free from such defects that would affect the specific properties of the geotextile, or its proper functioning.

6.2 General manufacturing procedures shall be performed in accordance with the manufacturer’s internal quality control guide and/or documents.

7. MQC Sampling, Testing, and Acceptance

7.1 Geotextiles shall be subject to sampling and testing to verify conformance with this specification. Sampling shall be in accordance with the most current modification of ASTM Standard D 4354, using the section titled, “Procedure for Sampling for Purchaser’s Specification Conformance Testing.” In the absence of purchaser’s testing, verification may be based on manufacturer’s certifications as a result of testing by the manufacturer of quality assurance samples obtained using the procedure for Sampling for Manufacturer’s Quality Assurance (MQA) Testing. A lot size shall be considered to be the shipment quantity of the given product or a truckload of the given product, whichever is smaller.

7.2 Testing shall be performed in accordance with the method referenced in this specification for the indicated application. The number of specimens to test per sample is specified by each test method. Geotextile product acceptance shall be based on ASTM D4759. Product acceptance is determined by comparing the average test results of all specimens within a given sample to the specification MARV. Refer to ASTM D 4759 for more details regarding geotextile acceptance procedures.

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer’s quality manual.

9. Shipment and Storage

9.1 Geotextile labeling, shipment, and storage shall follow ASTM D 4873. Product labels shall clearly show the manufacturer or supplier name, style, and roll number.
will meet published values. For normally distributed data, "MARV" is calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.

3.4 Minimum Value – The lowest sample value from documented manufacturing quality control test results for a defined population from one test method associated with one specific property.

3.5 Maximum Value – The highest sample value from documented manufacturing quality control test results for a defined population from one test method associated with one specific property.

3.6 Separation – The placement of a flexible porous geosynthetic between dissimilar materials so the integrity and functioning of both materials can remain intact or be improved.

Note 2: For separation of stone base courses overlying soil subgrades this primary function simultaneously prevents the stone from intruding down into the soil and the soil from pumping up into the stone.

4. Material Classification and Formulation

4.1 This specification covers geotextiles used as separation materials.

4.2 The polymer types are mainly polypropylene, but also polyester or polyethylene. Other polymers are also possible in this regard.

4.3 The type of geotextile style is not designated. However a distinction can be made based on the elongation criteria of 50%.

Note 3: It is assumed that nonwoven fabrics break at elongations higher than 50%. Woven fabrics always break at elongations significantly lower than 50%.

5. Specification Requirements

5.1 The geotextiles for use as separator shall conform to Tables 1 or 2. Table 1 is given in English units and Table 2 is in SI (Metric) units. The conversion from English to SI units is “soft”, i.e., rounded off to an approximate value. All test methods are based on ASTM Standards.

Note 4: The numeric relationships between this specification based on ASTM Test Methods and GRI – GT13(b) based on ISO Test Methods have been developed at the Geosynthetic Institute.
specification in a specific situation. Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application.

1.5 This standard specification does not address installation practice. This item is addressed in the geosynthetics literature dealing with this particular application and under unique situations might require modifications, e.g., higher values and/or additional test properties.

2. Referenced Documents

2.1 ASTM Standards

D 1883 Test Method for CBR (California Bearing Ratio) of Laboratory Compacted Soils
D 4354 Practice for Sampling of Geosynthetics for Testing
D 4533 Test Method for Trapezoidal Tearing Strength of Geotextiles
D 4632 Test Method for Grab Breaking Load and Elongation of Geotextiles
D 4759 Practice for Determining the Specification Conformance of Geosynthetics
D 4873 Guide for Identification, Storage and Handling of Geotextiles
D 5261 Test Method for Measuring Mass per Unit Area of Geotextiles
D 6241 Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Product Using a 50-mm Probe
D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus

2.2 AASHTO Specification

M288-05 Geotextile Specification for Highway Applications

3. Definitions

3.1 Formulation - The mixture of a unique combination of ingredients identified by type, properties and quantity. For geotextiles, a formulation is defined as the exact percentages and types of resin(s), additives and/or carbon black.

3.2 Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications [ref. EPA/600/R-93/182].

3.3 Minimum Average Roll Value (MARV) – For geosynthetics, a manufacturing quality control tool used to allow manufacturers to establish published values such that the user/purchaser will have a 97.7% confidence that the property in question
GRI GT13(a) – ASTM Version

Standard Specification for

"Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate"

This specification was developed by the Geosynthetic Research Institute (GRI) with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers geotextile test methods properties for subsequent use as separation between subgrade soil and aggregate predominantly in pavement systems.

Note 1: While separation occurs in every geotextile application, this pavement-related specification focuses on subgrade soils being “firm” as indicated by CBR values in ASTM D1883 higher than 3.0 (soaked) or 8.0 (unsoaked).

1.2 This specification sets forth a set of physical, mechanical and endurance properties that must be met, or exceeded, by the geotextile being manufactured.

1.3 In the context of quality systems and management, this specification represents a manufacturing quality control (MQC) document. However, its general use is essentially as a recommended design document.

1.4 This specification is intended to assure both good quality and performance of fabrics used as geotextile separators but is possibly not adequate for the complete
Adoption and Revision Schedule

for

“Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials”

Original: February 18, 2002

Revision 1: December 18, 2012: Replaced ASTM D4355 with ASTM D7238

Revision 2: March 3, 2016: Deleted ASTM D4833 Pin Puncture and ASTM D5495 Pyramid Puncture from the Standard
### USA Units

**Table 1(a) – Required Properties, Test Methods and Values for Geotextiles Used as Geomembrane Protection (or Cushioning) Materials**

<table>
<thead>
<tr>
<th>Property(1)</th>
<th>Test Method ASTM</th>
<th>Unit</th>
<th>Mass/Unit Area (oz/yd²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass per unit area</td>
<td>D5261</td>
<td>oz/yd²</td>
<td>10 12 16 .24 32 60</td>
</tr>
<tr>
<td>Grab tensile strength</td>
<td>D4632</td>
<td>lb</td>
<td>230 300 370 450 500 630</td>
</tr>
<tr>
<td>Grab tensile elongation</td>
<td>D4632</td>
<td>%</td>
<td>50 50 50 50 50 50</td>
</tr>
<tr>
<td>Trap. tear strength</td>
<td>D4533</td>
<td>lb</td>
<td>95 115 145 200 215 290</td>
</tr>
<tr>
<td>Puncture (CBR) strength</td>
<td>D6241</td>
<td>lb</td>
<td>700 800 900 1100 1700 2400</td>
</tr>
<tr>
<td>UV resistance(2)</td>
<td>D7238</td>
<td>%</td>
<td>70 70 70 70 70 70</td>
</tr>
</tbody>
</table>

**Notes:**

1. All values are MARV except UV resistance; it is a minimum value.
2. Evaluation to be on 2.0 inch strip tensile specimens per ASTM D 5035 after 500 lt. hrs. exposure.

### S.I. (Metric) Units

**Table 1(b) – Required Properties, Test Methods and Values for Geotextiles Used as Geomembrane Protection (or Cushioning) Materials**

<table>
<thead>
<tr>
<th>Property(1)</th>
<th>Test Method ASTM</th>
<th>Unit</th>
<th>Mass/Unit Area (g/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass per unit area</td>
<td>D5261</td>
<td>g/m²</td>
<td>340 406 542 812 1080 2000</td>
</tr>
<tr>
<td>Grab tensile strength</td>
<td>D4632</td>
<td>kN</td>
<td>1.02 1.33 1.64 2.00 2.25 2.80</td>
</tr>
<tr>
<td>Grab tensile elongation</td>
<td>D4632</td>
<td>%</td>
<td>50 50 50 50 50 50</td>
</tr>
<tr>
<td>Trap. tear strength</td>
<td>D4533</td>
<td>kN</td>
<td>0.42 0.51 0.64 0.89 0.96 1.27</td>
</tr>
<tr>
<td>Puncture (CBR) strength</td>
<td>D6241</td>
<td>kN</td>
<td>3.11 3.56 4.00 4.90 7.56 10.60</td>
</tr>
<tr>
<td>UV resistance(2)</td>
<td>D7238</td>
<td>%</td>
<td>70 70 70 70 70 70</td>
</tr>
</tbody>
</table>

**Notes:**

1. All values are MARV except UV resistance; it is a minimum value.
2. Evaluation to be on 50 mm strip tensile specimens per ASTM D5035 after 500 lt. hrs. exposure.
10. Certification

10.1 The contractor shall provide to the engineer a certificate stating the name of the manufacturer, product name, style number, chemical composition of the filaments or yarns, and other pertinent information to fully describe the geotextile.

10.2 The manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.

10.3 The manufacturer’s certificate shall state that the finished geotextile meets MARV requirements of the specification as evaluated under the manufacturer’s quality control program. A person having legal authority to bind the manufacturer shall attest to the certificate.

10.4 Either mislabeling or misrepresentation of materials shall be reason to reject those geotextile products.
7. MQC Sampling, Testing, and Acceptance

7.1 Geotextiles shall be subject to sampling and testing to verify conformance with this specification. Sampling shall be in accordance with the most current modification of ASTM Standard D 4354, using the section titled, “Procedure for Sampling for Purchaser's Specification Conformance Testing.” In the absence of purchaser's testing, verification may be based on manufacturer's certifications as a result of testing by the manufacturer of quality assurance samples obtained using the procedure for Sampling for Manufacturer's Quality Assurance (MQA) Testing. A lot size shall be considered to be the shipment quantity of the given product or a truckload of the given product, whichever is smaller.

7.2 Testing shall be performed in accordance with the method referenced in this specification for the indicated application. The number of specimens to test per sample is specified by each test method. Geotextile product acceptance shall be based on ASTM D4759. Product acceptance is determined by comparing the average test results of all specimens within a given sample to the specification MARV. Refer to ASTM D 4759 for more details regarding geotextile acceptance procedures.

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Shipment and Storage

9.1 Geotextile labeling, shipment, and storage shall follow ASTM D 4873. Product labels shall clearly show the manufacturer or supplier name, style, and roll number. Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.

9.2 Each geotextile roll shall be wrapped with a material that will protect the geotextile, including the ends of the roll, from damage due to shipment, water, sunlight and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

9.3 During storage, geotextile rolls shall be elevated off the ground and adequately covered to protect them from the following: site construction damage, precipitation, extended ultraviolet radiation including sunlight, chemicals that are strong-acids or strong bases, flames including welding sparks, temperatures in excess of 160°F (71°C), and any other environmental condition that may damage the property values of the geotextile.
Note 3: This particular specification for nonwoven protection geotextiles falls under the concept of MQC.

3.3 Minimum Average Roll Value (MARV) – For geosynthetics, a manufacturing quality control tool used to allow manufacturers to establish published values such that the user/purchaser will have a 97.7% confidence that the property in question will meet published values. For normally distributed data, “MARV” is calculated as the typical value minus two (2) standard deviations from documented quality control test results for a defined population from one specific test method associated with one specific property.

4. Material Classification and Formulation

4.1 This specification covers geotextiles used as protection (or cushioning) materials.

4.2 The type of resins are usually polypropylene, polyester or polyethylene, but other resins are also possible in this regard.

4.3 The type of geotextile style is designated as a nonwoven since research has shown these fabrics to be most effective in the typical applications toward which this specification is directed. While needle-punched nonwovens are usually used, heat bonded and resin dipped manufacturing styles (or others) can also be considered.

5. Specification Requirements

5.1 The geotextiles for use as protection (or cushioning) materials shall conform to Table 1. The table is given in English units and in SI (Metric) units. The conversion from English to SI units is “soft”.

5.2 Since there are a number of geotextile puncture test methods available, Table 2 is provided. Either of these tests can be considered to be an alternative test replacing ASTM D4833 in Table 1. The decision to make such a replacement must be agreed upon by the parties involved. The table is given in English units and in SI (Metric) units. The conversion from English to SI units is “soft”.

5.3 The required values for all properties in Tables 1 and 2 are to be minimum average roll values (MARV) except UV resistance which is a minimum value.

6. Workmanship and Appearance

6.1 The finished geotextile shall have good appearance qualities. It shall be free from such defects that would affect the specific properties of the geotextile, or its proper functioning.

6.2 General manufacturing procedures shall be performed in accordance with the manufacturer’s internal quality control guide and/or documents.
1.4 This standard specification is intended to assure good quality and performance of fabrics used as geotextile protection materials but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application.

1.5 This standard specification does not address installation practices or design guidance. Both of these items are addressed in the literature dealing with this particular application.

2. Referenced Documents

2.1 ASTM Standards

D 4354 Practice for Sampling of Geosynthetics for Testing
D 4533 Test Method for Trapezoidal Tearing Strength of Geotextiles
D 4632 Test Method for Grab Breaking Load and Elongation of Geotextiles
D 4759 Practice for Determining the Specification Conformance of Geosynthetics
D 4873 Guide for Identification, Storage and Handling of Geotextiles
D 5035 Test Method for Breaking Strength and Elongation of Textile Fabrics (2" Strip Method)
D 5261 Test Method for Measuring Mass per Unit Area of Geotextiles
D 6241 Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Product Using a 50-mm Probe
D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent Condensation Apparatus

2.2 AASHTO Specification

M288-05 Geotextile Specification for Highway Applications

3. Definitions

3.1 Formulation - The mixture of a unique combination of ingredients identified by type, properties and quantity. For nonwoven geotextiles, a formulation is defined as the exact percentages and types of resin(s), additives and/or carbon black.

3.2 Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications [ref. EPA/600/R-93/182].
GRI Test Method GT12(a)* - ASTM Version

Standard Specification for

“Test Methods and Properties for Nonwoven Geotextiles Used as Protection (or Cushioning) Materials”

This specification was developed by the Geosynthetic Research Institute (GRI) with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers nonwoven geotextile test properties for subsequent use as protection (or cushioning) materials.

Note 1: The typical use will be as a protective covering or underlayment of a geomembrane against puncture or tear due to rock, stones, concrete or other hard surfaces and/or objects.

1.2 This specification sets forth a set of physical, mechanical and endurance properties that must be met, or exceeded by the geotextile being manufactured.

1.3 In the context of quality systems and management, this specification represents a manufacturing quality control (MQC) document.

Note 2: Manufacturing quality control represents those actions taken by a manufacturer to assure that a product represents the stated objective and properties set forth in the specification.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

Copyright © 2002, 2013 Geosynthetic Institute
All rights reserved
GT12(a) - 1 of 7

Rev. 2: 3/3/16
Adoption and Revision Schedule for Seam Specification per GRI-GM19

"Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes"

Adopted: February 18, 2002

Revision 1: May 15, 2003; Increased selected shear and peel test requirements, per the following:

<table>
<thead>
<tr>
<th>Material</th>
<th>Test</th>
<th>Seam Type</th>
<th>Current GM19</th>
<th>Proposed GM19</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>GM19</td>
<td>GM19</td>
<td></td>
</tr>
<tr>
<td>HDPE</td>
<td>Shear</td>
<td>Hot Wedge</td>
<td>95% yield</td>
<td>95% yield</td>
<td>no change</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extrusion</td>
<td>95% yield</td>
<td>95% yield</td>
<td>no change</td>
</tr>
<tr>
<td></td>
<td>Peel</td>
<td>Hot Wedge</td>
<td>62% yield</td>
<td>72% yield</td>
<td>16% increase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extrusion</td>
<td>62% yield</td>
<td>62% yield</td>
<td>no change</td>
</tr>
<tr>
<td>LLDPE</td>
<td>Shear</td>
<td>Hot Wedge</td>
<td>1300 psi break</td>
<td>1500 psi break</td>
<td>15% increase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extrusion</td>
<td>1300 psi break</td>
<td>1500 psi break</td>
<td>15% increase</td>
</tr>
<tr>
<td></td>
<td>Peel</td>
<td>Hot Wedge</td>
<td>1100 psi break</td>
<td>1250 psi break</td>
<td>14% increase</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Extrusion</td>
<td>1100 psi break</td>
<td>1100 psi break</td>
<td>no change</td>
</tr>
</tbody>
</table>

Revision 2: January 28, 2005; added Note 6 (in three locations) stating that incursion is measured on an area basis and not depth as in ASTM D6392.

Revision 3: June 4, 2010; Removed Note 6 on peel incursion since ASTM D6392 (2008) now uses area of incursion whereas previously they used linear length of incursion. Thus ASTM is now in agreement with GM19 in this regard.

Revision 4: November 15, 2010; Added Note 6 (in three locations) stating what separation-in-plane (SIP) is, and is not, and that it is acceptable if the required strength, shear elongation and peel separation criteria are met.

Revision 5: July 12, 2011; AD1 and AD2 breaks are now unacceptable even if strength is achieved.

Revision 6: October 3, 2011; Added LLDPE-R to the various geomembrane types, in particular, Tables 2(c) and 2(d) and made editorial changes.

Revision 7: November 3, 2013; clarified issues of 4 out of 5 passing strength and 5 out of 5 passing locus-of-break, shear elongation and peel separation.

Revision 8: February 12, 2015; upgraded standards and terminology

GM19 - 13 of 13
Rev. 8: 2/12/2015
Table 3(a) – Seam Strength and Related Properties of Thermally Bonded Nonreinforced and Scrim Reinforced Flexible Polypropylene (fPP) Geomembranes (English Units)

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>30 mil-NR</th>
<th>40 mil-NR</th>
<th>36 mil-R(4)</th>
<th>45 mil-R(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot Wedge Seams(1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), lb/in. (NR); lb (R)</td>
<td>25</td>
<td>30</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>shear elongation(3), %</td>
<td>50</td>
<td>50</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>peel strength(2), lb/in. (NR); lb (R)</td>
<td>20</td>
<td>25</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Extrusion Fillet Seams</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), lb/in. (NR); lb (R)</td>
<td>25</td>
<td>30</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>shear elongation(3), %</td>
<td>50</td>
<td>50</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>peel strength(2), lb/in. (NR); lb (R)</td>
<td>20</td>
<td>25</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing.
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

Table 3(b) – Seam Strength and Related Properties of Thermally Bonded Nonreinforced and Scrim Reinforced Flexible Polypropylene (fPP) Geomembranes (S.I. Units)

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>0.75 mm-NR</th>
<th>1.0 mm-NR</th>
<th>0.91 mm-R(4)</th>
<th>1.14 mm-R(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hot Wedge Seams(1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), N/25 mm (NR); N (R)</td>
<td>110</td>
<td>130</td>
<td>890</td>
<td>890</td>
</tr>
<tr>
<td>shear elongation(3), %</td>
<td>50</td>
<td>50</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>peel strength(2), N/25 mm (NR); N (R)</td>
<td>85</td>
<td>110</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td><strong>Extrusion Fillet Seams</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), N/25 mm (NR); N (R)</td>
<td>110</td>
<td>130</td>
<td>890</td>
<td>890</td>
</tr>
<tr>
<td>shear elongation(3), %</td>
<td>50</td>
<td>50</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>peel strength(2), N/25 mm (NR); N (R)</td>
<td>85</td>
<td>110</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing.
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

GM19 - 12 of 13
Rev. 8: 2/12/2015
### Table 2(c) – Seam Strength and Related Properties of Thermally Bonded Scrime Reinforced Linear Low Density Polyethylene (LLDPE-R) Geomembranes (English Units)

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>36 mil(4)</th>
<th>45 mil(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Wedge Seams(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), lb</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>shear elongation(3), %</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>peel strength(2), lb</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Extrusion Fillet Seams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), lb</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>shear elongation(3), %</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>peel strength(2), lb</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

### Table 2(d) – Seam Strength and Related Properties of Thermally Bonded Scrime Reinforced Linear Low Density Polyethylene (LLDPE-R) Geomembranes (S.I. Units)

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>36 mil(4)</th>
<th>45 mil(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Wedge Seams(1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), N</td>
<td>890</td>
<td>890</td>
</tr>
<tr>
<td>shear elongation(3), %</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>peel strength(2), N</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Extrusion Fillet Seams</td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), N</td>
<td>890</td>
<td>890</td>
</tr>
<tr>
<td>shear elongation(3), %</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>peel strength(2), N</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens
Table 2(a) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured Linear Low Density Polyethylene (LLDPE) Geomembranes (English Units)

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>20 mils</th>
<th>30 mils</th>
<th>40 mils</th>
<th>50 mils</th>
<th>60 mils</th>
<th>80 mils</th>
<th>100 mils</th>
<th>120 mils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Wedge Seams(^{(1)})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(^{(2)}), lb/in.</td>
<td>30</td>
<td>45</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>120</td>
<td>150</td>
<td>180</td>
</tr>
<tr>
<td>shear elongation(^{(3)}), %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength(^{(2)}), lb/in.</td>
<td>25</td>
<td>38</td>
<td>50</td>
<td>63</td>
<td>75</td>
<td>100</td>
<td>125</td>
<td>150</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Extrusion Fillet Seams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(^{(2)}), lb/in.</td>
<td>30</td>
<td>45</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>120</td>
<td>150</td>
<td>180</td>
</tr>
<tr>
<td>shear elongation(^{(3)}), %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength(^{(2)}), lb/in.</td>
<td>22</td>
<td>34</td>
<td>44</td>
<td>57</td>
<td>66</td>
<td>88</td>
<td>114</td>
<td>136</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Notes for Tables 2(a) and 2(b):
1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens. the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 2(b) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured Linear Low Density Polyethylene (LLDPE) Geomembranes (S.I. Units)

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>0.50 mm</th>
<th>0.75 mm</th>
<th>1.0 mm</th>
<th>1.25 mm</th>
<th>1.5 mm</th>
<th>2.0 mm</th>
<th>2.5 mm</th>
<th>3.0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Wedge Seams(^{(1)})</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(^{(2)}), N/25 mm</td>
<td>131</td>
<td>197</td>
<td>263</td>
<td>328</td>
<td>394</td>
<td>525</td>
<td>657</td>
<td>788</td>
</tr>
<tr>
<td>shear elongation(^{(3)}), %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength(^{(2)}), N/25 mm</td>
<td>109</td>
<td>166</td>
<td>219</td>
<td>276</td>
<td>328</td>
<td>438</td>
<td>547</td>
<td>657</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Extrusion Fillet Seams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(^{(2)}), N/25 mm</td>
<td>131</td>
<td>197</td>
<td>263</td>
<td>328</td>
<td>394</td>
<td>525</td>
<td>657</td>
<td>788</td>
</tr>
<tr>
<td>shear elongation(^{(3)}), %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength(^{(2)}), N/25 mm</td>
<td>95</td>
<td>150</td>
<td>190</td>
<td>250</td>
<td>290</td>
<td>385</td>
<td>500</td>
<td>595</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

GM19 - 10 of 13
Rev. 8: 2/12/2015
Table 1(a) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured
High Density Polyethylene (HDPE) Geomembranes (English Units)

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>30 mils</th>
<th>40 mils</th>
<th>50 mils</th>
<th>60 mils</th>
<th>80 mils</th>
<th>100 mils</th>
<th>120 mils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Wedge Seams(1) shear strength(2), lb/in.</td>
<td>57</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>160</td>
<td>200</td>
<td>240</td>
</tr>
<tr>
<td>shear elongation at break(3), %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength(2), lb/in.</td>
<td>45</td>
<td>60</td>
<td>76</td>
<td>91</td>
<td>121</td>
<td>151</td>
<td>181</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Extrusion Fillet Seams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), lb/in.</td>
<td>57</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>160</td>
<td>200</td>
<td>240</td>
</tr>
<tr>
<td>shear elongation at break(3), %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength(2), lb/in.</td>
<td>39</td>
<td>52</td>
<td>65</td>
<td>78</td>
<td>104</td>
<td>130</td>
<td>156</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>

Notes for Tables 1(a) and 1(b):
1. Also for hot air and ultrasonic seaming methods
2. Value listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 1(b) – Seam Strength and Related Properties of Thermally Bonded Smooth and Textured
High Density Polyethylene (HDPE) Geomembranes (S.I. Units)

<table>
<thead>
<tr>
<th>Geomembrane Nominal Thickness</th>
<th>0.75 mm</th>
<th>1.0 mm</th>
<th>1.25 mm</th>
<th>1.5 mm</th>
<th>2.0 mm</th>
<th>2.5 mm</th>
<th>3.0 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot Wedge Seams(1) shear strength(2), N/25 mm</td>
<td>250</td>
<td>350</td>
<td>438</td>
<td>525</td>
<td>701</td>
<td>876</td>
<td>1050</td>
</tr>
<tr>
<td>shear elongation at break(3), %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength(2), N/25 mm</td>
<td>197</td>
<td>263</td>
<td>333</td>
<td>398</td>
<td>530</td>
<td>661</td>
<td>793</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Extrusion Fillet Seams</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>shear strength(2), N/25 mm</td>
<td>250</td>
<td>350</td>
<td>438</td>
<td>525</td>
<td>701</td>
<td>876</td>
<td>1050</td>
</tr>
<tr>
<td>shear elongation at break(3), %</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>peel strength(2), N/25 mm</td>
<td>170</td>
<td>225</td>
<td>285</td>
<td>340</td>
<td>455</td>
<td>570</td>
<td>680</td>
</tr>
<tr>
<td>peel separation, %</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
<td>25</td>
</tr>
</tbody>
</table>
S = separation in (%)
A = average depth of separation, or incursion (in.² or mm²)
A₀ = original bonding distance (in.² or mm²)

Note 4 (Repeated): The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%
Extrusion Fillet: AD1, AD2
Exception: AD-WLD (unless strength is achieved)

Note 5 (Repeated): Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

7. Retest and Rejection

7.1 If the results of the testing of a sample do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the construction quality control or construction quality assurance plan for the particular site under construction.

8. Certification

8.1 Upon request of the construction quality assurance officer or certification engineer, an installer’s certification that the geomembrane was installed and tested in accordance with this specification, together with a report of the test results, shall be furnished at the completion of the installation.
Note 5 (Repeated): Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

6.3 fPP Seams – For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in shear should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide grab tests. In addition, the shear percent elongation on the unreinforced specimens, calculated as follows, should exceed the values given in Tables 3(a) and 3(b). All five out of five specimens should meet the shear elongation requirement.

\[ E = \frac{L}{L_o} \times 100 \]  

where
E = elongation (%)
L = extension at end of test (in. or mm)
L_o = original gauge length (usually 1.0 in. or 25 mm)

Note 3 (Repeated): The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as “not applicable” in Tables 3(a) and 3(b).

For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in peel should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are grab tests. In addition, the peel percent separation (or incursion) should not exceed the values given in Tables 3(a) and 3(b). All five out of five specimens should meet the peel separation value. The values should be based on the proportion of area of separated bond to the area of the original bonding as follows.

\[ S = \frac{A}{A_o} \times 100 \]  

where
where
\[ E = \text{elongation (\%)} \]
\[ L = \text{extension at end of test (in. or mm)} \]
\[ L_o = \text{original average length (usually 1.0 in. or 25 mm)} \]

Note 3 (Repeated): The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as "not applicable" in Tables 2 (c) and (d).

For LLDPE seams (smooth, textured and scrim reinforced), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 2(a) through 2(d). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 2(a) through 2(d). All five out of five specimens shall meet the peel separation value. The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

\[ S = \frac{A}{A_o} (100) \]  \hspace{1cm} (2)

where
\[ S = \text{separation (\%)} \]
\[ A = \text{average depth of separation, or incursion (in.}^2 \text{ or mm}^2) \]
\[ A_o = \text{original bonding distance (in.}^2 \text{ or mm}^2) \]

Note 4 (Repeated): The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code):

- **Hot Wedge:** AD and AD-Brk > 25%
- **Extrusion Fillet:** AD1, AD2
- **Exception:** AD-WLD (unless strength is achieved)
the proportion of area of separated bond to the area of the original bonding as follows:

\[ S = \frac{A}{A_0} \times 100 \]  

(2)

where

\( S \) = separation (%)  
\( A \) = average area of separation, or incursion (in\(^2\) or mm\(^2\))  
\( A_0 \) = original bonding area (in\(^2\) or mm\(^2\))

Note 4: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code):

- Hot Wedge: AD and AD-Brk > 25%
- Extrusion Fillet: AD1, AD2
- Exception: AD-WLD (unless strength is achieved)

Note 5: Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

6.2 LLDPE seams – For LLDPE seams (smooth, textured and scrim reinforced), the strength of four out of five 1.0 in. (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 2(a) through 2(d). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide grab tests. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 2(a) through 2(d). All five out of five should meet the shear elongation requirement.

\[ E = \frac{L}{L_o} \times 100 \]  

(1)
5. Sample and Specimen Preparation

5.1 The spacing for taking field seam samples for destructive testing is provided in GRI-GM29 (DRAFT), a standard-of-practice. The process describes a progression from the most restrictive interval of 1 per 500 feet (1 per 150 m) to the complete use and reliance of the electrical leak location survey (ELLS) method. Intermediate between these extremes are variations depending upon the installers experience and performance.

5.2 The size of field seam samples is to be according to the referenced test method, e.g., ASTM D6392 or site-specific CQA plan.

5.3 The individual test specimens taken from the field seam samples are to be tested according to the referenced test method, i.e., ASTM D6392 for HDPE, LLDPE and fPP, and ASTM D751 (modified to a 150 mm + seam width gage length) for fPP-R. The specimens are to be conditioned prior to testing according to these same test methods and evaluated accordingly.

6. Assessment of Seam Test Results

6.1 HDPE seams – For HDPE seams (both smooth and textured), the strength of four out of five 1.0 inch (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values. In addition, five out five specimens should meet the shear percent elongation, calculated as follows, and exceed the values given in Tables 1(a) and 1(b):

\[ E = \frac{L}{L_0} (100) \]  \hspace{1cm} (1)

where

- \( E \) = elongation (%)
- \( L \) = extension at end of test (in. or mm)
- \( L_0 \) = original average length (usually 1.0 in. or 25 mm)

Note 3: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For HDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 1(a) and 1(b) for all five out of five specimens. The value shall be based on
3. Definition

3.1 Geomembrane, n – An essentially impermeable geosynthetic composed of one or more synthetic sheets used for the purpose of liquid, gas or solid containment.

3.2 Hot Wedge Seaming – A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a hot metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Seams of this type can be made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual hot wedge seams or double-track seams.

3.3 Hot Air Seaming – This seaming technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate localized surface melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond.

3.4 Ultrasonic Seaming - A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a ultrasonically vibrated metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this type are made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual-track seams or double-track seams.

3.5 Extrusion Fillet Seaming – This seaming technique involves extruding molten resin at the edge of an overlapped geomembrane on another to form a continuous bond. A depreciated method called “extrusion flat” seaming extrudes the molten resin between the two overlapped sheets. In all types of extrusion seaming the surfaces upon which the molten resin is applied must be suitably prepared, usually by a slight grinding or buffing.

4. Significance and Use

4.1 The various methods of field fabrication of seams in polyolefin geomembranes are covered in existing ASTM standards mentioned in the referenced document section. What is not covered in those documents is the numeric values of strength and related properties that the completed seam must meet, or exceed. This specification provides this information insofar as minimum, or maximum, property values are concerned when the field fabricated seams are sampled and laboratory tested in shear and peel. A separate GRI standard, GRI-GM29 (DRAFT), provides guidance as to the spacing that destructive samples should be taken in typical field installation projects.
Note 2: Other acceptable, but less frequently used, methods of seaming are hot air and ultrasonic methods. They are inferred as being a subcategory of hot wedge seaming.

1.4 This specification does not suggest a specific distance between destructive seam samples to be taken in the field, i.e., the sampling interval. A separate GRI Standard Practice is focused on this issue, see GRI-GM29.

1.5 This specification is only applicable to laboratory testing.

1.6 This specification does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards

D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
D7747 Standard Test Method for Determining Integrity of Seams Produced Using Thermo-Fusion Methods for Reinforced Geomembranes by the Strip Tensile Method

2.2 EPA Standards

EPA 600/2.88/052 (NTIS PB-89-129670)
Lining of Waste Containment and Other Containment Facilities

2.3 GRI Standards

GM13 Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes
GM14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes
GM17 Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes
GM18 Test Properties and Testing Frequency for Flexible Polypropylene (fPP and fPP-R) Geomembranes
GM20 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts
GM25 Test Property and Testing Frequency for Scrim Reinforced Linear Low Density Polyethylene Geomembranes
GM29 Practice for Field Integrity Evaluation of Geomembrane Seams (and Sheet) Using Destructive and Nondestructive Testing
GRI Test Method GM19*

Standard Specification for

Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification addresses the required seam strength and related properties of thermally bonded polyolefin geomembranes; in particular, high density polyethylene (HDPE), linear low density polyethylene both nonreinforced (LLDPE) and scrim reinforced (LLDPE-R) and flexible polypropylene both nonreinforced (fPP) and scrim reinforced (fPP-R).

1.2 Numeric values of seam strength and related properties are specified in both shear and peel modes.

Note 1: This specification does not address the test method details or specific testing procedures. It refers to the relevant ASTM test methods where applicable.

1.3 The thermal bonding methods focused upon are hot wedge (single and dual track) and extrusion fillet.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 5-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

All rights reserved
GM19 - 1 of 13
Rev. 8: 2/12/2015
For a batch of size "n", the "D" value should yield a risk of 0.5% or less of penalizing good seaming practice, i.e., $P_a \geq 99.5\%$. In other words, the probability for good seaming practice to be penalized is extremely small, i.e., less than 0.5%.

The above criteria is subjective. Nevertheless, it is felt to be adequate since the rights of both the installer and the owner/regulator are protected. Recognize that a sampling plan with tighter control (i.e., smaller values of "I" and "D") might seem to be more ideal at first glance, but it may result in a significant increase in the required number of destructive tests, i.e., it may be counter productive.

As an illustration, Figure B2 shows the graphic procedure of obtaining the "I" and "D" values for a batch of 50 samples (n=50) and an anticipated failure percentage of 4%. [In other words, it illustrates the procedure of obtaining one particular pair of numbers listed in Table 2, namely, "I" and "D" equal to 3 and 6, respectively.] Note that each OC curve shown in Figure B2 corresponds to a specific "c" value and is obtained via a Poisson distribution table.

Figure B2 can also used to determine the values of "I" and "D" for sampling plans with the same batch size (i.e., n = 50) but different anticipated failure percentage. The rest of the values listed in Table 2 can be verified in a similar manner using OC curves corresponding to different batch sizes.

![Figure B2](image_url)

Figure B2 - The Determination of the Values of "I" and "D" for a Batch with 50 Samples and an Anticipated Failure Percentage of 4.0%.
An OC curve can be developed by determining the probability of acceptance for several values of the percent defects. To do so, a statistical distribution of the acceptance probability has to be assumed first. There are three distributions which can be used: hypergeometric, binomial and Poisson distribution. The Poisson distribution is generally preferable due to the ease of calculation. It is used in this guide. The Poisson distribution function to be applied to an acceptance sampling plan is as follows:

\[ p\left(\text{exactly } c \text{ defects in a batch of size } n\right) = \frac{e^{-np}(np)^c}{c!} \]  

(B1)

Most statistics books provide Poisson distribution tables which give the probability of "c" or less defects in a batch of size "n" from a lot having a fraction of defect "p".

The Selection of the "I" and "D" Values Listed in Table 2
As mentioned earlier, each of the sampling plans recommended in this guide consists of three variables: the batch size "n", the values of "I" and "D". Note that the values of "I" and "D" are specific values of "c" mentioned in Equation B1. The "I" value corresponds to the judgment criterion of rewarding good seaming practice, i.e., increasing the sampling interval if the number of failed samples does not exceed this particular value. The "D" value, on the other hand, corresponds to the judgment criterion of penalizing poor seaming practice, i.e., decreasing the sampling interval if the number of failed samples equals or exceeds this particular value.

The concept of the OC curves is used to determine the actual values of I's and D's for different sampling plans. The criteria used are as follows:

- For a batch of size "n", the "I" value should yield a 80–90% probability of rewarding good seaming practice, i.e., 80% < P_a < 90%.
GM 14 - Appendix A - The Selection of the "I" and "D" Values

In this appendix, the procedure used for selecting the "I" and "D" values listed in Table 2 is presented. The required background, e.g., the concept of sampling risk and the operating characteristics (OC) curves, are briefly discussed.

Sampling Risk

Sampling involves a degree of risk that the actual samples do not adequately reflect the conditions of the lot. For example, when using the sampling plan recommended in this guide, there are two common risks [see Juran and Gryna (1980) and Juran et. al (1974) for details]:

1. A good seaming practice might be penalized. This is generally referred as the installer's risk and denoted as the $\alpha$ risk.

2. A poor seaming practice might go undetected. This is generally referred as an owner/regulators risk and denoted as the $\beta$ risk.

The effects (impacts) of the relative degree of these two risks are summarized in Table B1.

<table>
<thead>
<tr>
<th>Relative Degree</th>
<th>Installers ((\alpha)) Risk</th>
<th>Owner/Regulators ((\beta)) Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Loose CQA control; low testing cost</td>
<td>Tight CQA control; high testing cost</td>
</tr>
<tr>
<td>High</td>
<td>Tight CQA control; high testing cost</td>
<td>Loose CQA control; low testing cost</td>
</tr>
</tbody>
</table>

Operating Characteristics (OC) Curves

Both of the risks can be quantified by sampling-plan-specific operating characteristics (OC) curves. The OC curve for a sampling plan is a graph which plots the probability that the sampling plan will accept a lot (i.e., the $P_a$ value) versus the percent defective samples in that particular lot. Note that the term "sampling plan" used here corresponds to a batch of "n" destructive testing samples and the criteria for adjusting the sampling interval. Recall Table 2 in the main body of this guide. Figure B1 illustrates the concept of OC curves. In Figure B1, the dashed curve represents an "ideal" OC curve. Here it is desired to accept all lots having less or equal than 2% and reject all lots having greater than 2% failures. In reality, all sampling plans have risks that a "good" lot will be rejected or a "bad" lot will be accepted. This is illustrated by the solid S-shaped curve shown in Figure B1. It is seen that this particular sampling plan will have a 5% risk (100% - 95%) of rejecting a lot having only 1% defects (i.e., a "good" lot) and a 10% risk of accepting a lot having 5% defects (i.e., a "bad" lot).
Table 4(b) - Results of Example 3 (in English Units) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Poor" Quality Installer

<table>
<thead>
<tr>
<th>Batch number</th>
<th>Sampling Interval (m)</th>
<th>No. of Remaining Samples Required</th>
<th>Batch size</th>
<th>Cumulative Distance (m)</th>
<th>Number of failures</th>
<th>Decision made</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500</td>
<td>360</td>
<td>50</td>
<td>25000</td>
<td>3</td>
<td>Stay</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>310</td>
<td>50</td>
<td>50000</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>260</td>
<td>32</td>
<td>66000</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>228</td>
<td>32</td>
<td>82000</td>
<td>3</td>
<td>Decrease</td>
</tr>
<tr>
<td>5</td>
<td>400</td>
<td>245</td>
<td>32</td>
<td>94800</td>
<td>3</td>
<td>Decrease</td>
</tr>
<tr>
<td>6</td>
<td>320</td>
<td>266</td>
<td>32</td>
<td>105040</td>
<td>1</td>
<td>Increase</td>
</tr>
<tr>
<td>7</td>
<td>400</td>
<td>187</td>
<td>32</td>
<td>117840</td>
<td>1</td>
<td>Increase</td>
</tr>
<tr>
<td>8</td>
<td>500</td>
<td>124</td>
<td>20</td>
<td>127840</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>9</td>
<td>500</td>
<td>104</td>
<td>20</td>
<td>137840</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>10</td>
<td>500</td>
<td>84</td>
<td>13</td>
<td>144340</td>
<td>2</td>
<td>Decrease</td>
</tr>
<tr>
<td>11</td>
<td>400</td>
<td>89</td>
<td>13</td>
<td>149540</td>
<td>2</td>
<td>Decrease</td>
</tr>
<tr>
<td>12</td>
<td>320</td>
<td>95</td>
<td>13</td>
<td>153700</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>13</td>
<td>320</td>
<td>82</td>
<td>13</td>
<td>157860</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>14</td>
<td>320</td>
<td>69</td>
<td>13</td>
<td>162020</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>15</td>
<td>320</td>
<td>56</td>
<td>13</td>
<td>166180</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>16</td>
<td>400</td>
<td>35</td>
<td>8</td>
<td>169380</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>17</td>
<td>400</td>
<td>27</td>
<td>5</td>
<td>171380</td>
<td>1</td>
<td>Decrease</td>
</tr>
<tr>
<td>18</td>
<td>320</td>
<td>27</td>
<td>5</td>
<td>172980</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>19</td>
<td>400</td>
<td>18</td>
<td>3</td>
<td>174180</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>20</td>
<td>500</td>
<td>12</td>
<td>2</td>
<td>175180</td>
<td>1</td>
<td>Decrease</td>
</tr>
<tr>
<td>21</td>
<td>400</td>
<td>12</td>
<td>2</td>
<td>175980</td>
<td>1</td>
<td>Decrease</td>
</tr>
<tr>
<td>22</td>
<td>320</td>
<td>13</td>
<td>3</td>
<td>176140</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>23</td>
<td>400</td>
<td>10</td>
<td>2</td>
<td>176780</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>24</td>
<td>500</td>
<td>6</td>
<td>2</td>
<td>177140</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>25</td>
<td>600</td>
<td>5</td>
<td>2</td>
<td>177980</td>
<td>0</td>
<td>Done</td>
</tr>
</tbody>
</table>

Total Number of tests per 54,000 m of seam project = 412

5.5 Summary

This guide illustrates by means of hypothetical examples how a CQA and/or CQC organization can modify the sampling interval for taking destructive samples from a geomembrane seaming project. It is based on the method of attributes which is common to statistical control methods. The methodology uses sequential sampling to proceed from one decision to the next until the project is complete.

The result in using this guide for the above purpose is to reward good seaming performance by taking fewer destructive samples, and to penalize poor seaming performance by taking additional destructive samples. In the example illustrations, good seaming resulted in taking 265 samples (versus 360), or a decrease of 26% from the originally set constant interval of 1 sample per 150 m (500 ft). Conversely, poor seaming resulted in taking 412 samples (versus 360), or a 14% increase in the originally set constant interval of 1 sample per 150 m (500 ft.) of seam length.
Example 3 - Using the same project seam length and start-up sampling frequency as Example 1, assume that the start-up batch of 50 samples had 3 failures. The decision is then to continue at a 1 destructive sample in 150 m (500 ft) sampling interval. Thus the second batch size is again 50 samples as it was with Example 2, see Table 4. Table 4(a) is in S.I. units and Table 4(b) is in English units. Now assume in the second batch there are 2 failures. The decision is to again continue at a 1 destructive sample in 150 m (500 ft) sampling interval. From Table 1, the third batch size is then decreased to 32 samples. The process is continued in this manner until the project is concluded. For this hypothetical situation Table 4 illustrates that 412 samples are necessary. Note that by a constant interval of 1 sample in 150 m (500 ft), 360 samples would have been necessary. Furthermore, a good seamer (as illustrated in Example 2) would only have had to take 265 samples.

Table 4(a) - Results of Example 3 (in S.I. Units) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Poor" Quality Installer

<table>
<thead>
<tr>
<th>Batch number</th>
<th>Sampling Interval (m)</th>
<th>No. of Remaining Samples Required</th>
<th>Batch size</th>
<th>Cumulative Distance (m)</th>
<th>Number of failures</th>
<th>Decision made</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>150</td>
<td>360</td>
<td>50</td>
<td>7500</td>
<td>3</td>
<td>Stay</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
<td>310</td>
<td>50</td>
<td>15000</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>3</td>
<td>150</td>
<td>260</td>
<td>32</td>
<td>19800</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>4</td>
<td>150</td>
<td>228</td>
<td>32</td>
<td>24600</td>
<td>3</td>
<td>Decrease</td>
</tr>
<tr>
<td>5</td>
<td>120</td>
<td>245</td>
<td>32</td>
<td>28440</td>
<td>3</td>
<td>Decrease</td>
</tr>
<tr>
<td>6</td>
<td>100</td>
<td>256</td>
<td>32</td>
<td>31640</td>
<td>1</td>
<td>Increase</td>
</tr>
<tr>
<td>7</td>
<td>120</td>
<td>186</td>
<td>32</td>
<td>35480</td>
<td>1</td>
<td>Increase</td>
</tr>
<tr>
<td>8</td>
<td>150</td>
<td>123</td>
<td>20</td>
<td>38480</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>9</td>
<td>150</td>
<td>103</td>
<td>20</td>
<td>41480</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>10</td>
<td>150</td>
<td>83</td>
<td>13</td>
<td>43430</td>
<td>2</td>
<td>Decrease</td>
</tr>
<tr>
<td>11</td>
<td>120</td>
<td>88</td>
<td>13</td>
<td>44990</td>
<td>2</td>
<td>Decrease</td>
</tr>
<tr>
<td>12</td>
<td>100</td>
<td>90</td>
<td>13</td>
<td>46290</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>13</td>
<td>100</td>
<td>77</td>
<td>13</td>
<td>47590</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>14</td>
<td>100</td>
<td>64</td>
<td>13</td>
<td>48890</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>15</td>
<td>100</td>
<td>51</td>
<td>13</td>
<td>50190</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>16</td>
<td>120</td>
<td>32</td>
<td>8</td>
<td>51150</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>17</td>
<td>120</td>
<td>24</td>
<td>5</td>
<td>51750</td>
<td>1</td>
<td>Decrease</td>
</tr>
<tr>
<td>18</td>
<td>100</td>
<td>23</td>
<td>5</td>
<td>52250</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>19</td>
<td>120</td>
<td>15</td>
<td>3</td>
<td>52610</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>20</td>
<td>150</td>
<td>9</td>
<td>2</td>
<td>52910</td>
<td>1</td>
<td>Decrease</td>
</tr>
<tr>
<td>21</td>
<td>120</td>
<td>9</td>
<td>2</td>
<td>53150</td>
<td>1</td>
<td>Decrease</td>
</tr>
<tr>
<td>22</td>
<td>100</td>
<td>11</td>
<td>3</td>
<td>53210</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>23</td>
<td>120</td>
<td>7</td>
<td>2</td>
<td>53390</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>24</td>
<td>150</td>
<td>5</td>
<td>2</td>
<td>53510</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>25</td>
<td>180</td>
<td>3</td>
<td>2</td>
<td>53750</td>
<td>0</td>
<td>Done</td>
</tr>
</tbody>
</table>

Total Number of tests per 54,000 m of seam project = 412
Table 3(a) - Results of Example 2 (in S.I. Units) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Good" Quality Installer

<table>
<thead>
<tr>
<th>Batch number</th>
<th>Sampling Interval (m)</th>
<th>No. of Remaining Samples Required</th>
<th>Batch size</th>
<th>Cumulative Distance (m)</th>
<th>Number of failures</th>
<th>Decision made</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>150</td>
<td>360</td>
<td>50</td>
<td>7500</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>2</td>
<td>150</td>
<td>310</td>
<td>50</td>
<td>15000</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>3</td>
<td>180</td>
<td>217</td>
<td>32</td>
<td>20760</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>4</td>
<td>215</td>
<td>155</td>
<td>32</td>
<td>27640</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>5</td>
<td>215</td>
<td>123</td>
<td>20</td>
<td>31940</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>6</td>
<td>215</td>
<td>103</td>
<td>20</td>
<td>36240</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>7</td>
<td>260</td>
<td>68</td>
<td>13</td>
<td>39620</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>8</td>
<td>260</td>
<td>55</td>
<td>13</td>
<td>43000</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>9</td>
<td>310</td>
<td>35</td>
<td>8</td>
<td>45480</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>10</td>
<td>310</td>
<td>27</td>
<td>8</td>
<td>47960</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>11</td>
<td>310</td>
<td>19</td>
<td>5</td>
<td>49510</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>12</td>
<td>310</td>
<td>14</td>
<td>3</td>
<td>50440</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>13</td>
<td>310</td>
<td>11</td>
<td>3</td>
<td>51370</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>14</td>
<td>310</td>
<td>8</td>
<td>2</td>
<td>51990</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>15</td>
<td>310</td>
<td>6</td>
<td>2</td>
<td>52610</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>16</td>
<td>310</td>
<td>4</td>
<td>2</td>
<td>53230</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>17</td>
<td>310</td>
<td>2</td>
<td>2</td>
<td>53850</td>
<td>0</td>
<td>Done</td>
</tr>
</tbody>
</table>

Total Number of tests per 54,000 m of seam project = 265

Table 3(b) - Results of Example 2 (in English Units) Illustrating the Variation of the Sampling Interval Based on a 2.0% Anticipated Failure Percentage With a "Good" Quality Installer

<table>
<thead>
<tr>
<th>Batch number</th>
<th>Sampling Interval (m)</th>
<th>No. of Remaining Samples Required</th>
<th>Batch size</th>
<th>Cumulative Distance (m)</th>
<th>Number of failures</th>
<th>Decision made</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500</td>
<td>360</td>
<td>50</td>
<td>25000</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>310</td>
<td>50</td>
<td>50000</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>3</td>
<td>600</td>
<td>217</td>
<td>32</td>
<td>69200</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>4</td>
<td>720</td>
<td>154</td>
<td>32</td>
<td>92240</td>
<td>2</td>
<td>Stay</td>
</tr>
<tr>
<td>5</td>
<td>720</td>
<td>122</td>
<td>20</td>
<td>106640</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>6</td>
<td>720</td>
<td>102</td>
<td>20</td>
<td>121040</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>7</td>
<td>850</td>
<td>69</td>
<td>13</td>
<td>132090</td>
<td>1</td>
<td>Stay</td>
</tr>
<tr>
<td>8</td>
<td>850</td>
<td>56</td>
<td>13</td>
<td>143140</td>
<td>0</td>
<td>Increase</td>
</tr>
<tr>
<td>9</td>
<td>1000</td>
<td>37</td>
<td>8</td>
<td>151140</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>10</td>
<td>1000</td>
<td>29</td>
<td>8</td>
<td>159140</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>11</td>
<td>1000</td>
<td>21</td>
<td>5</td>
<td>164140</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>12</td>
<td>1000</td>
<td>16</td>
<td>5</td>
<td>169140</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>13</td>
<td>1000</td>
<td>11</td>
<td>3</td>
<td>172140</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>14</td>
<td>1000</td>
<td>8</td>
<td>2</td>
<td>174140</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>15</td>
<td>1000</td>
<td>6</td>
<td>2</td>
<td>176140</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>16</td>
<td>1000</td>
<td>4</td>
<td>2</td>
<td>178140</td>
<td>0</td>
<td>Stay</td>
</tr>
<tr>
<td>17</td>
<td>1000</td>
<td>2</td>
<td>1</td>
<td>179140</td>
<td>0</td>
<td>Done</td>
</tr>
</tbody>
</table>

Total Number of tests per 180,000 ft of seam project = 266
continued until the project is finished. Two examples will be provided using the above sampling table both with anticipated failure percentages of 2.0%: **Example 2 illustrates good seaming**, and **Example 3 illustrates poor seaming**.

Example 2 - Using the same project seam length and start-up sampling frequency as in the previous example assume that the start-up batch of 50 samples in the previous example had 2-failures. The decision is then to continue at a 1 destructive sample in 150 m (500 ft) sampling interval. Thus the second batch size from Table 1 is again 50 samples, see Table 3. Table 3(a) is in S.I. units and Table 3(b) is in English units. Now assume in the second batch there are no failures. This allows the sampling interval to be increased, e.g., to 1 sample in 180 m (600 ft). From Table 1, the third batch size is then decreased to 32 samples. The process is continued in this manner until the project is concluded. For this hypothetical situation Table 3(a) illustrates that 265 samples (or 266 samples when using the English units in Table 3(b)) are necessary. Note that by using a constant interval of 1 sample in 150 m (500 ft), 360 samples would have been necessary. Also note that the maximum sampling interval was fixed at 310 m (1000 ft).

**Note 4** - This example, and the following one, use a changing sampling interval of ± 20% from the previous value. That is, when good seaming allows for an increase in sampling interval; the progression being from 150, 180, 215, 260 to 310 m (500, 600, 720, 850 to 1000 ft), respectively. A maximum interval of 310 m (1000 ft) is recommended, but clearly this value is at the discretion of the organizations involved. Conversely, poor seaming requires a decrease in sampling interval; the progression being from 150, 120, 100, 80 to 65 m (500, 400, 320, 250 to 200 ft), respectively. A minimum interval of 65 m (200 ft) is recommended, but clearly this decision is also at the discretion of the organizations involved.
relatively high number of failures (where the sampling interval should be decreased). Table 2 provides this information which is based upon the operation characteristic (OC) curves of Appendix B.

Example 1 (cont.) - Assuming an anticipated failure percentage of 2% (recall Note - 2), Table 2 results in the three categories shown below:

- 0 or 1 failure out of 50; the sampling interval can be increased
- 2 or 3 failures out of 50; the sampling frequency should remain at 1 sample per 150 m (500 ft)
- 4 or more failures out of 50; the sampling interval should be decreased

Table 2: Sampling Table Containing the Number of Failed Samples to be used for Interval Sampling Interval Modification, see Appendix A for details

<table>
<thead>
<tr>
<th>No. of Required Samples Based on Initial or Modified Sampling Interval</th>
<th>No. of Samples Needed (Batch Size) to Determine Subsequent Sampling Interval</th>
<th>Anticipated Failure Percentage*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1%</td>
</tr>
<tr>
<td>2 - 8</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>9 - 15</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>16 - 25</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>26 - 50</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>51 - 90</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>91 - 150</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>151 - 280</td>
<td>32</td>
<td>0</td>
</tr>
<tr>
<td>281 - 500</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>501 - 1200</td>
<td>80</td>
<td>1</td>
</tr>
<tr>
<td>1201 - 3200</td>
<td>125</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No. of Required Samples Based on Initial or Modified Sampling Interval</th>
<th>No. of Samples Needed (Batch Size) to Determine Subsequent Sampling Interval</th>
<th>Anticipated Failure Percentage*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>2 - 8</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>9 - 15</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>16 - 25</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>26 - 50</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>51 - 90</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>91 - 150</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>151 - 280</td>
<td>32</td>
<td>2</td>
</tr>
<tr>
<td>281 - 500</td>
<td>50</td>
<td>4</td>
</tr>
<tr>
<td>501 - 1200</td>
<td>80</td>
<td>6</td>
</tr>
<tr>
<td>1201 - 3200</td>
<td>125</td>
<td>9</td>
</tr>
</tbody>
</table>

No: *To be selected by CQA, owner or regulatory organizations
1 = Increase the sampling interval if the number of failed samples found in the batch does not exceed the tabulated value.
D = Decrease the sampling interval if the number of failed samples found in the batch equals or exceeds the tabulated value.

5.4 Modification of Start-Up Sampling Interval - Depending upon the outcome of the previous section, the start-up sampling interval may be modified to a new value which will then require a new batch size to verify the modification. The process is then
5. Suggested Methodology

Using the concepts embodied in the method of attributes, the following procedure is based on adjustments to sequential sampling.

5.1 Typical Field Situation - In order to begin the process, a project-specific total seam length must be obtained from the installers panel (roll) layout plan. Also, an initial, or start-up, sampling interval must be decided upon. From this information the total number of samples that are required based on the start-up sampling interval can be obtained.

Example 1 - A given project has 54,000 m (180,000 ft) of field seaming. The start-up sampling frequency is 1 sample per 150 m (500 ft). Therefore, the total number of samples required if the start-up interval is kept constant will be:

\[
\frac{54,000}{150} = 360 \text{ samples}
\]

5.2 Determination of Initial Batch Size - Using the table shown below, the initial batch size from which to possibly modify the start-up sampling interval is obtained.

Table 1 - Batch Size Determination, after ANSI/ASQC Z1.4 [1993]

<table>
<thead>
<tr>
<th>No. of Required Samples Based on Initial or Modified Sampling Interval</th>
<th>No. of Samples Needed (Batch Size) to Determine Subsequent Sampling Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - 8</td>
<td>2</td>
</tr>
<tr>
<td>9 - 15</td>
<td>3</td>
</tr>
<tr>
<td>16 - 25</td>
<td>5</td>
</tr>
<tr>
<td>26 - 50</td>
<td>8</td>
</tr>
<tr>
<td>51 - 90</td>
<td>13</td>
</tr>
<tr>
<td>91 - 150</td>
<td>20</td>
</tr>
<tr>
<td>151 - 280</td>
<td>32</td>
</tr>
<tr>
<td>281 - 500</td>
<td>50</td>
</tr>
<tr>
<td>501 - 1200</td>
<td>80</td>
</tr>
<tr>
<td>1201 - 3200</td>
<td>125</td>
</tr>
</tbody>
</table>

Example 1 (cont.) - For 360 samples, a batch size of 50 is necessary. As production seaming progresses, these 50 samples are tested (either as they are taken or in a batch) and the number of failures is determined.

5.3 Verification of Start-Up Sampling Interval - A sampling table is now used which separates the number of failures within this initial batch size into three categories: a relatively low number of failures (where the sampling interval can be increased), the anticipated number of failures (where the sampling interval is maintained), or a
3.2 The guide then gives the procedure for establishing the initial number of samples needed for a possible modification to the start-up sampling interval. This is called the initial batch. Based upon the number of failed samples in the initial batch, the spacing is either increased (for good seaming), kept the same, or decreased (for poor seaming).

3.3 A second batch size is then determined and the process is continued. Depending on the project size, i.e., the total length of seaming, a number of decision cycles can occur until the project is finished.

3.4 It is seen that the number of samples required for the entire project is either fewer than the start-up frequency (for good seaming); the same as the start-up frequency (for matching the initial anticipated failure percentage); or more than the start-up frequency (for poor seaming).

4. Significance and Use

4.1 Construction quality assurance (CQA) and construction quality control (CQC) organizations, as well as owner/operators and agency regulators can use this guide to vary the sampling interval of geomembrane seam samples (i.e., the taking of field samples for destructive shear and peel testing) from an initial, or start-up, interval. This initial interval is often one destructive seam sample in every 150 m (500 ft) of seam length.

4.2 The guide leads to increasing the sampling interval for good seaming practice (hence fewer destructive samples) and to decreasing the sampling interval for poor seaming practice (hence additional destructive samples).

4.3 Use of the guide should provide an incentive for geomembrane installers to upgrade the quality and performance of their field seaming activities. In so doing, the cutting of fewer destructive samples will lead to overall better quality of the entire liner project, since the patching of previously taken destructive samples is invariably of poorer quality than the original seam itself.

Note 3 - It is generally accepted that field patching of areas where destructive samples had been taken using extrusion fillet seaming is less desirable than the original seam which was made by hot wedge welding.

4.4 Control charts are described in GRI-GM20 which can also be used by geomembrane installers and their construction quality control (CQC) personnel for improvement in overall job quality and identification of poorly performing seaming personnel and/or equipment.
1.4 The outcome of using the guide rewards good seaming performance resulting from a record of passing destructive seam tests. It also penalizes poor seaming performance resulting from a record of excessively failing seam tests.

1.5 This guide does not address the actual seam testing procedures that are used for acceptance or failure of the geomembrane seam test specimens themselves. Depending on the type of geomembrane being deployed one should use ASTM D4437, D3083, D751 and D413 for testing details in this regard. The project-specific CQA plan should define the particular criteria used in acceptance or failure.

1.6 An alternative to this method of attributes is that of using control charts for determining the variable interval for taking destructive seam samples. See GRI-GM20 in this regard.

2. Referenced Documents

2.1 ASTM Standards:
D4437 Practice for Determining the Integrity of Field Seams Used in Joining Flexible Polymeric Sheet Geomembranes
D3083 Specification for Flexible Poly (Vinyl Chloride) Plastic Sheet for Pond, Canal, and Reservoir Lining
D751 Method of Testing Coated Fabrics
D413 Test Methods for Rubber Property - Adhesion to Flexible Substrate

2.2 Other Standards
ANSI/ASQC Z1.4 [1993]
Sampling Procedures and Tables for Inspection by Attributes

2.3 GRI Standards
GM20 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts

3. Summary of Guide

3.1 Use of this guide requires the establishment of an anticipated geomembrane seam failure percentage (ranging from 1 to 8%) and an initial, or start-up, sampling interval.

Note 2 - The value of anticipated failure percentage is an important consideration. It dictates each decision as to a possible increase or decrease in interval spacing from the preceding value. The percentage itself comes from historical data of the construction quality assurance (CQA) organization or regulatory agency. It is related to a number of factors including criticality of installation, type of geomembrane, type of seaming method and local ambient conditions.

The actual value is admittedly subjective and should be made known in advance to the geomembrane installer before bidding the project. Use of an unrealistically low value of anticipated failure percentage, e.g., < 1.0%, will likely result in field difficulties insofar as decreased sampling
Standard Guide for

"Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes"

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrants or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This guide is focused on selecting the spacing interval for taking destructive seam samples of field deployed geomembranes as a particular job progresses based on an installer’s ongoing record of pass - or - fail testing.

Note 1 - While subjective at this time, the guide is most applicable to large geomembrane seaming projects which require more than 100 destructive seam samples based upon the typical sampling strategy of 1 destructive sample per 150 m (500 ft).

1.2 This guide is essentially applicable to production seams. Caution should be exercised in using the guide for projects that involve complex geometries, multiple penetrations, or extreme weather conditions.

1.3 The primary target audiences for this guide are construction quality assurance (CQA) organizations, construction quality control (CQC) organizations, facility owner/operators and agency regulators having permitting authority.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.
Adoption and Revision Schedule for HDPE Specification per GRI-GM13

“Test Methods, Test Properties, Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes”

Adopted: June 17, 1997

Revision 1: November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.

Revision 2: April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: “(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)” and to Note (4) in the property tables.

Revision 3: June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the designated test method.

Revision 4: December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to “strength” and “elongation”.

Revision 5: May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.

Revision 6: June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.

Revision 7: February 20, 2006: Added Note 6 on Asperity Height clarification with respect to shear strength.

Revision 8: Removed recommended warranty from specification.

Revision 9: June 1, 2009: Replaced GRI-GM12 test for asperity height of textured geomembranes with ASTM D 7466.

Revision 10 April 11, 2011: Added alternative carbon black content test methods

Revision 11 December 13, 2012: Replaced GRI-GM11 with the equivalent ASTM D 7238.

Revision 12 November 14, 2014: Increased minimum acceptable stress crack resistance time from 300 to 500 hours. Also, increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).

Revision 13 November 4, 2015: Removed Footnote (1) on asperity height from tables.

Revision 14 January 6, 2016: Removed Trouser Tear from Note 5.
## Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test Method</th>
<th>0.75 mm</th>
<th>1.00 mm</th>
<th>1.25 mm</th>
<th>1.50 mm</th>
<th>2.00 mm</th>
<th>2.50 mm</th>
<th>3.00 mm</th>
<th>Testing Frequency (minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness mils (min. ave.)</td>
<td>D 5994</td>
<td>nom. (-5%)</td>
<td>nom. (-5%)</td>
<td>nom. (-5%)</td>
<td>nom. (-5%)</td>
<td>nom. (-5%)</td>
<td>nom. (-5%)</td>
<td>nom. (-5%)</td>
<td>per roll</td>
</tr>
<tr>
<td>lowest individual for 8 out of 10 values</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td></td>
</tr>
<tr>
<td>lowest individual for any of the 10 values</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td></td>
</tr>
<tr>
<td>Asperity Height mils (min. ave.)</td>
<td>D 7466</td>
<td>0.40 mm</td>
<td>0.40 mm</td>
<td>0.40 mm</td>
<td>0.40 mm</td>
<td>0.40 mm</td>
<td>0.40 mm</td>
<td>0.40 mm</td>
<td>every 2nd roll (1)</td>
</tr>
<tr>
<td>Formulated Density (min. ave.)</td>
<td>D 1505D/792</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>90,000 kg</td>
</tr>
<tr>
<td>Tensile Properties (min. ave.) (2)</td>
<td>D 6693</td>
<td>Type IV</td>
<td>11 kN/m</td>
<td>15 kN/m</td>
<td>18 kN/m</td>
<td>22 kN/m</td>
<td>29 kN/m</td>
<td>37 kN/m</td>
<td>44 kN/m</td>
</tr>
<tr>
<td>yield strength</td>
<td>8 kN/m</td>
<td>10 kN/m</td>
<td>13 kN/m</td>
<td>16 kN/m</td>
<td>21 kN/m</td>
<td>26 kN/m</td>
<td>32 kN/m</td>
<td>37 kN/m</td>
<td>44 kN/m</td>
</tr>
<tr>
<td>break strength</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
</tr>
<tr>
<td>yield elongation</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>break elongation</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>Tear Resistance (min. ave.)</td>
<td>D 1004</td>
<td>93 N</td>
<td>125 N</td>
<td>156 N</td>
<td>187 N</td>
<td>249 N</td>
<td>311 N</td>
<td>374 N</td>
<td>20,000 kg</td>
</tr>
<tr>
<td>Puncture Resistance (min. ave.)</td>
<td>D 4833</td>
<td>200 N</td>
<td>267 N</td>
<td>333 N</td>
<td>400 N</td>
<td>534 N</td>
<td>667 N</td>
<td>800 N</td>
<td>20,000 kg</td>
</tr>
<tr>
<td>Stress Crack Resistance (3)</td>
<td>D 5397</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>per GRI GM10</td>
</tr>
<tr>
<td>Carbon Black Content (range)</td>
<td>D 4218 (4)</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>9,000 kg</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>D 5596</td>
<td>note (5)</td>
<td>note (5)</td>
<td>note (5)</td>
<td>note (5)</td>
<td>note (5)</td>
<td>note (5)</td>
<td>note (5)</td>
<td>20,000 kg</td>
</tr>
<tr>
<td>Oxidative Induction Time (OIT) (min. ave.) (6)</td>
<td>D 3895</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>90,000 kg</td>
</tr>
<tr>
<td>Standard OIT</td>
<td>or —</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>20,000 kg</td>
</tr>
<tr>
<td>High Pressure OIT</td>
<td>D 5885</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>per each formulation</td>
</tr>
<tr>
<td>Oven Aging at 85°C (6). (7)</td>
<td>D 5721</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
</tr>
<tr>
<td>Standard OIT (min. ave.) - % retained after 90 days</td>
<td>or —</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
</tr>
<tr>
<td>High Pressure OIT (min. ave.) - % retained after 90 days</td>
<td>D 5885</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
</tr>
<tr>
<td>Standard OIT (min. ave.)</td>
<td>or —</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>High Pressure OIT (min. ave.) - % retained after 1600 hrs (10)</td>
<td>D 5885</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>

(1) Alternate the measurement side for double sided textured sheet
(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
(3) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
(4) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MOC testing.
(5) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.
(6) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3
(7) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
(8) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
(9) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.
### Table 2(a) – High Density Polyethylene (HDPE) Geomembrane - Textured

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test Method</th>
<th>30 mils</th>
<th>40 mils</th>
<th>50 mils</th>
<th>60 mils</th>
<th>80 mils</th>
<th>100 mils</th>
<th>120 mils</th>
<th>Testing Frequency (minimum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness mils (min. ave.)</td>
<td>D 5994</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>per roll</td>
</tr>
<tr>
<td>• lowest individual for 8 out of 10 values</td>
<td></td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td>-10%</td>
<td></td>
</tr>
<tr>
<td>• lowest individual for any of the 10 values</td>
<td></td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td>-15%</td>
<td></td>
</tr>
<tr>
<td>Asperity Height mils (min. ave.)</td>
<td>D 7466</td>
<td>16 mil</td>
<td>16 mil</td>
<td>16 mil</td>
<td>16 mil</td>
<td>16 mil</td>
<td>16 mil</td>
<td>16 mil</td>
<td>every 2nd roll (1)</td>
</tr>
<tr>
<td>Formulated Density (min. ave.)</td>
<td>D 1505/5792</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>200,000 lb</td>
</tr>
<tr>
<td>Tensile Properties (min. ave.) (2)</td>
<td>D 6693</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20,000 lb</td>
</tr>
<tr>
<td>• yield strength</td>
<td>Type IV</td>
<td>63 lb/in</td>
<td>84 lb/in</td>
<td>105 lb/in</td>
<td>126 lb/in</td>
<td>168 lb/in</td>
<td>210 lb/in</td>
<td>252 lb/in</td>
<td></td>
</tr>
<tr>
<td>• break strength</td>
<td></td>
<td>45 lb/in</td>
<td>60 lb/in</td>
<td>75 lb/in</td>
<td>90 lb/in</td>
<td>120 lb/in</td>
<td>150 lb/in</td>
<td>180 lb/in</td>
<td></td>
</tr>
<tr>
<td>• yield elongation</td>
<td></td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>• break elongation</td>
<td></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Tear Resistance (min. ave.)</td>
<td>D 1004</td>
<td>21 lb</td>
<td>28 lb</td>
<td>35 lb</td>
<td>42 lb</td>
<td>56 lb</td>
<td>70 lb</td>
<td>84 lb</td>
<td>45,000 lb</td>
</tr>
<tr>
<td>Puncture Resistance (min. ave.)</td>
<td>D 4833</td>
<td>45 lb</td>
<td>60 lb</td>
<td>75 lb</td>
<td>90 lb</td>
<td>120 lb</td>
<td>150 lb</td>
<td>180 lb</td>
<td>45,000 lb</td>
</tr>
<tr>
<td>Stress Crack Resistance (3)</td>
<td>D 5397</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>per GRI GM10</td>
</tr>
<tr>
<td>Carbon Black Content (range)</td>
<td>D 4218 (4)</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>2.0-3.0 %</td>
<td>20,000 lb</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>D 5596</td>
<td>note (3)</td>
<td>note (3)</td>
<td>note (3)</td>
<td>note (3)</td>
<td>note (3)</td>
<td>note (3)</td>
<td>note (3)</td>
<td>45,000 lb</td>
</tr>
<tr>
<td>Oxidative Induction Time (OIT) (min. ave.) (6)</td>
<td>D 3895</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>200,000 lb</td>
</tr>
<tr>
<td>(a) Standard OIT</td>
<td>D 5885</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td></td>
</tr>
<tr>
<td>(b) High Pressure OIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oven Aging at 85°C (6)</td>
<td>D 3762</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>per each formulation</td>
</tr>
<tr>
<td>(a) Standard OIT</td>
<td>D 3895</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>(b) High Pressure OIT</td>
<td>D 5885</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>(a) Standard OIT</td>
<td>D 3895</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) High Pressure OIT</td>
<td>D 5885</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td></td>
</tr>
</tbody>
</table>

(1) Alternate the measurement side for double sided textured sheet
(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.

Yield elongation is calculated using a gage length of 1.3 inches.

Break elongation is calculated using a gage length of 2.0 inches.

(3) SP-NCTL per ASTM D5397 Appendix, is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.

The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views. 9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HIP-OIT value.
### Table 1(b) – High Density Polyethylene (HPDE) Geomembrane - Smooth

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test Method</th>
<th>0.75 mm</th>
<th>1.00 mm</th>
<th>1.25 mm</th>
<th>1.50 mm</th>
<th>2.00 mm</th>
<th>2.50 mm</th>
<th>3.00 mm</th>
<th>Testing Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness - mils (min. ave.)</td>
<td>D5199</td>
<td>nom. (mil)</td>
<td>-10%</td>
<td>nom. (mil)</td>
<td>-10%</td>
<td>nom. (mil)</td>
<td>-10%</td>
<td>nom. (mil)</td>
<td>-10%</td>
</tr>
<tr>
<td>Formulated Density (min.)</td>
<td>D 1505/D 792</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>0.940 g/cc</td>
<td>90,000 kg</td>
</tr>
<tr>
<td>Tensile Properties (I) (min. ave.)</td>
<td>D 6693</td>
<td>Type IV</td>
<td>11 kN/m</td>
<td>15 kN/m</td>
<td>18 kN/m</td>
<td>22 kN/m</td>
<td>29 kN/m</td>
<td>37 kN/m</td>
<td>44 kN/m</td>
</tr>
<tr>
<td>~ yield strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>~ break strength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>~ yield elongation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>~ break elongation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tear Resistance (min. ave.)</td>
<td>D 1004</td>
<td>93 N</td>
<td>125 N</td>
<td>156 N</td>
<td>187 N</td>
<td>249 N</td>
<td>311 N</td>
<td>374 N</td>
<td>20,000 kg</td>
</tr>
<tr>
<td>Puncture Resistance (min. ave.)</td>
<td>D 4833</td>
<td>240 N</td>
<td>320 N</td>
<td>400 N</td>
<td>480 N</td>
<td>640 N</td>
<td>800 N</td>
<td>960 N</td>
<td>20,000 kg</td>
</tr>
<tr>
<td>Stress Crack Resistance (2)</td>
<td>D 5397</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>500 hr.</td>
<td>per GRI GM-10</td>
</tr>
<tr>
<td>Carbon Black Content - %</td>
<td>D 4218 (3)</td>
<td>2.0-3.0%</td>
<td>2.0-3.0%</td>
<td>2.0-3.0%</td>
<td>2.0-3.0%</td>
<td>2.0-3.0%</td>
<td>2.0-3.0%</td>
<td>2.0-3.0%</td>
<td>9,000 kg</td>
</tr>
<tr>
<td>Carbon Black Dispersion</td>
<td>D 5396</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>note (4)</td>
<td>20,000 kg</td>
</tr>
<tr>
<td>Oxidative Induction Time (OIT) (min. ave. (5)</td>
<td>D 3895</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>100 min.</td>
<td>90,000 kg</td>
</tr>
<tr>
<td>(a) Standard OIT</td>
<td>D 5885</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>400 min.</td>
<td>90,000 kg</td>
</tr>
<tr>
<td>(b) High Pressure OIT</td>
<td>D 3895</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>per each formulation</td>
</tr>
<tr>
<td>Oven Aging at 85°C (5). (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Standard OIT (min. ave.) - % retained after 90 days</td>
<td>D 5721</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>55%</td>
<td>per each formulation</td>
</tr>
<tr>
<td>(b) High Pressure OIT (min. ave.) - % retained after 90 days</td>
<td>D 5885</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>80%</td>
<td>per each formulation</td>
</tr>
<tr>
<td>(a) Standard OIT (min. ave.)</td>
<td>D 3895</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs (9)</td>
<td>D 5885</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>9,000 kg</td>
</tr>
</tbody>
</table>

1. Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
2. Yield elongation is calculated using a gage length of 33 mm
3. Break elongation is calculated using a gage length of 50 mm
4. Carbon black dispersion (only near spherical agglomerates) for 10 different views:
5. The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
6. It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.
7. The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.
8. Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.
9. UV resistance is based on percent retained value regardless of the original HP-OIT value.
Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth

<table>
<thead>
<tr>
<th>Properties</th>
<th>Test Method</th>
<th>Thickness (min. ave.)</th>
<th>Formulated Density mg/l (min.)</th>
<th>Tensile Properties (1) (min. ave.)</th>
<th>Tear Resistance (min. ave.)</th>
<th>Puncture Resistance (min. ave.)</th>
<th>Stress Crack Resistance (2) (App.)</th>
<th>Carbon Black Content (range)</th>
<th>Oxidative Induction Time (OIT) (min. ave.) (5)</th>
<th>UV Resistance (7)</th>
<th>Carbon Black Dispersion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>D5199</td>
<td>D 1505/D 792</td>
<td>D 6693</td>
<td>D 1004</td>
<td>D 4833</td>
<td>D 5397 (App.)</td>
<td>D 4218 (3)</td>
<td>D 5596</td>
<td>D 7238</td>
<td>D 5885</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>Type IV</td>
<td>21 lb</td>
<td>54 lb</td>
<td>500 hr.</td>
<td>20.0-3.0%</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>63 lb/in.</td>
<td>28 lb</td>
<td>72 lb</td>
<td>500 hr.</td>
<td>2.0-3.0%</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>84 lb/in.</td>
<td>35 lb</td>
<td>90 lb</td>
<td>500 hr.</td>
<td>2.0-3.0%</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>105 lb/in.</td>
<td>42 lb</td>
<td>108 lb</td>
<td>500 hr.</td>
<td>2.0-3.0%</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>126 lb/in.</td>
<td>56 lb</td>
<td>144 lb</td>
<td>500 hr.</td>
<td>2.0-3.0%</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>168 lb/in.</td>
<td>70 lb</td>
<td>180 lb</td>
<td>500 hr.</td>
<td>2.0-3.0%</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>210 lb/in.</td>
<td>84 lb</td>
<td>216 lb</td>
<td>500 hr.</td>
<td>2.0-3.0%</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>252 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>456 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>380 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>304 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>280 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>228 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>184 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>128 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>102 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>80 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>60 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>40 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>20 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>10 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>nom.</td>
<td>0.940 g/cc</td>
<td>0 lb/in.</td>
<td>45,000 lb</td>
<td>45,000 lb</td>
<td>500 hr.</td>
<td>20,000 lb</td>
<td>note (4)</td>
<td>N.R. (8)</td>
<td>note (4)</td>
</tr>
</tbody>
</table>

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.

(2) The yield stress used to calculate the applied load for the SP-NCT1 test should be the manufacturer’s mean value via MQC testing.

(3) Other methods such as D 1603 (tub furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:

9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.
7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.
Note 6: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 8: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.
5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HDPE geomembranes and Table 2 is for single and double sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of 23°C ± 2°C. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of 21°C ± 2°C. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of 23°C ± 2°C should be utilized for testing purposes.

Note 4: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693)
- Wide Width Tensile
- Water Vapor Transmission
- Water Absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Multi-Axial Burst
- Various Toxicity Tests

Note 5: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet (see Note 6)

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

Formulation - The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

Nominal - Representative value of a measurable property determined under a set of conditions, by which a product may be described. Abbreviated as nom. in Tables 1 and 2.

4. Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.
values for test indicated, may be necessary under conditions of a particular application.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
D 1603 Test Method for Carbon Black in Olefin Plastics
D 3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5397 Procedure to Perform a Single Point Notched Constant Tensile Load – (SP-NCTL) Test: Appendix
D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes
D 6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
D 7466 Test Method for Measuring the Asperity Height of Textured Geomembranes

2.2 GRI Standards

GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet
Standard Specification for

“Test Methods, Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes” SM

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

   Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive...
10. Revision Schedule

Revision 1 – Adjusted details in Table 1.

Revision 2 – Increased 200 to 300 hours per GM13 revision
   Increased noncomplying specifier from 100 to 150 hours
   Changed ASTM D638 to ASTM D6693

Revision 3 – Decreased frequency of testing from 1 resin lot to 2 resin lots. See Section 7.1.

Revision 4 - July 23, 2015 - Increased SCR value from 300 to 500 hours per GM13.
   Increased noncomplying specifier from 150 to 250 hours. Added Note 7.
   The standard’s identification was changed from a specification to a guide
   which better reflects the content of the document.
to 200,000 lb.). Thus, the frequency of testing is every two (2) railroad cars of the above capacity (or equivalent).

Note 10: If multiple gauges of sheet are made from a given resin lot only the sheet with highest gauge thickness needs to be tested to comply with this guide.

7.2 Samples can also be taken from a small scale laboratory extruder, however, the correlation of results to the as-manufactured sheet must be developed on a material and process specific basis.

7.3 Test specimens are to be taken in the cross machine direction of the geomembrane sheet under consideration.

7.4 The constant load applied to the test specimen(s) shall be 30% of the yield stress per ASTM D6693. The yield stress value used in the test shall be the manufacturer's mean value for the geomembrane resin/formulation under consideration.

7.5 The criteria to be used for pass/fail decisions shall be set forth in Table 1.

Table 1 – Various SP-NCTL Test Criteria for Pass/Fail Decisions

<table>
<thead>
<tr>
<th>Test Cycle</th>
<th>Yield Stress (based on ASTM D 638)</th>
<th>Number of Test Specimens</th>
<th>Passing Criteria</th>
<th>If Noncompliance Occurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>the manufacturer's mean value via MQC testing</td>
<td>5</td>
<td>4 out of 5 with ( F_i &gt; 500 ) hr (noncomplying specimen with ( F_i &gt; 250 ) hr)</td>
<td>retest using cycle B</td>
</tr>
<tr>
<td>B</td>
<td>the manufacturer's mean value via MQC testing</td>
<td>5</td>
<td>4 out of 5 with ( F_i &gt; 500 ) hr (noncomplying specimen with ( F_i &gt; 250 ) hr)</td>
<td>reject railcar or perform full retest using cycle C</td>
</tr>
<tr>
<td>C</td>
<td>the manufacturer's mean value via MQC testing</td>
<td>30</td>
<td>Onset of brittle portion of curve ( T_i &gt; 250 ) hr</td>
<td>reject railcar</td>
</tr>
</tbody>
</table>

8. Certification

8.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the geomembrane was manufactured and tested in accordance with this guide together with a report of the test results shall be furnished.

9. Retest and Rejection

9.1 If the results of any test do not conform to the requirements of this guide, retesting to determine conformity may be performed as agreed upon between the parties involved.
6.7 The transition time ($T_i$) shall be identified as the time corresponding to the onset point of the brittle portion of the curve provided that such point has a lower failure time than any point in the transition region of the curve. If no such point has been determined, back extrapolation of the brittle curve shall be used to identify a smooth curve from the points located in the transition region.

6.8 The minimum value for the transition time for an acceptable HDPE geomembrane sheet using the above procedure shall be 250 hours.

Note 9: The original value of 100 hours\textsuperscript{1} transition time value was deduced from a database which included fourteen commercial virgin geomembranes and seven field exhumed geomembranes. The majority of the evaluated geomembranes had a thickness of 2.0 mm (0.080 in.). In light of recent upgrade of SCR to 500 hours this value is now increased to 250 hours.

6.9 For sheets with transition times well in excess of 250 hours the determination of the complete brittle portion of the curve can be extremely long. For example, if the test is ongoing and a linear ductile line is still in evidence after 1000 hours, a conclusion can be reached that the geomembrane sheet under consideration will possess a transition time greater than 100 hrs. In this case, the test can be concluded and a report written as to the satisfaction of this guide.

6.10 A full NCTL test shall be conducted on each resin/formulation used by the geomembrane manufacturer.

7. SP-NCTL Tests per ASTM D 5397-Appendix

7.1 SP-NCTL tests per the Appendix of ASTM D 5397 shall be performed on samples of geomembrane sheet for each two resin lots. For the purposes of this guide, a lot is defined as a railcar of pellets which is typically in the range of 70,000 Kg to 90,000 Kg (150,000

Note 7: The solution should be changed every 1000 h or sooner.

5.7 The constant load test device shall be equipped with timers and other incidental items per ASTM D5397.

6. NCTL Tests per ASTM D5397

6.1 Data Required - Per ASTM D5397, data sets of percent yield stress (\(\% \sigma_y\)) versus average failure time (\(F_t\)) shall be generated.

6.2 A minimum of thirty test specimens are die cut in one direction from the sample of the geomembrane sheet (3 replicates at 10 different loads). The longitudinal axis of the dumbbell shaped test specimens will generally be the cross machine direction of the geomembrane sheet.

6.3 The test specimens, in sets of three, are subjected to each applied stress. The applied stress levels should range from approximately 50% to 20% of the yield strength, in maximum increments of 5%.

6.4 Tests at the lowest stress level shall start first and incrementally increase through each stress interval to the highest stress level.

6.5 For this guide focused on manufacturing quality control (MQC) testing, the yield value used to calculate the applied loads shall be the manufacturer's mean value for the geomembrane resin/formulation under consideration.

Note 8: For manufacturing quality assurance (MQA) testing, the yield value will generally be from five tests per ASTM D6693 for the particular resin/formulation under consideration. Since this is a statistically small sample, the value will generally be different (higher or lower) than the manufacturer's mean value of yield stress. Communication between the parties involved is recommended to resolve possible differences.

6.6 The resulting test data shall be presented on a log-log plot of the percent yield stress versus average failure time of the three tests at each load, as shown in Figure 1. At least 3 points shall be located in the ductile region of the curve and at least 3 points shall be located in the brittle region of the curve. Adequate points shall be available to define the shape of the transition region of the curve.
4.2 Test specimens can also be taken from a small scale laboratory extruder, however, the
correlation of results to the as-manufactured sheet is unknown. If the results are used to
estimate the quality of as-manufactured sheet, a correlation must be developed on a
material and process specific basis.

Note 2: Since thermal history during processing is recognized as an important variable,
test results obtained on sheet produced by small scale laboratory extruder could be different from test results obtained on sheets produced on full size
commercial equipment.

5. Test Specimens and General Conditions

5.1 Geomembrane sheet thicknesses that are applicable for this guide are from 0.75 mm (30
mil) to 3.0 mm (120 mils).

Note 3: It should be noted that the failure time at any applied stress level is somewhat
effected by the thickness of the geomembrane sheet. Generally, specimens of
small thickness will result in a longer failure times than those of large thickness
due to their density variation.

5.2 Dimensions of the individual dumbbell shaped test specimens shall be in accordance with
ASTM D1822 for both the NCTL and SP-NCTL tests.

5.3 The thickness of the test specimens must be within 5% of the nominal thickness of the
gemembrane sheet.

5.4 Per ASTM D5397 and its Appendix, the notch depths for both NCTL and SP-NCTL test
specimens shall be such that a ligament of 80% of nominal sheet thickness remains after
notching to sustain the applied loads.

5.5 The yield stress used for calculating the percent applied loads in Section 6.4 shall be
obtained according to ASTM D6693.

Note 4: The applied stress to be imposed on the notched test specimens are percentages
of the yield stress of the sheet per ASTM D6693 at 21°C ± 2°C. In contrast, the
NCTL and SP-NCTL tests are tested at 50 ± 1°C.

5.6 Test specimens shall be immersed in a suitable bath containing a 10% Igepal (CO
630)/90% tap water solution, maintained at 50°C ± 1°C.

Note 5: In case of disputes between the parties involved, deionized water should be used
instead of tap water.

Note 6: It is generally considered good practice to use deionized water so as to maintain
the wetting agent solution for the maximum time possible.
acceptable times without failure. The guide is oriented toward test specimens taken from fabricated geomembrane sheets. It also recommends the frequency of such testing.

1.4 For textured or structured geomembranes the test specimens must be taken within the smooth (nontextured) surfaces along the edges of the sheet.

1.5 In the context of quality systems and management, this guide is focused on manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product(s) represent the stated objective and properties set forth in this guide.

2. Referenced Documents

2.1 ASTM Standards

D6693 - Test Method for Tensile Properties of Plastics
D883 - Definitions of Terms Relating to Plastics
D1822 - Test Method for Tensile-Impact Energy to Break Plastics and Electrical Insulating Materials
D5397 - Evaluation of Stress Crack Resistance of Polyolefin Geomembranes Using Notched Constant Tensile Load Test
D5397 Appendix - The Single Point Notch Constant Tension Load Test

3. Classification

3.1 This guide covers the stress crack resistance of HDPE geomembranes. According to ASTM D 883, stress crack is defined as "an external or internal crack in a plastic caused by tensile stresses less than its short-time mechanical strength."

3.2 This guide focuses on those geomembranes produced from virgin polyethylene in the density range of 0.932 g/cc or greater. When formulated with typical amounts of carbon black and additives, the resulting minimum density is 0.940 g/cc. This compounded material is commonly referred to as HDPE in the geomembrane industry.

3.3 While stress cracking in plastics is a fundamental resin property it should be recognized that it can be influenced by the thermal history of the sheet during the manufacturing process.

4. Sample Preparation

4.1 Test specimens to be used for the full NCTL test and the SP-NCTL test are taken directly from samples of the as-manufactured geomembrane sheet. They should be taken at uniform distances across the roll width with the exception of textured surfaces as discussed in section 1.4.
GRI Guide GM10

"The Stress Crack Resistance of HDPE Geomembrane Sheet"

This guide was developed by the Geosynthetic Research Institute (GRI) with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new guides on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this guide either at this time or in the future.

1. Scope

1.1 This guide covers polyethylene in the resin density range of 0.932 g/cc or greater, which results in a geomembrane with minimum density of 0.940 g/cc when mixed with carbon black and additives. This compounded material is commonly referred to in the geomembrane industry as high density polyethylene (HDPE) and this terminology will be used accordingly in this guide.

1.2 This guide uses data obtained from the Notched Constant Tensile Load (NCTL) test, per ASTM D5397 Test Method, to generate a behavioral curve. It then prescribes the procedure to be used to obtain the transition time (T₁) from this curve and furthermore sets a minimum value for "T₁". The guide is oriented toward test specimens taken from fabricated sheets of the geomembrane under consideration. The guide also recommends the frequency of such testing.

1.3 This guide also addresses data obtained from the Single Point-Notched Constant Tensile Load (SP-NCTL) test, per the Appendix of the ASTM D 5397 Test Method. It prescribes the number and orientation of test specimens and sets a value for minimum...
Appendix A

GRI Prescribed Testing
approval. The POR will provide an engineer's certification that the liner and leachate collection system were constructed in accordance with the approved construction drawings and specifications. QA/QC documentation will be included in the LIT Report.

The LIT Report shall be submitted to the ODEQ at the conclusion of the composite liner and leachate collection system construction. The LIT Report shall be placed in the site operating record.

At a minimum, the LIT Report contains:

- A summary of major construction activities;
- A summary of conformance test results;
- A summary of laboratory and field test results;
- Sampling and testing location drawings;
- A summary of repairs and their locations;
- A description of significant construction problems and the resolution of these problems;
- A list of changes from the construction drawings and specifications and the justification for these changes;
- As-built record drawings;
- Invert elevations to the nearest 0.01 foot at least every 25 feet along each leachate collection pipe, grade changes, and at all connections to structures;
- Results of the initial leachate collection pipe clean out; and
- A statement of compliance with the construction documents and design intent, signed and sealed by a professional engineer registered in the State of Oklahoma.
7.1.2 Observation and Test Data Sheets

Observation and test data sheets should include the following information as appropriate for the form being used:

- Date, project name, and location;
- A unique number for cross-referencing and document control;
- Weather data, as applicable;
- A reduced-scale site plan showing sample and test locations;
- Test equipment calibrations, if applicable;
- A summary of test results identified as passing, failing, or, in the event of a failed test, retest;
- Completed calculations; and
- Signature of the CQA Monitor.

7.1.3 Nonconformance Reports

In the event of a nonconformance event, a nonconformance verification report form is included with the daily report. Procedures for implementing and resolving any nonconformance to the specification are outlined in Section 2.4 of this QA/QC Plan.

7.2 PHOTOGRAPHS

Construction activities will be photographed. Photographs will be taken to document any significant problems encountered, corrective actions, and construction progress. The photographs are identified by number, location, time, date, and photographer. The photographer should document the subject of the photograph, either on the back of the picture or in a photograph log.

7.3 DESIGN AND SPECIFICATION CHANGES

Design and specification changes may be required during construction and are only made with written agreement of the design engineer, owner, and contractor. These changes are made by a change order to the contract. The regulatory agencies are notified by the POR of any signification changes. When change orders are issued, they are prepared by the owner with technical input from the design engineer and POR. The owner distributes change orders to the required parties for signature and execution.

7.4 LINER INSTALLATION AND TESTING REPORT

At the completion of the project, the POR will submit a LIT Report documenting the construction of the composite liner system and leachate collections system to the ODEQ for
7.0 DOCUMENTATION

The quality assurance program depends on thorough monitoring and documentation of all construction activities during liner and leachate collection system installation. Therefore, the POR and CQA Monitor will document that all quality assurance requirements are addressed and satisfied. Documentation consists of daily record-keeping, testing and installation reports, nonconformance reports (if necessary), progress reports, design and specification revisions, and a LIT Report as required by OAC 252:515-11-6.

7.1 DAILY RECORD KEEPING

At a minimum, daily records consist of construction progress, daily construction reports, observation and test data sheets, and, as needed, nonconformance/corrective measure reports. All forms are copied to the POR for review.

7.1.1 Daily Record of Construction Progress

The daily field report will summarize ongoing construction and discussions with the contractor and will be prepared by the CQA Monitor. At a minimum, the report will include the following:

- Date, project name, project number, and location;
- A unique number for cross-referencing and document control;
- Weather data;
- A description of all ongoing construction for the day in the area of the CQA Monitor's responsibility;
- An inventory of equipment used by the contractor;
- Items of discussion and names of parties involved in discussions;
- A brief description of tests and observations, identified as passing or failing, or, in the event of failure, a retest;
- Areas of nonconformance/corrective actions, if any, (nonconformance/corrective action form to be attached);
- Summary of materials received and quality documentation;
- Follow-up information on previously reported problems or deficiencies;
- Record of any site visitors; and
- Signature of CQA Monitor.
6.0 CONSTRUCTION QUALITY ASSURANCE FOR DRAINAGE AGGREGATE

6.1 DRAINAGE AGGREGATE

The drainage aggregate will consist of materials that comply with the specifications and have a hydraulic conductivity greater than or equal to $1.0 \times 10^{-2}$ cm/sec. The granular drainage material should be tested by the supplier for gradation (ASTM D422), hydraulic conductivity (ASTM D2434), and calcium carbonate content (ASTM D3042) at the supply source at a minimum of 1 test per 5,000 cubic yards or per lined area. The material shall be free of organics, foreign objects, and other deleterious materials. The physical characteristics of the material shall be evaluated through visual observation and laboratory testing before construction and visual observations during construction. The material may be tested during construction at the discretion of the CQA Monitor.

6.1.1 Installation

The drainage aggregate will be placed on top of the geotextile that overlies the geomembrane using low ground pressure equipment as outlined in Section 4.4. The drainage aggregate shall be placed by spreading a minimum of 12 inches of material in front of the spreading equipment. Under no circumstances shall the construction equipment come in direct contact with the installed geosynthetics.

During construction, the CQA Monitor will:

- Verify that underlying geosynthetic installations are not damaged during placement operations, or mark damaged geosynthetics and verify that damage is repaired; and

- Monitor haul road thickness over geosynthetics installations and verify that equipment hauling and materials placement meets equipment specifications.
- Property data sheet including all specified properties measured using test methods indicated in the specifications, or equivalent; and

- A certification that property values given in the properties sheet are minimum values and are guaranteed by the pipe manufacturer.

The CQA Monitor will observe that:

- The property values certified by the pipe manufacturer meet all of the specifications; and

- The measurements of properties by the pipe manufacturer are properly documented and that the test methods used are acceptable.

5.1.3 Installation

Prior to pipe installation, the CQA Monitor must observe the following:

- All lines and grades have been verified by the surveyor;

- The pipe trenches are swept clean of any deleterious material that may damage the pipe or geomembrane, or may clog the pipe; and

- Pipe perforations are the correct size and are properly spaced according to the specifications. Perforations shall be factory machined.

During pipe and fitting installation, the CQA Monitor must:

- Observe that pipes and fittings are not broken, cracked, or otherwise damaged or unsatisfactory. For fusion welded pipe, the pipe installer will provide for a fusion surface area that is clean and free of moisture, dust, dirt, debris of any kind, or other foreign material;

- Observe that the pipe and fittings are being constructed in accordance with specifications and accepted practices; and

- Observe that the people and equipment utilized to install the pipe do not damage the pipe or any other component of the liner system.

Surveying shall include invert elevations to the nearest 0.01 foot at least every 25 feet along each collection pipe, at changes in grade, and at all connections to structures.
5.0 CONSTRUCTION QUALITY ASSURANCE FOR PIPING

5.1 HDPE PIPING

This section describes CQA procedures for the installation of the HDPE pipe for the leachate collection system. Proper installation of pipe is essential to ensure that the systems operate as intended.

5.1.1 Delivery

During delivery, the CQA Monitor must verify the following:

- That upon delivery, the pipe and fittings are in compliance with the requirements of the specifications;
- Stacking or insertion of other construction materials onto or into the pipe and fittings is prohibited. The CQA Monitor will periodically examine the storage area to observe that the pipe and fittings are undamaged and have been protected;
- That upon transporting pipe and fittings from the storage location to the construction site, the contractor uses pliable straps, slings, or rope to lift the pipe;
- That the contractor lifts pipe greater than 20 feet in length with at least two support points;
- Equipment used to unload the pipe does not damage the pipe;
- The pipe is stacked consistent with the manufacturer's recommendations;
- All documentation required by the specifications has been received; and
- Each section is marked according to specification requirements, including pipe manufacturer, SDR size, ASTM designation, and date of manufacturer.

Any damaged pipe must be rejected and removed from the site, or stored at a location separate from the accepted pipe designated by the Owner. All pipe that does not have proper manufacturer's documentation must also be stored at a separate location, until all documentation has been received and approved.

5.1.2 Conformance Testing

The pipe manufacturer will provide the Owner and the POR with a quality control certificate for each lot or batch of pipe provided. The quality control certificate will be signed by a responsible party employed by the pipe manufacturer, such as the production manager.

Prior to the installation of pipe, the pipe manufacturer will provide the following to the CQA Monitor:
<table>
<thead>
<tr>
<th>Equipment Ground Pressure</th>
<th>Minimum Lift Thickness (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤5</td>
<td>10</td>
</tr>
<tr>
<td>5 - 8</td>
<td>18</td>
</tr>
<tr>
<td>8 - 16</td>
<td>24</td>
</tr>
<tr>
<td>&gt; 16</td>
<td>36</td>
</tr>
</tbody>
</table>
• There are no excessively soft areas that could result in damage to the geotextile or the underlying geosynthetics.

During geotextile placement, the CQA Monitor must observe the following:

• The geotextile as it is deployed. Record all defects and disposition of the defects;

• That equipment used does not damage the geotextile;

• That people working on the geotextile do not smoke, wear shoes that could damage the geotextile, or engage in other activities that could damage the geotextile;

• That the geotextile is securely anchored as required in the construction drawings and specifications; and

• That the seams are overlapped and that the panels are being joined in accordance with the specifications.

4.3.4 Geotextile Repairs

Repair procedures include:

• Patching - used to repair large holes, tears, large defects, and destructive sample locations; and

• Removal - used to replace areas with large defects where the preceding method is not appropriate.

4.4 Equipment on Geosynthetic Material

Construction equipment on the composite liner system will be minimized to reduce the potential for liner puncture. The CQA Monitor will verify that small equipment such as generators are placed on scrap liner material (rub sheet) above geosynthetic materials in the composite liner system. Aggregate drainage layers, drainage layer, and/or general fill that is placed on the geosynthetics will be placed using low ground pressure equipment. The CQA Monitor will verify that the geosynthetics are not displaced while the soil layers are being placed.

Unless otherwise specified by the POR, all lifts of leachate collection layer and/or general fill that is placed on the geosynthetics shall conform to the following guidelines presented in Table 5 below.
4.3 GEOTEXTILE

The geotextile will be placed between the geomembrane and leachate collection layer. The geotextile material shall be equivalent to the geotextile description included in Appendix B.

4.3.1 Delivery

During delivery, the CQA monitor must observe the following:

- Equipment used to unload the rolls will not damage the geotextile;

- Rolls are wrapped in impermeable and opaque protection covers;

- All documentation required by the specifications has been received and reviewed for compliance with the specifications;

- Each roll is marked or tagged with the manufacturer's name, project identification, lot number, roll number, and roll dimensions;

- Materials are stored in a location that will protect the rolls from precipitation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions; and

- Damaged rolls are rejected and removed from the site or stored at a location separate from accepted rolls.

4.3.2 Testing and Certification

Prior to installation of the geotextile, the geotextile manufacturer shall provide the Owner and/or POR the GRI prescribed test results for the geotextile material to be installed. These results shall be reviewed to verify that the geotextile conforms to the project specifications. The GRI prescribed tests for geotextiles are referenced so as to consistently include ASTM requirements and associated additions and revisions. Current GRI prescribed test methods for geotextile cushions (GT12a) and geotextile filters (GR13a) are located in Appendix A.

For each of the properties listed by GRI test methods, the material shall meet current industry standards for the geotextile material type (e.g., woven, non-woven) and unit weight. The POR may request additional testing at his/her discretion.

4.3.3 Geotextile Installation

Prior to geotextile installation, the CQA Monitor must observe the following:

- The supporting surface does not contain stones that could damage the geotextile or the underlying geosynthetics; and
- Removal – used to replace areas with large defects where the preceding methods are not appropriate. Also used to remove excess material (wrinkles, fishmouths, intersections, etc.) from the installed geomembrane. Areas of removal must be patched or capped.

Repair procedures include the following:

- Abrade geomembrane surfaces to be repaired (extrusion welds only) no more than 1 hour before the repair;

- Clean and dry all surfaces at the time of repair;

- Verify acceptance of the repair procedures, materials, and techniques by the CQA Monitor in advance of the specific repair; and

- Extend patches or caps at least 6 inches beyond the edge of the defect, and round all corners of material to be patched and patches to a radius of at least 3 inches. Bevel the top edges of patches before extrusion welding.

### 4.2.10 Wrinkles

During placement of materials over the geomembrane, temperature changes or creep may cause wrinkles to develop in the geomembrane. Any wrinkles that can fold over must be allowed to contract by liner temperature reduction. In no case can material be placed over the geomembrane, which could result in the geomembrane folding. Panels that are being seamed together should be at approximately the same temperature and have approximately the same amount of wrinkling. The CQA Monitor must monitor geomembrane for wrinkles and notify the contractor if wrinkles are being covered with material. The CQA Monitor is then responsible for documenting corrective action to remove the wrinkles.

### 4.2.11 Geomembrane Acceptance

The contractor retains all ownership and responsibility for the geomembrane until acceptance by the Owner. In the event the contractor is responsible for placing materials over the geomembrane, the contractor retains all ownership and responsibility for the geomembrane until all required documentation is complete and the cover material is placed. After panels are placed, seamed, tested successfully, and repairs made, the completed installation is walked by the Owner's and contractor's representatives. Any damage or defect found during this inspection is repaired properly by the installer. The installation is not accepted until it meets the requirements of both representatives. In addition, the geomembrane is accepted by the POR only when the following has been completed:

- The installation is finished;

- All seams have been inspected and verified to be acceptable;

- All required laboratory and field tests have been completed and reviewed;

- All required contractor-supplied documentation has been received and reviewed; and
8. The CQA Monitor shall document pertinent destructive test information on a Destructive Test Record and record the destructive test locations. Pertinent information to be logged for each sample includes seam number, destructive test number, welder, date, time.

9. If possible the independent third party laboratory should provide tests results within 24 hours to the CQA monitor. Certified test results are to be provided within five days.

10. The CQA Monitor must immediately notify the contractor in the event of a failed test result. The geomembrane shall not be covered, except as necessary to provide wind protection, until passing results are received from the testing laboratory.

4.2.8.3 Procedure for Destructive Test Failure

1. Two additional destructive samples shall be collected, one on each side of the failed test location at least 10 feet from its location.

2. The same testing procedures as described above shall apply to determine whether the additional samples pass or fail.

3. If the additional tests pass, the portion of the seam between two passing test locations shall either be reconstructed or cap stripped.

4. If either of the additional tests fails, the process shall be repeated until a seam length is bounded by two passing tests. At that point, the seam between the two passing test locations shall either be reconstructed or cap stripped.

5. All repaired or replaced seams shall be nondestructively tested to verify their integrity. Repairs shall be noted on a Repair Record and the locations of repairs shall be recorded.

4.2.9 Repairs

- Any portion of the geomembrane that is flawed or fails a nondestructive or destructive test, or portions where destructive tests were cut or nondestructive tests left cuts or holes, must be repaired in accordance with the specifications. The CQA Monitor must locate and record all repairs. Repair techniques include the following:
  - Patching – used to repair large holes, tears, large panel defects, undispersed raw materials, contamination by foreign matter, and destructive sample locations;
  - Extrusion – used to repair small defects in the panels and seams. In general, this procedure should be used for defects less than ½ inch in the largest dimension;
  - Capping – used to repair failed welds or to cover seams where welds or bonded sections cannot be nondestructively tested (also used to cap T-seams where wedge-welding is used); and
• Weld contamination;
• Insufficient overlap;
• Adverse weather conditions;
• Possibility of moisture, dust, dirt, debris, and other foreign material in the seam; and
• Failing tests.

There are two types of destructive testing required for the geomembrane installation: peel adhesion (peel) and bonded seam strength (shear). The purpose of peel and shear tests is to evaluate seam strength and long-term performance. Shear strength measures the continuity of tensile strength through the seam and into the parent material. Peel strength determines weld quality. Test welds must be allowed to cool naturally to ambient temperature before testing. Destructive testing must be performed concurrently with seaming operations, not at the completion of the entire installation.

Destructive test samples shall be collected at a frequency of one per 500 feet of seam length per machine as seaming progresses in an effort to detect possible problems in a timely manner. A minimum of one destructive test sample should be collected from an extrusion weld, if extrusion welding is used. The following procedures shall be followed by the Geomembrane Contractor:

1. The CQA Monitor shall randomly select a seam location to be sampled and tested. All destructive sample locations shall be marked on the geomembrane liner.

2. The Geomembrane Contractor shall cut three samples at the selected location: one each for the Geomembrane Contractor, Independent Third Party Laboratory, and the Owner’s archives.

3. Each sample shall be a minimum of 12 inches wide by 18 inches long (or according to minimum laboratory requirements) with the seam centered lengthwise.

4. The Geomembrane Contractor shall perform field tests prior to the next day’s seaming.

5. The Geomembrane Contractor shall field test ten 1 inch wide test specimens (five for peel and five for shear strength) using the specifications outlined in GRI GM19.

6. The Owner or CQA Monitor shall coordinate with an independent third party laboratory to perform the same test procedures on the laboratory samples.

7. For HDPE, GRI GM19 should be utilized to assess the seam test results. If the results of the testing show a sample does not conform to the requirements, retesting should be addressed by the procedures outlined below. Such criteria shall apply to both the field tests and the third party laboratory tests. Should environmental conditions during testing detrimentally affect field test results, the laboratory tests shall govern.
5. Once a tight seal is assured, observe the area for approximately 10 seconds looking for the presence of recurring soap bubbles on the seam.

6. Should leaks (bubbles) be observed, mark the location of each leak, repair the marked areas, and retest as appropriate.

7. Should no leaks be detected, release the pressure on the vacuum box and move the box to the next adjacent test location maintaining a minimum 3 inch overlap, if applicable.

8. Record appropriate test information on the Nondestructive Test Record and record the nondestructive test locations.

Should specific locations exist where nondestructive testing is not possible or practical, seams shall be tested according to a method agreed upon by the POR and the ODEQ.

During nondestructive testing, the CQA Monitor shall perform the following:

- Review technical specifications regarding test procedures;
- Verify that equipment operators are fully-trained and qualified to perform their work;
- Verify that test equipment meets project specifications;
- Verify that the entire length of each seam is tested in accord with the specifications;
- Observe all continuity testing and record results;
- Verify that all testing is completed in accordance with the project specifications;
- Identify the failed areas by marking them with a waterproof marker compatible with the geomembrane, and inform the contractor of the areas that require repair;
- Verify that all repairs are completed and tested according to project specifications; and
- Record all completed and tested repairs.

4.2.8.2 Destructive Seam Testing

Destructive seam tests will be performed independently by the installer and CQA consultant at intervals stated in the project specifications. However, the CQA Monitor must perform additional tests if there is suspicion that a seam does not meet specification requirements. Reasons for performing additional tests may include, but are not limited to:

- Wrinkling in seam area;
- Excess crystalline;
- Suspect seaming equipment or techniques;
4.2.8.1 Nondestructive Seam Testing

The purpose of nondestructive testing is to detect discontinuities or holes in the seam, and it indicates whether a seam is continuous and non-leaking. All seams that are welded during installation of the geomembrane shall be nondestructively tested by the Geomembrane Contractor and overseen by the CQA Monitor to check the integrity of the seams. Nondestructive tests shall be conducted using the air pressure test or the vacuum test.

**HDPE Liner Air Pressure Test**

Air pressure testing will be completed on seams that have been welded with a fusion welder (wedge welder) using an air pump capable of sustaining 25 to 30 pounds per square inch (psi) of pressure. The following procedures shall be followed by the Geomembrane Contractor:

1. Seal one end of the seam channel to be tested.
2. Insert a sharp, hollow needle or other approved pressure feed device with a pressure gauge into the sealed end of the seam.
3. Energize the air pump to verify the unobstructed passage of air through the seam channel. Should the verification fail, locate the obstruction and test the seam on both sides of the obstruction.
4. Seal the other end of the seam channel.
5. Energize the air pump to a pressure of between 25 and 30 psi, close valve, and allow 2 minutes for the injected air to reach equilibrium in the channel prior to recording the initial pressure reading.
6. Sustain pressure for 5 minutes and record final pressure reading.
7. Should the air pressure decrease by more than 2 psi during the 5 minute test period or the initial pressure not stabilize, locate the faulty area of the seam, make repairs, and retest.
8. If the air pressure test passes, the air channel should be cut at the opposite end of the gauge to deflate the seam channel.
9. Record appropriate test information on the Nondestructive Test Record and record the nondestructive test locations.

**HDPE Vacuum Test**

Vacuum testing will be completed on HDPE seams that have been welded with an extrusion welder or when the geometry of a seam makes it impossible or impractical to test using the air pressure test. The following procedures shall be followed by the Geomembrane Contractor:

1. Trim excess overlap from the seam edges.
2. Wet the area to be tested with a soap and water solution.
3. Place the vacuum box assembly over the wetted area and apply sufficient pressure to "seat" the box on the test area.
4. Create a vacuum of 3 to 5 psi to the box, using the pressure gauge on the box to observe pressure readings.
assigned to each seam that reflects the two panels being joined together and written on the panels at both ends of the seam for field identification purposes. The CQA Monitor shall measure the seams and record the measurements on a Seam Record. Additional information to be documented may include date and time of seaming, the welder’s initials, machine number, machine speed, and set temperature.

During geomembrane welding operations, the CQA Monitor must verify the following:

- The contractor has the number of welding apparatuses and spare parts necessary to perform the work;
- Equipment used for welding will not damage the geomembrane;
- The extrusion welder is purged before beginning a weld until all the heat-degraded extrudate is removed (extrusion welding only);
- Seam grinding has been completed less than one hour before seam welding, and the upper sheet is beveled (extrusion welding only);
- Grind marks do not extend more than 1/4 inch from the edge of the weld;
- The ambient temperature is between 40°F and 104°F;
- The ends of old welds, more than five minutes old, are ground to expose new material before restarting a weld (extrusion welding only);
- The contact surfaces of the sheets are clean, free of dust, grease, dirt, debris, and moisture before welding;
- The weld is free of dust, rocks, and other debris;
- The seams are overlapped a minimum of 3 inches for extrusion and 4 inches for hot wedge welding, or in accordance with manufacturer’s recommendations, whichever is more stringent;
- No solvents or adhesives are present in the seam area;
- The procedure used to temporarily hold the panels together does not damage the panels and does not preclude CQA testing;
- The panels are welded in accordance with the plans and specifications; and
- There is no free moisture in the weld area.

4.2.8 Construction Testing

Construction testing is performed on seams welded at the construction site. These tests include quality control and quality assurance testing performed by the contractor.
Verify that field seaming will be performed by a hot shoe fusion welder, an extrusion welder, or an alternative method approved by the ODEQ and POR prior to use in the field.

The CQA Monitor must inform both the contractor and the POR if any of the above conditions are not met.

4.2.5 Geomembrane Anchor Trench

Anchor trenches shall be excavated by the Owner or the project earthwork contractor to the lines and widths depicted on the approved permit or design plans prior to geomembrane placement. Sharp bends and edges in the anchor trench shall be minimized to avoid potential stresses to the geomembrane. The geomembrane should be placed in the anchor trench to the dimensions shown on the construction drawings. Excess material must be removed before the anchor trench is backfilled. The geomembrane anchor trench is left open until panels are seamed together. Expansion and contraction of the geomembrane should be accounted for in the liner placement. The anchor trench should be filled at sundown or in the morning when temperatures are coolest to reduce bridging of the geomembrane.

4.2.6 Trial Welds

Prior to seaming the geomembrane panels, trial welds made by the welding equipment to be used during that day's work shall be made and tested. The trial welds shall be made by the same machine/operator combination and under the same conditions as will be encountered during actual seaming operations. Trial welds shall be made at the beginning of each work day, at approximately 5 hour intervals thereafter, and whenever a new welding machine/operator combination begins work. The trial weld sample must be 3 feet long and 12 inches wide, with the seam centered lengthwise. The CQA Monitor must observe all welding operations, quantitatively test each trial weld for peel and shear, and record the results. The trial weld must meet specified requirements for peel and shear and the break must be ductile or a film tearing bond (FTB) for a wedge weld. If at any time the CQA Monitor believes that an operator or welding apparatus is not functioning properly, a trial weld test must be performed. If there are wide changes in temperature, humidity, or wind speed, the trial weld test should be repeated. The trial weld test sample must be allowed to cool to ambient temperature before testing.

Testing shall include shear and peel tests on ten separate samples (five for shear, five for peel), using the specifications outlined in GRI GM19.

Should trial welds fail, adjustments shall be made to the welder, as necessary, and new specimens shall be cut and tested. If repeat tests also fail, the subject welding machine shall not be used for seaming until deficiencies are corrected and passing trial welds are achieved. All trial welds shall be documented by the CQA Monitor on a Trial Weld Record.

4.2.7 Field Seaming

The CQA Monitor shall observe panel welding to assure the welding area is generally clean and free of moisture, dirt, and debris. Fishmouths and wrinkles at seam overlaps that cannot be welded shall be cut out and patched with an extrusion welded patch. A seam number shall be
Steps shall be taken to prevent water from migrating under the geomembrane during and after deployment. Overlapping of the panels or completion of seaming for those panels deployed prior to the end of the work day shall be used as appropriate to minimize the potential for such occurrence. Additionally, temporary or permanent berms shall be constructed where necessary to redirect surface water away from the construction area.

During panel placement, the CQA Monitor should:

- Record panel numbers and dimensions on a panel/seam log;

- Observe the geomembrane surface as it is deployed and record all panel defects and repair of the defects. All repairs must be made in accordance with the specifications;

- Verify that equipment used does not damage the geomembrane during handling or equipment transit by contact with hydrocarbons, or by other means;

- Verify that the soil liner beneath the geomembrane has not been damaged since previous acceptance;

- Verify there are no stones, construction debris, or other items beneath the geomembrane that could cause damage to the geomembrane;

- Verify that the geomembrane is not dragged across an unprotected surface. If the geomembrane is dragged across an unprotected surface, the geomembrane must be inspected for scratches and repaired or rejected, if necessary;

- Record weather conditions, including temperature, wind, and humidity. The geomembrane must not be deployed in the presence of excess moisture (fog, dew, mist, etc.). In addition, geomembrane should only be seamed when the ambient air temperature is between 40°F and 104°F, unless trial weld tests for the seaming demonstrate adequate results at other temperatures. The geomembrane should not be deployed during excessive winds that can lift and move the geomembrane panels;

- Verify that people working on the geomembrane do not smoke, wear shoes that could damage the liner, or engage in activities that could damage the liner;

- Verify that the method used to deploy the geomembrane minimizes wrinkles or fishmouths so that the geomembrane is anchored and ballasted to prevent movement by the wind. (The contractor is responsible for any damage resulting to or from windblown geomembrane);

- Verify that no more panels are deployed than can be seamed on the same day;

- Verify that no base T-seam is closer than 5 feet to the toe of the slope;

- Verify that field seams are minimized in corners and odd-shaped geometric locations; and
<table>
<thead>
<tr>
<th>Test Type</th>
<th>Method</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Puncture Strength</td>
<td>D4833</td>
<td>Per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td>Tear Resistance</td>
<td>D1004</td>
<td>Per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td>Destructive Seam and Field Testing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shear and Peel</td>
<td>D6392</td>
<td>1/500 linear feet of seam</td>
</tr>
<tr>
<td>Air Pressure</td>
<td>D5820</td>
<td>All dual track hot wedge weld seams</td>
</tr>
<tr>
<td>Vacuum</td>
<td>D5641</td>
<td>All non-air pressure tested seams when possible</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td>As necessary with concurrence with ODEQ</td>
</tr>
</tbody>
</table>

**4.2.4 Panel Placement**

At the conclusion of soil liner construction, the geomembrane shall be installed by a third-party geosynthetics contractor. Prior to installation of the geomembrane, the subgrade (top of clay liner beneath geomembrane) shall be free of debris, roots, and angular or sharp rocks. The subgrade (top of clay liner beneath geomembrane) shall be of such compaction so as to provide a firm, unyielding foundation sufficient for deployment vehicles to move about the construction area without rutting and pumping. The geomembrane installer will complete a Subgrade Acceptance Form for inclusion in the construction documentation report.

During placement, the CQA Monitor must maintain up-to-date logs documenting panel and roll numbers, seam numbers, test locations and results, repair locations and results, and nondestructive testing information. The CQA Monitor will review the contractor-prepared as-built (record) drawings, using the logs as reference.

Geomembrane panels shall be deployed and immediately assigned a number according to a panel numbering system. Panels shall be placed down the slope and not across it. Panels shall be physically identified in the field with a grease pencil (or equivalent) for reference during seaming and testing operations and project as-built records. Destructive and nondestructive test locations, as well as repair locations, shall be appropriately identified for documentation purposes. Panels will be deployed with a rubber-tired front loader and special roller bar to assist with unrolling the geomembrane panels at specified locations. Care shall be used in the deployment of geomembrane panels such that traffic is minimized and equipment does not damage the geomembrane or supporting subgrade surface. Sandbags or other approved loading shall be used as necessary to prevent uplift of panels by the wind or migration of storm water beneath the panels. Panels shall not be deployed in areas of standing water or on frozen subgrade. Damage done to panels during deployment shall be noted and repaired by patching and/or spot welding as approved by the POR. No more panels shall be deployed than can be seamed during that day.
<table>
<thead>
<tr>
<th>Test</th>
<th>Type of Test</th>
<th>Test Method (ASTM)</th>
<th>Frequency of Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin</td>
<td>Specific Gravity/Density</td>
<td>D1505 / D792</td>
<td>Per 200,000 lbs and every resin lot</td>
</tr>
<tr>
<td></td>
<td>Melt Flow Index</td>
<td>D1238</td>
<td>Per 200,000 lbs and every resin lot</td>
</tr>
<tr>
<td></td>
<td>Thickness</td>
<td>D5199 (Smooth) or D5994 (Textured)</td>
<td>Per roll of Geomembrane</td>
</tr>
<tr>
<td></td>
<td>Specific Gravity/Density</td>
<td>D1505 / D792</td>
<td>Per 200,000 lbs</td>
</tr>
<tr>
<td></td>
<td>Tensile Properties</td>
<td>D6693</td>
<td>Per 20,000 lbs</td>
</tr>
<tr>
<td></td>
<td>Tear Resistance</td>
<td>D1004</td>
<td>Per 45,000 lbs</td>
</tr>
<tr>
<td></td>
<td>Puncture Strength</td>
<td>D4833</td>
<td>Per 45,000 lbs</td>
</tr>
<tr>
<td></td>
<td>Stress Crack Resistance</td>
<td>D5397</td>
<td>Per GR1 GM10</td>
</tr>
<tr>
<td></td>
<td>Carbon Black Content</td>
<td>D1603</td>
<td>Per 20,000 lbs</td>
</tr>
<tr>
<td></td>
<td>Carbon Black Dispersion</td>
<td>D5596</td>
<td>Per 45,000 lbs</td>
</tr>
<tr>
<td></td>
<td>Oxidation Induction Time</td>
<td>D3895 or D5885</td>
<td>Per 200,000 lbs</td>
</tr>
<tr>
<td></td>
<td>Oven Aging</td>
<td>D5721</td>
<td>For each formulation</td>
</tr>
<tr>
<td></td>
<td>UV Resistance</td>
<td>D7238</td>
<td>For each formulation</td>
</tr>
<tr>
<td></td>
<td>Thickness</td>
<td>D5199 (Smooth) or D5994 (Textured)</td>
<td>Per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td></td>
<td>Specific Gravity/Density</td>
<td>D1505 / D792</td>
<td>Per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td></td>
<td>Carbon Black Content</td>
<td>D1603</td>
<td>Per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td></td>
<td>Carbon Black Dispersion</td>
<td>D5596</td>
<td>Per 100,000 ft² and every resin lot</td>
</tr>
<tr>
<td></td>
<td>Tensile Properties</td>
<td>D638/GRI GM13</td>
<td>Per 100,000 ft² and every resin lot</td>
</tr>
</tbody>
</table>
4.2.2 Submittal Review

Prior to installation of the geomembrane portion of the liner, the geomembrane installer shall submit to the POR or his/her representative the manufacturer's quality control testing results for the geomembrane to be installed. These results shall be reviewed to verify that the geomembrane conforms to the project specifications. The GRI prescribed tests for geomembranes are referenced so as to consistently include ASTM requirements and associated additions and revisions. Current GRI prescribed test methods for HDPE geomembranes (GM13) are located in Appendix A.

4.2.3 Quality Assurance Conformance Testing

After delivery or at the manufacturer's plant, the CQA Monitor shall obtain geomembrane samples at a frequency of one per 100,000 square feet and every resin lot.

4.2.3.1 Sampling Procedure

Samples will be taken either at the manufacturing plant by the testing laboratory before rolls are shipped or at the site by the CQA Monitor after rolls are shipped. In either case, the sampling procedures are the same.

Specimens should be taken across the entire roll width and should not include the first 1 foot. Five 1 foot by 1 foot specimens should be taken from the roll. Specimen locations should be evenly spaced across the roll width and be limited to the first 5 feet of geomembrane (i.e., taken near the end of the roll). The five specimens constitute one sample. The sampler should mark the roll identification number on each specimen. The five specimens from any one sample should be taped together or otherwise packaged so that they do not become separated before arriving at the testing laboratory. A test request sheet should be included with each shipment. Samples should be shipped so that they arrive at the laboratory within 24 hours after sampling. In addition, a minimum 1 foot by 5 foot specimen from each sample should be retained by the testing laboratory at least until the project is completed. Any roll that cannot be identified shall be rejected by the CQA Monitor.

4.2.3.2 Tests

For each of the properties listed by GRI test methods, the material shall meet current industry standards and project specifications for the geomembrane material type and thickness (e.g., 60 mil HDPE, textured). The POR may request additional testing at his/her discretion. The owner should be notified of submittals that have not been made at the required time. Submittal should be consistent with the specifications requirements and any deficiencies should be reported to the owner. The tests to be conducted by the laboratory are included in Table 4.
4.0 CONSTRUCTION QUALITY ASSURANCE FOR GEOSYNTHETICS

4.1 INTRODUCTION

This section describes CQA procedures for the installation of the geosynthetic components at the SORD. The overall goal of the geosynthetics quality assurance program is to assure that proper construction techniques and procedures are used and that the project is built in accordance with the project construction drawings and specifications. Another function of the quality assurance program is to identify problems that may occur during construction and to verify that these problems are avoided or corrected before construction is complete. The program includes the following:

1) A review of the contractor's quality control submittals,

2) Material evaluation (conformance testing),

3) Construction testing, and

4) Construction observation.

Conformance testing refers to material testing that takes place before material installation. Construction testing includes activities that occur during installation. Activities will be conducted in accordance with this manual, and the project construction drawings and specifications.

4.2 GEOMEMBRANE

4.2.1 Delivery

Upon delivery of the geomembrane, the CQA Monitor will verify that:

- The geomembrane is delivered in rolls and not folded. Folded geomembrane is not acceptable because the highly crystalline structure of the geomembrane will be damaged if it is folded. Any evidence of folding or other shipping damage is cause for rejection of the material;

- Equipment used to unload and store the rolls does not damage the geomembrane;

- The geomembrane is stored in an acceptable location and in accordance with the specifications. The geomembrane is protected from puncture, dirt, grease, mud, mechanical abrasions, excessive heat, or other damage; and

- All manufacturing documentation required by the specifications has been received. Geomembrane that does not have proper manufacturer's documentation must be stored at a separate location until all documentation has been received, reviewed, and accepted.
- Top of soil liner;
- Top of leachate collection layer;
- Top of protective cover layer; and
- Invert elevations of the collection pipes to the nearest 0.01 foot at least every 25 feet along each collection pipe, at changes in grade, and at all connections to structures.

The tolerances applicable in setting survey stakes will be as set forth in the specifications.
• Test compaction and moisture content at required frequencies;
• Sample and perform classification testing at required frequencies;
• Obtain Shelby tube samples at required frequencies;
• Verify that completed grades meet slope requirements; and
• Verify that final grading meets tolerance requirements.

3.5.5 Leachate Collection Layer Placement

• Obtain samples of leachate collection material for testing;
• Review material submittals;
• Perform sampling and gradation, permeability, and calcium carbonate content (aggregate only) testing of material prior to installation at the frequencies established in this manual;
• Verify that underlying geomembrane installations are complete before material installation;
• Verify thickness of material placed by direct field measurements of in-place material; and
• Monitor placement of material and mark any geomembrane damaged during material installation. Verify that damage is repaired.

3.5.6 Drainage Aggregate Placement

• Obtain samples of drainage aggregate material for testing;
• Review material submittals;
• Perform sampling and gradation, permeability, and calcium carbonate content testing of material prior to installation at the frequencies established in this manual;
• Verify that underlying geomembrane installations are complete before material installation;
• Monitor placement of material and mark any geomembrane damaged during material installation. Verify that damage is repaired.

3.6 Construction Surveys

Elevations shall be determined by the Surveyor on a minimum 100 foot grid at the following locations:

• Top of subgrade;
3.5.1 Excavation to Design Grade

- Verify that stripping is complete and spoils are placed in designated stockpiles;
- Verify that construction staking is performed before work; and
- Review survey with design engineer.

3.5.2 Selective Soil Stockpiling

- Visually monitor excavation to identify soil types;
- Confirm soil types by sampling and visual classification;
- Notify contractor of visual classification and identify stockpile that should receive excavated soil; and
- Monitor excavation, visually classify soil, and recommend stockpile location to contractor.

3.5.3 General Fill Placement

- Verify subgrade is scarified and recompacted to design requirements;
- Verify removal and stockpiling of oversized material;
- Verify that source of material is suitable for general fill;
- Verify lift thickness;
- Test compaction and moisture content at required frequencies;
- Sample and perform classification testing at required frequencies;
- Verify that completed grades meet slope requirements; and
- Verify that final grading meets tolerance requirements.

3.5.4 Soil Liner Placement

- Verify subgrade is scarified and recompacted to design requirements;
- Verify removal and stockpiling of oversized material;
- Verify that source of material is suitable for soil liner;
- Verify lift thickness;
<table>
<thead>
<tr>
<th>Test (ASTM No.)</th>
<th>Subgrade/General Fill</th>
<th>Soil Liner</th>
<th>Leachate Collection (Sand)</th>
<th>Leachate Collection (Aggregate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture Density Relationship (D698 or D1557)</td>
<td>1/10,000 cy per material type</td>
<td>1/10,000 cy per material type</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Moisture/Density of Soil In-Place (D6938)</td>
<td>3 per acre per 6-inch lift</td>
<td>3 per acre per 6-inch lift</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Moisture Content Oven Drying (D2216 or D4643)</td>
<td>N/A</td>
<td>1/10 in-place moisture density tests</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Visual Classification (D2487 and D2488)</td>
<td>N/A</td>
<td>Continual during placement</td>
<td>Continual during placement</td>
<td>Continual during placement</td>
</tr>
<tr>
<td>Liquid Limit, Plastic Limit Determinations (D4318)</td>
<td>1/10,000 cy per material type</td>
<td>1/10,000 cy per material type</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Gradation (D422 or D1140)</td>
<td>1/10,000 cy per material type</td>
<td>1/10,000 cy per material type</td>
<td>1/100,000 sf per material type</td>
<td>1/5,000 cy</td>
</tr>
<tr>
<td>Hydraulic Conductivity (D2434 or D5084)</td>
<td>N/A</td>
<td>2 per acre for top 12 inches of floor liner; 1 per acre for top 12 inches of sidewall liner</td>
<td>1/100,000 sf per material type</td>
<td>1/5,000 cy</td>
</tr>
<tr>
<td>Carbonate Content (D3042)</td>
<td>N/A</td>
<td>N/A</td>
<td>NA</td>
<td>1/5,000 cy</td>
</tr>
<tr>
<td>Thickness Verification</td>
<td>100 foot square grid with a minimum of 2 reference points</td>
<td>100 foot square grid with a minimum of 2 reference points</td>
<td>100 foot square grid with a minimum of 2 reference points</td>
<td>NA</td>
</tr>
</tbody>
</table>

### 3.5 Monitoring Requirements

Earthwork components of the construction are summarized in Section 3.2. Each component has specific construction requirements that must be monitored. The following sections list monitoring requirements for each type of earthwork.
Examples of conditions that may warrant additional tests include the following:

- Compactors slip while compacting;
- Excessive pumping or cracking of fill;
- Lift thickness greater than specified;
- Dirt-clogged rollers used to compact the fill;
- Improperly ballasted compactor;
- Adverse weather;
- Equipment breakdown;
- Work conducted in difficult areas; and
- High frequency of failed tests.
Table 2. Applicable ASTM Standards

<table>
<thead>
<tr>
<th>Standard</th>
<th>Test Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM D698</td>
<td>Laboratory compaction characteristics of soil using standard effort</td>
</tr>
<tr>
<td>ASTM D1557</td>
<td>Laboratory compaction characteristics of soil using modified effort</td>
</tr>
<tr>
<td>ASTM D422</td>
<td>Particle size analysis of soils</td>
</tr>
<tr>
<td>ASTM D6938</td>
<td>In-Place Density and Water Content of Soil and Soil Aggregate by Nuclear Methods (shallow depth)</td>
</tr>
<tr>
<td>ASTM D2937</td>
<td>Density of soil and soil aggregate in place by drive cylinder methods</td>
</tr>
<tr>
<td>ASTM D1556</td>
<td>Density and unit weight of soil in place by the sandcone method</td>
</tr>
<tr>
<td>ASTM D2216</td>
<td>Laboratory determination of water (moisture) content of soil and rock by the oven drying method</td>
</tr>
<tr>
<td>ASTM D4643</td>
<td>Determination of water (moisture) content of soil by the microwave oven method</td>
</tr>
<tr>
<td>ASTM D2434</td>
<td>Permeability of porous granular soils</td>
</tr>
<tr>
<td>ASTM D5084</td>
<td>Hydraulic conductivity of saturated porous materials</td>
</tr>
<tr>
<td>ASTM D4318</td>
<td>Liquid limits, plastic limit, and plasticity index of soils (Atterberg limits)</td>
</tr>
<tr>
<td>ASTM D1140</td>
<td>Amount of material in soils finer than the No. 200 sieve</td>
</tr>
<tr>
<td>ASTM C136</td>
<td>Sieve analysis of fine and coarse aggregate</td>
</tr>
<tr>
<td>ASTM D2487</td>
<td>Soil classification</td>
</tr>
<tr>
<td>ASTM D1587</td>
<td>Thin walled Shelby tube sampling</td>
</tr>
<tr>
<td>ASTM D3042</td>
<td>Insoluble residue in carbonate aggregates</td>
</tr>
</tbody>
</table>

3.4.2 Test Frequencies

Table 3 establishes the test frequencies for earthwork construction quality assurance per OAC 252:515-11. The test frequencies listed establish a minimum number of required tests. Additional testing must be conducted whenever work or materials are suspect, marginal, or of poor quality. Additional testing may also be performed to provide additional data for engineering evaluation. Any retests performed as a result of a failing test do not contribute to the total number of tests performed in satisfying the minimum test frequency.
- Mark damaged geosynthetics and verify that damage is repaired;
- Monitor haul road thickness over geosynthetics installations and verify that equipment hauling and materials placement meet equipment specifications; and
- Verify corrective action measures as determined by the verification survey. (The POR will coordinate with the project surveyor to perform a thickness verification survey of the drainage layer materials upon completion of placement operations.)

3.3 MATERIAL EVALUATION

3.3.1 Testing

Prior to the start of construction, sources will be identified for each material and samples tested to determine whether the materials meet project specifications. Samples will be obtained in accordance with applicable ASTM standards. Record samples and results of the testing will be maintained and stored at the project site. The frequency of material evaluation testing is shown in Table 3.

3.3.2 Materials Submittals

Material submittals may be used by the CQA Monitor to establish the acceptability of materials. When sample submittals are required, they will be made available to the CQA Monitor. Acceptance and proper review of submittals are the responsibility of the POR.

3.4 CONSTRUCTION TESTING

3.4.1 Test Procedures

The CQA Monitor must perform the various field and laboratory tests in accordance with the applicable standard, as specified in the construction documents or this manual. In most instances, the applicable procedure is an ASTM standard. Where called for in this manual or in the construction documents, the applicable ASTM Standards are included in Table 2 below.

Construction testing is conducted during construction activities. During progress of the work, additional procedures may be needed for other testing or sampling. If such procedures do not exist, or if they exist and need to be modified, written procedures must be developed by the POR.
During construction, the CQA Monitor will:

- Verify that grade control construction staking is performed prior to work;
- Verify that underlying geosynthetics installations are not damaged during placement operations. Mark damaged geosynthetics and verify that damage is repaired;
- Monitor haul road thickness over geosynthetics installations and verify that equipment hauling and materials placement meet equipment specifications; and
- Verify corrective action measures as determined by the verification survey. (The POR will coordinate with the project surveyor to perform a thickness verification survey of the drainage layer materials upon completion of placement operations.)

3.2.5 Protective Cover Layer

The protective cover layer shall consist of either a 5 foot layer of uncompacted select waste or an additional 12 inch drainage layer with a hydraulic conductivity greater than or equal to $1 \times 10^{-3}$ cm/sec. If select waste is utilized as a protective cover layer, the select waste will contain no construction and demolition (C&D) waste, lumber, rock larger than 2 inch diameter, loads containing structural or scrap metal, fencing material, utility poles, large bulky items, or any other material that may puncture the liner. SORD will provide on-site personnel to remove any nonconforming waste while placing the first 5 foot lift of waste. The select waste will be placed or rolled into position on the drainage layer; the select waste will not be dumped or pushed across the top of the drainage layer. The select waste will be placed in one lift with a dozer and left uncompacted. Within 10 days of the completion of the first 5 foot lift of select waste, a signed letter from the landfill operator or other SORD representative that no nonconforming waste was placed in the first lift will be sent to the ODEQ.

If a 12 inch drainage layer is utilized as a protective cover layer, a minimum of 36 inches of sand should be maintained between the haul trucks and the installed geosynthetics. The protective cover layer soil layer will be placed using low ground pressure equipment and shall be placed in a manner which will prevent abrasion of the underlying geosynthetics by pushing the material across the geosynthetics. A minimum of 12 inches of sand should be maintained between the spreading equipment and the installed geosynthetics. Under no circumstances shall the construction equipment come in direct contact with the installed geosynthetics.

The thickness of the drainage layer shall be verified with surveying procedures. Thickness shall be determined using the same 100 foot grid used for the liner thickness verification with a minimum of two reference points. The test results for the drainage layer will be included in the LIT Report.

During construction, the CQA Monitor will:

- Verify that grade control construction staking is performed prior to work;
- Verify that underlying geosynthetics installations are not damaged during placement operations;
the previously compacted lift; therefore, the lift thickness must not be greater than the length of the foot. Adequate cleaning devices must be in place and maintained on the compaction roller so that the feet do not become clogged with clayey soils to the point that they cannot achieve full penetration. The footed roller is necessary to create bonding between soil particles, to reduce the individual clod size, and to achieve a blending of the soil matrix through its kneading action. Multiple passes are recommended for a vehicle with front and rear drums.

Soil liner construction should not be conducted in adverse weather conditions (heavy rain, freezing temperatures, etc.).

The finished surface of the soil liner must be finely graded by rolling with a smooth, steel-wheeled roller to obtain a uniform and smooth surface. The surface of the soil liner shall then be observed by the CQA Monitor for gravel, rock pieces, ruts, and deleterious materials that might impact the integrity of the overlying geomembrane. All voids created by removing gravel, rock pieces, or other deleterious materials will be backfilled with liner material to the density specifications outlined for soil liner construction and tested at the discretion of the CQA Monitor.

The top of the soil liner shall be surveyed on a 100 foot grid with a minimum of two reference points to provide verification of liner thickness.

The soil liner shall be prevented from losing moisture prior to placement of the geomembrane. Preserving the moisture content of the soil liner will be dependent on the earthwork contractor's means and methods and is subject to the POR approval. The POR shall provide daily certification that the liner is of uniform grade with no ruts, meets the minimum moisture content requirements, and the surface is free of debris, rock greater than 1 inch in diameter, plant materials, frozen materials, foreign objects, and other deleterious materials.

3.2.4 Leachate Collection Layer

The leachate collection layer shall consist of a 12 inch drainage layer with a hydraulic conductivity greater than or equal to $1 \times 10^{-3}$ cm/sec. Before the drainage layer soil is placed over the geotextile, all destructive and nondestructive testing must be completed on the underlying geomembrane and approved by the POR.

During placement of the drainage layer, a minimum of 36 inches of sand should be maintained between the haul trucks and the installed geosynthetics. The drainage layer soil layer will be placed using low ground pressure equipment and shall be placed in a manner which will prevent abrasion of the underlying geosynthetics by pushing the material across the geosynthetics. A minimum of 12 inches of sand should be maintained between the spreading equipment and the installed geosynthetics. Under no circumstances shall the construction equipment come in direct contact with the installed geosynthetics.

The thickness of the drainage layer shall be verified with surveying procedures. Thickness shall be determined using the same 100 foot grid used for the liner thickness verification with a minimum of two reference points. The test results for the drainage layer will be included in the LIT Report.
The CQA Monitor will approve the prepared subgrade prior to the placement of soil liner or general fill. Approval will be based on a review of test information, if applicable, and CQA monitoring of the subgrade preparation.

3.2.2 General Fill

General fill material placed below the soil liner will be placed in uniform lifts that do not exceed 9 inches in loose thickness and are compacted to at least 95 percent of standard Proctor (ASTM D 698) at a moisture content ranging from one percentage point below optimum to three percentage points above optimum. The top 6 inches of compacted fill material underlying the soil liner will have a maximum particle size of 1 inch diameter.

3.2.3 Soil Liner

The soil liner will consist of a minimum 24 inch thick compacted soil layer (measured perpendicular to the subgrade surface layer). The hydraulic conductivity of the compacted soil liner shall not exceed $1 \times 10^{-7}$ centimeters per second (cm/sec). The requirements for the soil liner material shall be as follows (minor deviations may be allowed at the discretion of the POR so long as the hydraulic conductivity requirement is met).

<table>
<thead>
<tr>
<th>Table 1. Soil Liner Material Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasticity Index</td>
</tr>
<tr>
<td>Liquid Limit</td>
</tr>
<tr>
<td>Percent Passing #200 Sieve</td>
</tr>
<tr>
<td>Percent Retained on #4 Sieve</td>
</tr>
</tbody>
</table>

The soil liner material will consist of relatively homogeneous cohesive materials, which are free of debris, rock greater than 1 inch in diameter, plant materials, frozen materials, foreign objects, organics, and other deleterious materials. The soil liner material should be placed in maximum 9-inch loose lifts to produce a compacted lift thickness of approximately 6 inches. The material will be compacted to a minimum of 95 percent of the maximum dry density as determined by standard Proctor (ASTM D 698), or 90 percent of the maximum dry density as determined by the modified Proctor (ASTM 1557) at a moisture content equal to or greater than the optimum moisture content.

Water shall be applied as necessary to the material and worked evenly into the material with the compaction equipment. Water used for the soil liner must be clean and not contaminated by waste or any objectionable material. Storm water collected on-site may be utilized if it has not come into contact with solid waste.

The soil liner must be compacted with a heavy, footed roller. The lift thickness shall be controlled so that there is total penetration through the loose lift under compaction into the top of
3.0 CONSTRUCTION QUALITY ASSURANCE FOR EARTHWORK

3.1 INTRODUCTION

The overall goal of the earthwork quality assurance program is to assure that proper construction techniques and procedures are used and that the project is built in accord with the project construction drawings and specifications. Another function of the quality assurance program is to identify problems that may occur during construction and to verify that these problems are avoided or corrected before construction is completed.

Construction must be conducted consistent with the project construction drawings and specifications. To monitor conformance, a quality assurance testing program will be implemented that includes:

1) A review of the contractor's quality control submittals,
2) Material evaluation,
3) Construction testing, and
4) Construction observation.

Activities will be conducted in accordance with this manual, and the project construction drawings and specifications.

3.2 EARTHWORK CONSTRUCTION

3.2.1 Subgrade

The prepared subgrade must conform to the Excavation Plan of the construction drawings. Prior to beginning liner construction, the liner subgrade area will be proof-rolled with heavy, rubber-tired construction equipment to detect unstable areas. Unstable areas will be undercut to firm material and refilled with suitable compacted earth fill. If subgrade is achieved through excavation, the upper 6 inches of the subgrade will be compacted to a minimum of 90 percent of the maximum dry density as determined by the Standard Proctor (ASTM D 698), unless the subgrade is part of the perimeter berm. Perimeter berm soils shall be compacted to 95 percent of the maximum dry density at a moisture content varying from one percentage point below optimum to three percentage points above optimum.

The CQA Monitor will visually examine the subgrade preparation to evaluate its suitability as a foundation for the compacted soil liner. The CQA Monitor may find that physical testing is necessary to evaluate the prepared subgrade.

The subgrade shall be surveyed on a 100 foot grid to provide verification of liner thickness with a minimum of two reference points.
2.3.6 Processing Project Records

Project records are completed as needed. Use of the project records is limited to the scope for which they are intended. The record must be completed by filling in all the blanks provided on the form and followed by the signature of the individual completing the form. All project records must be maintained by the CQA Monitor.

2.4 DOCUMENTATION AND CONTROL OF NONCONFORMANCE

2.4.1 Observation of Nonconformance

Whenever a nonconformance is discovered or observed in the construction process, product, job-related materials, documentation, or elsewhere, the CQA Monitor must notify the contractor and POR as soon as possible.

2.4.2 Determining Extent of Nonconformance

Whenever a nonconformance is discovered or observed in the construction process, product, job-related materials, documentation, or elsewhere, the CQA Monitor will determine the extent of the nonconformance. The extent of the deficiency may be determined by additional sampling, testing, observations, review of records, or any other means deemed appropriate.

2.4.3 Documenting Nonconformance

All nonconformances must be documented in writing on the daily records, logs, and elsewhere, as appropriate. The documentation must occur immediately upon determining the extent of the nonconformance. For those nonconformances that are considered serious or complex in nature, or that require an engineering evaluation, a nonconformance report will be initiated and issued to the project manager, design engineer, POR, and contractor.

2.4.4 Corrective Measures

For a simple or routine nonconformance, corrective measures will be determined by specification direction, or if none exists, the CQA Monitor, POR, and contractor will discuss standard construction methods to correct the deficiency. For those nonconformances requiring a nonconformance report, the design engineer must determine corrective measures. A copy of the nonconformance report, with the corrective measure determination, is forwarded to the POR and contractor for implementation of the corrective action.

2.4.5 Verification of Corrective Measures

Upon notification by the contractor that corrective measures are complete, the CQA Monitor verifies its completion. The verification must be accomplished by observations or retesting and photographs. Written documentation of the corrective measures must be made by the CQA Monitor on daily reports, logs and forms, and the nonconformance report. Verification of corrective measures is reviewed by the POR.
subcontractors. The contractor is expected to cooperate with the CQA Monitor to achieve a quality product.

2.2.6 Responsibilities of the Surveyor

The surveyor will work at the direction of the contractor and/or the owner to provide grade staking for establishing required elevations to construct the project in accordance with the design intent.

2.3 CONTROL OF DOCUMENTS, RECORDS, AND FORMS

2.3.1 Project Control of Construction Documents

Construction documents, including specifications, drawings, and change orders, are controlled by the design engineer. The POR maintains one or more copies of the most current set of construction documents for use by the CQA Monitor. Upon issuance of new copies or revisions, it is the responsibility of the owner to notify the contractor and CQA staffs of the revisions, provide revised construction documents, and order the recall of all unrevised copies of the construction documents.

2.3.2 Project Control of As-Built Information

As-built information is controlled by the CQA Monitor and surveyor. During the progress of the work, the POR and design engineer obtain as-built information provided by the contractor, CQA Monitor, surveyor, or others. At the completion of the project, this information is presented to the CQA consultant for use in preparing record drawings of the construction. Final as-built drawings are included with the LIT Report.

2.3.3 Project Control of Forms

Daily report forms, test report forms, and other project forms are controlled by the CQA Monitor, who maintains a master of each form. Upon issuance of a new form, the CQA Monitor must recall and remove all superseded copies along with the master.

2.3.4 Processing Daily Reports

Each CQA Monitor writes a daily record of work progress. The daily reports are reviewed by the POR, who maintains a complete file of daily reports.

2.3.5 Processing Test Reports

A test report must be completed by the CQA Monitor whenever testing is performed. The test reports must be peer-reviewed. The review includes a check for mathematical accuracy, conformance to test requirements, conformance to specifications, and a check for clarity, legibility, traceability, and completeness. The review must be evidenced by the signature of the reviewer. Copies of all test reports are transmitted weekly to the POR, and the original is maintained by the CQA Monitor.
• Resolve any outstanding problems or disputes.

2.1.3 Additional Meetings

As required, special meetings will be held to discuss problems or nonconformance. Persons attending will be determined on as-needed basis. If the problem requires a design modification and subsequent change order, the design engineer should also be present.

2.2 RESPONSIBILITY OF CONSTRUCTION PERSONNEL

2.2.1 Responsibilities of the Project Manager

The project manager is the primary owner representative for the project. The project manager defines the overall project scope and has the authority to make changes to that scope, if needed (with proper regulatory coordination).

2.2.2 Responsibilities of the Operations Supervisor

The operations supervisor will be on site full-time as the owner representative for the project.

2.2.3 Responsibilities of the POR

The POR acts as an auditor to verify and document the proper and complete implementation of the quality assurance program. The POR will be responsible for documenting the construction and preparing the LIT Report. The LIT Report will include a statement by the POR as to whether the construction was performed in general conformance with the contract drawings and specifications and design intent. The POR, in cooperation with the design engineer, must approve all design changes and clarifications to design questions.

2.2.4 Responsibilities of the CQA Monitor

The CQA Monitor represents the POR and Owner by observing and testing the contractor's work activities. The CQA Monitor documents the activities of the contractor in sufficient detail and with the continuity to provide a high level of confidence that the work product follows the intent of the construction documents. The CQA Monitor also performs tests, when appropriate, to provide a high level of confidence that the characteristics of the materials and services meet the requirements of the construction documents.

Whenever a CQA Monitor performs visual observations or performs tests, he/she is responsible for timely preparation and processing of all required documentation and reports. Accurate and concise reports must be prepared for all monitoring activities and for each test performed. Section 7 of this document describes documentation requirements.

2.2.5 Responsibilities of the Contractor

The responsibilities of the contractor include scheduling, performing the work within the timeframe and budget agreed to in the contract, and performing the work in accordance with the plans and specifications. The contractor is also responsible for coordinating with any
2.0 GENERAL REQUIREMENTS

2.1 MEETINGS

To facilitate construction and clearly define construction goals and activities, close coordination between the owner, design engineer, CQA personnel, and contractor is essential. To meet this objective, preconstruction and progress meetings will be held.

2.1.1 Preconstruction Meeting

A preconstruction meeting shall be held at the site prior to commencing construction and will be attended by the owner, POR, contractor, and design engineer. The purpose of the preconstruction meeting will be to:

- Identify key personnel;
- Review the construction drawings, specifications, CQA program, work area security, safety procedures, and related issues;
- Define lines of communication and authority;
- Establish reporting and documentation procedures;
- Review testing equipment and procedures;
- Establish testing protocols and procedures for correcting and documenting construction or nonconformance;
- Conduct a site inspection to discuss work areas, stockpile areas, laydown areas, access roads, haul roads, and related items; and
- Review the project schedule.

2.1.2 Progress Meetings

Informal progress meetings are recommended before the start of work throughout the project. At a minimum, this meeting will be attended by the owner and/or representative and contractor. During liner installation, the progress meetings will be attended by the CQA Monitor and contractor. The purpose of these meetings is to:

- Discuss progress, problems, resolutions, and schedule;
- Review test data;
- Discuss the contractor's personnel and equipment assignments for the day;
- Review the previous day's activities and accomplishments; and
Surveyor
The individual or firm responsible for grade staking to establish required elevations to construct the project in accordance with the drawings and specifications.

Testing
Verification that materials meet specified requirements by subjecting that material to a set of physical, chemical, environmental, or operating conditions.

Testing Laboratory
A laboratory capable of conducting the tests required by this QA/QC Plan and the specifications. Testing may be done by the same laboratory or by a separate soils testing laboratory and a geosynthetics testing laboratory.

USCS
Unified Soil Classification System (ASTM D2487)
Design Engineer
The individuals or firms responsible for the design and preparation of the contract documents.

Earthwork
A construction activity involving the use of soil materials as defined in the construction specifications and Section 3 of this Plan.

Excavation
Excavation of materials from areas identified on the construction drawings.

Geomembrane
An essentially impermeable synthetic membrane, also referred to as flexible membrane liner (FML), used as a solid or liquid barrier.

Nonconformance
A deficiency in characteristic, documentation, or procedure that renders the quality of an item or activity unacceptable or indeterminate. Examples of nonconformance include, but are not limited to, physical defects, test failures, and inadequate documentation.

Panel
A unit area of the geomembrane which will be seamed in the field or in the fabricator's plant.

Procedure
A document that specifies or describes how an activity is to be performed.

Project Documents
Contractor submittals, construction drawings, record drawings, specifications, shop drawings, construction quality control and quality assurance plans, safety plan, and project schedule.

Project Manager
Owner's representative with overall project responsibility.

Quality Assurance
A planned and systematic pattern of procedures and documentation designed to provide adequate confidence that materials or services meet contractual and regulatory requirements, and that these materials will perform satisfactorily in service.

Quality Control
Those actions that provide a means of measuring and regulating the characteristics of a material or service to comply with the requirements of the construction documents. Quality control will be performed by the contractor, manufacturers, suppliers, and subcontractors.

Record Drawings
Drawings recording the constructed dimensions, details, and coordinates of the project (also referred to as "as-builts").
1.3 DEFINITIONS

Whenever the terms listed below are used, the intent and meaning will be interpreted as indicated.

ASTM
American Society for Testing and Materials.

Construction Drawings
The official plans, profiles, typical cross sections, elevations, and details, as well as their amendments and supplemental drawings, which show the locations, character, dimensions, and details of the work to be performed. Construction drawings are also referred to as the "plans."

Construction Quality Assurance (CQA)
A planned and systematic series of observations and tests designed to provide adequate confidence that materials and services meet contractual and regulatory requirements.

Construction Quality Assurance Consultant (CQA Consultant)
The consulting firm responsible for implementation of the CQA program.

Construction Quality Assurance Monitor (CQA Monitor)
Site representative(s) of the POR responsible for documenting field observations and tests.

Construction Quality Assurance Professional of Record (POR)
The POR is an authorized representative of the owner and has responsibility for construction quality assurance reporting and confirming that the facility was constructed in general accordance with construction drawings and specifications approved by the permitting agency. The POR is identified as the "Engineer" in the project specifications. The POR must be registered as a Professional Engineer in the State of Oklahoma. The POR may also be known in applicable regulations and guidelines as the CQA Engineer, Resident Project Representative, Geotechnical Professional (GP), or the Geotechnical Quality Control/Quality Assurance Professional (GQCP).

Construction Specifications
The qualitative requirements for products, materials, and workmanship upon which the construction is based. Construction specifications are also referred to as "specifications."

Contract Documents
The official set of documents issued by the owner, which includes bidding requirements, contract forms, contract conditions, construction specifications or drawings, addenda, and contract modifications.

Contractor
The person or persons, firm, partnership, corporation, or any combination, private, municipal, or public, which, as an independent contractor, has entered into a contract with the owner.
1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this Quality Assurance/Quality Control (QA/QC Plan) is to describe the quality assurance procedures to be used during construction of the liner and leachate collection components at the Southern Oklahoma Regional Disposal Landfill (SORD) in accordance with OAC 252:515 as promulgated by the Oklahoma Department of Environmental Quality (ODEQ) and the EPA Technical Guidance Document: Quality Assurance and Quality Control for Waste Containment Facilities (EPA/600/R-93182, September 1993). The primary goals of the quality assurance program are to:

- Determine if proper construction techniques, materials, and procedures are used;
- Determine if the intent of the construction documents and project design reports are met; and
- Identify construction problems and provide a mechanism for resolution.

Upon completion of construction, information generated through the quality assurance program will be used to prepare a Liner Installation and Testing (LIT) Report.

This QA/QC Plan replaces the previous plan approved by ODEQ.

1.2 DOCUMENT FORMAT

The QA/QC Plan is a revision to previous plans prepared for SORD and is presented in seven sections. Section 1 is the introduction and presents the document format, definitions, and terms used throughout the document. Section 2 presents general requirements of the quality assurance program and organization. Sections 3 through 6 present special requirements for specific work items of the construction, including procedures such as materials verification, test standards, testing frequencies, conformance and construction testing, sample numbering and processing, and monitoring for each work item. Section 7 presents methods of documentation and record-keeping. All parties involved in the construction should be thoroughly familiar with this document, the construction drawings, and the construction specifications.
7.1.3 Nonconformance Reports ............................................................ 39
7.2 Photographs .................................................................................. 39
7.3 Design and Specification Changes .................................................. 39
7.4 Liner Installation and Testing Report .............................................. 39

Appendices

Appendix A GRI Prescribed Testing
<table>
<thead>
<tr>
<th>Section</th>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.2</td>
<td>Test Frequencies</td>
<td>14</td>
</tr>
<tr>
<td>3.5</td>
<td>Monitoring Requirements</td>
<td>16</td>
</tr>
<tr>
<td>3.5.1</td>
<td>Excavation to Design Grade</td>
<td>17</td>
</tr>
<tr>
<td>3.5.2</td>
<td>Selective Soil Stockpiling</td>
<td>17</td>
</tr>
<tr>
<td>3.5.3</td>
<td>General Fill Placement</td>
<td>17</td>
</tr>
<tr>
<td>3.5.4</td>
<td>Soil Liner Placement</td>
<td>17</td>
</tr>
<tr>
<td>3.5.5</td>
<td>Leachate Collection Layer Placement</td>
<td>18</td>
</tr>
<tr>
<td>3.5.6</td>
<td>Drainage Aggregate Placement</td>
<td>18</td>
</tr>
<tr>
<td>3.6</td>
<td>Construction Surveys</td>
<td>18</td>
</tr>
<tr>
<td>4.0</td>
<td>Construction Quality Assurance for Geosynthetics</td>
<td>20</td>
</tr>
<tr>
<td>4.1</td>
<td>Introduction</td>
<td>20</td>
</tr>
<tr>
<td>4.2</td>
<td>Geomembrane</td>
<td>20</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Delivery</td>
<td>20</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Submittal Review</td>
<td>21</td>
</tr>
<tr>
<td>4.2.3</td>
<td>Quality Assurance Conformance Testing</td>
<td>21</td>
</tr>
<tr>
<td>4.2.3.1</td>
<td>Sampling Procedure</td>
<td>21</td>
</tr>
<tr>
<td>4.2.3.2</td>
<td>Tests</td>
<td>21</td>
</tr>
<tr>
<td>4.2.4</td>
<td>Panel Placement</td>
<td>23</td>
</tr>
<tr>
<td>4.2.5</td>
<td>Geomembrane Anchor Trench</td>
<td>25</td>
</tr>
<tr>
<td>4.2.6</td>
<td>Trial Welds</td>
<td>25</td>
</tr>
<tr>
<td>4.2.7</td>
<td>Field Seaming</td>
<td>25</td>
</tr>
<tr>
<td>4.2.8</td>
<td>Construction Testing</td>
<td>26</td>
</tr>
<tr>
<td>4.2.8.1</td>
<td>Nondestructive Seam Testing</td>
<td>27</td>
</tr>
<tr>
<td>4.2.8.2</td>
<td>Destructive Seam Testing</td>
<td>28</td>
</tr>
<tr>
<td>4.2.8.3</td>
<td>Procedure for Destructive Test Failure</td>
<td>30</td>
</tr>
<tr>
<td>4.2.9</td>
<td>Repairs</td>
<td>30</td>
</tr>
<tr>
<td>4.2.10</td>
<td>Wrinkles</td>
<td>31</td>
</tr>
<tr>
<td>4.2.11</td>
<td>Geomembrane Acceptance</td>
<td>31</td>
</tr>
<tr>
<td>4.3</td>
<td>Geotextile</td>
<td>32</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Delivery</td>
<td>32</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Testing and Certification</td>
<td>32</td>
</tr>
<tr>
<td>4.3.3</td>
<td>Geotextile Installation</td>
<td>32</td>
</tr>
<tr>
<td>4.3.4</td>
<td>Geotextile Repairs</td>
<td>33</td>
</tr>
<tr>
<td>4.4</td>
<td>Equipment on Geosynthetic Material</td>
<td>33</td>
</tr>
<tr>
<td>5.0</td>
<td>Construction Quality Assurance for Piping</td>
<td>35</td>
</tr>
<tr>
<td>5.1</td>
<td>HDPE Piping</td>
<td>35</td>
</tr>
<tr>
<td>5.1.1</td>
<td>Delivery</td>
<td>35</td>
</tr>
<tr>
<td>5.1.2</td>
<td>Conformance Testing</td>
<td>35</td>
</tr>
<tr>
<td>5.1.3</td>
<td>Installation</td>
<td>36</td>
</tr>
<tr>
<td>6.0</td>
<td>Construction Quality Assurance for Drainage Aggregate</td>
<td>37</td>
</tr>
<tr>
<td>6.1</td>
<td>Drainage Aggregate</td>
<td>37</td>
</tr>
<tr>
<td>6.1.1</td>
<td>Installation</td>
<td>37</td>
</tr>
<tr>
<td>7.0</td>
<td>Documentation</td>
<td>38</td>
</tr>
<tr>
<td>7.1</td>
<td>Daily Record Keeping</td>
<td>38</td>
</tr>
<tr>
<td>7.1.1</td>
<td>Daily Record of Construction Progress</td>
<td>38</td>
</tr>
<tr>
<td>7.1.2</td>
<td>Observation and Test Data Sheets</td>
<td>39</td>
</tr>
</tbody>
</table>
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Purpose</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Document Format</td>
<td>1</td>
</tr>
<tr>
<td>1.3 Definitions</td>
<td>2</td>
</tr>
<tr>
<td>2.0 General Requirements</td>
<td>5</td>
</tr>
<tr>
<td>2.1 Meetings</td>
<td>5</td>
</tr>
<tr>
<td>2.1.1 Preconstruction Meeting</td>
<td>5</td>
</tr>
<tr>
<td>2.1.2 Progress Meetings</td>
<td>5</td>
</tr>
<tr>
<td>2.1.3 Additional Meetings</td>
<td>6</td>
</tr>
<tr>
<td>2.2 Responsibility of Construction Personnel</td>
<td>6</td>
</tr>
<tr>
<td>2.2.1 Responsibilities of the Project Manager</td>
<td>6</td>
</tr>
<tr>
<td>2.2.2 Responsibilities of the Operations Supervisor</td>
<td>6</td>
</tr>
<tr>
<td>2.2.3 Responsibilities of the POR</td>
<td>6</td>
</tr>
<tr>
<td>2.2.4 Responsibilities of the CQA Monitor</td>
<td>6</td>
</tr>
<tr>
<td>2.2.5 Responsibilities of the Contractor</td>
<td>6</td>
</tr>
<tr>
<td>2.2.6 Responsibilities of the Surveyor</td>
<td>7</td>
</tr>
<tr>
<td>2.3 Control of Documents, Records, and Forms</td>
<td>7</td>
</tr>
<tr>
<td>2.3.1 Project Control of Construction Documents</td>
<td>7</td>
</tr>
<tr>
<td>2.3.2 Project Control of As-Built Information</td>
<td>7</td>
</tr>
<tr>
<td>2.3.3 Project Control of Forms</td>
<td>7</td>
</tr>
<tr>
<td>2.3.4 Processing Daily Reports</td>
<td>7</td>
</tr>
<tr>
<td>2.3.5 Processing Test Reports</td>
<td>7</td>
</tr>
<tr>
<td>2.3.6 Processing Project Records</td>
<td>8</td>
</tr>
<tr>
<td>2.4 Documentation and Control of Nonconformance</td>
<td>8</td>
</tr>
<tr>
<td>2.4.1 Observation of Nonconformance</td>
<td>8</td>
</tr>
<tr>
<td>2.4.2 Determining Extent of Nonconformance</td>
<td>8</td>
</tr>
<tr>
<td>2.4.3 Documenting Nonconformance</td>
<td>8</td>
</tr>
<tr>
<td>2.4.4 Corrective Measures</td>
<td>8</td>
</tr>
<tr>
<td>2.4.5 Verification of Corrective Measures</td>
<td>8</td>
</tr>
<tr>
<td>3.0 Construction Quality Assurance for Earthwork</td>
<td>9</td>
</tr>
<tr>
<td>3.1 Introduction</td>
<td>9</td>
</tr>
<tr>
<td>3.2 Earthwork Construction</td>
<td>9</td>
</tr>
<tr>
<td>3.2.1 Subgrade</td>
<td>9</td>
</tr>
<tr>
<td>3.2.2 General Fill</td>
<td>10</td>
</tr>
<tr>
<td>3.2.3 Soil Liner</td>
<td>10</td>
</tr>
<tr>
<td>3.2.4 Leachate Collection Layer</td>
<td>11</td>
</tr>
<tr>
<td>3.2.5 Protective Cover Layer</td>
<td>12</td>
</tr>
<tr>
<td>3.3 Material Evaluation</td>
<td>13</td>
</tr>
<tr>
<td>3.3.1 Testing</td>
<td>13</td>
</tr>
<tr>
<td>3.3.2 Materials Submittals</td>
<td>13</td>
</tr>
<tr>
<td>3.4 Construction Testing</td>
<td>13</td>
</tr>
<tr>
<td>3.4.1 Test Procedures</td>
<td>13</td>
</tr>
</tbody>
</table>
INDEX AND CERTIFICATION PAGE
REPORT INDEX

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Number of Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>2.0</td>
<td>General Requirements</td>
<td>4</td>
</tr>
<tr>
<td>3.0</td>
<td>Construction Quality Assurance for Earthwork</td>
<td>11</td>
</tr>
<tr>
<td>4.0</td>
<td>Construction Quality Assurance for Geosynthetics</td>
<td>15</td>
</tr>
<tr>
<td>5.0</td>
<td>Construction Quality Assurance for Piping</td>
<td>2</td>
</tr>
<tr>
<td>6.0</td>
<td>Construction Quality Assurance for Drainage Aggregate</td>
<td>1</td>
</tr>
<tr>
<td>7.0</td>
<td>Documentation</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Appendices</td>
<td>59</td>
</tr>
</tbody>
</table>

Certification

This Quality Assurance / Quality Control Plan has been prepared in accordance with good engineering practice including consideration of industry standards and the requirements of the Oklahoma Department of Environmental Quality.

Prepared by:

Floyd Cotter, P.E.
Vice President
SCS Engineers
Quality Assurance/Quality Control Plan for Liner and Leachate Collection System Installation and Testing

Presented To:
Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented From:
SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00
Quality Assurance/Quality Control Plan
for Liner and Leachate Collection
System Installation and Testing

Southern Oklahoma Regional Disposal Landfill

Presented to:
Southern Oklahoma Regional Disposal, Inc.

Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented by:

SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00

Offices Nationwide
www.scsengineers.com
Appendix G

Quality Assurance/Quality Control Plan for Liner and Leachate Collection
System Installation and Testing
Figure 3. **Ground Water Sampling Log** (with automatic data logging for most water quality parameters)

<table>
<thead>
<tr>
<th>Project</th>
<th>Site</th>
<th>Well No.</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well Depth</td>
<td>Screen Length</td>
<td>Well Diameter</td>
<td>Casing Type</td>
</tr>
<tr>
<td>Sampling Device</td>
<td>Tubing type</td>
<td>Water Level</td>
<td></td>
</tr>
<tr>
<td>Measuring Point</td>
<td>Other Info</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Sampling Personnel**

<table>
<thead>
<tr>
<th>Time</th>
<th>Pump Rate</th>
<th>Turbidity</th>
<th>Alkalinity</th>
<th>![Conc]</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Type of Samples Collected**

---

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: \( V_{\text{trap}} = \pi r^2 h \), \( V_{\text{spec}} = \frac{4}{3} \pi r^3 \)
Figure 2. Ground Water Sampling Log

<table>
<thead>
<tr>
<th>Time</th>
<th>pH</th>
<th>Temp</th>
<th>Cond.</th>
<th>Dis.O₂</th>
<th>Turb.</th>
<th>[ ]Conc</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Type of Samples Collected

Information: 2 in = 617 ml/ft, 4 in = 2470 ml/ft: Vol_{sp} = \pi r^2 h, Vol_{sph} = 4/3 \pi r^3


the well screen. This may require repeated recovery of the water during purging while leaving the pump in place within the well screen.

Use of low-flow techniques may be impractical in these settings, depending upon the water recharge rates. The sampler and the end-user of data collected from such wells need to understand the limitations of the data collected; i.e., a strong potential for underestimation of actual contaminant concentrations for volatile organics, potential false negatives for filtered metals and potential false positives for unfiltered metals. It is suggested that comparisons be made between samples recovered using low-flow purging techniques and samples recovered using passive sampling techniques (i.e., two sets of samples). Passive sample collection would essentially entail acquisition of the sample with no or very little purging using a dedicated sampling system installed within the screened interval or a passive sample collection device.

A. Low-Permeability Formations (<0.1 L/min recharge)

1. Low-Flow Purging and Sampling with Pumps

a. "portable or non-dedicated mode" - Lower the pump (one capable of pumping at <0.1 L/min) to mid-screen or slightly above and set in place for minimum of 48 hours (to lessen purge volume requirements). After 48 hours, use procedures listed in Part IV above regarding monitoring water quality parameters for stabilization, etc., but do not dewater the screen. If excessive drawdown and slow recovery is a problem, then alternate approaches such as those listed below may be better.

b. "dedicated mode" - Set the pump as above at least a week prior to sampling; that is, operate in a dedicated pump mode. With this approach significant reductions in purge volume should be realized. Water quality parameters should stabilize quite rapidly due to less disturbance of the sampling zone.

2. Passive Sample Collection

Passive sampling collection requires insertion of the device into the screened interval for a sufficient time period to allow flow and sample equilibration before extraction for analysis. Conceptually, the extraction of water from low yielding formations seems more akin to the collection of water from the unsaturated zone and passive sampling techniques may be more appropriate in terms of obtaining "representative" samples. Satisfying usual sample volume requirements is typically a problem with this approach and some latitude will be needed on the part of regulatory entities to achieve sampling objectives.

B. Fractured Rock

In fractured rock formations, a low-flow to zero purging approach using pumps in conjunction with packers to isolate the sampling zone in the borehole is suggested. Passive multi-layer sampling devices may also provide the most "representative" samples. It is imperative in these settings to identify flow paths or water-producing fractures prior to sampling using tools such as borehole flowmeters and/or geophysical tools.

After identification of water-bearing fractures, install packer(s) and pump assembly for sample collection using low-flow sampling in "dedicated mode" or use a passive sampling device which can isolate the identified water-bearing fractures.

VI. Documentation

The usual practices for documenting the sampling event should be used for low-flow purging and sampling techniques. This should include, at a minimum: information on the conduct of purging operations (flow-rate, drawdown, water-quality parameter values, volumes extracted and times for measurements), field instrument calibration data, water sampling forms and chain of custody forms. See Figures 2 and 3 and "Ground Water Sampling Workshop - A Workshop Summary" (U. S. EPA, 1995) for example forms and other documentation suggestions and information. This information coupled with laboratory analytical data and validation data are needed to judge the "useability" of the sampling data.

VII. Notice

The U.S. Environmental Protection Agency through its Office of Research and Development funded and managed the research described herein as part of its in-house research program and under Contract No. 68-C4-0031 to Dynamac Corporation. It has been subjected to the Agency's peer and administrative review and has been approved for publication as an EPA document. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

VIII. References


indicator parameters monitored can include pH, redox potential, conductivity, dissolved oxygen (DO) and turbidity. The last three parameters are often most sensitive. Pumping rate, drawdown, and the time or volume required to obtain stabilization of parameter readings can be used as a future guide to purge the well. Measurements should be taken every three to five minutes if the above suggested rates are used. Stabilization is achieved after all parameters have stabilized for three successive readings. In lieu of measuring all five parameters, a minimum subset would include pH, conductivity, and turbidity or DO. Three successive readings should be within ± 0.1 for pH, ± 3% for conductivity, ± 10 mv for redox potential, and ± 10% for turbidity and DO. Stabilized purge indicator parameter trends are generally obvious and follow either an exponential or asymptotic change to stable values during purging. Dissolved oxygen and turbidity usually require the longest time for stabilization. The above stabilization guidelines are provided for rough estimates based on experience.

H. Sampling, Sample Containers, Preservation and Decontamination

Upon parameter stabilization, sampling can be initiated. If an in-line device is used to monitor water quality parameters, it should be disconnected or bypassed during sample collection. Sampling flow rate may remain at established purge rate or may be adjusted slightly to minimize aeration, bubble formation, turbulent filling of sample bottles, or loss of volatiles due to extended residence time in tubing. Typically, flow rates less than 0.5 L/min are appropriate. The same device should be used for sampling as was used for purging. Sampling should occur in a progression from least to most contaminated well, if this is known. Generally, volatile (e.g., solvents and fuel constituents) and gas sensitive (e.g., Fe²⁺, CH₄, H₂S/HS⁻, alkalinity) parameters should be sampled first. The sequence in which samples for most inorganic parameters are collected is immaterial unless filtered (dissolved) samples are desired. Filtering should be done last and in-line filters should be used as discussed above. During both well purging and sampling, proper protective clothing and equipment must be used based upon the type and level of contaminants present.

The appropriate sample container will be prepared in advance of actual sample collection for the analyses of interest and include sample preservative where necessary. Water samples should be collected directly into this container from the pump tubing.

Immediately after a sample bottle has been filled, it must be preserved as specified in the site (QAPP). Sample preservation requirements are based on the analyses being performed (use site QAPP, FSP, RCRA guidance document [U. S. EPA, 1992] or EPA SW-846 [U. S. EPA, 1982]). It may be advisable to add preservatives to sample bottles in a controlled setting prior to entering the field in order to reduce the chances of improperly preserving sample bottles or introducing field contaminants into a sample bottle while adding the preservatives.

The preservatives should be transferred from the chemical bottle to the sample container using a disposable polyethylene pipet and the disposable pipet should be used only once and then discarded.

After a sample container has been filled with ground water, a Teflon™ (or tin)-lined cap is screwed on tightly to prevent the container from leaking. A sample label is filled out as specified in the FSP. The samples should be stored inverted at 4°C.

Specific decontamination protocols for sampling devices are dependent to some extent on the type of device used and the type of contaminants encountered. Refer to the site QAPP and FSP for specific requirements.

I. Blanks

The following blanks should be collected:

1. field blank: one field blank should be collected from each source water (distilled/deionized water) used for sampling equipment decontamination or for assisting well development procedures.

2. equipment blank: one equipment blank should be taken prior to the commencement of field work, from each set of sampling equipment to be used for that day. Refer to site QAPP or FSP for specific requirements.

3. trip blank: a trip blank is required to accompany each volatile sample shipment. These blanks are prepared in the laboratory by filling a 40-mL volatile organic analysis (VOA) bottle with distilled/deionized water.

V. Low-Permeability Formations and Fractured Rock

The overall sampling program goals or sampling objectives will drive how the sampling points are located, installed, and choice of sampling device. Likewise, site-specific hydrogeologic factors will affect these decisions. Sites with very low permeability formations or fractures causing discrete flow channels may require a unique monitoring approach. Unlike water supply wells, wells installed for ground-water quality assessment and restoration programs are often installed in low-water-yielding settings (e.g., clays, silts). Alternative types of sampling points and sampling methods are often needed in these types of environments, because low-permeability settings may require extremely low-flow purging (<0.1 L/min) and may be technology-limited. Where devices are not readily available to pump at such low flow rates, the primary consideration is to avoid dewatering of
1) General Considerations

There are no unusual requirements for ground-water sampling devices when using low-flow, minimal drawdown techniques. The major concern is that the device give consistent results and minimal disturbance of the sample across a range of low flow rates (i.e., < 0.5 L/min). Clearly, pumping rates that cause minimal to no drawdown in one well could easily cause significant drawdown in another well finished in a less transmissive formation. In this sense, the pump should not cause undue pressure or temperature changes or physical disturbance on the water sample over a reasonable sampling range. Consistency in operation is critical to meet accuracy and precision goals.

2) Advantages and Disadvantages of Sampling Devices

A variety of sampling devices are available for low-flow (minimal drawdown) purging and sampling and include peristaltic pumps, bladder pumps, electrical submersible pumps, and gas-driven pumps. Devices which lend themselves to both dedication and consistent operation at definable low-flow rates are preferred. It is desirable that the pump be easily adjustable and operate reliably at these lower flow rates. The peristaltic pump is limited to shallow applications and can cause degassing resulting in alteration of pH, alkalinity, and some volatiles loss. Gas-driven pumps should be a type that does not allow the gas to be in direct contact with the sampled fluid.

Clearly, bailers and other grab type samplers are ill-suited for low-flow sampling since they will cause repeated disturbance and mixing of stagnant water in the casing and the dynamic water in the screened interval. Similarly, the use of inertial lift foot-valve type samplers may cause too much disturbance at the point of sampling. Use of these devices also tends to introduce uncontrolled and unacceptable operator variability.

Summaries of advantages and disadvantages of various sampling devices are listed in Herzog et al. (1981), U. S. EPA (1992), Parker (1994) and Thunblad (1994).

E. Pump Installation

Dedicated sampling devices (left in the well) capable of pumping and sampling are preferred over any other type of device. Any portable sampling device should be slowly and carefully lowered to the middle of the screened interval or slightly above the middle (e.g., 1-1.5 m below the top of a 3 m screen). This is to minimize excessive mixing of the stagnant water in the casing above the screened interval zone water, and to minimize resuspension of solids which will have collected at the bottom of the well. These two disturbance effects have been shown to directly affect the time required for purging. There also appears to be a direct correlation between size of portable sampling devices relative to the well bore and purging purge volumes and times. The key is to minimize disturbance of water and solids in the well casing.

F. Filtration

Decisions to filter samples should be dictated by sampling objectives rather than as a fix for poor sampling practices, and field-filtering of certain components should not be the default. Consideration should be given as to what the application of field-filtration is trying to accomplish. For assessment of truly dissolved (as opposed to operationally dissolved [i.e., samples filtered with 0.45 μm filters]) concentrations of major ions and trace metals, 0.1 μm filters are recommended although 0.45 μm filters are normally used for most regulatory programs. Alkalinity samples must also be filtered if significant particulate calcium carbonate is suspected, since this material is likely to impact alkalinity titration results (although filtration itself may alter the CO₂ composition of the sample and, therefore, affect the results).

Although filtration may be appropriate, filtration of a sample may cause a number of unintended changes to occur (e.g., oxidation, aeration) possibly leading to filtration-induced artifacts during sample analysis and uncertainty in the results. Some of these unintended changes may be unavoidable but the factors leading to them must be recognized. Deleterious effects can be minimized by consistent application of certain filtration guidelines. Guidelines should address selection of filter type, media, pore size, etc. in order to identify and minimize potential sources of uncertainty when filtering samples.

In-line filtration is recommended because it provides better consistency through less sample handling, and minimizes sample exposure to the atmosphere. In-line filters are available in both disposable (barrel filters) and non-disposable (in-line filter holder, flat membrane filters) formats and various filter pore sizes (0.1-5.0 μm). Disposable filter cartridges have the advantage of greater sediment handling capacity when compared to traditional membrane filters. Filters must be pre-rinsed following manufacturer’s recommendations. If there are no recommendations for rinsing, pass through a minimum of 1 L of ground water following purging and prior to sampling. Once filtration has begun, the filter cake may develop as particles larger than the pore size accumulate on the filter membrane. The result is that the effective pore diameter of the membrane is reduced and particles smaller than the stated pore size are excluded from the filtrate. Possible corrective measures include prefiltering (with larger pore size filters), minimizing particle loads to begin with, and reducing sample volume.

G. Monitoring of Water Level and Water Quality Indicator Parameters

Check water level periodically to monitor drawdown in the well as a guide to flow rate adjustment. The goal is minimal drawdown (<0.1 m) during purging. This goal may be difficult to achieve under some circumstances due to geologic heterogeneities within the screened interval, and may require adjustment based on site-specific conditions and personal experience. In-line water quality indicator parameters should be continuously monitored during purging. The water quality
• reduced stress on the formation (minimal drawdown);
• less mixing of stagnant casing water with formation water;
• reduced need for filtration and, therefore, less time required for sampling;
• smaller purging volume which decreases waste disposal costs and sampling time;
• better sample consistency; reduced artificial sample variability.

Some disadvantages of low-flow purging are:
• higher initial capital costs,
• greater set-up time in the field,
• need to transport additional equipment to and from the site,
• increased training needs,
• resistance to change on the part of sampling practitioners,
• concern that new data will indicate a change in conditions and trigger an action.

IV. Low-Flow (Minimal Drawdown) Sampling Protocols

The following ground-water sampling procedure has evolved over many years of experience in ground-water sampling for organic and inorganic compound determinations and as such summarizes the authors’ (and others) experiences to date (Barcelona et al., 1984, 1994; Barcelona and Helfrich, 1986; Puls and Barcelona, 1989; Puls et al., 1990, 1992; Puls and Powell, 1992; Puls and Paul, 1995). High-quality chemical data collection is essential in ground-water monitoring and site characterization. The primary limitations to the collection of representative ground-water samples include: mixing of the stagnant casing and fresh screen waters during insertion of the sampling device or ground-water level measurement device; disturbance and resuspension of settled solids at the bottom of the well when using high pumping rates or raising and lowering a pump or bailer; introduction of atmospheric gases or degassing from the water during sample handling and transfer, or inappropriate use of vacuum sampling device, etc.

A. Sampling Recommendations

Water samples should not be taken immediately following well development. Sufficient time should be allowed for the ground-water flow regime in the vicinity of the monitoring well to stabilize and to approach chemical equilibrium with the well construction materials. This lag time will depend on site conditions and methods of installation but often exceeds one week.

Well purging is nearly always necessary to obtain samples of water flowing through the geologic formations in the screened interval. Rather than using a general but arbitrary guideline of purging three casing volumes prior to sampling, it is recommended that an in-line water quality measurement device (e.g., flow-through cell) be used to establish the stabilization time for several parameters (e.g., pH, specific conductance, redox, dissolved oxygen, turbidity) on a well-specific basis. Data on pumping rate, drawdown, and volume required for parameter stabilization can be used as a guide for conducting subsequent sampling activities.

The following are recommendations to be considered before, during and after sampling:
• use low-flow rates (<0.5 L/min), during both purging and sampling to maintain minimal drawdown in the well;
• maximize tubing wall thickness, minimize tubing length;
• place the sampling device intake at the desired sampling point;
• minimize disturbances of the stagnant water column above the screened interval during water level measurement and sampling device insertion;
• make proper adjustments to stabilize the flow rate as soon as possible;
• monitor water quality indicators during purging;
• collect unfiltered samples to estimate contaminant loading and transport potential in the subsurface system.

B. Equipment Calibration

Prior to sampling, all sampling device and monitoring equipment should be calibrated according to manufacturer’s recommendations and the site Quality Assurance Project Plan (QAPP) and Field Sampling Plan (FSP). Calibration of pH should be performed with at least two buffers which bracket the expected range. Dissolved oxygen calibration must be corrected for local barometric pressure readings and elevation.

C. Water Level Measurement and Monitoring

It is recommended that a device be used which will least disturb the water surface in the casing. Well depth should be obtained from the well logs. Measuring to the bottom of the well casing will only cause resuspension of settled solids from the formation and require longer purging times for turbidity equilibration. Measure well depth after sampling is completed. The water level measurement should be taken from a permanent reference point which is surveyed relative to ground elevation.

D. Pump Type

The use of low-flow (e.g., 0.1-0.5 L/min) pumps is suggested for purging and sampling all types of analytes. All pumps have some limitation and these should be investigated with respect to application at a particular site. Bailers are inappropriate devices for low-flow sampling.
flow purging has the advantage of minimizing mixing between the overlying stagnant casing water and water within the screened interval.

A. Low-Flow Purging and Sampling

Low-flow refers to the velocity with which water enters the pump intake and that is imparted to the formation pore water in the immediate vicinity of the well screen. It does not necessarily refer to the flow rate of water discharged at the surface which can be affected by flow regulators or restrictions. Water level drawdown provides the best indication of the stress imparted by a given flow-rate for a given hydrological situation. The objective is to pump in a manner that minimizes stress (drawdown) to the system to the extent practical taking into account established site sampling objectives. Typically, flow rates on the order of 0.1 - 0.5 L/min are used, however this is dependent on site-specific hydrogeology. Some extremely coarse-textured formations have been successfully sampled in this manner at flow rates to 1 L/min. The effectiveness of using low-flow purging is intimately linked with proper screen location, screen length, and well construction and development techniques. The reestablishment of natural flow paths in both the vertical and horizontal directions is important for correct interpretation of the data. For high resolution sampling needs, screens less than 1 m should be used. Most of the need for purging has been found to be due to passing the sampling device through the overlying casing water which causes mixing of these stagnant waters and the dynamic waters within the screened interval. Additionally, there is disturbance to suspended sediment collected in the bottom of the casing and the displacement of water out into the formation immediately adjacent to the well screen. These disturbances and impacts can be avoided using dedicated sampling equipment, which precludes the need to insert the sampling device prior to purging and sampling.

Isolation of the screened interval water from the overlying stagnant casing water may be accomplished using low-flow minimal drawdown techniques. If the pump intake is located within the screened interval, most of the water pumped will be drawn in directly from the formation with little mixing of casing water or disturbance to the sampling zone. However, if the wells are not constructed and developed properly, zones other than those intended may be sampled. At some sites where geologic heterogeneities are sufficiently different within the screened interval, higher conductivity zones may be preferentially sampled. This is another reason to use shorter screened intervals, especially where high spatial resolution is a sampling objective.

B. Water Quality Indicator Parameters

It is recommended that water quality indicator parameters be used to determine purging needs prior to sample collection in each well. Stabilization of parameters such as pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature and turbidity should be used to determine when formation water is accessed during purging. In general, the order of stabilization is pH, temperature, and specific conductance, followed by oxidation-reduction potential, dissolved oxygen and turbidity. Temperature and pH, while commonly used as purging indicators, are actually quite insensitive in distinguishing between formation water and stagnant casing water; nevertheless, these are important parameters for data interpretation purposes and should also be measured. Performance criteria for determination of stabilization should be based on water-level drawdown, pumping rate and equipment specifications for measuring indicator parameters. Instruments are available which utilize in-line flow cells to continuously measure the above parameters.

It is important to establish specific well stabilization criteria and then consistently follow the same methods thereafter, particularly with respect to drawdown, flow rate and sampling device. Generally, the time or purge volume required for parameter stabilization is independent of well depth or well volumes. Dependent variables are well diameter, sampling device, hydrogeochemistry, pump flow rate, and whether the devices are used in a portable or dedicated manner. If the sampling device is already in place (i.e., dedicated sampling systems), then the time and purge volume needed for stabilization is much shorter. Other advantages of dedicated equipment include less purge water for waste disposal, much less decontamination of equipment, less time spent in preparation of sampling as well as time in the field, and more consistency in the sampling approach which probably will translate into less variability in sampling results. The use of dedicated equipment is strongly recommended at wells which will undergo routine sampling over time.

If parameter stabilization criteria are too stringent, then minor oscillations in indicator parameters may cause purging operations to become unnecessarily protracted. It should also be noted that turbidity is a very conservative parameter in terms of stabilization. Turbidity is always the last parameter to stabilize. Excessive purge times are invariably related to the establishment of too stringent turbidity stabilization criteria. It should be noted that natural turbidity levels in ground water may exceed 10 nephelometric turbidity units (NTU).

C. Advantages and Disadvantages of Low-Flow (Minimum Drawdown) Purging

In general, the advantages of low-flow purging include:

- samples which are representative of the mobile load of contaminants present (dissolved and colloid-associated);
- minimal disturbance of the sampling point thereby minimizing sampling artifacts;
- less operator variability, greater operator control;
1) Questions of Scale

A sampling plan designed to collect representative samples must take into account the potential scale of changes in site conditions through space and time as well as the chemical associations and behavior of the parameters that are targeted for investigation. In subsurface systems, physical (i.e., aquifer) and chemical properties over time or space are not statistically independent. In fact, samples taken in close proximity (i.e., within distances of a few meters) or within short time periods (i.e., more frequently than monthly) are highly auto-correlated. This means that designs employing high-sampling frequency (e.g., monthly) or dense spatial monitoring designs run the risk of redundant data collection and misleading inferences regarding trends in values that aren’t statistically valid. In practice, contaminant detection and assessment monitoring programs rarely suffer these over-sampling concerns. In corrective-action evaluation programs, it is also possible that too little data may be collected over space or time. In these cases, false interpretation of the spatial extent of contamination or underestimation of temporal concentration variability may result.

2) Target Parameters

Parameter selection in monitoring program design is most often dictated by the regulatory status of the site. However, background water quality constituents, purging indicator parameters, and contaminants, all represent targets for data collection programs. The tools and procedures used in these programs should be equally rigorous and applicable to all categories of data, since all may be needed to determine or support regulatory action.

C. Sampling Point Design and Construction

Detailed site characterization is central to all decision-making purposes and the basis for this characterization resides in identification of the geologic framework and major hydro-stratigraphic units. Fundamental data for sample point location include: subsurface lithology, head-differences and background geochemical conditions. Each sampling point has a proper use or uses which should be documented at a level which is appropriate for the program’s data quality objectives. Individual sampling points may not always be able to fulfill multiple monitoring objectives (e.g., detection, assessment, corrective action).

1) Compatibility with Monitoring Program and Data Quality Objectives

Specifics of sampling point location and design will be dictated by the complexity of subsurface lithology and variability in contaminant and/or geochemical conditions. It should be noted that, regardless of the ground-water sampling approach, few sampling points (e.g., wells, drive-points, screened augers) have zones of influence in excess of a few feet. Therefore, the spatial frequency of sampling points should be carefully selected and designed.

2) Flexibility of Sampling Point Design

In most cases well-point diameters in excess of 1 7/8 inches will permit the use of most types of submersible pumping devices for low-flow (minimal drawdown) sampling. It is suggested that short (e.g., less than 1.6 m) screens be incorporated into the monitoring design where possible so that comparable results from one device to another might be expected. Short, of course, is relative to the degree of vertical water quality variability expected at a site.

3) Equilibration of Sampling Point

Time should be allowed for equilibration of the well or sampling point with the formation after installation. Placement of well or sampling points in the subsurface produces some disturbance of ambient conditions. Drilling techniques (e.g., auger, rotary, etc.) are generally considered to cause more disturbance than direct-push technologies. In either case, there may be a period (i.e., days to months) during which water quality near the point may be distinctly different from that in the formation. Proper development of the sampling point and adjacent formation to remove fines created during emplacement will shorten this water quality recovery period.

III. Definition of Low-Flow Purging and Sampling

It is generally accepted that water in the well casing is non-representative of the formation water and needs to be purged prior to collection of ground-water samples. However, the water in the screened interval may indeed be representative of the formation, depending upon well construction and site hydrogeology. Wells are purged to some extent for the following reasons: the presence of the air interface at the top of the water column resulting in an oxygen concentration gradient with depth, loss of volatiles up the water column, leaching from or sorption to the casing or filter pack, chemical changes due to clay seals or backfill, and surface infiltration.

Low-flow purging, whether using portable or dedicated systems, should be done using pump-intake located in the middle or slightly above the middle of the screened interval. Placement of the pump too close to the bottom of the well will cause increased entrainment of solids which have collected in the well over time. These particles are present as a result of well development, prior purging and sampling events, and natural colloidal transport and deposition. Therefore, placement of the pump in the middle or toward the top of the screened interval is suggested. Placement of the pump at the top of the water column for sampling is only recommended in unconfined aquifers, screened across the water table, where this is the desired sampling point.
objectives, then appropriate location, screen length, well diameter, slot size, etc. for the monitoring well network can be decided. This is especially critical for new in situ remedial approaches or natural attenuation assessments at hazardous waste sites.

In general, the overall goal of any ground-water sampling program is to collect water samples with no alteration in water chemistry; analytical data thus obtained may be used for a variety of specific monitoring programs depending on the regulatory requirements. The sampling methodology described in this paper assumes that the monitoring goal is to sample monitoring wells for the presence of contaminants and it is applicable whether mobile colloids are a concern or not and whether the analytes of concern are metals (and metalloids) or organic compounds.

II. Monitoring Objectives and Design Considerations

The following issues are important to consider prior to the design and implementation of any ground-water monitoring program, including those which anticipate using low-flow purging and sampling procedures.

A. Data Quality Objectives (DQOs)

Monitoring objectives include four main types: detection, assessment, corrective-action evaluation and resource evaluation, along with hybrid variations such as site-assessments for property transfers and water availability investigations. Monitoring objectives may change as contamination or water quality problems are discovered. However, there are a number of common components of monitoring programs which should be recognized as important regardless of initial objectives. These components include:

1) Development of a conceptual model that incorporates elements of the regional geology to the local geologic framework. The conceptual model development also includes initial site characterization efforts to identify hydrostratigraphic units and likely flow-paths using a minimum number of borings and well completions;

2) Cost-effective and well documented collection of high quality data utilizing simple, accurate, and reproducible techniques; and

3) Refinement of the conceptual model based on supplementary data collection and analysis.

These fundamental components serve many types of monitoring programs and provide a basis for future efforts that evolve in complexity and level of spatial detail as purposes and objectives expand. High quality, reproducible data collection is a common goal regardless of program objectives.

High quality data collection implies data of sufficient accuracy, precision, and completeness (i.e., ratio of valid analytical results to the minimum sample number called for by the program design) to meet the program objectives. Accuracy depends on the correct choice of monitoring tools and procedures to minimize sample and subsurface disturbance from collection to analysis. Precision depends on the repeatability of sampling and analytical protocols. It can be assured or improved by replication of sample analyses including blanks, field/lab standards and reference standards.

B. Sample Representativeness

An important goal of any monitoring program is collection of data that is truly representative of conditions at the site. The term representativeness applies to chemical and hydrogeologic data collected via wells, borings, piezometers, geophysical and soil gas measurements, lysimeters, and temporary sampling points. It involves a recognition of the statistical variability of individual subsurface physical properties, and contaminant or major ion concentration levels, while explaining extreme values. Subsurface temporal and spatial variability are facts. Good professional practice seeks to maximize representativeness by using proven accurate and reproducible techniques to define limits on the distribution of measurements collected at a site. However, measures of representativeness are dynamic and are controlled by evolving site characterization and monitoring objectives. An evolutionary site characterization model, as shown in Figure 1, provides a systematic approach to the goal of consistent data collection.

![Evolutionary Site Characterization Model](image)

Figure 1. Evolutionary Site Characterization Model

The model emphasizes a recognition of the causes of the variability (e.g., use of inappropriate technology such as using bailers to purge wells; imprecise or operator-dependent methods) and the need to control avoidable errors.
chemical and biological subsurface processes. With greater appreciation of the role of heterogeneity, it became evident that subsurface pollution was ubiquitous and encompassed the unsaturated zone to the deep subsurface and included unconsolidated sediments, fractured rock, and aquitards or low-yielding or impermeable formations. Small-scale processes and heterogeneities were shown to be important in identifying contaminant distributions and in controlling water and contaminant flow paths.

It is beyond the scope of this paper to summarize all the advances in the field of ground-water quality investigations and remediation, but two particular issues have bearing on ground-water sampling today: aquifer heterogeneity and colloidal transport. Aquifer heterogeneities affect contaminant flow paths and include variations in geology, geochemistry, hydrology and microbiology. As methods and the tools available for subsurface investigations have become increasingly sophisticated and understanding of the subsurface environment has advanced, there is an awareness that in most cases a primary concern for site investigations is characterization of contaminant flow paths rather than entire aquifers. In fact, in many cases, plume thickness can be less than well screen lengths (e.g., 3-6 m) typically installed at hazardous waste sites to detect and monitor plume movement over time. Small-scale differences have increasingly been shown to be important and there is a general trend toward smaller diameter wells and shorter screens.

The hydrogeochemical significance of colloidal-size particles in subsurface systems has been realized during the past several years (Gschwend and Reynolds, 1987; McCarthy and Zachara, 1989; Puls, 1990; Ryan and Gschwend, 1990). This realization resulted from both field and laboratory studies that showed faster contaminant migration over greater distances and at higher concentrations than flow and transport model predictions would suggest (Buddemeier and Hunt, 1988; Enfield and Bengtsson, 1988; Penrose et al., 1990). Such models typically account for interaction between the mobile aqueous and immobile solid phases, but do not allow for a mobile, reactive solid phase. It is recognition of this third phase as a possible means of contaminant transport that has brought increasing attention to the manner in which samples are collected and processed for analysis (Puls et al., 1990; McCarthy and Degueldre, 1993; Backhus et al., 1993; U.S. EPA, 1995). If such a phase is present in sufficient mass, possesses high sorption reactivity, large surface area, and remains stable in suspension, it can serve as an important mechanism to facilitate contaminant transport in many types of subsurface systems.

Colloids are particles that are sufficiently small so that the surface free energy of the particle dominates the bulk free energy. Typically, in ground water, this includes particles with diameters between 1 and 1000 nm. The most commonly observed mobile particles include: secondary clay minerals; hydrous iron, aluminum, and manganese oxides; dissolved and particulate organic materials, and viruses and bacteria. These reactive particles have been shown to be mobile under a variety of conditions in both field studies and laboratory column experiments, and as such need to be included in monitoring programs where identification of the total mobile contaminant loading (dissolved + naturally suspended particles) at a site is an objective. To that end, sampling methodologies must be used which do not artificially bias naturally suspended particle concentrations.

Currently the most common ground-water purging and sampling methodology is to purge a well using bailers or high speed pumps to remove 3 to 5 casing volumes followed by sample collection. This method can cause adverse impacts on sample quality through collection of samples with high levels of turbidity. This results in the inclusion of otherwise immobile artificial particles which produce an overestimation of certain analytes of interest (e.g., metals or hydrophobic organic compounds). Numerous documented problems associated with filtration (Danielsson, 1982; Laxen and Chandler, 1982; Horowitz et al., 1992) make this an undesirable method of rectifying the turbidity problem, and include the removal of potentially mobile (contaminant-associated) particles during filtration, thus artificially biasing contaminant concentrations low. Sampling-induced turbidity problems can often be mitigated by using low-flow purging and sampling techniques.

Current subsurface conceptual models have undergone considerable refinement due to the recent development and increased use of field screening tools. So-called hydraulic push technologies (e.g., cone penetrometer, Geoprobe®, QED HydroPunch®) enable relatively fast screening site characterization which can then be used to design and install a monitoring well network. Indeed, alternatives to conventional monitoring wells are now being considered for some hydrogeologic settings. The ultimate design of any monitoring system should however be based upon adequate site characterization and be consistent with established monitoring objectives.

If the sampling program objectives include accurate assessment of the magnitude and extent of subsurface contamination over time and/or accurate assessment of subsequent remedial performance, then some information regarding plume delineation in three-dimensional space is necessary prior to monitoring well network design and installation. This can be accomplished with a variety of different tools and equipment ranging from hand-operated augers to screening tools mentioned above and large drilling rigs. Detailed information on ground-water flow velocity, direction, and horizontal and vertical variability are essential to accurate baseline data requirements. Detailed soil and geologic data are required prior to and during the installation of sampling points. This includes historical as well as detailed soil and geologic logs which accumulate during the site investigation. The use of borehole geophysical techniques is also recommended. With this information (together with other site characterization data) and a clear understanding of sampling
Ground Water Issue

LOW-FLOW (MINIMAL DRAWDOWN)
GROUND-WATER SAMPLING PROCEDURES

by Robert W. Puls¹ and Michael J. Barcelona²

Background

The Regional Superfund Ground Water Forum is a group of ground-water scientists, representing EPA's Regional Superfund Offices, organized to exchange information related to ground-water remediation at Superfund sites. One of the major concerns of the Forum is the sampling of ground water to support site assessment and remedial performance monitoring objectives. This paper is intended to provide background information on the development of low-flow sampling procedures and its application under a variety of hydrogeologic settings. It is hoped that the paper will support the production of standard operating procedures for use by EPA Regional personnel and other environmental professionals engaged in ground-water sampling.

For further information contact: Robert Puls, 405-436-8543, Subsurface Remediation and Protection Division, NRMRL, Ada, Oklahoma.

I. Introduction

The methods and objectives of ground-water sampling to assess water quality have evolved over time. Initially the emphasis was on the assessment of water quality of aquifers as sources of drinking water. Large water-bearing units were identified and sampled in keeping with that objective. These were highly productive aquifers that supplied drinking water via private wells or through public water supply systems. Gradually, with the increasing awareness of subsurface pollution of these water resources, the understanding of complex hydrogeochemical processes which govern the fate and transport of contaminants in the subsurface increased. This increase in understanding was also due to advances in a number of scientific disciplines and improvements in tools used for site characterization and ground-water sampling. Ground-water quality investigations where pollution was detected initially borrowed ideas, methods, and materials for site characterization from the water supply field and water analysis from public health practices. This included the materials and manner in which monitoring wells were installed and the way in which water was brought to the surface, treated, preserved and analyzed. The prevailing conceptual ideas included convenient generalizations of ground-water resources in terms of large and relatively homogeneous hydrologic units. With time it became apparent that conventional water supply generalizations of homogeneity did not adequately represent field data regarding pollution of these subsurface resources. The important role of heterogeneity became increasingly clear not only in geologic terms, but also in terms of complex physical,

¹National Risk Management Research Laboratory, U.S. EPA
²University of Michigan

Superfund Technology Support Center for Ground Water
National Risk Management Research Laboratory
Subsurface Protection and Remediation Division
Robert S. Kerr Environmental Research Center
Ada, Oklahoma
Appendix C

Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures
Field Sampling Sheet

Project Name: ___________________________ Monitoring Point: ___________________________
Project Location: ___________________________ Date (s): ___________________________
Project Number: ___________________________

Field Team Members
Name: ___________________________ Affiliation: ___________________________
Name: ___________________________ Affiliation: ___________________________

Weather Conditions
Temp: _________ °F Wind Direction: N S E W (circle two if needed)
Precipitation: None Light Heavy Sky: Cloudy Sunny Partly

Well Observations
Well Pad: ___________________________
Casing: ___________________________
Protective Casing: ___________________________
Reference Mark/Identification: ___________________________

Locks
Yes No

Protective Casing
Well

Groundwater Level Measurements
Static Water Level: _________ feet below TOC
Total Depth: _________ feet below TOC

Date/TimeMeasured: ___________________________

Purging Activities
Purged By: ___________________________
Purge Date: ___________________________
Purge Method: Bailer Dedicated Pump Non-Dedicated Pump (circle one)
Well Diameter: 1-inch 2-inch 3-inch 4-inch Other _________ (circle one)
Purge Volume Calculation: _________ gallons Total Purge Volume: _________ gallons
Initial Parameter Readings: _________ pH _________ Spec. Cond. _________ Temp
Physical appearance of purge water: ___________________________

<table>
<thead>
<tr>
<th>Purge Time</th>
<th>Cumulative Purge Vol. (gallons)</th>
<th>Purge Rate (ml/min)</th>
<th>pH</th>
<th>Specific Conductivity (μS)</th>
<th>Temp (°C)</th>
<th>Other</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sampling Activities
Sampled By: ___________________________
Sample Date/Time: ___________________________
Sample Method: Bailer Dedicated Pump Non-Dedicated Pump (circle one)
Sample Parameters: _________ pH _________ Spec. Cond. _________ Temp
Water Level: _________ feet below TOC

Observations/Comments: (i.e., equipment malfunctions, contamination sources, sampling difficulties; duplicate sample)

Form Completed By: ___________________________ Date: ___________________________
Appendix B

Example Form
# LOG OF BORING NO. B-8

**Project Description:** SORD SANITARY LANDFILL  
ARDMORE, OKLAHOMA

## MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Samples</th>
<th>Symbol / USCS</th>
<th>Location</th>
<th>Surface El.</th>
<th>814.1' MSL</th>
</tr>
</thead>
<tbody>
<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>
</tbody>
</table>
| 40          | 96       |               | Sample #6 taken from auger cuttings  
Augered into saturated Sand @ 38'. Boring was drilled to 60' to accommodate electric logging tools.  
Total Depth - 60'  
Water levels:  
6/20: 1225 - 38.8'  
1500 - 32.5'  
6/23: 0700 - 32.6'  
6/24: 1600 - 32.8'  
Boring was drilled with 8-inch diameter hollow stem augers and sampled with 3 1/2-inch diameter split tube barrel. |          |             |
| 45          |         |               |          |             |            |
| 50          |         |               |          |             |            |

**Completion Depth:** 60.0'

**Date Boring Started:** 6/20/94

**Date Boring Completed:** 6/20/94

**Engineer/Geologist:** JIM CHRISTIE

**Project No.:** NES93280

**Remarks:** Static Water Level was 32.8'

**Freese and Nichols, Inc.:** The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

**Plate A-25**
## LOG OF BORING NO. B-8

**Project Description:** SORD SANITARY LANDFILL
ARDMORE, OKLAHOMA

### Location:
Surface El.: 814.1' MSL

### MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth, Feet</th>
<th>Samples</th>
<th>Material Description</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows / Foot Penetrometer</th>
<th>% Passing No. 200 Sieve</th>
<th>Unit Dry Weight, lb/ft$^3$</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>S1</td>
<td>CLAY (CH) (2.5 YR 3/4) dark reddish brown, high plasticity, very stiff to hard, moist</td>
<td>4.5</td>
<td>21.5</td>
<td>-</td>
<td>57</td>
<td>19</td>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.5</td>
<td>S2</td>
<td>CLAY (CL) (10 YR 6/4) light yellowish brown and (5 YR 6/3), light reddish brown, low plasticity, hard, sandy, scattered gravel from 10.5'-13.9', moist</td>
<td>4.5</td>
<td>7.7</td>
<td>-</td>
<td>38</td>
<td>14</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19.0</td>
<td>S3</td>
<td>SAND (SM) (10 YR 6/1) gray, fine grained, dense, moist, saturated @ 38'</td>
<td>4.5</td>
<td>4.8</td>
<td>-</td>
<td>25</td>
<td>12</td>
<td>13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-25</td>
<td>S4</td>
<td>CLAY (CL) lens from 23.0' to 24.5'</td>
<td>10.9</td>
<td>48</td>
<td>-</td>
<td>21</td>
<td>27</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Completion Depth:** 60.0'

**Remarks:** Static Water Level was 32.8'

**Date Boring Started:** 6/20/94
**Date Boring Completed:** 6/20/94
**Engineer/Geologist:** JIM CHRISTIE
**Project No.:** NES93280

---

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.
# LOG OF BORING NO. B-7

**Project Description:** SORD SANITARY LANDFILL  
ARDMORE, OKLAHOMA  

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Samples</th>
<th>Symbol / USC</th>
<th>Location:</th>
<th>Surface El.: 833.4' MSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>70.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MATERIAL DESCRIPTION**

-Saturated @ 57'

Total Depth - 70'  
Boring location sized by NESI  
After completion of boring, water level was 59.6'  
Boring was drilled with 8-inch diameter hollow stem augers and sampled with 3 1/2-inch diameter split tube barrel.

<table>
<thead>
<tr>
<th>Total G.T (gpm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Pocket Penetrometer Blows / FT</th>
<th>Liquid Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.5</td>
<td>18</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

Completion Depth: 70.0'  
Remarks: Saturated at 57.0'. Water level at completion was 59.6'.

Date Boring Started: 6/24/94  
Date Boring Completed: 6/24/94  
Engineer/Geologist: JIM CHRISTIE  
Project No.: NES93280

FREESE AND NICHOLS, INC.  

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.
**LOG OF BORING NO. B-7**

**Project Description:** SORD SANITARY LANDFILL
ARDMORE, OKLAHOMA

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Symbol</th>
<th>Samples / USCS</th>
<th>Location:</th>
</tr>
</thead>
<tbody>
<tr>
<td>30' (no recovery)</td>
<td>S3</td>
<td>27.0</td>
<td></td>
</tr>
<tr>
<td>30.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLAY SHALE, (2.5 YR 5/2) weak red, hard, massive, moist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAND (SC), (2.5 Y 7/2) light gray, fine grained, silty, dense, moist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLAY SHALE, (2.5 YR 5/2) weak red, hard, sandy, moist</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAND (SM), (7.5 YR N7/0) grey, medium to coarse grained, silty, clayey, dense, saturated @ 57°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Completion Depth:** 70.0'  
**Remarks:** Saturated at 57.0'. Water level at completion was 59.6'.

_Freese and Nichols, Inc.

The stratification lines represent approximate base boundaries._

_In situ, the transition may be gradual._

**Continued Next Page**
**LOG OF BORING NO. B-7**

**Project Description:**
SORD SANITARY LANDFILL  
ARDMORE, OKLAHOMA

<table>
<thead>
<tr>
<th>Depth, Feet</th>
<th>Symbol / USCS</th>
<th>Location</th>
<th></th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows / Foot</th>
<th>Pocket penetrometer, TSF</th>
<th>% Passing No. 200 Sieve</th>
<th>Unit Dry Weight, lb/ft³</th>
<th>Liquid Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>Surface Bl.: 833.4' MSL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**MATERIAL DESCRIPTION**

- **CLAY (CL),** cover material with 0.4' of trash from 1.5' to 1.9'
- **SAND (SP),** (10 YR 6/3) pale brown to (10 YR 8/6) yellow, fine to medium grained, dense, moist

<table>
<thead>
<tr>
<th>81</th>
<th></th>
<th>1.9</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>82</td>
<td></td>
<td>11.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **CLAY (CL),** (10 YR 6/3) pale brown to (2.5 YR 3/2) dusky red, high plasticity, stiff to hard, moist

| 52           |               | 14.2|     | 48 | 24 | 24 |     |     |                          |              |                 |

- **SAND (SC),** (10 YR 8/2) white to (10 YR 5/4) yellow brown, medium to coarse grained, dense, moist - very hard drilling from 27' to

Completion Depth: 70.0'  
Remarks: Saturated at 57.0'. Water level at completion was 59.6'.

FREES AND NICHOLS, INC.  
The stratification lines represent approximate strata boundaries.  
PLATE A- 21
# LOG OF BORING NO. B-6A

**Project Description:**
SORD SANITARY LANDFILL
ARDMORE, OKLAHOMA

---

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Symbol / USCS</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

### Location:
Surface El.: **855.2' MSL**

---

### MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>52.0</td>
<td>CLAY SHALE, (2.5 YR 4/2) weak red, blocky structure, angular sandstone fragments, hard, slightly moist</td>
</tr>
<tr>
<td>60.7</td>
<td>SAND (SP) (5 YR 7/1) light gray, fine grained, dense to weakly cemented, moist.</td>
</tr>
<tr>
<td></td>
<td>SANDSTONE, hard - refusal with auger @ 70°</td>
</tr>
<tr>
<td>70.0</td>
<td>Hole was dry upon completion</td>
</tr>
</tbody>
</table>

---

### Remarks:
The hole was dry upon completion and at 16 hour reading.

---

### Completion Details:
- **Completion Depth:** 70.0' feet
- **Date Boring Started:** 6/23/94
- **Date Boring Completed:** 6/23/94

---

**FREES AND NICHOLS, INC.**
The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.
### LOG OF BORING NO. B-6A

**Project Description:** SORD SANITARY LANDFILL  
ARDMORE, OKLAHOMA

**Location:**  
Surface El.: 855.2' MSL

**MATERIAL DESCRIPTION**

<table>
<thead>
<tr>
<th>Depth, Feet</th>
<th>Samples</th>
<th>Symbol / USCS</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows / Foot</th>
<th>Pocket Penetrometer, TSF</th>
<th>% Passing No. 200 Sieve</th>
<th>Unit Dry Weight, lb/ft³</th>
<th>Water Content, %</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td></td>
<td></td>
<td>35.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>S1</td>
<td>CLAY (CH), (5 YR 7/1) light gray, low plasticity, hard, moist</td>
<td>40.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>S2</td>
<td>CLAY (CH), (2.5 YR 4/2) weak red, high plasticity, hard, moist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>S3</td>
<td>SAND (SC), (5 YR 7/1) light gray, fine grained, dense, slightly moist</td>
<td>48.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Completion Depth:** 70.0'  
**Remarks:** The hole was dry upon completion and at 16 hour reading.

**Date Boring Started:** 6/23/94  
**Date Boring Completed:** 6/23/94  
**Engineer/Geologist:** JIM CHRISTIE  
**Project No.:** NES93280

*FREESIE AND NICHOLS, INC.*  
The stratification lines represent approximate strata boundaries.  
*Continued Next Page*  
*PLATE A- 19*
## LOG OF BORING NO. B-6A

**Project Description:**
SORD SANITARY LANDFILL
ARDMORE, OKLAHOMA

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Samples</th>
<th>Symbol / USC</th>
<th>Location</th>
<th>Surface El.: 855.2' MSL</th>
</tr>
</thead>
</table>

### MATERIAL DESCRIPTION

Boring located 8' west of B-6. Auger to 35.0' prior to coring.

| Completion Depth: 70.0' |
| Date Boring Started: 6/23/94 |
| Date Boring Completed: 6/23/94 |
| Engineer/Geologist: JIM CHRISTIE |
| Project No.: NES93280 |

Remarks: The hole was dry upon completion and at 16 hour reading.

---

*Continued Next Page*

The stratification lines represent approximate strata boundaries.

---

PLATE A- 18
**LOG OF BORING NO. B-6**

**Location:**
Surface El.: 855.0' MSL

**MATERIAL DESCRIPTION**

<table>
<thead>
<tr>
<th>Depth, Feet</th>
<th>Symbol</th>
<th>Material Description</th>
<th>Total Cc (ppm)</th>
<th>Penetrometer Blows / Foot</th>
<th>No. 200 Sieve</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>S4</td>
<td></td>
<td>26.2' - 27.6' CLAY (CL), light brown</td>
<td>12.0</td>
<td>31</td>
<td>15</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td></td>
<td></td>
<td>19.4</td>
<td>30</td>
<td>14</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S6</td>
<td></td>
<td>SANDSTONE, (10 YR 5/1) gray, hard</td>
<td>8.9</td>
<td>28</td>
<td>13</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No recovery from 32.5' to 35'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total Depth - 35'</td>
<td>35.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:** Water Level at completion was 30.0'. Static Water level was 25.0'.

**Completion Depth:** 35.0'
**Date Boring Started:** 6/23/94
**Date Boring Completed:** 6/23/94
**Engineer/Geologist:** JIM CHRISTIE
**Project No.:** NES93280

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.
**LOG OF BORING NO. B-6**

**Project Description:** SORD SANITARY LANDFILL  
ARDMORE, OKLAHOMA

<table>
<thead>
<tr>
<th>Depth, Feet</th>
<th>Symbol</th>
<th>Material Description</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows/Foot</th>
<th>Pocket Penetrometer, TSP</th>
<th>% Passing No. 200 Sieve</th>
<th>Unit Dry Weight, lb/cu ft.</th>
<th>Water Content, %</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>S1</td>
<td>CLAY (CL), cover material with 0.4' of trash from 1.6' to 2.0'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-10</td>
<td>S2</td>
<td>CLAY (CL), (2.5 YR 5/4) olive brown, high plasticity, hard, scattered sand laminae to 3.4', sand lens from 7' to 8.5', moist.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-20</td>
<td>S3</td>
<td>SAND (SP/SC), (10 YR 8/2) white to G.5 YR 5/4) olive brown, dense, clayey, saturated at 30'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Completion Depth:** 35.0'  
**Remarks:** Water Level at completion was 30.0'. Static Water level was 25.0'.

**Date Boring Started:** 6/23/94  
**Date Boring Completed:** 6/23/94  
**Engineer/Geologist:** JIM CHRISTIE  
**Project No.:** NES93280

**FREES AND NICHOLS, INC.**  
The stratification lines represent approximate in situ, the transition may be gradual.  
PLATE A-16
Augered from 40.0' to 50.0'. No samples were taken.

- Augered into Red CLAY-SHALE @ 40.0'

Total Depth - 50.0'
Water level was 35.8' after completion of boring.
Boring was drilled with 8-inch diameter hollow stem augers and sampled with 3 1/2-inch diameter split tube barrel.

 Completion Depth: 50.0'  Remarks: Water level was 35.8' after completion of boring
 Date Boring Started: 6/24/94  Date Boring Completed: 6/24/94
 Engineer/Geologist: JIM CHRISTIE Project No.: NES93280

FREESIE AND NICHOLS, INC. The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

PLATE A- 15
**LOG OF BORING NO. B-5**

**Project Description:** SORD SANITARY LANDFILL  
ARDMORE, OKLAHOMA

**Location:**  
Surface El.: 816.3' MSL

<table>
<thead>
<tr>
<th>Depth, Feet</th>
<th>Samples</th>
<th>Symbol / USCS</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr</th>
<th>Penetration Blaine</th>
<th>Penetration Erosion</th>
<th>% Passing No. 200 Sieve</th>
<th>Unit Dry Weight, lbf/ft^2</th>
<th>Water Content, %</th>
<th>Liquid Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>-50</td>
<td>S4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-35</td>
<td>S5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:** Water level was 35.8' after completion of boring

**Completion Depth:** 50.0'  
**Date Boring Started:** 6/24/94  
**Date Boring Completed:** 6/24/94  
**Engineer/Geologist:** JIM CHRISTIE  
**Project No.:** NES93280

*Continued Next Page*

**FRESE AND NICHOLS, INC.**  
The stratification lines represent approximate strata boundaries.

PLATE A- 14
LOG OF BORING NO. B-5

Project Description: SORD SANITARY LANDFILL
ARDMORE, OKLAHOMA

Location:
Surface El.: 816.3’ MSL

MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth, ft</th>
<th>Symbol / USCS</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration BR.</th>
<th>Penetration TSP</th>
<th>% Passing No. 200 sieve</th>
<th>Fineness Ratio</th>
<th>Water Content, %</th>
<th>Liquid Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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>
<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>
<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>
<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>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Completion Depth: 50.0’
Remarks: Water level was 35.8’ after completion of boring

Date Boring Started: 6/24/94
Date Boring Completed: 6/24/94
Engineer/Geologist: JIM CHRISTIE
Project No.: NES93280

FREUSE AND NICHOLS, INC.

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

Continued Next Page
LOG OF BORING NO. B-4

Project Description: SORD SANITARY LANDFILL
ARDMORE, OKLAHOMA

Location:
Surface El.: 816.0' MSL

<table>
<thead>
<tr>
<th>Depth, Feet</th>
<th>Samples</th>
<th>Symbol / USCS</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>513</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

MATERIAL DESCRIPTION

- Total Depth: 60.0'
- Hole was dry after completion.
- Date:
  - 6/22 - Dry
  - 6/23 - Dry
  - 6/24 - Dry
- Boring was drilled with 8-inch diameter hollow stem augers and sampled with 3 1/2-inch diameter split tube barrel.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows / Foot</th>
<th>Pocket Penetration, TSP</th>
<th>% Passing No. 200 Sieve</th>
<th>Unit Dry Weight, lb/ft³</th>
<th>Water Content, %</th>
<th>Plastic Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>60.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>48</td>
<td>15</td>
<td>33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks: Hole was dry after completion, and remained dry through 48 hour reading.

Completion Depth: 60.0'
Date Boring Started: 6/20/94
Date Boring Completed: 6/21/94
Engineer/Océologist: JIM CHRISTIE
Project No.: NES93280

The stratification lines represent approximate in situ strata boundaries.
### LOG OF BORING NO. B-4

**Project Description:** SORD SANITARY LANDFILL  
ARDMORE, OKLAHOMA

#### Location:
- Surface El.: 816.0' MSL

#### MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Samples</th>
<th>Symbol</th>
<th>USGS</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Pentavalent Cr (ppm)</th>
<th>Rb (ppm)</th>
<th>Zn (ppm)</th>
<th>K2O (ppm)</th>
<th>MgO (ppm)</th>
<th>Na2O (ppm)</th>
<th>Unit Dry Weight</th>
<th>Liquidity Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>87</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.2</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>89</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.2</td>
<td>20</td>
<td>16</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.9</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>91</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.7</td>
<td>20</td>
<td>14</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>92</td>
<td>CLAY SHALE, (2.5 YR 2/2) very dusky red, medium hard, massive, moist</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.5</td>
<td>84</td>
<td>22</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td></td>
<td>93</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24.9</td>
<td>105</td>
<td>23</td>
<td>82</td>
<td></td>
</tr>
</tbody>
</table>

**Completion Depth:** 60.0'

**Remarks:** Hole was dry after completion, and remained dry through 48 hour reading.

---

**FRESE AND NICHOLS, INC.**

- The stratification lines represent approximate strata boundaries.
- In situ, the transition may be gradual.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Samples</th>
<th>Symbol / USCS</th>
<th>Location:</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows / Foot</th>
<th>Vane Penetration, %</th>
<th>No. Std Deviation</th>
<th>Unit Dry Weight, g/cm³</th>
<th>Water Content, %</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>81</td>
<td></td>
<td></td>
<td>Surface H.: 816.0' MSL</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>82</td>
<td></td>
<td>SAND (SP), (10 YR N8) white, fine-grained, medium</td>
<td>20.2</td>
<td>18.2</td>
<td>4.5</td>
<td>20.2</td>
<td>49</td>
<td>24</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>83</td>
<td></td>
<td>CLAY (CL/CH), (2.5 YR 3/4) dark reddish brown, medium to high plasticity, stiff to hard, moist</td>
<td>8.4</td>
<td>34</td>
<td>8.4</td>
<td>34</td>
<td>13</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>84</td>
<td></td>
<td>SAND (SC), (10 YR N8) white, fine-grained, dense, clayey, moist</td>
<td>5.6</td>
<td>27</td>
<td>5.6</td>
<td>27</td>
<td>13</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17.0</td>
<td>85</td>
<td></td>
<td>CLAY (CL), variegated (10 YR 6/4) light yellowish brown and (5 YR 6/3) light reddish brown, low plasticity, hard, gravelly, moist</td>
<td>6.7</td>
<td>29</td>
<td>6.7</td>
<td>29</td>
<td>12</td>
<td>17</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>86</td>
<td></td>
<td>SAND (SP/SC), (10 YR 6/4) light yellow brown to (10 R 5/2) white, fine to medium grained, dense, clayey in upper 3.0', with cemented zones from 26.8'-27.2' and 36.0'-38.3', moist</td>
<td>6.3</td>
<td>NP</td>
<td>6.3</td>
<td>NP</td>
<td>NP</td>
<td>NP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td>Completion Depth: 60.0'</td>
<td>Remarks: Hole was dry after completion, and remained dry through 48 hour reading.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Continued Next Page

FRESEE AND NICHOLS, INC.

The stratification lines represent approximate strata boundaries.
In situ, the transition may be gradual.

PLATE A- 10
**LOG OF BORING NO. B-3**

**Project Description:** SORD SANITARY LANDFILL  
**ARDMORE, OKLAHOMA**

**Location:**  
Surface El.: 822.4' MSL

<table>
<thead>
<tr>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boring was drilled from 45.0' to 60.0' to accommodate electric logging tools.</td>
</tr>
<tr>
<td>Total Depth: 60.0'</td>
</tr>
<tr>
<td>Water levels:</td>
</tr>
<tr>
<td>6/21 - dry after completion</td>
</tr>
<tr>
<td>6/22 - 38.2'</td>
</tr>
<tr>
<td>6/23 - 35.9'</td>
</tr>
<tr>
<td>6/24 - 32.8'</td>
</tr>
<tr>
<td>Boring was drilled with 8-inch diameter hollow stem augers and sampled with 3 1/2-inch diameter split tube barrel.</td>
</tr>
</tbody>
</table>

**Completion Depth:** 60.0'  
**Remarks:** Hole was dry upon completion. Static water level was 32.5'.

---

**FREESE AND NICHOLS, INC.**

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.
<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Symbol / USCS</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows / Foot</th>
<th>Pocket Penetrometer, TSF</th>
<th>% Passing No. 200 Sieve</th>
<th>Unit Dry Weight, lb/ft³</th>
<th>Water Content, %</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>S6</td>
<td></td>
<td></td>
<td></td>
<td></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>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>S7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>S8</td>
<td>40.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>22.0</td>
<td>30</td>
<td>12</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CLAY SHALE, (2.5 YR 4/2) weak red, medium hard, massive, moist

-saturated at 37.0'

Completion Depth: 60.0'
Date Boring Started: 6/21/94
Date Boring Completed: 6/21/94
Engineer/Geologist: JIM CHRISTIE
Project No.: NES93280

Remarks: Hole was dry upon completion. Static water level was 32.5'

Continued Next Page

The stratification lines represent approximate in situ, the transition may be gradual.

PLATE A-8
<table>
<thead>
<tr>
<th>Depth, Feet</th>
<th>Samples</th>
<th>Symbol / USCDS</th>
<th>Location:</th>
<th>Total C (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Index</th>
<th>Plasticity Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>81</td>
<td></td>
<td>Surface El.: 822.4’ MSL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>SAND (SP), (10YR 6/4) light yellow brown, fine-grained, loose, slightly moist</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>S2</td>
<td></td>
<td>CLAY (CL/CH), (7.5YR 5/4) brown, high plasticity, hard, moist, occasional ferruginous sand laminae</td>
<td>4.5</td>
<td>19.6</td>
<td>52</td>
<td>14</td>
<td>38</td>
</tr>
<tr>
<td>15</td>
<td>S3</td>
<td></td>
<td>SAND (SM/SC), (10YR 7/1) light gray to (5Y 5/2) olive gray, fine to medium grained, dense, silty, cemented from 15.9'-16.2', 17.8'-18.0', 19.0'-20.0', 21.7'-21.8', and 22.1'-22.3', moist</td>
<td>4.5</td>
<td>8.0</td>
<td>25</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>20</td>
<td>S4</td>
<td></td>
<td>15.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>S5</td>
<td></td>
<td>7.0</td>
<td>33.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Completion Depth: 60.0’
Remarks: Hole was dry upon completion. Static water level was 32.5’
**LOG OF BORING NO. B-2**

**SORD SANITARY LANDFILL**  
**ARDMORE, OKLAHOMA**

### Location:
- Surface El.: 836.9' MSL

### MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Symbol</th>
<th>Samples / USCS</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows / Foot</th>
<th>Pocket Penetrometer, TSF</th>
<th>% Passing No. 200 Sieve</th>
<th>Unit Dry Weight, lb/ft³</th>
<th>Water Content, %</th>
<th>Liquid Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>-55</td>
<td>S7</td>
<td></td>
<td>57.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-60</td>
<td>S8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.4</td>
<td>18</td>
<td>13</td>
<td>5</td>
</tr>
</tbody>
</table>

CLAY SHALE, (7.5 YR N4/1) blue gray in upper 0.8', (2.5 YR N4/1) very dusky red from 57.8' to 65.0', hard, massive, moist

Total Depth - 65'
Boring was dry upon completion and remained dry after subsequent checks on 6/22, 6/23, and 6/24.
Boring was drilled with 8-inch diameter hollow stem augers and sampled with 3 1/2-inch diameter split tube barrel.

### Completion Depth:
- 65.0'

### Remarks:
- Hole was dry upon completion. Hole was dry at 48 hour reading.

---

**FREESRE AND NICHOLS, INC.**

The stratification lines represent approximate state boundaries.
# LOG OF BORING NO. B-2

**Project Description:** SORD SANITARY LANDFILL  
ARDMORE, OKLAHOMA

**Location:**  
Surface El.: 836.9’ MSL

## MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth (feet)</th>
<th>Symbol</th>
<th>Samples</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows / Foot</th>
<th>Pocket Penetrometer</th>
<th>% Passing No. 40 Sieve</th>
<th>% Passing No. 80 Sieve</th>
<th>Unit Bulk Density</th>
<th>Water Content, %</th>
<th>Liquid Limit</th>
<th>Plastic Limit</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>84</td>
<td></td>
<td></td>
<td>27.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td>30.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-35</td>
<td></td>
<td></td>
<td>34.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Remarks:**  
Hole was dry upon completion. Hole was dry at 48 hour reading.

**Completion Depth:** 65.0’

**Date Boring Started:** 6/21/94  
**Date Boring Completed:** 6/22/94  
**Engineer/Geologist:** JIM CHRISTIE  
**Project No.:** NES93280

**FRESE AND NICHOLS, INC.**  
The stratification lines represent approximate in situ, the transition may be gradual.

**PLATE A-2**
# LOG OF BORING NO. B-2

**Location:** Surface El.: 836.9' MSL

## MATERIAL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth, ft</th>
<th>Symbol</th>
<th>Description</th>
<th>Total Cr (ppm)</th>
<th>Hexavalent Cr (ppm)</th>
<th>Penetration Blows / Foot</th>
<th>O.C. Concentration %</th>
<th>Plasticity Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>0-5</td>
<td>CLAY (CH), (10 YR 8/3) pale brown, high plasticity, hard, moist</td>
<td>4.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>5-10</td>
<td>SAND (SP), (10 YR 8/1) white, fine grained, dense, moist, saturated @13'</td>
<td>7.6</td>
<td></td>
<td>23.0</td>
<td>57</td>
<td>23</td>
</tr>
<tr>
<td>S3</td>
<td>10-15</td>
<td>CLAY (CH), (10 R 4/4) weak red, high plasticity, very stiff</td>
<td>15.0</td>
<td></td>
<td>4.9</td>
<td>15.1</td>
<td>22</td>
</tr>
<tr>
<td>S4</td>
<td>15-20</td>
<td></td>
<td>4.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td>20-25</td>
<td></td>
<td>4.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Completion Depth:** 65.0'

**Remarks:** Hole was dry upon completion. Hole was dry at 48 hour reading.

---

*The stratification lines represent approximate strata boundaries.*

*In situ, the transition may be gradual.*

---

*Continued Next Page*

---

**FREESE AND NICHOLS, INC.**
**LOG OF BORING NO. B-1**

**Project Description:**  SORD SANITARY LANDFILL
ARDMORE, OKLAHOMA

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Samples</th>
<th>Symbol / USCS</th>
<th>Location:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Surface El.: 843.8' MSL</td>
</tr>
</tbody>
</table>

**MATERIAL DESCRIPTION**

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Symbol / USCS</th>
<th>Location:</th>
</tr>
</thead>
<tbody>
<tr>
<td>89</td>
<td></td>
<td>Saturated</td>
</tr>
<tr>
<td>61.0</td>
<td></td>
<td>CLAY SHALE, hard, massive, moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.5 YR 3/2) Blue grey 61.0' - 61.5'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.5 YR 3/2) dusky red 61.5' - 65.0'</td>
</tr>
<tr>
<td>65.0</td>
<td></td>
<td>Boring was drilled to 85' to accommodate electric logging tool.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TOTAL DEPTH - 85'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Water Levels:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6/23: 1000 - 74'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6/24: 0800 - 58.5'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Boring was drilled with 8-inch diameter hollow stem augers and sampled with 3 1/2-inch diameter split tube barrel.</td>
</tr>
</tbody>
</table>

**Remarks:** Water level was 57.9' upon completion. Static water level was 58.4'.

**Completion Depth:** 85.0'

**Date Boring Started:** 6/22/94
**Date Boring Completed:** 6/22/94
**Engineer/Geologist:** JIM CHRISTIE
**Project No.:** NES93280

FREESE AND NICHOLS, INC. The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.
**LOG OF BORING NO. B-1**

**Project Description:** SORD SANITARY LANDFILL  
ARDMORE, OKLAHOMA

**Location:**  
Surface El.: 843.8' MSL

---

**MATERIAL DESCRIPTION**

<table>
<thead>
<tr>
<th>Depth, ft.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>35.5' to 36.8'</td>
<td>SAND (SM) (2.5 Y 5/2) gray brown to (13 YR 6/2) gray brown, fine grained with grain size increasing with depth, dense, saturated @57.9'</td>
</tr>
</tbody>
</table>

- CLAY (CL) lens from 41.7' to 43.7'

<table>
<thead>
<tr>
<th>Completion Depth:</th>
<th>85.0'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date Boring Started:</td>
<td>6/22/94</td>
</tr>
<tr>
<td>Date Boring Completed:</td>
<td>6/22/94</td>
</tr>
<tr>
<td>Engineer/Geologist:</td>
<td>JIM CHRISTIE</td>
</tr>
<tr>
<td>Project No.:</td>
<td>NES93280</td>
</tr>
</tbody>
</table>

**Remarks:** Water level was 57.9' upon completion. Static water level was 58.4'

*Continued Next Page*
**LOG OF BORING NO. B-1**

**Project Description:** SORD SANITARY LANDFILL

**Location:** ARDMORE, OKLAHOMA

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Samples</th>
<th>Symbol / DECS</th>
<th>Location: Surface El.: 843.8' MSL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Samples</td>
<td>Symbol / DECS</td>
<td>Location: Surface El.: 843.8' MSL</td>
</tr>
<tr>
<td></td>
<td>Samples</td>
<td>Symbol / DECS</td>
<td>Location: Surface El.: 843.8' MSL</td>
</tr>
<tr>
<td></td>
<td>Samples</td>
<td>Symbol / DECS</td>
<td>Location: Surface El.: 843.8' MSL</td>
</tr>
<tr>
<td></td>
<td>Samples</td>
<td>Symbol / DECS</td>
<td>Location: Surface El.: 843.8' MSL</td>
</tr>
</tbody>
</table>

**MATERIAL DESCRIPTION**

<table>
<thead>
<tr>
<th>Depth, feet</th>
<th>Samples</th>
<th>Symbol / DECS</th>
<th>Location: Surface El.: 843.8' MSL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Samples</td>
<td>Symbol / DECS</td>
<td>Location: Surface El.: 843.8' MSL</td>
</tr>
<tr>
<td></td>
<td>Samples</td>
<td>Symbol / DECS</td>
<td>Location: Surface El.: 843.8' MSL</td>
</tr>
<tr>
<td></td>
<td>Samples</td>
<td>Symbol / DECS</td>
<td>Location: Surface El.: 843.8' MSL</td>
</tr>
<tr>
<td></td>
<td>Samples</td>
<td>Symbol / DECS</td>
<td>Location: Surface El.: 843.8' MSL</td>
</tr>
</tbody>
</table>

- **SAND** (SP), (10 YR 8/1) white, fine-grained, loose, slightly moist
  - Depth: 0 to 5
  - Penetration Blows / Foot: 6.5
  - Total Cr (ppm): 17.9
  - NP
  - NP
  - Plasticity Index

- **CLAY** (CL), (10 YR 6/1), gray, low plasticity, stiff, moist
  - Depth: 5 to 10
  - Penetration Blows / Foot: 3.5
  - Total Cr (ppm): 11.5
  - 37
  - 17
  - 20

- **CLAY** (CL/CH) (2.5 YR N/6) gray to (2.5 YR 4/2) weak red, high plasticity, hard, occasional sand lens, slightly moist
  - Depth: 10 to 20
  - Penetration Blows / Foot: 4.5
  - Total Cr (ppm): 11.7
  - 38
  - 18
  - 20

- **SANDSTONE** from 20.5' to 20.8'
  - Depth: 20 to 25
  - Penetration Blows / Foot: 4.5
  - Total Cr (ppm): 19.1
  - 57
  - 23
  - 34

**Remarks:** Water level was 57.9' upon completion. Static water level was 58.4'.

**Completion Depth:** 85.0'

**Date Boring Started:** 6/22/94

**Date Boring Completed:** 6/22/94

**Engineer/Geologist:** JIM CHRISTIE

**Project No.:** NES93280

**FREESE AND NICHOLS, INC.**

The stratification lines represent approximate strata boundaries. In situ, the transition may be gradual.

*Continued Next Page*
GROUND SURFACE

PROTECTIVE COVER: LOCKABLE STEEL COVER.

STICK UP: RISER PIPE EXTENDED TO APPROXIMATELY 3-FT ABOVE GROUND SURFACE.

CONCRETE APRON: 2-FT X 2FT X 4-IN THICK EXTENDING TO CASING SEAL

RISER PIPE: 2-IN PVC SCHEDULE 40 PIPE WITH FLUSH THREADED JOINTS

SCREEN: 2-IN PVC SCHEDULE 40 PIPE WITH FACTORY SLOTTED SCREEN (0.010-IN).

END CAP: 4-IN SCHEDULE 40 PVC Threaded Endcap

CASING SEAL: Bentonite chips, cement/bentonite grout, or bentonite grout placed from annular seal to within 2-ft of ground surface.

ANNULAR SEAL: At least 2-ft of hydrated bentonite placed on top of sand.

SAND FILTER: Silica sand, placed to 2-ft above the top of screen.
Appendix A

Boring Logs and Well Construction Diagram
NOTES:

1. BACKGROUND IMAGERY RETRIEVED FROM GOOGLE MAPS.
Figures
### Table 4
**Background and Routine Monitoring Parameters**

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oklahoma Groundwater Quality Constituents</strong></td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Carbonates</td>
<td>mg/L</td>
</tr>
<tr>
<td>Chemical Oxygen Demand</td>
<td>mg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>mg/L</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Nitrate/Nitrite</td>
<td>mg/L</td>
</tr>
<tr>
<td>pH</td>
<td>S.U.</td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Specific Conductivity</td>
<td>umhos/cm</td>
</tr>
<tr>
<td>Sulfate</td>
<td>mg/L</td>
</tr>
<tr>
<td>Total Dissolved Solids</td>
<td>mg/L</td>
</tr>
<tr>
<td><strong>Oklahoma Appendix A Constituents</strong></td>
<td></td>
</tr>
<tr>
<td>Acetone</td>
<td>ug/L</td>
</tr>
<tr>
<td>Acrylonitrile</td>
<td>ug/L</td>
</tr>
<tr>
<td>Antimony</td>
<td>mg/L</td>
</tr>
<tr>
<td>Arsenic</td>
<td>mg/L</td>
</tr>
<tr>
<td>Barium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Benzene</td>
<td>ug/L</td>
</tr>
<tr>
<td>Beryllium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Bromochloromethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>Bromodichloromethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>Bromoform; Tribromomethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td>ug/L</td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td>ug/L</td>
</tr>
<tr>
<td>Chlorobenzene</td>
<td>ug/L</td>
</tr>
<tr>
<td>Chloroethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>Chloroform</td>
<td>ug/L</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Cobalt</td>
<td>mg/L</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/L</td>
</tr>
<tr>
<td>Dibromochloromethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,2-Dibromo-3-chloropropene</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,2-Dibromoethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,2-Dichlorobenzene</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,4-Dichlorobenzene</td>
<td>ug/L</td>
</tr>
<tr>
<td>trans-1,4-Dichloro-2-butene</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,1-Dichloroethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,2-Dichloroethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,1-Dichloroethene</td>
<td>ug/L</td>
</tr>
<tr>
<td>cis-1,2-Dichloroethene</td>
<td>ug/L</td>
</tr>
<tr>
<td>trans-1,2-Dichloroethene</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,2-Dichloropropane</td>
<td>ug/L</td>
</tr>
<tr>
<td>cis 1,3-Dichloropropene</td>
<td>ug/L</td>
</tr>
<tr>
<td>trans 1,3-Dichloropropene</td>
<td>ug/L</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>ug/L</td>
</tr>
<tr>
<td>2-Hexanone</td>
<td>ug/L</td>
</tr>
<tr>
<td>Lead</td>
<td>ug/L</td>
</tr>
<tr>
<td>Bromomethane</td>
<td>mg/L</td>
</tr>
<tr>
<td>Chloromethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>Dibromomethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>Diphenylethylene</td>
<td>ug/L</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>ug/L</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>ug/L</td>
</tr>
<tr>
<td>Methyl iodide</td>
<td>ug/L</td>
</tr>
<tr>
<td>4-Methyl-2-pentanone</td>
<td>ug/L</td>
</tr>
<tr>
<td>Nickel</td>
<td>mg/L</td>
</tr>
<tr>
<td>Selenium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Silver</td>
<td>mg/L</td>
</tr>
<tr>
<td>Styrene</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,1,1,2-Tetrachloroethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,1,2,2-Tetrachloroethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>Tetrachloroethylene</td>
<td>ug/L</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>ug/L</td>
</tr>
<tr>
<td>Thallium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Toluene</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,1,1-Trichloroethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,1,2-Trichloroethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>Trichloroethene</td>
<td>ug/L</td>
</tr>
<tr>
<td>Trichlorofluoromethane</td>
<td>ug/L</td>
</tr>
<tr>
<td>1,2,3-Trichloropropane</td>
<td>ug/L</td>
</tr>
<tr>
<td>Vanadium</td>
<td>mg/L</td>
</tr>
<tr>
<td>Vinyl acetate</td>
<td>ug/L</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>ug/L</td>
</tr>
<tr>
<td>Xylenes</td>
<td>ug/L</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/L</td>
</tr>
</tbody>
</table>

**Field Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth to water</td>
<td>feet</td>
</tr>
<tr>
<td>Total well depth</td>
<td>feet</td>
</tr>
<tr>
<td>Temperature</td>
<td>°F</td>
</tr>
<tr>
<td>Specific conductivity</td>
<td>umhos/cm</td>
</tr>
<tr>
<td>pH</td>
<td>S.U.</td>
</tr>
<tr>
<td>Monitoring Point</td>
<td>Monitoring Location</td>
</tr>
<tr>
<td>------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>MW-1</td>
<td>Upgradient</td>
</tr>
<tr>
<td>MW-3</td>
<td>Downgradient</td>
</tr>
<tr>
<td>MW-6</td>
<td>Upgradient</td>
</tr>
<tr>
<td>MW-7</td>
<td>Downgradient</td>
</tr>
<tr>
<td>MW-8</td>
<td>Downgradient</td>
</tr>
<tr>
<td>MW-9</td>
<td>Downgradient</td>
</tr>
<tr>
<td>MW-10</td>
<td>Downgradient</td>
</tr>
<tr>
<td>MW-11</td>
<td>Downgradient</td>
</tr>
</tbody>
</table>
### Table 2
Historical Groundwater Elevations

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ-1</td>
<td>31.23</td>
<td>31.75</td>
<td>31.60</td>
<td>31.45</td>
<td>31.50</td>
<td>31.35</td>
<td>31.65</td>
<td>31.50</td>
<td>31.45</td>
<td>31.50</td>
<td>31.40</td>
<td>31.50</td>
<td>750.2644</td>
</tr>
<tr>
<td>PZ-2</td>
<td>48.39</td>
<td>48.80</td>
<td>48.80</td>
<td>48.80</td>
<td>48.65</td>
<td>48.70</td>
<td>49.00</td>
<td>49.05</td>
<td>49.00</td>
<td>49.00</td>
<td>48.90</td>
<td>48.75</td>
<td>761.3274</td>
</tr>
<tr>
<td>PZ-3</td>
<td>44.36</td>
<td>44.65</td>
<td>44.70</td>
<td>44.75</td>
<td>44.8</td>
<td>44.50</td>
<td>45.10</td>
<td>45.05</td>
<td>45.00</td>
<td>44.90</td>
<td>44.85</td>
<td>44.90</td>
<td>758.249</td>
</tr>
<tr>
<td>PZ-4</td>
<td>53.92</td>
<td>53.75</td>
<td>53.40</td>
<td>53.20</td>
<td>53.30</td>
<td>53.15</td>
<td>53.85</td>
<td>53.25</td>
<td>53.20</td>
<td>53.40</td>
<td>53.35</td>
<td>53.50</td>
<td>759.9752</td>
</tr>
<tr>
<td>PZ-5</td>
<td>36.61</td>
<td>36.15</td>
<td>35.40</td>
<td>34.50</td>
<td>35.20</td>
<td>35.00</td>
<td>34.75</td>
<td>35.40</td>
<td>35.25</td>
<td>35.10</td>
<td>35.20</td>
<td>35.10</td>
<td>727.7693</td>
</tr>
<tr>
<td>PZ-9</td>
<td>30.64</td>
<td>30.75</td>
<td>30.85</td>
<td>30.90</td>
<td>30.70</td>
<td>30.65</td>
<td>30.90</td>
<td>31.05</td>
<td>31.00</td>
<td>31.00</td>
<td>31.00</td>
<td>31.10</td>
<td>747.6212</td>
</tr>
<tr>
<td>PZ-16</td>
<td>65.22</td>
<td>65.35</td>
<td>65.10</td>
<td>64.90</td>
<td>65.00</td>
<td>64.70</td>
<td>65.00</td>
<td>65.10</td>
<td>65.00</td>
<td>65.00</td>
<td>65.05</td>
<td>65.00</td>
<td>766.2392</td>
</tr>
<tr>
<td>PZ-17</td>
<td>27.31</td>
<td>27.70</td>
<td>27.15</td>
<td>26.95</td>
<td>27.10</td>
<td>26.40</td>
<td>26.20</td>
<td>27.30</td>
<td>27.10</td>
<td>27.20</td>
<td>27.25</td>
<td>27.10</td>
<td>768.1514</td>
</tr>
<tr>
<td>PZ-19</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
</tr>
<tr>
<td>PZ-20</td>
<td>51.40</td>
<td>51.60</td>
<td>50.45</td>
<td>50.55</td>
<td>50.70</td>
<td>50.40</td>
<td>51.65</td>
<td>50.95</td>
<td>51.00</td>
<td>50.90</td>
<td>51.00</td>
<td>50.95</td>
<td>782.7632</td>
</tr>
<tr>
<td>PZ-1</td>
<td>33.49</td>
<td>33.80</td>
<td>32.90</td>
<td>33.10</td>
<td>32.75</td>
<td>32.40</td>
<td>33.25</td>
<td>33.10</td>
<td>33.20</td>
<td>33.10</td>
<td>32.95</td>
<td>33.05</td>
<td>782.2546</td>
</tr>
<tr>
<td>PZ-6</td>
<td>20.02</td>
<td>20.85</td>
<td>20.70</td>
<td>20.80</td>
<td>20.70</td>
<td>20.55</td>
<td>20.40</td>
<td>20.50</td>
<td>20.50</td>
<td>20.50</td>
<td>20.50</td>
<td>20.50</td>
<td>838.7465</td>
</tr>
<tr>
<td>PZ-7</td>
<td>53.46</td>
<td>53.90</td>
<td>53.50</td>
<td>53.40</td>
<td>53.20</td>
<td>53.25</td>
<td>53.60</td>
<td>53.45</td>
<td>53.50</td>
<td>53.40</td>
<td>53.30</td>
<td>53.50</td>
<td>778.7946</td>
</tr>
<tr>
<td>MW-2R</td>
<td>81.96</td>
<td>81.70</td>
<td>81.60</td>
<td>81.40</td>
<td>81.20</td>
<td>81.55</td>
<td>82.20</td>
<td>81.70</td>
<td>81.50</td>
<td>81.55</td>
<td>81.40</td>
<td>81.50</td>
<td>754.33</td>
</tr>
<tr>
<td>MW-4</td>
<td>27.49</td>
<td>27.90</td>
<td>27.60</td>
<td>26.65</td>
<td>28.00</td>
<td>27.60</td>
<td>28.00</td>
<td>27.95</td>
<td>27.70</td>
<td>27.60</td>
<td>27.40</td>
<td>27.60</td>
<td>753.73</td>
</tr>
</tbody>
</table>

**Notes**

All measurements have units of feet MSL
<table>
<thead>
<tr>
<th>Well ID</th>
<th>Monitoring Location</th>
<th>Monitoring Status</th>
<th>Northing</th>
<th>Easting</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Surface Elevation (MSL)</th>
<th>Top of Casing Elev. (MSL)</th>
<th>Total Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW-1</td>
<td>Upgradient</td>
<td>Detection</td>
<td>317365</td>
<td>2257165</td>
<td>N34° 12' 05.96&quot;</td>
<td>W97° 2' 43.09&quot;</td>
<td>832</td>
<td>863.32</td>
<td>51.74</td>
</tr>
<tr>
<td>MW-2R</td>
<td>Downgradient</td>
<td>Detection</td>
<td>318911</td>
<td>2257725</td>
<td>N34° 12' 21.20&quot;</td>
<td>W97° 2' 36.25&quot;</td>
<td>795</td>
<td>833.9</td>
<td>51.75</td>
</tr>
<tr>
<td>MW-3</td>
<td>Downgradient</td>
<td>Detection</td>
<td>318897</td>
<td>2256448</td>
<td>N34° 12' 21.18&quot;</td>
<td>W97° 2' 51.46&quot;</td>
<td>808</td>
<td>842.70</td>
<td>44.50</td>
</tr>
<tr>
<td>MW-4</td>
<td>Downgradient</td>
<td>Detection</td>
<td>319943</td>
<td>2256721</td>
<td>N34° 12' 31.50&quot;</td>
<td>W97° 2' 48.09&quot;</td>
<td>758</td>
<td>780.38</td>
<td>34.01</td>
</tr>
<tr>
<td>MW-5</td>
<td>Downgradient</td>
<td>Detection</td>
<td>319964</td>
<td>2257437</td>
<td>N34° 12' 31.64&quot;</td>
<td>W97° 2' 39.57&quot;</td>
<td>756</td>
<td>772.72</td>
<td>22.60</td>
</tr>
</tbody>
</table>

**Notes**
Groundwater data provided by Enviro Clean Cardinal, LLC
Tables
9.0 REFERENCES

SCS Engineers, 2018, Hydrogeologic and Geotechnical Investigation.


8.0 MONITORING REPORTS

Groundwater monitoring reports will be submitted for newly installed monitoring wells, background sampling, and routine monitoring.

8.1 MONITORING WELL INSTALLATION

A report summarizing monitoring well installation activities with a location map, boring log, and monitoring well completion diagram will be submitted to the OWRB and ODEQ on forms prescribed by the OWRB. The report will include the well development details and survey coordinates and elevations. The monitoring well installation report will be submitted within 60 days of installation of the monitoring well or last monitoring well of a group and may be submitted as part of the routine monitoring report.

8.2 BACKGROUND SAMPLING REPORT

A report summarizing the background sampling, statistical analysis, and results will be submitted to the ODEQ within 60 days of the last background sampling event. The report will include field data, monitoring well location maps, laboratory results, and statistical evaluations and summaries.

8.3 ROUTINE GROUNDWATER MONITORING REPORTS

A report summarizing the semi-annual sampling event will be submitted to the ODEQ within 60 days of the sampling date. The report will include field data, monitoring well location maps, groundwater flow summaries, laboratory results, and statistical evaluations and summaries.
If one or more assessment monitoring constituents are detected at statistically significant levels above the groundwater protection standard of OAC 252:515-9-96 in any sampling event, the SORD shall within 14 days of the finding:

- Notify the ODEQ in writing and place a notice in the operating record identifying the constituents that have exceeded the background levels;
- By certified mail with return receipt requested notify all persons who own the land or minerals or who reside on the land that directly overlies any part of the plume of contamination within one year time of travel if contaminants have migrated off-site;
- Submit for ODEQ a proposed plan and schedule for analyzing the environmental release from the facility and for developing appropriate corrective action;
- Submit to the ODEQ a copy of the notice sent to adjacent property owners along with a list of who was notified;
- Characterize the nature and extent of the release by installing additional monitoring wells as necessary; and
- Initiate an assessment of corrective action within 90 days.

7.2 CORRECTIVE MEASURES

If the assessment monitoring does not eliminate the landfill as the source of the SSI, then a corrective action program will be implemented following the described methods in OAC 252:515-9 Part 11 and Part 15.
7.0 STATISTICALLY SIGNIFICANT INCREASE

If there is a verified statistically significant increase (SSI) over background levels for one or more constituents at any monitoring well, the SORD:

- Must notify the ODEQ in writing within 14 days of the determination and place a notice in the operating record indicating which constituents have shown statistically significant changes from background levels; and
- Must establish an assessment monitoring program as discussed in Section 7.1 within 90 days of the determination and have the assessment monitoring program approved by the ODEQ; or
- May, during the 90-day development of an assessment monitoring program, demonstrate that a source other than the facility caused the contamination or that the SSI resulted from error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. A report documenting this demonstration shall be submitted to the ODEQ for approval.

If a successful demonstration is approved by the ODEQ, detection monitoring shall continue. If, at the end of the 90-day period, a successful demonstration is not made, the assessment monitoring program must be initiated.

7.1 ASSESSMENT MONITORING

Assessment monitoring shall be conducted at a frequency specified by the ODEQ. Groundwater shall be sampled and analyzed for the groundwater quality constituents in Table 4 as well as the constituents listed in Appendix C of OAC 252:515. The list of monitored constituents may be reduced with approval from the ODEQ. A minimum of one sample from each downgradient well and a minimum of four independent samples from each well shall be collected and analyzed to establish background for any detected constituents that are listed in Appendix C of OAC 252:515. The ODEQ may specify a subset of wells to be sampled and analyzed during assessment monitoring.

After obtaining the results from the initial assessment monitoring sampling event, the SORD must notify the ODEQ in writing within 14 days and place a notice in the operating record identifying the constituents that have been detected. Within 90 days and on at least a semi-annual basis thereafter, the SORD shall:

- Resample all wells;
- Conduct analyses for all constituents in the detection monitoring program and any other constituents specified by the ODEQ;
- Notify the ODEQ in writing and record the concentrations in the operation record; and
- Establish background concentrations for any constituents detected that are listed in Appendix C of OAC 252:515.

If the concentration of all assessment monitoring constituents is at or below background values for two consecutive sampling events using the approved statistical procedure, the SORD shall notify the ODEQ in writing and may return to detection monitoring upon approval by the ODEQ.
The use of laboratory-specific PQLs (or EQLs) already incorporates a measure of the statistical uncertainty that is associated with the measurement process. Any VOC detected and verified at a concentration above the PQL (or EQL) would be statistically significant, and therefore trigger assessment monitoring. These decision rules apply only in cases where the constituent has rarely, or never, been detected in background. VOCs detected at concentrations between the MDL and PQL will be reported but will not be considered statistically significant unless a verified concentration above the PQL is detected.

6.3 INORGANIC PARAMETERS

The statistical methodology for inorganic parameters in Detection Monitoring will include an intra-well and inter-well comparison of the detected constituent to the background data population for that constituent. The statistical limits for the background data set will be calculated using normal, lognormal, and nonparametric prediction limits depending on the distribution of the data set. A statistical program using combined Shewhart-CUSUM control charts and/or Prediction Interval Limits will be utilized in accordance with Unified Guidance Chapters 18-20.

For new monitoring wells, once four (4) rounds of background samples and one (1) detection event have been collected, an appropriate statistical method will be proposed to evaluate the data from these wells. Data evaluation will be performed in accordance with the Unified Guidance.
6.0 DATA EVALUATION

This section outlines the proposed evaluation methodology that will be used for detection of a release from the facility, utilizing PQLs (EQLS) as the reporting concentration limits for VOCs, and the Shewart-CUSUM control chart and/or Prediction Limits statistical comparisons. Data evaluation will be performed in accordance with the March 2009 Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance EPA 530/R-09-007 (Unified Guidance).

During background sample collection it will be necessary to examine the data for outliers, anomalies, and trends that might be an indication of a release. Outliers and anomalies are inconsistently large or small values that can occur due to sampling, laboratory, transportation or transcription errors, or even by chance alone. Significant trends indicate a source of systematic error or an actual contamination occurrence that must be evaluated and corrected before the detection monitoring program can be implemented. The inclusion of such values in the historical database used for statistical evaluation could cause misinterpretation of the data set and result in an artificial increase in the magnitude of statistical limits, which could result in an increase in the false negative rate (i.e., a decrease in the sensitivity of the statistical procedure).

To remove the possibility of historical outliers and trends creating false statistical limits, the data for each well and each constituent will be tested for the existence of outliers. Outliers in background data will be determined in accordance with Chapter 12 of the Unified Guidance. If a sample collected during background is found to be above the critical value for the sample of size (n-1), then the value is not used in the establishment of the statistical limit from the background data set. Outliers may be removed from consideration during the establishment of all statistical limits if some basis for a likely error or data discrepancy can be identified (Unified Guidance Section 5.2.3).

The statistical outlier and trend detection procedure will be performed for those wells that have had at least five (5) measurements for a given constituent. Once the background database is established, the outlier procedure described above may be applied and appropriate statistical limits set in accordance with the Unified Guidance.

6.1 STATISTICAL METHODOLOGY

For Detection Monitoring, this program will involve intra-well and inter-well analysis based on a comparison of well constituent concentrations to background data. Data evaluation will be performed in accordance with the Unified Guidance.

6.2 VOLATILE ORGANIC COMPOUNDS

PQLs assure that the quantitative value of the analyte is close to the measured value. Conversely, method detection limits (MDLS) indicate that the analyte is present in the sample with a specified degree of confidence. For analytes with estimated concentrations greater than the MDL but not the PQL, it can only be concluded that the true concentration is greater than zero; the actual concentration cannot be determined.
All standards and reagents used in laboratory procedures will be inventoried, labeled, logged and documented in accordance with Inorganics, Inorganics/Chemical Methods and Robotics, Semivolatiles and Volatiles documentation procedures. All stock standards shall be purchased as certified primary solutions from reputable, commercial lab suppliers, and prepared from neat chemicals with certified purity. Stock standards shall be combined and/or diluted into secondary dilution standards, which are then diluted into working standards.

5.3 INSTRUMENT MAINTENANCE

Routine maintenance is performed and documented for all major instruments. In addition, any service agreements for laboratory equipment are renewed annually. The EPA's "Good Automated Laboratory Practices" (GALPs) shall be followed in the laboratory.

5.4 METHOD DETECTION LIMITS

Method Detection Limits (MDLs) will be updated annually per method and matrix. The MDL findings are produced annually.
5.0 LABORATORY QUALITY CONTROL

5.1 ANALYTICAL BLANKS AND SPIKES

The selected laboratory will use method quality control procedures that are equivalent to those described in "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition, Final Update IV, February 2007" or an equivalent substitute as approved by ODEQ. Duplicate samples, method blanks, instrument/reagent blanks, matrix spikes, blank/water reagent spikes and surrogate spikes are typical quality control checks performed throughout the analytical process. With the exception of instrument/reagent blanks and surrogate spikes, these checks are performed at a frequency of 5% or 10% (i.e., 1 in 20 samples, 1 in 10 samples). Instrument/reagent blanks and surrogate spikes are performed on a daily or per sample (where required by method) frequency. Each of the above applied Quality Control checks will be compared against the Acceptance Criterion for each QC check to ensure that analytical quality is maintained.

The method blank is a blank solution which is treated as a sample for the parameter being measured, including all pretreatment/preparation procedures, and is analyzed in the same manner as the well samples to assess analytical accuracy and the potential for sample contamination. Instrument/reagent blanks are prepared on a daily basis (where used) to detect contamination or interferences in the sample treatment solvents and chemicals to ensure that none of these applied chemicals could systematically bias sample results.

Matrix spikes are well samples fortified with known concentrations of analytes expected to be in the sample. The percent recovery of any spiked analyte is taken as a measure of the bias of the analytical method caused by the sample matrix. Blank/reagent water spikes are blank solutions fortified with known concentrations of analytes expected to be in samples. These spikes may (reagent water spikes) or may not (blank spike) be taken through the full analytical procedure prior to analysis. The percent recovery of any spiked analyte is taken as a measure of control on the analytical procedure. Surrogate spikes are utilized where a compound of known amount which is not expected to be in the environmental sample is added to the sample. Volatile Organic Compound analysis uses this type of spike to measure method extraction efficiency. This spike is performed on every sample and QC sample where the analytical method requires it.

5.2 INSTRUMENT CALIBRATION

Applicable instruments are calibrated using calibration standards and method-specified calibration criteria. A solution containing various compounds of known concentrations is diluted and analyzed to establish calibration curves and is performed daily or per the method to monitor the accuracy and precision of the instrument. Instrument calibration is verified by analyzing a solution containing a known concentration of the pure compound(s) of interest and comparing it against the calibration curve. This standard compound is taken from the same stock as that used to develop the calibration curve. Calibration verification is done at a 5% frequency, or as the method requires, to check the stability of the calibration curve as well as the accuracy and precision of the system or analyst.
4.0 SAMPLE QUALITY CONTROL/QUALITY ASSURANCE

Quality control and quality assurance (QA/QC) samples will be collected to assist in maintaining the integrity of the data. The QA/QC samples are an integral part of maintaining the validity of the data and, therefore, are subject to the same handling and chain of custody protocols as the groundwater samples.

Groundwater samples will be collected in a manner so that chemical testing and evaluation of the samples will provide an accurate representation of the quality of the in-situ groundwater at the depth and location screened in the aquifer. This will require that all field equipment be calibrated prior to use and re-calibrated in the field before use, as necessary. Additionally, a number of factors must be considered that can affect the quality of the groundwater samples. These include the preparation of sample containers, sample collection, sample packaging and shipping, and laboratory analysis. As an aid in the detection and identification of errors, several types of field samples have been devised for quality assurance and quality control.

4.1 FIELD, TRIP, AND EQUIPMENT BLANKS

Trip and field blanks will be utilized during each round of sampling at the site. The trip blank will be provided by the analytical laboratory supplying the sample container. The trip blank, containing laboratory-grade deionized water will remain unopened and sent from and to the laboratory in the same manner as the site well samples. A field blank will be prepared in the field by pouring laboratory-grade deionized water into one of the clean sample containers opened in the field. The field blank will then be sealed and shipped in the same manner as the environmental samples. In the event that non-dedicated sampling equipment is utilized, a field equipment (rinse) blank will be prepared by rinsing laboratory-grade deionized water over the sampling equipment immediately subsequent to decontamination and prior to sampling and capturing the rinse water in a sample container.

4.2 DUPLICATE SAMPLE

A duplicate sample will be collected from one well during each round of sampling at the site. The duplicate sample will be collected in the field using a matching set of sampling bottles and preservatives as the regular sample. Each duplicate sample will be collected by alternating filling between the regular sample bottles and the duplicate sample bottles, proceeding in the designated sampling order (i.e. VOAs first). Duplicate samples should not be physically different from regular samples in color, turbidity, or other physical characteristics.
3.7 Sample Preservation

Sample containers, preservation, handling, and analysis will meet the specifications described by "Test Methods for Evaluating Solid Waste Physical/Chemical Methods, third edition, Final Update IV, February 2007" or an equivalent substitute as approved by ODEQ. Sample containers will be supplied by the laboratory for each sampling event. The sample containers will be labeled to indicate the test parameters required. The appropriate preservatives will be added to each sample container based on the required analytical method.

3.8 Chain of Custody

Chain-of-Custody procedures will allow for the possession and handling of samples to be traced from the time of collection through laboratory analysis. All sample containers will be labeled to avoid misidentification, have proper seals, and indicate test parameters required. Chain-of-Custody procedures will prevent potential tampering with samples collected. At the time each sample is collected, Chain-of-Custody will be completed and placed in the sample-shipping container.

3.9 Sample Shipment

After collection and sample preservation, the labeled sample containers will be placed in an insulated shipping container using frozen ice packs or other suitable frozen material for temperature control. All samples included in the sample container will be packed in a manner which will minimize the potential for container breakage. An original Chain of Custody Form will be sealed in a water resistant bag and placed with the appropriate sample bottle set. A copy will be maintained by the sampling personnel. Actual forms utilized may vary in format, but the information indicated is considered typical. The sample container will then be sealed with a custody seal for detection of unauthorized opening or potential tampering with sample containers and sent to the designated analytical laboratory. All shipments will be scheduled for next day delivery. The temperature of the samples will be recorded when the sample container arrives at the analytical laboratory to assure that the appropriate sample temperature was maintained during shipment.
Purging may be considered complete when:

- Standard 3 to 5 well volume method - A minimum of three well volumes (based upon well construction records) have been evacuated from the well and two of the field measured parameters (pH, specific conductance and temperature) have stabilized, or to 5 well volumes, or until the well is pumped/bailed dry. If standard purge methods are used, then the well volume can be determined by using the inset chart. If three well volumes cannot be obtained due to the well being pumped or bailed dry, the well will be allowed to recover and then sampled. If sufficient water is not available for sampling within 24 hours of purging for slowly recovering wells, the well will be considered dry, and no sample will be collected.

- If low-flow (or minimal drawdown) techniques are used, purging activities will be accomplished using flow-control submersible bladder pumps. Purging rates will be monitored and depth to water measurements recorded to assure that evacuation rates do not induce a substantial lowering of the potentiometric head elevation within the well. Flow rates will vary for each well, but rates of approximately 0.1 to 0.5 L/min are typical. Purging of pump discharge lines is necessary prior to the collection of field parameter samples for field analysis using appropriate meters.

### 3.6 Sample Collection

Samples will be collected from each well using either a dedicated or disposable Teflon or polyethylene bailer or through the discharge of pumps used to evacuate the well. Samples will be collected at a rate that minimizes potential alteration of the sample due to agitation or oxidation. Pumping rates for collection of samples for volatiles analysis (VOAs, etc.) will be approximately 0.1 L/min or less, to the extent practical based on the sampling equipment used. Pumping rates for collection of other analyses may be increased, but will be adjusted to a rate that also prevents chemical alteration.

If low-flow sampling methods are employed, the sampling rate is not to exceed the purging rate, with flow rates of approximately 0.1 to 0.5 L/min recommended (EPA/540/S-95/504). Sampling pumps are to be operated in a continuous manner so that they do not produce samples that are aerated in the return tube or upon discharge. Groundwater samples will be collected as soon as possible after well evacuation.

Samples will be collected and containerized in the order of the volatilization sensitivity of the parameter (i.e., volatile organics, organic compounds, inorganic species, and major cations and anions). The samples will be collected in appropriate containers with the appropriate sample preservative as described in subsequent sections.
3.4 Water Level Measurements

Prior to groundwater purging and sampling, water level measurements will be taken at each well location utilizing a dedicated or portable water level indicator, tape, or other suitable measuring device capable of achieving an accuracy of 0.01 foot. The measuring device will be used in accordance with the manufacturer's recommendations and/or directions. Prior to measuring, all equipment which may contact the groundwater will be decontaminated with distilled water. All wells will be measured for depth to water immediately prior to purging. Measurements of the depth to water from the top of the well casing will be to the nearest 0.01 foot, and the values will be recorded on the Field Sampling Sheets. Total well depths shall be obtained annually or if evidence of well tampering exists.

3.5 Well Purging

Immediately prior to sampling at each well location, the water within the well will be evacuated until measured water quality parameters indicate that formation water has entered the well or until a sufficient volume of water has been removed to assure that stagnant water has been purged from the well. The wells will be evacuated using the standard 3 to 5 well volume purging method or by low-flow (minimal drawdown) sampling methods. Low-flow sampling methods are preferred. If low-flow methods are used, all procedures will be in accordance with EPA/540/S-95/504, "Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures". This document has been included as Appendix C.

Procedures for low-flow sampling will include:

- Draw down will be attempted to be kept to a minimum.
- Purging is complete when at least three parameters of the field measured water quality parameters have stabilized for 3 successive readings.
- At least one volume of tubing & pump purged before readings are counted. The volume of tubing & pump will be written on field datasheets along with cumulative volumes and times of parameter readings.
- At least 3 minutes minimum between parameter readings

During purging, representative samples of discharged water are to be periodically collected in clean containers or through a continuous flow cell and analyzed for field water quality parameters. Parameter results will be used to evaluate groundwater characteristics to aid in determining when formation water is entering the well. At a minimum, the following parameters will be measured in the field: pH, specific conductance, turbidity, and temperature. Other field parameters such as dissolved oxygen (DO) and oxidation-reduction (redox) potential may be used to assist in evaluating purge effectiveness. Water quality parameters can be considered stable if three successive readings are within ±0.1 for pH, ±3% for conductivity, ±10 mv for redox potential, and ±10% for turbidity and DO. It should be noted that the turbidity reading is desired to stabilize at a value below 10 Nephelometric Turbidity Units (NTUs).
3.0 SAMPLING PROCEDURES

The following subsections summarize specific tasks involved in sampling of the groundwater monitoring system. Samples will be obtained from the facility groundwater monitoring system by a sampling technician fully trained in the required sampling procedures.

3.1 Well Inspection

Prior to performing any purging or sampling, each monitoring well will be inspected to assess integrity of the well components. The condition of each well will be evaluated for any physical damage that may have been caused by the operation of site equipment or other vehicular traffic. The security of each well will be assessed in order to confirm that no outside source contaminants have been introduced to the well. All inspection information, as well as the date and time, general weather conditions, and sampling personnel identification, will be documented on the Field Sampling Sheet presented in Appendix B. The actual form utilized may vary in format but the information indicated will be recorded.

3.2 Sample Collection Procedures

For sample collection, each monitoring well in the groundwater monitoring system will be sampled utilizing equipment and methodologies that minimize the potential for alteration or contamination of the sample and that are capable of obtaining a sample representative of the formation groundwater. Care will be taken to avoid placing clean sampling equipment on the ground or on any contaminated surface. Additionally, personnel who contact sampling equipment which may contact the interior of the monitoring well or the groundwater shall wear powderless latex (or equivalent) gloves. If contamination is known to exist at certain locations, non-contaminated wells will be sampled prior to those wells which are known to be contaminated.

3.3 Equipment Decontamination

All equipment which may contact the interior of the well or groundwater will be decontaminated in the field immediately prior to use, or in the office/lab and protected using aluminum foil and/or plastic bags. Decontamination procedures will be documented for each sampling event. The decontamination procedure will consist of the following steps:

- Wash with laboratory grade soap (such as Alconox or Liquinox);
- Triple rinse with distilled or deionized water; and
- Air dry prior to use.

Personnel who contact sampling equipment subsequent to decontamination shall wear powderless latex (or equivalent) gloves. Gloves will be replaced immediately if they become contaminated or torn.
2.2.3 Monitoring Constituents

The constituents for background and detection monitoring are listed in OAC 252:515-9-31(d) and include pH and specific conductance at each groundwater monitoring point. The background and detection monitoring parameters are listed in Table 4. These constituents shall be used unless alternative constituents are approved in accordance with OAC 252:515-9-72.
2.1.3 Monitoring Well Redevelopment
Monitoring wells will be redeveloped when 15% or more of the well screen is occluded or the turbidity appears to be increasing. Monitoring well redevelopment will follow the procedures listed above.

2.1.4 Monitoring Well Sealing and Abandonment
If any monitoring well or piezometer requires abandonment, the sealing and abandonment will be conducted in accordance with the OWRB as stated in the OAC 785:35. The three monitoring wells (MW-2R, MW-4, and MW-5) will be abandoned by an Oklahoma certified well driller following these procedures.

2.2 GROUNDWATER MONITORING PARAMETERS AND SAMPLING SCHEDULE

The following sections outline the detection monitoring procedures and the sampling requirements to obtain groundwater samples to determine background groundwater quality.

2.2.1 Background Monitoring
Background groundwater quality is required to be established at each monitoring well in accordance with OAC 252:515-9-31. Four quarters of statistically independent data are required to be collected for each parameter or constituent. At a minimum, wells should be monitored for constituents listed in 252:515-9-31(d)(1). Background groundwater data should contain the natural variations in groundwater chemistry. Ideally, the background data should contain enough data points to conduct the selected statistical analysis and exhibit any seasonal, temporal, or spatial variability. The background groundwater quality data should be representative of the groundwater quality near the landfill but not impacted by the landfill.

If new wells are installed near an existing well that monitors the same formation with a similar screen depth, it may be possible to use the existing well's background data for the newly installed monitoring well. A confirmation sample should be collected from the newly installed monitoring well and compared to the previous monitoring well's background data. If the confirmation sample results are statistically similar to the previous monitoring well's background data, the monitoring well may be placed into routine detection monitoring. The ODEQ's approval for waiving the background sampling requirements should be obtained before proceeding with any replacement monitoring well installations.

2.2.2 Detection Monitoring
Groundwater samples for detection monitoring should be collected following the same sampling procedures used to collect the background groundwater quality samples. Samples are to be collected from the monitoring wells semi-annually. A report of the sampling results and results of the statistical analysis will be submitted to the ODEQ within 60 days of the sampling date.
2.0 GROUNDWATER MONITORING

This section presents the existing and proposed monitoring well networks, sampling schedule, and monitoring parameters for SORD.

2.1 GROUNDWATER MONITORING NETWORK

The groundwater monitoring system shall be installed and yield groundwater samples from the uppermost aquifer that represent the quality of background groundwater that has not been affected by the SORD and that represent the quality of groundwater that has passed underneath the SORD. The groundwater monitoring network currently approved for the SORD consists of five monitoring wells as shown on Figure 2. The existing monitoring well coordinates and elevations are presented on Table 1, and the historical groundwater elevations are presented in Table 2.

Groundwater monitoring wells were installed on land owned by the SORD at a distance of no more than 150 meters from the permitted waste boundary of the disposal area. One monitoring well is located upgradient of the landfill (MW-1) and four monitoring wells are downgradient (MW-2R, MW-3, MW-4 and MW-5). Because the horizontal expansion will be contiguous with the existing landfill, three monitoring wells (MW-2R, MW-4, and MW-5) are proposed to be removed from the groundwater monitoring network and will be plugged and abandoned in accordance with the OWRB requirements stated in OAC 785:35. Also, six new detection wells (MW-6, MW-7, MW-8, MW-9, MW-10, and MW-11) located downgradient of the expansion area are proposed. Existing piezometer PZ-9 will become MW-9 and existing piezometer PZ-5 will become MW-11. Figure 2 shows the location of all abandoned, existing, and proposed borings, piezometers, and detection wells. The proposed monitoring well coordinates and elevations are presented in Table 3. Boring logs and a typical well construction diagram for existing and proposed monitoring wells are included in Appendix A.

2.1.1 Monitoring Well Installation

The SORD will provide the ODEQ two weeks written notice prior to any drilling. The monitoring wells will be installed in accordance with OAC 785:35 and registered online or by mail with the OWRB within 60 days after installation by a licensed monitoring well installation contractor.

2.1.2 Monitoring Well Development

Monitoring wells will be developed through the use of a surge block and pump or bailer. The surge block will be moved vigorously through the screened interval or the saturated portion if the screen extends above the water table in order to suspend sediment in the well and remove fines from the filter pack. The pump or bailer will then be used to remove the water from the monitoring well. The use of the surge block may require several iterations until the water runs clear. Once one well volume has been removed from the monitoring well, the pH, specific conductance, and temperature of the water will be measured and recorded. The monitoring well will be purged until the groundwater quality measurements stabilize between purged well volumes or the purged water is clear.
1.0 INTRODUCTION

This Groundwater Monitoring Plan is intended to assist the operators of Southern Oklahoma Regional Disposal, Inc. in conducting the sampling and analysis of groundwater at the Southern Oklahoma Regional Landfill (SORD). The SORD is located in the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. The SORD is located off of State Highway 199 approximately 4 miles east of Ardmore, Oklahoma. The site is bounded on the north, south, east, and west by undeveloped pasture and forest (Figure 1).

The objective of the groundwater monitoring system is to assess potential changes in groundwater quality and determine if these changes are the result of an impact by the landfill. Groundwater data is evaluated by establishing sample locations and developing an appropriate statistical background level for the comparison of compliance data. Background data is collected from locations where the groundwater has not been impacted by the landfill or during times when the groundwater has not been impacted by the landfill. Once appropriate background concentrations have been established, compliance data are statistically evaluated with respect to the background data.

This Groundwater Monitoring Plan describes the hydrogeological setting, the monitoring network, background and monitoring parameters, sampling frequency, sampling procedures, and statistical methods. The procedures in this Groundwater Monitoring Plan were developed following ODEQ regulations and the US EPA's guidance for statistical analysis of groundwater monitoring data.
8.1 Monitoring Well Installation
8.2 Background Sampling Report
8.3 Routine Groundwater Monitoring Reports
9.0 References

List of Figures

No.
1 Site Location
2 Groundwater Monitoring Network

List of Tables

No.
1 Existing Groundwater Monitoring Device Summary
2 Historical Groundwater Elevations
3 Proposed Groundwater Monitoring Well Network
4 Background and Detection Monitoring Parameters

Appendices

Appendix A Boring Logs and Well Construction Diagram
Appendix B Example Form
Appendix C Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0 Groundwater Monitoring</td>
<td>2</td>
</tr>
<tr>
<td>2.1 Groundwater Monitoring Network</td>
<td>2</td>
</tr>
<tr>
<td>2.1.1 Monitoring Well Installation</td>
<td>2</td>
</tr>
<tr>
<td>2.1.2 Monitoring Well Development</td>
<td>2</td>
</tr>
<tr>
<td>2.1.3 Monitoring Well Redevelopment</td>
<td>3</td>
</tr>
<tr>
<td>2.1.4 Monitoring Well Sealing and Abandonment</td>
<td>3</td>
</tr>
<tr>
<td>2.2 Groundwater Monitoring Parameters and Sampling Schedule</td>
<td>3</td>
</tr>
<tr>
<td>2.2.1 Background Monitoring</td>
<td>3</td>
</tr>
<tr>
<td>2.2.2 Detection Monitoring</td>
<td>3</td>
</tr>
<tr>
<td>2.2.3 Monitoring Constituents</td>
<td>4</td>
</tr>
<tr>
<td>3.0 Sampling Procedures</td>
<td>5</td>
</tr>
<tr>
<td>3.1 Well Inspection</td>
<td>5</td>
</tr>
<tr>
<td>3.2 Sample Collection Procedures</td>
<td>5</td>
</tr>
<tr>
<td>3.3 Equipment Decontamination</td>
<td>5</td>
</tr>
<tr>
<td>3.4 Water Level Measurements</td>
<td>6</td>
</tr>
<tr>
<td>3.5 Well Purging</td>
<td>6</td>
</tr>
<tr>
<td>3.6 Sample Collection</td>
<td>7</td>
</tr>
<tr>
<td>3.7 Sample Preservation</td>
<td>8</td>
</tr>
<tr>
<td>3.8 Chain of Custody</td>
<td>8</td>
</tr>
<tr>
<td>3.9 Sample Shipment</td>
<td>8</td>
</tr>
<tr>
<td>4.0 Sample Quality Control/Quality Assurance</td>
<td>9</td>
</tr>
<tr>
<td>4.1 Field, Trip, and Equipment Blanks</td>
<td>9</td>
</tr>
<tr>
<td>4.2 Duplicate Sample</td>
<td>9</td>
</tr>
<tr>
<td>5.0 Laboratory Quality Control</td>
<td>10</td>
</tr>
<tr>
<td>5.1 Analytical Blanks and Spikes</td>
<td>10</td>
</tr>
<tr>
<td>5.2 Instrument Calibration</td>
<td>10</td>
</tr>
<tr>
<td>5.3 Instrument Maintenance</td>
<td>11</td>
</tr>
<tr>
<td>5.4 Method Detection Limits</td>
<td>11</td>
</tr>
<tr>
<td>6.0 Data Evaluation</td>
<td>12</td>
</tr>
<tr>
<td>6.1 Statistical Methodology</td>
<td>12</td>
</tr>
<tr>
<td>6.2 Volatile Organic Compounds</td>
<td>12</td>
</tr>
<tr>
<td>6.3 Inorganic Parameters</td>
<td>13</td>
</tr>
<tr>
<td>7.0 Statistically Significant Increase</td>
<td>14</td>
</tr>
<tr>
<td>7.1 Assessment Monitoring</td>
<td>14</td>
</tr>
<tr>
<td>7.2 Corrective Measures</td>
<td>15</td>
</tr>
<tr>
<td>8.0 Monitoring Reports</td>
<td>16</td>
</tr>
</tbody>
</table>
INDEX AND CERTIFICATION PAGE

REPORT INDEX

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Number of Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>2.0</td>
<td>Groundwater Monitoring</td>
<td>3</td>
</tr>
<tr>
<td>3.0</td>
<td>Sampling Procedures</td>
<td>4</td>
</tr>
<tr>
<td>4.0</td>
<td>Sample Quality Control/Quality Assurance</td>
<td>1</td>
</tr>
<tr>
<td>5.0</td>
<td>Laboratory Quality Control</td>
<td>2</td>
</tr>
<tr>
<td>6.0</td>
<td>Data Evaluation</td>
<td>2</td>
</tr>
<tr>
<td>7.0</td>
<td>Statistically Significant Increase</td>
<td>2</td>
</tr>
<tr>
<td>8.0</td>
<td>Monitoring Reports</td>
<td>1</td>
</tr>
<tr>
<td>9.0</td>
<td>References</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Tables and Figures</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Appendix A</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Appendix B</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Appendix C</td>
<td>13</td>
</tr>
</tbody>
</table>

Certification
This report has been prepared for exclusive use by Southern Oklahoma Regional Disposal, Inc. for the Southern Oklahoma Regional Disposal Landfill (SORD) for specific application to the project discussed, and it has been prepared in accordance with generally accepted engineering practices and the requirements of the Oklahoma Department of Environmental Quality.

Prepared by:

Floyd Cotter, P.E.
Vice President
SCS Engineers
Groundwater Monitoring Plan

Presented To:
Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented From:
SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00
Groundwater Monitoring Plan

Southern Oklahoma Regional Disposal Landfill

Presented to:
Southern Oklahoma Regional Disposal, Inc.

Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented by:

SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00

Offices Nationwide
www.scsengineers.com
Appendix D

Groundwater Monitoring Plan
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 38 ft to 51 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Surface Seal Interval: From 0 ft to 36 ft
Type of Annular Seal: n/a
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Material: Bentonite Granules/Chips
Filter Pack Seal Interval: From 36 ft to 38 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling ___ ft
Estimated yield of well ___ gpm
First water zone ___ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FROM (ft)</td>
<td>TO (ft)</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>Sand</td>
<td>29</td>
<td>43</td>
</tr>
<tr>
<td>Clay</td>
<td>43</td>
<td>47</td>
</tr>
<tr>
<td>Sand</td>
<td>47</td>
<td>53</td>
</tr>
<tr>
<td>Clay</td>
<td>53</td>
<td>54</td>
</tr>
<tr>
<td>Sand</td>
<td>54</td>
<td>56</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>56</td>
<td>75</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? No
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: n/a
Total Depth of well being plugged ___ ft.
Was the well contaminated or was it plugged as though it was contaminated? n/a
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? n/a
Was the grout tremied? n/a
Backfilled with n/a
Backfilled from ___ ft. to ___ ft.
Grouted with n/a
Grouted from ___ ft. to ___ ft.
Grouted with Cement
Grouted from ___ ft. to ___ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
D/PC No: DPC-0269
Operator Name: CHARLES CLARK
OP No: OP-1210
Date: 10/04/2016
Comments: Bentonite Chips from 51 ft. to 75 ft.
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176569

Quarters SW-NW-NW Section 19 Township 04S Range 03E1

Latitude 34.1998172 Longitude -97.03783

Date collected (latitude and longitude), if different from date the well was drilled: 08/16/2016
Method latitude and longitude was collected: GPS - uncorrected data

County Carter
WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088, Ardmore, OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-20

TYPE OF WORK: Monitoring Well

USE OF WELL: Site Assessment

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 08/16/2016
Number of wells or borings represented by this log 1
*(Borings are within the same 10 acre-tract and with the same general depths and lithologies)*

Hole Diameter ___ inches to a depth of ___ ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: ___ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft
1) Well Casing Material PVC Casing Diameter ___ inches Casing From ___ ft to ___ ft

SCREEN OR PERFORATION INFORMATION
Type of Screen: PVC Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch) From ___ ft to ___ ft.
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 33 ft to 45 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Surface Seal Interval: From 0 ft to 31 ft
Type of Annular Seal: n/a
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Material: Bentonite Granules/Chips
Filter Pack Seal Interval: From 31 ft to 33 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling: ___ ft
Estimated yield of well: ___ gpm
First water zone: ___ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCLOSED FROM (ft.)</th>
<th>TO (ft.)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandy Clay</td>
<td>0</td>
<td>5</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>5</td>
<td>15</td>
<td>N</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>15</td>
<td>19</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>19</td>
<td>21</td>
<td>N</td>
</tr>
<tr>
<td>Clay</td>
<td>21</td>
<td>28</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>28</td>
<td>30</td>
<td>N</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>30</td>
<td>31</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>31</td>
<td>41</td>
<td>N</td>
</tr>
<tr>
<td>Clay</td>
<td>41</td>
<td>92</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? Yes/No: No
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? Yes/No: n/a
Distance of well from possible source: ___ ft. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: n/a
Total Depth of well being plugged: ___ ft.
Was the well contaminated or was it plugged as though it was contaminated? Yes/No: n/a
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? Yes/No: n/a
Was the grout tremied? Yes/No: n/a
Backfilled with: n/a
Grouted with: n/a
Grouted with: Cement
Backfilled from ___ ft. to ___ ft.
Grouted from ___ ft. to ___ ft.
Grouted from ___ ft. to ___ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
D/PC No.: DPC-0269
Operator Name: CHARLES CLARK
OP No.: OP-1210
Date: 10/04/2016
Comments: Bentonite Chips from 45 ft. to 92 ft.
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176567

Quarters NE-NE
Section 24
Township 04S
Range 02E

Latitude 34.19875
Longitude -97.0384333

Date collected (latitude and longitude), if different from date the well was drilled: 08/15/2016
Method latitude and longitude was collected: GPS - uncorrected data

County Carter
WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore, OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-19

TYPE OF WORK: Monitoring Well

USE OF WELL: Site Assessment

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 08/15/2016
Number of wells or borings represented by this log
* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)
Hole Diameter 5 in, inches to a depth of 92 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: ___ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft
1) Well Casing Material PVC Casing Diameter 2 inches Casing From 0 ft to 35 ft

SCREEN OR PERFORATION INFORMATION
Type of Screen: PVC Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch) From .35 ft to .45 ft.
FILTER PACK INFORMATION
Filter Pack Material: ___

WELL SEAL INFORMATION
Type of Surface Seal: ___
Surface Seal Interval: From ___ ft to ___ ft
Type of Annular Seal: ___
Annular Seal Interval: From ___ ft to ___ ft
Filter Pack Seal Material: ___
Filter Pack Seal Interval: From ___ ft to ___ ft

TYPE OF COMPLETION: ___

HYDROLOGIC INFORMATION
Depth to water at time of drilling: ___ ft
Estimated yield of well: ___ gpm
First water zone: ___ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FROM (ft)</td>
<td>TO (ft)</td>
</tr>
<tr>
<td>Sandstone</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Sandy Silt</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Sandstone</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Red Silty Clay</td>
<td>10</td>
<td>60</td>
</tr>
<tr>
<td>Shale</td>
<td>60</td>
<td>64</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? ___
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? ___
Distance of Well is ___ ft. from possible source. Type of possible source: ___

PLUGGING INFORMATION
Date Well or Boring Was Plugged: 07/13/2016
Total Depth of well being plugged: 64 ft.
Was the well contaminated or was it plugged as though it was contaminated? ___
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? ___
Was the grout tremied? ___
Backfilled with: Native Materials
Backfilled from: 0 ft. to 4 ft.
Grouted with: Cement Grout
Grouted from: 4 ft. to 64 ft.
Grouted with: Cement
Grouted from: 4 ft. to 64 ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
Operator Name: BILLY GRAHAM
Date: 10/04/2016
Comments: n/a

http://www.owrbc.ok.gov/wd/reporting/printreport.php?siteid=176555
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176555

Quarters SE-NW-NE
Section 24
Township 04S
Range 02E

Latitude 34.1988667
Longitude -97.0399

Date collected (latitude and longitude), if different from date the well was drilled: 07/13/2016
Method latitude and longitude was collected: GPS - uncorrected data

County Carter
WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-18

TYPE OF WORK: Geotechnical Boring

USE OF WELL: Soil Evaluation

Variance Request No. (if applicable) n/a

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 07/13/2016
Number of wells or borings represented by this log 1
* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)
Hole Diameter 6 inches to a depth of 64 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: 
Surface Pipe Diameter  inches Surface Pipe From  ft to  ft

SCREEN OR PERFORATION INFORMATION
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 28 ft to 41 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Surface Seal Interval: From 0 ft to 26 ft
Type of Annular Seal: n/a
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Material: Bentonite Granules/Chips
Filter Pack Seal Interval: From 26 ft to 28 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling: __ ft
Estimated yield of well: __ gpm
First water zone: __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FROM (ft)</td>
<td>TO (ft)</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>Sand</td>
<td>29</td>
<td>43</td>
</tr>
<tr>
<td>Clay</td>
<td>43</td>
<td>47</td>
</tr>
<tr>
<td>Sand</td>
<td>47</td>
<td>53</td>
</tr>
<tr>
<td>Clay</td>
<td>53</td>
<td>54</td>
</tr>
<tr>
<td>Sand</td>
<td>54</td>
<td>56</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>56</td>
<td>58</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? No
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: n/a
Total Depth of well being plugged: __ ft.
Was the well contaminated or was it plugged as though it was contaminated? n/a
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? n/a
Was the grout tremied? n/a
Backfilled with: n/a
Backfilled from __ ft. to __ ft.
Grouted with n/a
Grouted from __ ft. to __ ft.
Grouted with Cement
Grouted from __ ft. to __ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
Operator Name: CHARLES CLARK
Date: 10/04/2016
Comments: Bentonite Chips from 45 ft to 92 ft.

D/PC No.: DPC-0269
OP No.: OP-1210

http://www.owrb.ok.gov/wd/reporting/printreport.php?siteid=176568
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176568

Quarters SW-NW-NW Section 19 Township 04S Range 03E1

Latitude 34.1998167 Longitude -97.03785

Date collected(latitude and longitude), if different from date the well was drilled: 08/15/2016

Method latitude and longitude was collected: GPS - uncorrected data

County Carter

WELL OWNER - NAME AND ADDRESS

Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore, OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-17

TYPE OF WORK: Monitoring Well

USE OF WELL: Site Assessment

NEW WELL CONSTRUCTION DATA

Date Well or Boring Was Completed 08/15/2016

Number of wells or borings represented by this log 1

* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)

Hole Diameter 5 inches to a depth of 58 ft

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.

Surface Pipe Material: ___ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft
1) Well Casing Material PVC Casing Diameter ___ inches Casing From 0 ft to 30 ft

SCREEN OR PERFORATION INFORMATION

Type of Screen: PVC Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch) From 30 ft to 40 ft

Variance Request No. (if applicable) n/a

Phone ______ Zip 73402

Water Rights #: ___
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 58 ft to 71 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Type of Annular Seal: n/a
Surface Seal Interval: From 0 ft to 56 ft
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Material: Bentonite Granules/Chips
Filter Pack Seal Interval: From 56 ft to 58 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling: __ ft
Estimated yield of well: __ gpm
First water zone: __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCLOSED FROM (ft.)</th>
<th>TO (ft.)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>0</td>
<td>50</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>50</td>
<td>54</td>
<td>N</td>
</tr>
<tr>
<td>Clay</td>
<td>54</td>
<td>59</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>59</td>
<td>70</td>
<td>N</td>
</tr>
<tr>
<td>Clay</td>
<td>70</td>
<td>94</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>94</td>
<td>100</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? Yes
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: n/a
Total Depth of well being plugged: __ ft
Was the well contaminated or was it plugged as though it was contaminated? n/a
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? n/a
Was the grout tremied? n/a
Backfilled with: n/a
Grouted with: n/a
Grouted with: Cement
Backfilled from __ ft. to __ ft.
Grouted from __ ft. to __ ft.
Grouted from __ ft. to __ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
D/PC No.: DPC-0269
Operator Name: CHARLES CLARK
OP No.: OP-1210
Date: 10/04/2016
Comments: Bentonite Chips from 71 ft. to 100 ft.
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Well ID: 176566

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

Legal Location
North

Quarters NE-NE-NE Section 24 Township 04S Range 02E1

Latitude 34.20095 Longitude -97.0384167

Date collected (latitude and longitude), if different from date the well was drilled: 08/11/2016

Method latitude and longitude was collected: GPS - uncorrected data

WELL ID NUMBER: 176566

County Carter

WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-16

TYPE OF WORK: Monitoring Well

USE OF WELL: Site Assessment

Variance Request No. (if applicable) n/a

Phone _____ Zip 73402

Water Rights #: __

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 08/11/2016
Number of wells or borings represented by this log __
* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)
Hole Diameter ___ inches to a depth of ___ ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: ___ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft
1) Well Casing Material PVC Casing Diameter ___ inches Casing From ___ ft to ___ ft

SCREEN OR PERFORATION INFORMATION
Type of Screen: PVC Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch) From ___ ft to ___ ft.
FILTER PACK INFORMATION
Filter Pack Material: 

WELL SEAL INFORMATION
Type of Surface Seal: n/a
Type of Annular Seal: n/a
Filter Pack Seal Material: n/a
Surface Seal Interval: From n/a ft to n/a ft
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Interval: From n/a ft to n/a ft

TYPE OF COMPLETION: 

HYDROLOGIC INFORMATION
Depth to water at time of drilling: 
Estimated yield of well: 
First water zone: 31 ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCLOSED FROM (ft)</th>
<th>TO (ft)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reddish Brown Clay</td>
<td>0</td>
<td>50</td>
<td>N</td>
</tr>
<tr>
<td>Red Clay w/Limestone</td>
<td>50</td>
<td>60</td>
<td>N</td>
</tr>
<tr>
<td>Clay</td>
<td>60</td>
<td>72</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>72</td>
<td>74</td>
<td>N</td>
</tr>
<tr>
<td>Limestone</td>
<td>74</td>
<td>75</td>
<td>N</td>
</tr>
<tr>
<td>Clay</td>
<td>75</td>
<td>91</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>91</td>
<td>95</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? n/a
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: 08/08/2016
Total Depth of well being plugged: 95 ft.
Was the well contaminated or was it plugged as though it was contaminated? Yes
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? Yes
Was the grout tremied? Yes
Backfilled with: Native Materials
Grouted with: Cement Grout
Grouted with: Cement
Backfilled from: 0 ft. to 4 ft.
Grouted from: 4 ft. to 95 ft.
Grouted from: 4 ft. to 95 ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES, CORP.
D/PC No.: DPC-0269
Operator Name: CHARLES CLARK
OP No.: OP-1210
Date: 10/04/2016
Comments: n/a
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176563

County Carter
WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore, OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-15
TYPE OF WORK: Geotechnical Boring
USE OF WELL: Soil Evaluation

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 08/08/2016
Number of wells or borings represented by this log 1
* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)
Hole Diameter 6 inches to a depth of 95 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: ___ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft

SCREEN OR PERFORATION INFORMATION
FILTER PACK INFORMATION
Filter Pack Material: __

WELL SEAL INFORMATION
Type of Surface Seal: n/a
Type of Annular Seal: n/a
Filter Pack Seal Material: n/a
Surface Seal Interval: From n/a ft to n/a ft
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Interval: From n/a ft to n/a ft

TYPE OF COMPLETION: __

HYDROLOGIC INFORMATION
Depth to water at time of drilling: __ ft
Estimated yield of well: __ gpm
First water zone: __2 ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED FROM (ft)</th>
<th>TO (ft)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reddish Brown Silty Clay</td>
<td>0</td>
<td>20</td>
<td>N</td>
</tr>
<tr>
<td>Tan Sand</td>
<td>20</td>
<td>21</td>
<td>N</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>21</td>
<td>32</td>
<td>N</td>
</tr>
<tr>
<td>Tan Sand</td>
<td>32</td>
<td>34</td>
<td>N</td>
</tr>
<tr>
<td>Silty Clay w/Shale</td>
<td>34</td>
<td>85</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? n/a
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: 07/12/2016
Total Depth of well being plugged: 85 ft.
Was the well contaminated or was it plugged as though it was contaminated? Yes
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? Yes
Was the grout tremied? Yes
Backfilled with: Native Materials
Backfilled from 0 ft. to 4 ft.
Grouted with: Cement Grout
Grouted from 4 ft. to 85 ft.
Grouted with: Cement
Grouted from 4 ft. to 85 ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES, CORP.
D/PC No.: DPC-0269
Operator Name: BILLY GRAHAM
OP No.: OP-0957
Date: 10/04/2016
Comments: n/a
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176554

Quarters NW-NE-NE Section 24 Township 04S Range 02E1

Latitude 34.2008667 Longitude -97.04115

Date collected (latitude and longitude), if different from date the well was drilled: 07/12/2016

Method latitude and longitude was collected: GPS - uncorrected data

County Carter

WELL OWNER: NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-14

TYPE OF WORK: Geotechnical Boring

USE OF WELL: Soil Evaluation

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 07/12/2016

Number of wells or borings represented by this log: 1

* Borings are within the same 10 acre-tract and with the same general depths and lithologies

Hole Diameter: 6 inches to a depth of 85 ft.

CASING INFORMATION
Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: __ Surface Pipe Diameter: ___ inches Surface Pipe From: ___ ft to ___ ft

SCREEN OR PERFORATION INFORMATION

FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 23 ft to 36 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Type of Annular Seal: n/a
Surface Seal Interval: From 0 ft to 21 ft
Annular Seal Interval: From 21 ft to n/a ft
Filter Pack Material: Bentonite Granules/Chips
Filter Pack Interval: From 21 ft to 23 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling ___ ft
Estimated yield of well ___ gpm
First water zone ___ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCONTERED</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FROM (ft.)</td>
<td>TO (ft.)</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sand</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>7</td>
<td>11</td>
</tr>
<tr>
<td>Sand</td>
<td>11</td>
<td>16</td>
</tr>
<tr>
<td>Clay</td>
<td>16</td>
<td>26</td>
</tr>
<tr>
<td>Sand</td>
<td>26</td>
<td>32</td>
</tr>
<tr>
<td>Limestone</td>
<td>32</td>
<td>33</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>33</td>
<td>39</td>
</tr>
<tr>
<td>Limestone</td>
<td>39</td>
<td>40</td>
</tr>
<tr>
<td>Clay</td>
<td>40</td>
<td>70</td>
</tr>
<tr>
<td>Sand</td>
<td>70</td>
<td>74</td>
</tr>
<tr>
<td>Clay</td>
<td>74</td>
<td>75</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? _No_
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? _n/a_
Distance of Well is _n/a_ from possible source. Type of possible source: _n/a_

PLUGGING INFORMATION
Date Well or Boring Was Plugged _n/a_
Total Depth of well being plugged ___ ft.
Was the well contaminated or was it plugged as though it was contaminated? _n/a_
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? _n/a_
Was the grout tremied? _n/a_
Backfilled with _n/a_
Backfilled from ___ ft. to ___ ft.
Grouted with _n/a_
Grouted from ___ ft. to ___ ft.
Grouted with _Cement_
Grouted from ___ ft. to ___ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES, CORP.
Operator Name: CHARLES CLARK
Date: 10/04/2016

Comments: Bentonite Chips from 36 ft. to 75 ft.
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176564

Quarters SW-SE-SE  Section 13  Township 04S  Range 02W

Latitude 34.2022833  Longitude -97.0411333

Date collected (latitude and longitude), if different from date the well was drilled: 08/10/2016
Method latitude and longitude was collected: GPS - uncorrected data

County Carter
WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088, Ardmore, OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-13

TYPE OF WORK: Monitoring Well
USE OF WELL: Site Assessment

Variance Request No. (if applicable) n/a

Phone
Zip 73402

Water Rights #: ___

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 08/10/2016
Number of wells or borings represented by this log ___
* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)
Hole Diameter ___ inches to a depth of ___ ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: ___ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft
1) Well Casing Material PVC  Casing Diameter ___ inches Casing From ___ ft to ___ ft

SCREEN OR PERFORATION INFORMATION
Type of Screen: PVC  Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch)  From 25 ft to 35 ft.
FILTER PACK INFORMATION
Filter Pack Material: n/a

WELL SEAL INFORMATION
Type of Surface Seal: n/a
Type of Annular Seal: n/a
Filter Pack Seal Material: n/a
Surface Seal Interval: From _n/a_ ft to _n/a_ ft
Annular Seal Interval: From _n/a_ ft to _n/a_ ft
Filter Pack Seal Interval: From _n/a_ ft to _n/a_ ft

TYPE OF COMPLETION: __

HYDROLOGIC INFORMATION
Depth to water at time of drilling __ ft
Estimated yield of well __ gpm
First water zone __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FROM (ft.)</td>
<td>TO (ft.)</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>Gravely Clay</td>
<td>16</td>
<td>21</td>
</tr>
<tr>
<td>Red Clay</td>
<td>21</td>
<td>26</td>
</tr>
<tr>
<td>Light Gray Sandstone</td>
<td>26</td>
<td>30</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>Light Gray Sand</td>
<td>34</td>
<td>40</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? n/a
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: 07/13/2016
Total Depth of well being plugged: __ ft
Was the well contaminated or was it plugged as though it was contaminated? Yes
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? Yes
Was the grout tremied? Yes
Backfilled with Native Materials
Grouted with Cement Grout
Grouted with Cement
Backfilled from _0_ ft. to _4_ ft.
Grouted from _4_ ft. to _40_ ft.
Grouted from _4_ ft. to _40_ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES, CORP.
D/PC No: DPC-0269
Operator Name: BILLY GRAHAM
OP No: OP-0957
Date: 10/04/2016
Comments: n/a
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

Well ID: 176556

WELL ID NUMBER: 176556

Quarters SF-SW-SE
Section 13
Township 04S
Range 02E

Latitude 34.2023667
Longitude -97.0436667

Date collected (latitude and longitude), if different from date the well was drilled: 07/13/2016

Method latitude and longitude was collected: GPS - uncorrected data

County Carter

WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore, OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-12

TYPE OF WORK: Geotechnical Boring

USE OF WELL: Soil Evaluation

NEW WELL CONSTRUCTION DATA

Date Well or Boring Was Completed 07/13/2016

Number of wells or borings represented by this log

* (Borings are within the same 10 acre tract and with the same general depths and lithologies)

Hole Diameter 6 inches to a depth of 40 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.

Surface Pipe Material: Surface Pipe Diameter inches Surface Pipe From ft to ft

SCREEN OR PERFORATION INFORMATION

http://www.owrb.ok.gov/nd/reporting/printreport.php?siteid=176556
FILTER PACK INFORMATION
Filter Pack Material: __

WELL SEAL INFORMATION
Type of Surface Seal: n/a
Surface Seal Interval: From ___ ft to ___ ft
Type of Annular Seal: n/a
Annular Seal Interval: From ___ ft to ___ ft
Filter Pack Seal Material: n/a
Filter Pack Seal Interval: From ___ ft to ___ ft

TYPE OF COMPLETION: __

HYDROLOGIC INFORMATION
Depth to water at time of drilling: ___ ft
Estimated yield of well: ___ gpm
First water zone: ___ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCLOSED FROM (ft)</th>
<th>TO (ft)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silty Clay</td>
<td>0</td>
<td>12</td>
<td>N</td>
</tr>
<tr>
<td>Weathered Sandstone</td>
<td>12</td>
<td>15</td>
<td>N</td>
</tr>
<tr>
<td>Red Clay</td>
<td>15</td>
<td>20</td>
<td>N</td>
</tr>
<tr>
<td>Limestone w/Clay</td>
<td>20</td>
<td>40</td>
<td>N</td>
</tr>
<tr>
<td>Red Clay</td>
<td>40</td>
<td>48</td>
<td>N</td>
</tr>
<tr>
<td>Sandstone</td>
<td>48</td>
<td>50</td>
<td>N</td>
</tr>
<tr>
<td>Shale</td>
<td>50</td>
<td>55</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? n/a
Are there any potential sources of pollution or wastewater lagoons within 300 ft of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: 07/14/2016
Total Depth of well being plugged: 55 ft.
Was the well contaminated or was it plugged as though it was contaminated? Yes
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? Yes
Was the grout tremied? Yes
Backfilled with: Native Materials
Backfilled from 0 ft to 4 ft.
Grouted with: Cement Grout
Grouted from 4 ft to 55 ft.
Grouted with: Cement
Grouted from 4 ft to 55 ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
D/PC No.: DPC-0269
Operator Name: BILLY GRAHAM
OP No.: OP-0957
Date: 10/04/2016
Comments: n/a
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176558

Wells ID: 176558

Quarters SW-SW-SE Section 13 Township 04S Range 02E1

Latitude 34.2026333 Longitude -97.0455833

Date collected (latitude and longitude), if different from date the well was drilled: 07/14/2016

Method latitude and longitude was collected: GPS - uncorrected data

County Carter

WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis.
Address/City/State PO Box 1088 Ardmore OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-11

TYPE OF WORK: Geotechnical Boring

USE OF WELL: Soil Evaluation

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 07/14/2016
Number of wells or borings represented by this log
*(Borings are within the same 10 acre-tract and with the same general depths and lithologies)*
Hole Diameter 6 inches to a depth of 55 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: ___ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft

SCREEN OR PERFORATION INFORMATION

FILTER PACK INFORMATION
Filter Pack Material: 

WELL SEAL INFORMATION
Type of Surface Seal: n/a
Type of Annular Seal: n/a
Surface Seal Interval: From n/a ft to n/a ft
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Interval: From n/a ft to n/a ft

TYPE OF COMPLETION: 

HYDROLOGIC INFORMATION
Depth to water at time of drilling __ ft
Estimated yield of well __ gpm
First water zone __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCLOSED FROM (ft.)</th>
<th>ENCLOSED TO (ft.)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silty Clay</td>
<td>0</td>
<td>12</td>
<td>N</td>
</tr>
<tr>
<td>Weathered Sandstone</td>
<td>12</td>
<td>15</td>
<td>N</td>
</tr>
<tr>
<td>Red Clay</td>
<td>15</td>
<td>20</td>
<td>N</td>
</tr>
<tr>
<td>Limestone w/Clay</td>
<td>20</td>
<td>40</td>
<td>N</td>
</tr>
<tr>
<td>Red Clay</td>
<td>40</td>
<td>48</td>
<td>N</td>
</tr>
<tr>
<td>Sandstone</td>
<td>48</td>
<td>50</td>
<td>N</td>
</tr>
<tr>
<td>Shale</td>
<td>50</td>
<td>53</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? n/a
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged 07/14/2016
Total Depth of well being plugged 53 ft.
Was the well contaminated or was it plugged as though it was contaminated? Yes
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? Yes
Was the grout tremied? Yes
Backfilled with Native Materials
Grouted with Cement Grout
Grouted with Cement
Backfilled from 0 ft. to 4 ft.
Grouted from 4 ft. to 53 ft.
Grouted from 4 ft. to 53 ft.

Firm Name ASSOCIATED ENVIRONMENTAL INDUSTRIES, CORP.
D/PC No. DPC-0269
Operator Name BILLY GRAHAM
OP No. OP-0957
Date 10/04/2016
Comments: n/a
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176557

Quarters SW-SW-SE
Section 13
Township 04S
Range 02E1

Latitude 34.222167
Longitude -97.0469167

Date collected (latitude and longitude), if different from date the well was drilled: 07/14/2016

Method latitude and longitude was collected: GPS - uncorrected data

County Carter

WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088, Ardmore, OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-10

TYPE OF WORK: Geotechnical Boring

USE OF WELL: Soil Evaluation

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 07/14/2016
Number of wells or borings represented by this log 1
* (Borings are within the same 10 acre tract and with the same general depths and lithologies)
Hole Diameter 6 inches to a depth of 53 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: __ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft

SCREEN OR PERFORATION INFORMATION

http://www.awrb.ok.gov/wd/reporting/printreport.php?siteid=176557
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 18 ft to 31 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Type of Annular Seal: n/a
Filter Pack Seal Material: Bentonite Granules/Chips
Surface Seal Interval: From __ ft to 16 ft
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Interval: From 16 ft to 18 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling __ ft
Estimated yield of well __ gpm
First water zone __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED FROM (ft)</th>
<th>ENCOUNTERED TO (ft)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silty Clay</td>
<td>0</td>
<td>24</td>
<td>N</td>
</tr>
<tr>
<td>Sand</td>
<td>24</td>
<td>26</td>
<td>N</td>
</tr>
<tr>
<td>Clay</td>
<td>26</td>
<td>61</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? No
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: n/a
Total Depth of well being plugged: __ ft.
Was the well contaminated or was it plugged as though it was contaminated? n/a
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? n/a
Was the grout tremied? n/a
Backfilled with: n/a
Backfilled from __ ft to __ ft.
Grouted with: n/a
Grouted from __ ft to __ ft.
Grouted with: Cement
Grouted from __ ft to __ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES, CORP.
DPC No. DPC-0269
Operator Name: CHARLES CLARK
OP No. OP-1210
Date: 10/04/2016
Comments: Bentonite Chips from 31 ft to 61 ft.

http://www.owrb.ok.gov/wd/reporting/printreport.php?siteid=176565
Well ID: 176565

MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176565

Quarters SE-SE-SE 
Section 13 
Township 04S 
Range 02E

Latitude 34.2035333 
Longitude -97.0396

Date collected (latitude and longitude), if different from date the well was drilled: 08/10/2016

Method latitude and longitude was collected: GPS - uncorrected data

County: Carter
WELL OWNER - NAME AND ADDRESS
Well Owner: Southern Oklahoma Regional Dis
Address/City/State: PO Box 1088, Ardmore, OK
Finding Location: 31 SORD Drive, Ardmore, OK
Well Name: B-9

TYPE OF WORK: Monitoring Well

USE OF WELL: Site Assessment

NEW WELL CONSTRUCTION DATA

Date Well or Boring Was Completed: 08/10/2016
Number of wells or borings represented by this log: 1
*(Borings are within the same 10 acre-tract and with the same general depths and lithologies)*

Hole Diameter 5 inches to a depth of 61 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.*

Surface Pipe Material: 
Surface Pipe Diameter __ inches 
Surface Pipe From __ ft to __ ft
1) Well Casing Material PVC Casing Diameter __ inches Casing From __ ft to __ ft

SCREEN OR PERFORATION INFORMATION

Type of Screen: PVC 
Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch) From __ ft to __ ft

Variance Request No. (if applicable) n/a

Phone __________
Zip __________

Water Rights #: __________
FILTER PACK INFORMATION
Filter Pack Material: __

WELL SEAL INFORMATION
Type of Surface Seal: n/a
Surface Seal Interval: From n/a ft to n/a ft
Type of Annular Seal: n/a
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Material: n/a
Filter Pack Seal Interval: From n/a ft to n/a ft

TYPE OF COMPLETION: __

HYDROLOGIC INFORMATION
Depth to water at time of drilling: __ ft
Estimated yield of well: __ gpm
First water zone: __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED FROM (ft.)</th>
<th>TO (ft.)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Soil</td>
<td>0</td>
<td>3</td>
<td>N</td>
</tr>
<tr>
<td>Reddish Brown Clay</td>
<td>3</td>
<td>31</td>
<td>N</td>
</tr>
<tr>
<td>Gravely Sand</td>
<td>31</td>
<td>38</td>
<td>N</td>
</tr>
<tr>
<td>Reddish Brown Clay</td>
<td>38</td>
<td>55</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? n/a
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: 08/02/2016
Total Depth of well being plugged: 55 ft.
Was the well contaminated or was it plugged as though it was contaminated? Yes
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? Yes
Was the grout tremied? Yes
Backfilled with: Native Materials
Backfilled from 0 ft. to 4 ft.
Grouted with: Cement Grout
Grouted from 4 ft. to 55 ft.
Grouted with: Cement
Grouted from 4 ft. to 55 ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES, CORP.
D/PC No. DPC-0269
Operator Name: BILLY GRAHAM
OP No. OP-0957
Date: 10/04/2016
Comments: n/a
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176561

Quarters  SW-SE-SE   Section  12   Township  04S   Range  02E1

Latitude  34.2035   Longitude  -97.0412333

Date collected (latitude and longitude), if different from date the well was drilled: 08/02/2016

Method latitude and longitude was collected: GPS - uncorrected data

County  Carter

WELL OWNER - NAME AND ADDRESS

Well Owner  Southern Oklahoma Regional Dist
Address/City/State  PO Box 1088, Ardmore, OK
Finding Location  31 SORD Drive, Ardmore, OK
Well Name  B-8

TYPE OF WORK:  Geotechnical Boring

USE OF WELL:  Soil Evaluation

NEW WELL CONSTRUCTION DATA

Date Well or Boring Was Completed  08/02/2016

Number of wells or borings represented by this log  

* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)

Hole Diameter  6 inches  to a depth of  55  ft.

CASING INFORMATION  *Note: If surface casing is used please indicate that on the appropriate well casing information line.

Surface Pipe Material:  
Surface Pipe Diameter  inches  Surface Pipe From  ft to  ft

SCREEN OR PERFORATION INFORMATION

http://www.owrb.ok.gov/wd/reporting/printreport.php?siteid=176561
FILTER PACK INFORMATION
Filter Pack Material: n/a

WELL SEAL INFORMATION
Type of Surface Seal: n/a
Type of Annular Seal: n/a
Filter Pack Seal Material: n/a

Surface Seal Interval: From _n/a_ ft to _n/a_ ft
Annular Seal Interval: From _n/a_ ft to _n/a_ ft
Filter Pack Seal Interval: From _n/a_ ft to _n/a_ ft

TYPE OF COMPLETION: _

HYDROLOGIC INFORMATION
Depth to water at time of drilling _ _ ft
Estimated yield of well _ _ gpm
First water zone _ _ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCLOSED FROM TO</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(ft.)</td>
<td>(ft.)</td>
</tr>
<tr>
<td>Fill</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Reddish Brown Clay</td>
<td>5</td>
<td>23</td>
</tr>
<tr>
<td>Limestone &amp; Clay</td>
<td>23</td>
<td>43</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? n/a
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is _n/a_ from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: 08/02/2016
Total Depth of well being plugged: 43 ft.
Was the well contaminated or was it plugged as though it was contaminated? _Yes_
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? _Yes_
Was the grout tremied? _Yes_
Backfilled with _Native Materials_
Grouted with _Cement Grount_
Grouted with _Cement_
Backfilled from _0_ ft. to _4_ ft.
Grouted from _4_ ft. to _43_ ft.
Grouted from _4_ ft. to _43_ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES, CORP.
D/PC No.: DPC-0269
Operator Name: BILLY GRAHAM
OP No.: OP-0957
Date: 10/04/2016
Comments: n/a
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176560

Quarters SW-SE-SE
Section 13
Township 04S
Range 02E

Latitude 34.2035167
Longitude -97.0427

Date collected (latitude and longitude), if different from date the well was drilled: 08/02/2016

Method latitude and longitude was collected: GPS - uncorrected data

County Carter
WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088, Ardmore, OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-7

TYPE OF WORK: Geotechnical Boring

USE OF WELL: Soil Evaluation

WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 08/02/2016
Number of wells or borings represented by this log 1
* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)
Hole Diameter 6 inches to a depth of 43 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: ___ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft

SCREEN OR PERFORATION INFORMATION

http://www.owrb.ok.gov/wwd/reporting/printreport.php?siteId=176560

1/2
FILTER PACK INFORMATION
Filter Pack Material: n/a

WELL SEAL INFORMATION
Type of Surface Seal: n/a
Type of Annular Seal: n/a
Filter Pack Seal Material: n/a
Surface Seal Interval: From _n/a_ ft to _n/a_ ft
Annular Seal Interval: From _n/a_ ft to _n/a_ ft
Filter Pack Seal Interval: From _n/a_ ft to _n/a_ ft

TYPE OF COMPLETION: n/a

HYDROLOGIC INFORMATION
Depth to water at time of drilling: _n/a_ ft
Estimated yield of well: _n/a_ gpm
First water zone: _n/a_ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED FROM (ft.)</th>
<th>TO (ft.)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Soil</td>
<td></td>
<td>0 - 3</td>
<td>N</td>
</tr>
<tr>
<td>Reddish Brown Clay</td>
<td>3 - 35</td>
<td></td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? _n/a_
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? _n/a_
Distance of Well is _n/a_ from possible source. Type of possible source: _n/a_

PLUGGING INFORMATION
Date Well or Boring Was Plugged: 08/02/2016
Total Depth of well being plugged: _35_ ft.
Was the well contaminated or was it plugged as though it was contaminated? _Yes_
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? _Yes_
Was the grout tremied? _Yes_
Backfilled with _Native Materials_
Grouted with _Cement Grout_
Grouted with _Cement_
Backfilled from _0_ ft. to _4_ ft.
Grouted from _4_ ft. to _35_ ft.
Grouted from _4_ ft. to _35_ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES, CORP.
D/PC No. DPC-0269
Operator Name: BILLY GRAHAM
OP No. OP-0957
Date: 10/04/2016
Comments: _n/a_
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176559

Quarters SE-SW-SE  Section 13  Township 04S  Range 02E1

Latitude 34.2033833  Longitude -97.0442333

Date collected (latitude and longitude), if different from date the well was drilled: 08/02/2016
Method latitude and longitude was collected: GPS - uncorrected data

County Carter
WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088, Ardmore, OK
Finding Location 31 SORD Drive, Ardmore, OK
Well Name B-6

TYPE OF WORK: Geotechnical Boring

USE OF WELL: Soil Evaluation

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 08/02/2016
Number of wells or borings represented by this log
*(Borings are within the same 10 acre-tract and with the same general depths and lithologies)
Hole Diameter __ inches to a depth of __ ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: __  Surface Pipe Diameter ___ inches  Surface Pipe From ___ ft to ___ ft

SCREEN OR PERFORATION INFORMATION
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 33 ft to 45 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Type of Annular Seal: Cement Grout
Filter Pack Seal Material: Bentonite Granules/Chips
Surface Seal Interval: From 0 ft to 2 ft
Annular Seal Interval: From 2 ft to 30 ft
Filter Pack Seal Interval: From 30 ft to 33 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling: __ ft
Estimated yield of well: __ gpm
First water zone: __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FROM (ft)</td>
<td>TO (ft)</td>
</tr>
<tr>
<td>Clay</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>Sandstone</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Reddish Brown Silty Clay</td>
<td>10</td>
<td>45</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? Yes
Are there any potential sources of pollution or wastewater lagoons within 300 ft of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: n/a
Total Depth of well being plugged: __ ft.
Was the well contaminated or was it plugged as though it was contaminated? n/a
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? n/a
Was the grout tremied? n/a
Backfilled with: n/a
Backfilled from __ ft to __ ft.
Grouted with: n/a
Grouted from __ ft to __ ft.
Grouted with: __ cement
Grouted from __ ft to __ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
D/PC No.: DPC-0269
Operator Name: BILLY GRAHAM
OP No.: OP-0957
Date: 10/04/2016
Comments: n/a
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 176562

Quarters NW-SE-NW Section 19 Township 04S Range 03E1

Latitude 34.19708 Longitude -97.03826

Date collected (latitude and longitude), if different from date the well was drilled: 08/01/2016
Method latitude and longitude was collected: GPS - uncorrected data

County: Carter
WELL OWNER - NAME AND ADDRESS
Well Owner: Southern Oklahoma Regional Dis
Address/City/State: PO Box 1088 Ardmore OK
Finding Location: 31 SORD Drive, Ardmore, OK
Well Name: B-5

TYPE OF WORK: Monitoring Well
USE OF WELL: Site Assessment

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed: 08/01/2016
Number of wells or borings represented by this log: 1
* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)
Hole Diameter: 6 inches to a depth of: 45 ft

CASING INFORMATION
*Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: __ Surface Pipe Diameter __ inches Surface Pipe From __ ft to __ ft
1) Well Casing Material: PVC Casing Diameter __ inches Casing From __ ft to __ ft

SCREEN OR PERFORATION INFORMATION
Type of Screen: PVC Type of Slots or Openings: Factory Slotted - 10 skt (0.010 inch) From __ ft to __ ft.

Variance Request No. (if applicable): n/a
Phone __________ Zip 73402
Water Rights #: __________

http://www.owrb.ok.gov/wd/reporting/printreport.php?siteid=176562
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 68 ft to 82 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Surface Seal Interval: From 0 ft to 66 ft
Type of Annular Seal: n/a
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Material: Bentonite Granules/Chips
Filter Pack Seal Interval: From 66 ft to 68 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling: __ ft
Estimated yield of well: __ gpm
First water zone: __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED FROM (ft.)</th>
<th>ENCOUNTERED TO (ft.)</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROCK</td>
<td>0</td>
<td>4</td>
<td>N</td>
</tr>
<tr>
<td>SILT SAND</td>
<td>4</td>
<td>17.5</td>
<td>N</td>
</tr>
<tr>
<td>CLAY</td>
<td>17.5</td>
<td>69</td>
<td>N</td>
</tr>
<tr>
<td>CALCITE</td>
<td>69</td>
<td>69.4</td>
<td>N</td>
</tr>
<tr>
<td>CLAY</td>
<td>69.4</td>
<td>71.5</td>
<td>N</td>
</tr>
<tr>
<td>CALCITE</td>
<td>71.5</td>
<td>75.5</td>
<td>N</td>
</tr>
<tr>
<td>CLAY</td>
<td>75.5</td>
<td>80</td>
<td>N</td>
</tr>
<tr>
<td>CALCITE</td>
<td>80</td>
<td>81.5</td>
<td>N</td>
</tr>
<tr>
<td>CLAY</td>
<td>81.5</td>
<td>93.5</td>
<td>N</td>
</tr>
<tr>
<td>CALCITE</td>
<td>93.5</td>
<td>93.6</td>
<td>N</td>
</tr>
<tr>
<td>CLAY</td>
<td>93.6</td>
<td>100</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? No
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: n/a
Total Depth of well being plugged: __ ft.
Was the well contaminated or was it plugged as though it was contaminated? n/a
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? n/a
Was the grout tremied? n/a
Backfilled with: n/a
Backfilled from __ ft. to __ ft.
Grouted with: n/a
Grouted from __ ft. to __ ft.
Grouted with: Cement
Grouted from __ ft. to __ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
D/PC No.: DPC-0269
Operator Name: CHARLES CLARK
OP No.: OP-1210
Date: 03/31/2016
Comments: Bentonite Chips from 82 ft. to 100 ft.
**MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT**

Oklahoma Water Resources Board  
3800 North Classen Boulevard  
Oklahoma City, OK 73118  
Telephone (405) 530-8800

**WELL ID NUMBER:** 173197

**Quarters** | **SW-NE-NE**  
---|---  
**Section** | 24  
**Township** | 04S  
**Range** | 02E1

**Latitude:** 34.1988167  
**Longitude:** -97.0412  

Date collected(latitude and longitude), if different from date the well was drilled: 02/01/2016

Method latitude and longitude was collected: GPS - uncorrected data

---

**County:** Carter  
**WELL OWNER - NAME AND ADDRESS**  
Well Owner: Southern Oklahoma Regional Dis  
Address/City/State: PO Box 1088, Ardmore, OK  
Finding Location: 31 SORD Dr., Ardmore, OK  
Well Name: B4  
**TYPE OF WORK:** Monitoring Well  
**USE OF WELL:** Site Assessment

**NEW WELL CONSTRUCTION DATA**  
Date Well or Boring Was Completed: 02/01/2016  
Number of wells or borings represented by this log: 1  
*(Borings are within the same 10 acre-tract and with the same general depths and lithologies)*  
Hole Diameter: 6 inches to a depth of 100 ft.

**CASING INFORMATION** *Note: If surface casing is used please indicate that on the appropriate well casing information line.*  
Surface Pipe Material:  
Surface Pipe Diameter: ___ inches  
Surface Pipe From ___ ft to ___ ft

1) Well Casing Material: PVC  
Casing Diameter: 2 inches  
Casing From 0 ft to 70 ft

**SCREEN OR PERFORATION INFORMATION**  
Type of Screen: PVC  
Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch)  
From 70 ft to 80 ft.

---

3/31/2016
Date: 03/31/2016
Comments: Bentonite Chips from 92 ft. to 110 ft.
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 78 ft to 92 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Surface Seal Interval: From 0 ft to 76 ft
Type of Annular Seal: n/a
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Material: Bentonite Granules/Chips
Filter Pack Seal Interval: From 76 ft to 78 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling: __ ft
Estimated yield of well: __ gpm
First water zone: __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FROM (ft)</td>
<td>TO (ft)</td>
</tr>
<tr>
<td>Silt Clay</td>
<td>0</td>
<td>31</td>
</tr>
<tr>
<td>Calcite Vein</td>
<td>31</td>
<td>31.3</td>
</tr>
<tr>
<td>Clay</td>
<td>31.3</td>
<td>44</td>
</tr>
<tr>
<td>Calcite</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>Clay</td>
<td>45</td>
<td>48</td>
</tr>
<tr>
<td>Calcite</td>
<td>48</td>
<td>48.2</td>
</tr>
<tr>
<td>Clay</td>
<td>48.2</td>
<td>49</td>
</tr>
<tr>
<td>Calcite</td>
<td>48.8</td>
<td>49</td>
</tr>
<tr>
<td>Clay</td>
<td>49</td>
<td>63</td>
</tr>
<tr>
<td>Calcite</td>
<td>63</td>
<td>65</td>
</tr>
<tr>
<td>Clay</td>
<td>65</td>
<td>83</td>
</tr>
<tr>
<td>Calcite</td>
<td>83</td>
<td>84.5</td>
</tr>
<tr>
<td>Clay</td>
<td>84.5</td>
<td>87</td>
</tr>
<tr>
<td>Calcite</td>
<td>87</td>
<td>87.3</td>
</tr>
<tr>
<td>Clay</td>
<td>87.3</td>
<td>98</td>
</tr>
<tr>
<td>Calcite</td>
<td>98</td>
<td>103</td>
</tr>
<tr>
<td>Clay</td>
<td>103</td>
<td>110</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? _No_
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? _n/a_
Distance of Well is _n/a_ from possible source. Type of possible source: _n/a_

PLUGGING INFORMATION
Date Well or Boring Was Plugged: _n/a_
Total Depth of well being plugged: __ ft.
Was the well contaminated or was it plugged as though it was contaminated? _n/a_
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? _n/a_
Was the grout tremied? _n/a_
Backfilled with _n/a_
Grouted with _n/a_
Grouted with _Cement_
Backfilled from __ ft. to __ ft.
Grouted from __ ft. to __ ft.
Grouted from __ ft. to __ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
D/PC No: DPC-0269
Operator Name: CHARLES CLARK
OP No: OP-1210

3/31/2016
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

Legal Location
North

Quarters SE-NE-NE Section 24 Township 04S Range 02E1

Latitude 34.1997972 Longitude -97.040025

Date collected(latitude and longitude), if different from date the well was drilled:
02/02/2016

Method latitude and longitude was collected: GPS - uncorrected data

County Carter
WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore OK
Finding Location 31 SORD Dr. Ardmore, OK
Well Name B3

TYPE OF WORK: Monitoring Well

Variance Request No. (if applicable) n/a

USE OF WELL: Site Assessment

Phone __________
Zip 73402

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 02/02/2016
Number of wells or borings represented by this log 1
* (Borings are within the same 10 acre-tract and with the same general depths and lithologies)
Hole Diameter 6 inches to a depth of 110 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: __ Surface Pipe Diameter __ inches Surface Pipe From __ ft to __ ft
1) Well Casing Material PVC Casing Diameter 2 inches Casing From 0 ft to 80 ft

SCREEN OR PERFORATION INFORMATION
Type of Screen: PVC Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch) From 80 ft to 90 ft.
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 54 ft to 68 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Type of Annular Seal: n/a
Filter Pack Seal Material: Bentonite Granules/Chips
Surface Seal Interval: From 0 ft to 52 ft
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Interval: From 52 ft to 54 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling: ___ ft
Estimated yield of well: ___ gpm
First water zone: ___ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED</th>
<th></th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FROM (ft)</td>
<td>TO (ft)</td>
<td></td>
</tr>
<tr>
<td>CLAY</td>
<td>0</td>
<td>6</td>
<td>N</td>
</tr>
<tr>
<td>CONGLOMERATE</td>
<td>6</td>
<td>14</td>
<td>N</td>
</tr>
<tr>
<td>CLAY</td>
<td>14</td>
<td>30</td>
<td>N</td>
</tr>
<tr>
<td>SANDY CLAY</td>
<td>30</td>
<td>33</td>
<td>N</td>
</tr>
<tr>
<td>CLAY</td>
<td>33</td>
<td>60</td>
<td>N</td>
</tr>
<tr>
<td>SAND &amp; GRAVEL</td>
<td>60</td>
<td>64.5</td>
<td>N</td>
</tr>
<tr>
<td>CLAY</td>
<td>64.5</td>
<td>86</td>
<td>N</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? No
Are there any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: n/a
Total Depth of well being plugged: ___ ft.
Was the well contaminated or was it plugged as though it was contaminated? n/a
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? n/a
Was the grout tremied? n/a
Backfilled with: n/a
Backfilled from ___ ft to ___ ft.
Grouted with: n/a
Grouted from ___ ft to ___ ft.
Grouted with: Cement
Grouted from ___ ft to ___ ft.

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
D/PC No. DPC-0269
Operator Name: CHARLES CLARK
OP No. OP-1210
Date: 03/31/2016
Comments: Bentonite Chips from 68 ft. to 86 ft.
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 173199

Quarters SE-SE-SE Section 13 Township 04S Range 02E1

Latitude 34.2022833 Longitude -97.0397333

Date collected (latitude and longitude), if different from date the well was drilled: 02/03/2016

Method latitude and longitude was collected: GPS - uncorrected data

County Carter

WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore OK
Finding Location 31 SORD Dr Ardmore, OK
Well Name B2

TYPE OF WORK: Monitoring Well

USE OF WELL: Site Assessment

Variance Request No. (if applicable) n/a

Phone

Zip 73402

Water Rights #: ___

NEW WELL CONSTRUCTION DATA

Date Well or Boring Was Completed 02/03/2016

Number of wells or borings represented by this log 1

* (Borings are within the same 10 acre tract and with the same general depths and lithologies)

Hole Diameter 6 inches to a depth of 86 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.

Surface Pipe Material: ___ Surface Pipe Diameter ___ inches Surface Pipe From ___ ft to ___ ft.

1) Well Casing Material PVC Casing Diameter 2 inches Casing From 0 ft to 56 ft

SCREEN OR PERFORATION INFORMATION

Type of Screen: PVC Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch) From 56 ft to 66 ft.

http://www.owrb.ok.gov/wd/reporting/printreport.php?siteid=173199

3/31/2016
FILTER PACK INFORMATION
Filter Pack Material: Sand 20-40 (medium)
Filter Pack Interval: From 49 ft to 63 ft

WELL SEAL INFORMATION
Type of Surface Seal: Cement Grout
Surface Seal Interval: From 0 ft to 47 ft
Type of Annular Seal: n/a
Annular Seal Interval: From n/a ft to n/a ft
Filter Pack Seal Material: Bentonite Granules/Chips
Filter Pack Seal Interval: From 47 ft to 49 ft

TYPE OF COMPLETION: Above Ground

HYDROLOGIC INFORMATION
Depth to water at time of drilling: __ ft
Estimated yield of well: __ gpm
First water zone: __ ft

LITHOLOGY DESCRIPTION

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>ENCOUNTERED</th>
<th>SATURATED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FROM (ft)</td>
<td>TO (ft)</td>
</tr>
<tr>
<td>CLAY</td>
<td>0</td>
<td>24.5</td>
</tr>
<tr>
<td>CALCITE</td>
<td>24.5</td>
<td>25</td>
</tr>
<tr>
<td>CLAY</td>
<td>25</td>
<td>33</td>
</tr>
<tr>
<td>CALCITE</td>
<td>33</td>
<td>34.5</td>
</tr>
<tr>
<td>CLAY</td>
<td>34.5</td>
<td>39.5</td>
</tr>
<tr>
<td>CALCITE</td>
<td>39.5</td>
<td>40.5</td>
</tr>
<tr>
<td>CLAY</td>
<td>40.5</td>
<td>53</td>
</tr>
<tr>
<td>CALCITE</td>
<td>53</td>
<td>61</td>
</tr>
<tr>
<td>CLAY</td>
<td>61</td>
<td>75</td>
</tr>
<tr>
<td>CALCITE</td>
<td>73</td>
<td>75</td>
</tr>
<tr>
<td>CLAY</td>
<td>75</td>
<td>81</td>
</tr>
</tbody>
</table>

WELL LOCATION TO POTENTIAL SOURCES OF POLLUTION
Has this well been disinfected after completion of work? No
Are than any potential sources of pollution or wastewater lagoons within 300 ft. of the well? n/a
Distance of Well is n/a from possible source. Type of possible source: n/a

PLUGGING INFORMATION
Date Well or Boring Was Plugged: n/a
Total Depth of well being plugged: __ ft.
Was the well contaminated or was it plugged as though it was contaminated? n/a
If the well or boring was plugged as if it was contaminated, was the casing removed or perforated? n/a
Was the grout tremied? n/a
Backfilled with n/a
Grouted with n/a
Grouted with Cement

Firm Name: ASSOCIATED ENVIRONMENTAL INDUSTRIES CORP.
D/PC No.: DPC-0269
Operator Name: CHARLES CLARK
OP No.: OP-1210
Date: 03/31/2016
Comments: Bentonite Chips from 63 ft. to 81 ft.
MULTI-PURPOSE WELL COMPLETION & PLUGGING REPORT

Oklahoma Water Resources Board
3800 North Classen Boulevard
Oklahoma City, OK 73118
Telephone (405) 530-8800

WELL ID NUMBER: 173198

Quarters SF-SW-SE Section 13 Township 04S Range 02E1

Latitude 34.2023583 Longitude -97.0427778

Date collected (latitude and longitude), if different from date the well was drilled:
02/02/2016

Method latitude and longitude was collected: GPS - uncorrected data

County Carter

WELL OWNER - NAME AND ADDRESS
Well Owner Southern Oklahoma Regional Dis
Address/City/State PO Box 1088 Ardmore OK
Finding Location 31 SORD Dr. Ardmore, OK
Well Name B1

TYPE OF WORK: Monitoring Well

USE OF WELL: Site Assessment

NEW WELL CONSTRUCTION DATA
Date Well or Boring Was Completed 02/02/2016
Number of wells or borings represented by this log 1
(Borings are within the same 10 acre tract and with the same general depths and lithologies)
Hole Diameter 6 inches to a depth of 81 ft.

CASING INFORMATION *Note: If surface casing is used please indicate that on the appropriate well casing information line.
Surface Pipe Material: Surface Pipe Diameter inches Surface Pipe From ft to ft
1) Well Casing Material PVC Casing Diameter 2 inches Casing From 0 ft to 51 ft

SCREEN OR PERFORATION INFORMATION
Type of Screen: PVC Type of Slots or Openings: Factory Slotted - 10 slot (0.010 inch) From 51 ft to 61 ft.


3/31/2016
Appendix F

Multi-Purpose Well Completion and Plugging Reports
WELL TEST ANALYSIS

Data Set: Date: 12/18/17 Time: 11:09:44

PROJECT INFORMATION

Company: SCS Engineers
Client: SORD
Project: 27215136
Location: Ardmore, Oklahoma
Test Well: PZ-17
Test Date: 9/8/2016

AQUIFER DATA

Saturated Thickness: 55 ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (PZ-17 OUT)

Initial Displacement: 2.315 ft
Total Well Penetration Depth: 10 ft
Casing Radius: 0.085 ft
Static Water Column Height: 14.56 ft
Screen Length: 10 ft
Well Radius: 0.33 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice

K = 1.101E-5 ft/sec
y0 = 2.005 ft
WELL TEST ANALYSIS

Data Set:
Date: 12/18/17

PROJECT INFORMATION

Company: SCS Engineers
Client: SORD
Project: 27215136
Location: Ardmore, Oklahoma
Test Well: PZ-17
Test Date: 9/8/2016

AQUIFER DATA

Saturated Thickness: 55 ft
Anisotropy Ratio (Kz/Kr): 1

WELL DATA (PZ-17 IN)

Initial Displacement: 3.914 ft
Total Well Penetration Depth: 10 ft
Casing Radius: 0.085 ft
Static Water Column Height: 14.45 ft
Screen Length: 10 ft
Well Radius: 0.33 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 3.381E-6 ft/sec
y0 = 0.7373 ft
WELL TEST ANALYSIS

Data Set: T:Sord\Hydro\Slug Test Data\AQTESOLV\PZ16-OUT.aqt
Date: 12/18/17

PROJECT INFORMATION

Company: SCS Engineers
Client: SORD
Project: 27215136
Location: Ardmore, Oklahoma
Test Well: PZ-16
Test Date: 9/8/2016

AQUIFER DATA

Saturated Thickness: 55. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (PZ-16 OUT)

Initial Displacement: 2.4 ft
Total Well Penetration Depth: 10. ft
Casing Radius: 0.085 ft
Static Water Column Height: 8.314 ft
Screen Length: 10. ft
Well Radius: 0.33 ft

SOLUTION

Aquifer Model: Unconfined
K = 4.764E-6 ft/sec
y0 = 1.473 ft
Solution Method: Bouwer-Rice
WELL TEST ANALYSIS

Data Set:
Date: 12/18/17
Time: 10:50:00

PROJECT INFORMATION

Company: SCS Engineers
Client: SORD
Project: 27215136
Location: Ardmore, Oklahoma
Test Well: PZ-16
Test Date: 9/8/2016

AQUIFER DATA

Saturated Thickness: 55. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (PZ-16 IN)

Initial Displacement: 1.835 ft
Total Well Penetration Depth: 10. ft
Casing Radius: 0.085 ft
Static Water Column Height: 8.283 ft
Screen Length: 10. ft
Well Radius: 0.33 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 5.346E-6 ft/sec
y0 = 0.8766 ft
WELL TEST ANALYSIS

Date: 12/18/17
Time: 10:37:40

PROJECT INFORMATION

Company: SCS Engineers
Client: SORD
Project: 27215136
Location: Ardmore, Oklahoma
Test Well: PZ-13
Test Date: 9/8/2016

AQUIFER DATA

Saturated Thickness: 55 ft
Anisotropy Ratio (Kz/Kr): 1

WELL DATA (PZ-13)

Initial Displacement: 3.569 ft
Total Well Penetration Depth: 10 ft
Casing Radius: 0.085 ft
Static Water Column Height: 12.7 ft
Screen Length: 10 ft
Well Radius: 0.33 ft

SOLUTION

Aquifer Model: Unconfined
K = 5.994E-8 ft/sec
Solution Method: Bouwer-Rice
y0 = 2.634 ft
WELL TEST ANALYSIS

Data Set:
Date: 12/18/17
Time: 09:56:37

PROJECT INFORMATION

Company: SCS Engineers
Client: SORD
Project: 27215136
Location: Ardmore, Oklahoma
Test Well: PZ-5
Test Date: 9/8/2016

AQUIFER DATA

Saturated Thickness: 55. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (PZ-5 OUT)

Initial Displacement: 1.893 ft
Static Water Column Height: 9.054 ft
Total Well Penetration Depth: 10. ft
Screen Length: 10. ft
Casing Radius: 0.085 ft
Well Radius: 0.33 ft

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 3.627E-6 ft/sec
y0 = 0.2298 ft
WELL TEST ANALYSIS

Data Set: T:\Sord\Hydro\Slug Test Data\AQTESOLV\PZ5-IN.aqt
Date: 12/18/17

PROJECT INFORMATION

Company: SCS Engineers
Client: SORD
Project: 27215136
Location: Ardmore, Oklahoma
Test Well: PZ-5
Test Date: 9/8/2016

AQUIFER DATA

Saturated Thickness: 55. ft
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA (PZ-5 IN)

Initial Displacement: 1.218 ft
Total Well Penetration Depth: 10. ft
Casing Radius: 0.085 ft
Static Water Column Height: 9.95 ft
Screen Length: 10. ft
Well Radius: 0.33 ft

SOLUTION

Aquifer Model: Unconfined
K = 1.941E-6 ft/sec
y0 = 0.2609 ft
Solution Method: Bouwer-Rice
Appendix E

AQTESOLV Analysis Graphs
FLEXIBLE WALL PERMEABILITY
ASTM D 5084

METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE: SCS/SOR/W/WK
PROJECT NUMBER: 1652180
SAMPLE ID: B-20 SS-11 25.0-26.0'
SAMPLE TYPE: UD

Flow Pump 2
Flow Pump Speed 8
Technician SDM

Sample Data, Initial

<table>
<thead>
<tr>
<th>Height, inches</th>
<th>B-Value, f</th>
<th>Diameter, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.212</td>
<td>0.96</td>
<td>2.879</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area, cm²</th>
<th>Cell Pres.</th>
<th>Mass, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>42.00</td>
<td>90.0</td>
<td>716.48</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume, cm³</th>
<th>Top Pres.</th>
<th>Moisture Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>333.69</td>
<td>80.0</td>
<td>14.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mass, g</th>
<th>716.48</th>
<th>Dry Density, pcf</th>
</tr>
</thead>
<tbody>
<tr>
<td>716.48</td>
<td>80.0</td>
<td>117.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Spec. Gravity(assumed)</th>
<th>Head, max.</th>
<th>Moisture Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.700</td>
<td>128.72</td>
<td>18.38</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume Solids, cm³</th>
<th>Head, min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>232.10</td>
<td>128.72</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Void Ratio</th>
<th>Saturation, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.44</td>
<td>88.4%</td>
</tr>
</tbody>
</table>

Flow Pump Rate: 1.12E-04 cm³/sec
USCS

Sample Data, Final

<table>
<thead>
<tr>
<th>Height, inches</th>
<th>Diameter, inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.207</td>
<td>2.932</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Area, cm²</th>
<th>Mass, g</th>
<th>Moisture Content, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>43.56</td>
<td>741.85</td>
<td>18.38</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Volume, cm³</th>
<th>Mass, g</th>
<th>Dry Density, pcf</th>
</tr>
</thead>
<tbody>
<tr>
<td>354.83</td>
<td>626.67</td>
<td>110.21</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wt Soil &amp; Tare, g</th>
<th>Wt Soil &amp; Tare, f</th>
<th>Wt Tare</th>
<th>Wt Moisture Lost</th>
<th>Water Content %</th>
</tr>
</thead>
<tbody>
<tr>
<td>716.48</td>
<td>626.67</td>
<td>0.00</td>
<td>89.81</td>
<td>14.33%</td>
</tr>
</tbody>
</table>

DESCRIPTION
- 

<table>
<thead>
<tr>
<th>TIME FUNCTIONS, SECONDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>08/29/16</td>
</tr>
<tr>
<td>08/29/16</td>
</tr>
<tr>
<td>08/29/16</td>
</tr>
<tr>
<td>08/29/16</td>
</tr>
</tbody>
</table>

TRANSCRIBED FROM ORIGINAL DATA SHEETS

PERMEABILITY REPORTED AS ** 1.6E-07 cm/sec **
### FLEXIBLE WALL PERMEABILITY

**ASTM D 5884**

**METHOD D, CONSTANT RATE OF FLOW**

<table>
<thead>
<tr>
<th>PROJECT TITLE</th>
<th>SCS/SORD/OK</th>
<th>Board #</th>
<th>8</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROJECT NUMBER</td>
<td>1652183</td>
<td></td>
<td>Flow Pump</td>
<td>2</td>
</tr>
<tr>
<td>SAMPLE ID</td>
<td>B-17 SS-9</td>
<td></td>
<td>Flow Pump Speed</td>
<td>7</td>
</tr>
<tr>
<td>SAMPLE TYPE</td>
<td>UD</td>
<td></td>
<td>Technician</td>
<td>SM</td>
</tr>
</tbody>
</table>

#### Sample Data, Initial
- **Height, inches**: 3.120
- **Diameter, Inches**: 2.857
- **Area, cm²**: 41.36
- **Volume, cm³**: 327.77
- **Mass, g**: 682.23
- **Moisture Content, %**: 17.2
- **Dry Density, pcf**: 110.8
- **Spec. Gravity (assumed)**: 2.700
- **Volume Solids, cm³**: 215.54
- **Volume Voids, cm³**: 112.23
- **Void Ratio**: 0.52
- **Saturation, %**: 89.3%

#### Sample Data, Final
- **Height, inches**: 3.161
- **Diameter, Inches**: 2.897
- **Area, cm²**: 42.53
- **Volume, cm³**: 341.44
- **Mass, g**: 706.76
- **Moisture Content, %**: 21.44
- **Dry Density, pcf**: 106.36
- **Volume Solids, cm³**: 215.54
- **Volume Voids, cm³**: 125.90
- **Void Ratio**: 0.58
- **Saturation, %**: 99.1%

#### DESCRIPTION
- Flow Pump Rate: 2.38E-04 cm³/sec
- USCS: -

<table>
<thead>
<tr>
<th>DATE</th>
<th>DAY</th>
<th>HOUR</th>
<th>MIN</th>
<th>TEMP (°C)</th>
<th>dt (min)</th>
<th>dt,acc (min)</th>
<th>dt (sec)</th>
<th>dt,acc (sec)</th>
<th>Reading (psi)</th>
<th>Head (cm)</th>
<th>Gradient</th>
<th>Permeability (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>9</td>
<td>50</td>
<td>20.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.12</td>
<td>78.78</td>
<td>9.81</td>
<td>5.7E-07</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>9</td>
<td>55</td>
<td>20.0</td>
<td>5</td>
<td>5</td>
<td>300</td>
<td>0</td>
<td>1.12</td>
<td>78.78</td>
<td>9.81</td>
<td>5.7E-07</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>10</td>
<td>0</td>
<td>20.0</td>
<td>5</td>
<td>10</td>
<td>300</td>
<td>0</td>
<td>1.12</td>
<td>78.78</td>
<td>9.81</td>
<td>5.7E-07</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>10</td>
<td>5</td>
<td>20.0</td>
<td>5</td>
<td>15</td>
<td>300</td>
<td>0</td>
<td>1.12</td>
<td>78.78</td>
<td>9.81</td>
<td>5.7E-07</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>10</td>
<td>10</td>
<td>20.0</td>
<td>5</td>
<td>20</td>
<td>300</td>
<td>0</td>
<td>1.12</td>
<td>78.78</td>
<td>9.81</td>
<td>5.7E-07</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>10</td>
<td>15</td>
<td>20.0</td>
<td>5</td>
<td>25</td>
<td>300</td>
<td>0</td>
<td>1.12</td>
<td>78.78</td>
<td>9.81</td>
<td>5.7E-07</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>10</td>
<td>20</td>
<td>20.0</td>
<td>5</td>
<td>30</td>
<td>300</td>
<td>0</td>
<td>1.12</td>
<td>78.78</td>
<td>9.81</td>
<td>5.7E-07</td>
</tr>
</tbody>
</table>

**PERMEABILITY REPORTED AS** 5.7E-07 cm/sec **

---

**Golder Associates Inc.**
FLEXIBLE WALL PERMEABILITY
ASTM D 5084
METHOD D, CONSTANT RATE OF FLOW

PROJECT TITLE   SCS/SORO/OK
PROJECT NUMBER  1652183
SAMPLE ID       B-16 SS-4 15.0-16.0'
SAMPLE TYPE     UD

Sample Data, Initial

Height, inches   2.845  B-Value, f  1.00
Diameter, inches  2.813  Cell Pres.  90.0
Area, cm²        40.10  Bot. Pres.  80.0
Volume, cm³      289.74  Top Pres.  80.0
Mass, g          637.67  Tot. B.P.  80.0
Moisture Content, %  10.7  Head, max. 135.05
Dry Density, pcf  124.0  Head, min. 135.05
Spec. Gravity(assumed)  2.700  Max. Grad. 18.67
Volume Solids, cm³  213.25  Min. Grad. 18.67
Volume Voids, cm³  76.49
Void Ratio        0.36
Saturation, %     80.9%

Sample Data, Final

Height, inches   2.848
Diameter, inches  2.873
Area, cm²        41.82
Volume, cm³      302.55
Mass, g          657.86
Moisture Content, %  14.25
Dry Density, pcf  118.75
Spec. Gravity(assumed)  2.700
Volume Solids, cm³  213.25
Volume Voids, cm³  89.30
Void Ratio        0.42
Saturation, %     91.9%

Flow Pump Rate   2.25E-05 cm³/sec
USCS -

DESCRIPTION -

WATER CONTENTS
Sample
Sample
Wt Soil & Tare, i g  637.67  665.95
Wt Soil & Tare, f g  575.79  583.90
Wt Tare g          0.00  8.28
Wt Moisture Lost g  61.88  82.05
Wt Dry Soil g      575.79  575.62
Water Content %    10.75%  14.25%

TIME FUNCTIONS, SECONDS

<table>
<thead>
<tr>
<th>DATE</th>
<th>DAY</th>
<th>HOUR</th>
<th>MIN</th>
<th>TEMP (°C)</th>
<th>dt (min)</th>
<th>dt,acc (min)</th>
<th>dt (sec)</th>
<th>dt,acc (sec)</th>
<th>Reading (psl)</th>
<th>Head (cm)</th>
<th>Gradient</th>
<th>Permeability (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>08/29/16</td>
<td>42611</td>
<td>11</td>
<td>50</td>
<td>20.3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.92</td>
<td>135.05</td>
<td>18.67</td>
<td>2.9E-08</td>
</tr>
<tr>
<td>08/29/16</td>
<td>42611</td>
<td>11</td>
<td>55</td>
<td>20.3</td>
<td>5</td>
<td>5</td>
<td>300</td>
<td>300</td>
<td>1.92</td>
<td>135.05</td>
<td>18.67</td>
<td>2.9E-08</td>
</tr>
<tr>
<td>08/29/16</td>
<td>42611</td>
<td>12</td>
<td>0</td>
<td>20.3</td>
<td>5</td>
<td>10</td>
<td>300</td>
<td>600</td>
<td>1.92</td>
<td>135.05</td>
<td>18.67</td>
<td>2.9E-08</td>
</tr>
<tr>
<td>08/29/16</td>
<td>42611</td>
<td>12</td>
<td>5</td>
<td>20.3</td>
<td>5</td>
<td>15</td>
<td>300</td>
<td>900</td>
<td>1.92</td>
<td>135.05</td>
<td>18.67</td>
<td>2.9E-08</td>
</tr>
<tr>
<td>08/29/16</td>
<td>42611</td>
<td>12</td>
<td>10</td>
<td>20.3</td>
<td>5</td>
<td>20</td>
<td>300</td>
<td>1200</td>
<td>1.92</td>
<td>135.05</td>
<td>18.67</td>
<td>2.9E-08</td>
</tr>
<tr>
<td>08/29/16</td>
<td>42611</td>
<td>12</td>
<td>15</td>
<td>20.3</td>
<td>5</td>
<td>25</td>
<td>300</td>
<td>1500</td>
<td>1.92</td>
<td>135.05</td>
<td>18.67</td>
<td>2.9E-08</td>
</tr>
<tr>
<td>08/29/16</td>
<td>42611</td>
<td>12</td>
<td>20</td>
<td>20.3</td>
<td>5</td>
<td>30</td>
<td>300</td>
<td>1800</td>
<td>1.92</td>
<td>135.05</td>
<td>18.67</td>
<td>2.9E-08</td>
</tr>
</tbody>
</table>

TRANSCRIBED FROM ORIGINAL DATA SHEETS

PERMEABILITY REPORTED AS ** 2.9E-08 cm/sec **

DATE 8/29/16
CHECK
REVIEW
APPROVE

Golder Associates Inc.
### Flexible Wall Permeability

**ASTM D 5084**

**Method D, Constant Rate of Flow**

**Project Title:** SCS/SORD/OK

**Sample ID:** B-9 SS-3

**Sample Type:** UD

**Flow Pump Rate:** 4.26E-05 cm³/sec

**USCS:** -

<table>
<thead>
<tr>
<th>DATE</th>
<th>DAY</th>
<th>HOUR</th>
<th>MIN</th>
<th>TEMP (°C)</th>
<th>dt (min)</th>
<th>dt,acc (min)</th>
<th>dt (sec)</th>
<th>dt,acc (sec)</th>
<th>Reading (psl)</th>
<th>Head (cm)</th>
<th>Gradient</th>
<th>Permeability (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>9</td>
<td>0</td>
<td>19.6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.52</td>
<td>106.92</td>
<td>13.28</td>
<td>7.6E-08</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>9</td>
<td>5</td>
<td>19.6</td>
<td>5</td>
<td>5</td>
<td>300</td>
<td>300</td>
<td>1.52</td>
<td>106.92</td>
<td>13.28</td>
<td>7.6E-08</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>9</td>
<td>10</td>
<td>19.6</td>
<td>5</td>
<td>10</td>
<td>300</td>
<td>600</td>
<td>1.52</td>
<td>106.92</td>
<td>13.28</td>
<td>7.6E-08</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>9</td>
<td>15</td>
<td>19.6</td>
<td>5</td>
<td>15</td>
<td>300</td>
<td>900</td>
<td>1.52</td>
<td>106.92</td>
<td>13.28</td>
<td>7.6E-08</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>9</td>
<td>20</td>
<td>19.6</td>
<td>5</td>
<td>20</td>
<td>300</td>
<td>1200</td>
<td>1.52</td>
<td>106.92</td>
<td>13.28</td>
<td>7.6E-08</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>9</td>
<td>25</td>
<td>19.6</td>
<td>5</td>
<td>25</td>
<td>300</td>
<td>1500</td>
<td>1.52</td>
<td>106.92</td>
<td>13.28</td>
<td>7.6E-08</td>
</tr>
<tr>
<td>08/30/16</td>
<td>42612</td>
<td>9</td>
<td>30</td>
<td>19.6</td>
<td>5</td>
<td>30</td>
<td>300</td>
<td>1800</td>
<td>1.52</td>
<td>106.92</td>
<td>13.28</td>
<td>7.6E-08</td>
</tr>
</tbody>
</table>

**Transcribed from Original Data Sheets**

**Permeability Reported As:** 7.6E-08 cm/sec

---

**Golder Associates Inc.**
### SUMMARY OF SOIL DATA

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Soil Classification</th>
<th>Natural Moisture %</th>
<th>Atterberg Limits</th>
<th>Grain Size Distribution</th>
<th>Compaction</th>
<th>Unit Weight</th>
<th>Permeability (cm/sec)</th>
<th>Additional Tests Conducted (See Notes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-9 SS-3</td>
<td>UD</td>
<td>-</td>
<td>-</td>
<td>18.0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18.0</td>
<td>7.6E-08</td>
</tr>
<tr>
<td>B-13 SS-8</td>
<td>UD</td>
<td>21.0-23.0'</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>108.7</td>
<td>Not Testable</td>
</tr>
<tr>
<td>B-16 SS-4</td>
<td>UD</td>
<td>15.0-16.0'</td>
<td>-</td>
<td>10.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>124.0</td>
<td>2.9E-08</td>
</tr>
<tr>
<td>B-17 SS-9</td>
<td>UD</td>
<td>15.0-16.0'</td>
<td>-</td>
<td>17.2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>110.8</td>
<td>5.7E-07</td>
</tr>
<tr>
<td>B-19 SS-8</td>
<td>UD</td>
<td>25.0-27.0'</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Not Testable</td>
<td></td>
</tr>
<tr>
<td>B-20 SS-11</td>
<td>UD</td>
<td>25.0-26.0'</td>
<td>-</td>
<td>14.3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>117.2</td>
<td>1.6E-07</td>
</tr>
</tbody>
</table>

**ABBREVIATIONS:**
- **LIQUID LIMIT (LL)**
- **PLASTIC LIMIT (PL)**
- **PLASTICITY INDEX (PI)**
- **LIQUIDITY INDEX (LI)**
- **SPECIFIC GRAVITY (Gs)**
- **MOISTURE (Mc)**

**NOTES:**
- **T** = TRIAXIAL TEST
- **U** = UNCONFINED COMPRESSION TEST
- **C** = CONSOLIDATION TEST
- **DS** = DIRECT SHEAR TEST
- **O** = ORGANIC CONTENT
- **P** = pH

*Golder Associates Inc.*
### Flexible Wall Permeability

**ASTM D 5894**

**Method D, Constant Rate of Flow**

<table>
<thead>
<tr>
<th>Sample ID</th>
<th>B-18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Type</td>
<td>Bulk</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Sample Data, Initial</strong></th>
<th></th>
<th><strong>Sample Data, Final</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Height, inches</td>
<td>3.088</td>
<td>Height, inches</td>
<td>3.066</td>
</tr>
<tr>
<td>Diameter, inches</td>
<td>2.790</td>
<td>Diameter, inches</td>
<td>2.809</td>
</tr>
<tr>
<td>Area, cm²</td>
<td>39.44</td>
<td>Area, cm²</td>
<td>39.98</td>
</tr>
<tr>
<td>Volume, cm³</td>
<td>301.35</td>
<td>Volume, cm³</td>
<td>311.36</td>
</tr>
<tr>
<td>Mass, g</td>
<td>555.96</td>
<td>Mass, g</td>
<td>607.14</td>
</tr>
<tr>
<td>Moisture Content, %</td>
<td>20.78</td>
<td>Moisture Content, %</td>
<td>31.90</td>
</tr>
<tr>
<td>Dry Density,pcf</td>
<td>95.31</td>
<td>Dry Density,pcf</td>
<td>92.25</td>
</tr>
<tr>
<td>Specific Gravity (assumed)</td>
<td>2.700</td>
<td>Specific Gravity (assumed)</td>
<td>170.48</td>
</tr>
<tr>
<td>Volume Solids, cm³</td>
<td>170.48</td>
<td>Volume Solids, cm³</td>
<td>140.88</td>
</tr>
<tr>
<td>Volume Void, cm³</td>
<td>130.87</td>
<td>Volume Void, cm³</td>
<td>90.77</td>
</tr>
<tr>
<td>Void Ratio</td>
<td>0.77</td>
<td>Void Ratio</td>
<td>0.83</td>
</tr>
<tr>
<td>Saturation, %</td>
<td>73.1%</td>
<td>Saturation, %</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

**WATER CONTENTS**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Initial</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt Soil &amp; Tare, i</td>
<td>555.96</td>
<td>615.16</td>
</tr>
<tr>
<td>Wt Soil &amp; Tare, f</td>
<td>460.31</td>
<td>468.42</td>
</tr>
<tr>
<td>Wt Tare</td>
<td>607.14</td>
<td>8.40</td>
</tr>
<tr>
<td>Wt Moisture Lost</td>
<td>95.65</td>
<td>146.74</td>
</tr>
<tr>
<td>Wt Dry Soil</td>
<td>460.31</td>
<td>460.02</td>
</tr>
<tr>
<td>Water Content</td>
<td>20.78%</td>
<td>31.90%</td>
</tr>
</tbody>
</table>

**DESCRIPTION**

CLAY, trace fine to coarse sand; red.

**Flow Pump Rate** 4.256-0.05 cm³/sec

**USCS** CH

<table>
<thead>
<tr>
<th>TIME FUNCTIONS, SECONDS</th>
<th></th>
<th><strong>dP</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DATE</strong></td>
<td><strong>DAY</strong></td>
<td><strong>HOUR</strong></td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>10</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>10</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>10</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>10</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>10</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>10</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>10</td>
</tr>
</tbody>
</table>

*TRANSCRIPTION FROM ORIGINAL DATA SHEETS

**PERMEABILITY REPORTED AS** 7.5E-08 cm/sec
**FLEXIBLE WALL PERMEABILITY**

**ASTM D 5084**

**METHOD D, CONSTANT RATE OF FLOW**

<table>
<thead>
<tr>
<th>PROJECT TITLE</th>
<th>SCS/SORD/OK</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROJECT NUMBER</td>
<td>1652183</td>
</tr>
<tr>
<td>SAMPLE ID</td>
<td>B-13</td>
</tr>
<tr>
<td>SAMPLE TYPE</td>
<td>Bulk</td>
</tr>
</tbody>
</table>

| Flow Pump | 2 |
| Flow Pump Speed | 9 |

**Board #** | 5 |

**COMMENTS**: The sample was remolded to 95.3% of the Maximum Dry Density and OPTM + 0.1% (using ASTM D 698).

<table>
<thead>
<tr>
<th>Sample Data, Initial</th>
<th>Sample Data, Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height, inches</td>
<td>3.012</td>
</tr>
<tr>
<td>Diameter, inches</td>
<td>2.790</td>
</tr>
<tr>
<td>Area, cm²</td>
<td>39.44</td>
</tr>
<tr>
<td>Volume, cm³</td>
<td>301.75</td>
</tr>
<tr>
<td>Mass, g</td>
<td>583.43</td>
</tr>
<tr>
<td>Moisture Content, %</td>
<td>16.77</td>
</tr>
<tr>
<td>Dry Density, pcf</td>
<td>103.32</td>
</tr>
<tr>
<td>Spec. Gravity (assumed)</td>
<td>2.700</td>
</tr>
<tr>
<td>Volume Solids, cm³</td>
<td>185.05</td>
</tr>
<tr>
<td>Volume Voids, cm³</td>
<td>116.79</td>
</tr>
<tr>
<td>Void Ratio</td>
<td>0.63</td>
</tr>
<tr>
<td>Saturation, %</td>
<td>71.8%</td>
</tr>
</tbody>
</table>

**Sample**

<table>
<thead>
<tr>
<th>WATER CONTENTS</th>
<th>Initial</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wt Soil &amp; Tare, i g</td>
<td>583.43</td>
<td>625.41</td>
</tr>
<tr>
<td>Wt Soil &amp; Tare, f g</td>
<td>499.65</td>
<td>507.86</td>
</tr>
<tr>
<td>Wt Tare g</td>
<td>0.00</td>
<td>8.56</td>
</tr>
<tr>
<td>Wt Moisture Lost g</td>
<td>83.78</td>
<td>117.55</td>
</tr>
<tr>
<td>Wt Dry Soil g</td>
<td>499.65</td>
<td>499.30</td>
</tr>
<tr>
<td>Water Content %</td>
<td>16.77%</td>
<td>23.54%</td>
</tr>
</tbody>
</table>

**DESCRIPTION**

Silt, Clay, trace fine to coarse sand, trace gravel; red.

**Flow Pump Rate** | 4.26E-05 cm³/sec |
**USCS** | CL |

<table>
<thead>
<tr>
<th>TIME FUNCTIONS, SECONDS</th>
<th>dp</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATE</td>
<td>DAY</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
</tr>
</tbody>
</table>

*TRANSCRIBED FROM ORIGINAL DATA SHEETS

**PERMEABILITY REPORTED AS** | 7.8E-08 cm/sec **

**DATE** | 9/14/16

**CHECK** | REVIEW | APPROVE

**Golder Associates Inc.**
**FLEXIBLE WALL PERMEABILITY**  
ASTM D 5084  
**METHOD B, CONSTANT RATE OF FLOW**

**PROJECT TITLE**  
SCS/SORD/OK

**PROJECT NUMBER**  
1652183

**SAMPLE ID**  
B-5

**SAMPLE TYPE**  
Bulk

**COMMENTS**  
The sample was remolded to 95.3% of the Maximum Dry Density and OPTM + 0.3% (using ASTM D 698).

<table>
<thead>
<tr>
<th>Sample Data, Initial</th>
<th>Sample Data, Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height, inches</td>
<td>Height, inches</td>
</tr>
<tr>
<td>3.001</td>
<td>3.001</td>
</tr>
<tr>
<td>Diameter, inches</td>
<td>Diameter, inches</td>
</tr>
<tr>
<td>2.790</td>
<td>2.781</td>
</tr>
<tr>
<td>Area, cm²</td>
<td>Area, cm²</td>
</tr>
<tr>
<td>39.44</td>
<td>39.19</td>
</tr>
<tr>
<td>Volume, cm³</td>
<td>Volume, cm³</td>
</tr>
<tr>
<td>300.65</td>
<td>298.72</td>
</tr>
<tr>
<td>Mass, g</td>
<td>Mass, g</td>
</tr>
<tr>
<td>584.55</td>
<td>603.82</td>
</tr>
<tr>
<td>Moisture Content, %</td>
<td>Moisture Content, %</td>
</tr>
<tr>
<td>19.66</td>
<td>23.60</td>
</tr>
<tr>
<td>Dry Density, psf</td>
<td>Dry Density, psf</td>
</tr>
<tr>
<td>101.39</td>
<td>102.05</td>
</tr>
<tr>
<td>2.700</td>
<td>1.892</td>
</tr>
<tr>
<td>Volume Solids, cm³</td>
<td>Volume Solids, cm³</td>
</tr>
<tr>
<td>180.93</td>
<td>180.93</td>
</tr>
<tr>
<td>Volume Voids, cm³</td>
<td>Volume Voids, cm³</td>
</tr>
<tr>
<td>119.72</td>
<td>117.78</td>
</tr>
<tr>
<td>Void Ratio</td>
<td>Void Ratio</td>
</tr>
<tr>
<td>0.66</td>
<td>0.65</td>
</tr>
<tr>
<td>Saturation, %</td>
<td>Saturation, %</td>
</tr>
<tr>
<td>80.2%</td>
<td>97.9%</td>
</tr>
</tbody>
</table>

**WATER CONTENTS**  
Sample Initial Final

| Wt Soil & Tare, g | 584.55 | 611.92 |
| Wt Soil & Tare, f | 488.52 | 496.66 |
| Wt Tare, g        | 0.00   | 8.33   |
| Wt Moisture Lost  | 96.93  | 115.26 |
| Wt Dry Soil, g    | 488.52 | 488.33 |
| Water Content %   | 19.66% | 23.60% |

**DESCRIPTION**  
sandy CLAY, fine to coarse, trace fine to coarse gravel; red.

| Flow Pump Rate | 4.26E-05 cm³/sec |
| USCS          | CH               |

**TIME FUNCTIONS, SECONDS**

<table>
<thead>
<tr>
<th>DATE</th>
<th>DAY</th>
<th>HOUR</th>
<th>MIN</th>
<th>TEMP (°C)</th>
<th>dt (min)</th>
<th>dt,acc (min)</th>
<th>dt (sec)</th>
<th>dt,acc (sec)</th>
<th>Reading (psi)</th>
<th>Head (cm)</th>
<th>Gradient</th>
<th>Permeability (cm/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>8</td>
<td>0</td>
<td>19.5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>144.20</td>
<td>18.92</td>
<td></td>
<td>5.8E-08</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>8</td>
<td>5</td>
<td>19.5</td>
<td>5</td>
<td>5</td>
<td>300</td>
<td>300</td>
<td>144.20</td>
<td>18.92</td>
<td></td>
<td>5.8E-08</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>8</td>
<td>10</td>
<td>19.5</td>
<td>5</td>
<td>10</td>
<td>300</td>
<td>600</td>
<td>144.20</td>
<td>18.92</td>
<td></td>
<td>5.8E-08</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>8</td>
<td>15</td>
<td>19.5</td>
<td>5</td>
<td>15</td>
<td>300</td>
<td>900</td>
<td>144.20</td>
<td>18.92</td>
<td></td>
<td>5.8E-08</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>8</td>
<td>20</td>
<td>19.5</td>
<td>5</td>
<td>20</td>
<td>300</td>
<td>1200</td>
<td>144.20</td>
<td>18.92</td>
<td></td>
<td>5.8E-08</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>8</td>
<td>25</td>
<td>19.5</td>
<td>5</td>
<td>25</td>
<td>300</td>
<td>1500</td>
<td>144.20</td>
<td>18.92</td>
<td></td>
<td>5.8E-08</td>
</tr>
<tr>
<td>09/14/16</td>
<td>42627</td>
<td>8</td>
<td>30</td>
<td>19.5</td>
<td>5</td>
<td>30</td>
<td>300</td>
<td>1800</td>
<td>144.20</td>
<td>18.92</td>
<td></td>
<td>5.8E-08</td>
</tr>
</tbody>
</table>

**TRANSCRIBED FROM ORIGINAL DATA SHEETS**

**PERMEABILITY REPORTED AS** **5.8E-08 cm/sec**

Golder Associates Inc.
<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Soil Classification</th>
<th>Natural Moisture %</th>
<th>Atterberg Limits</th>
<th>Grain Size Distribution</th>
<th>Compaction</th>
<th>Unit Weight</th>
<th>Permeability (cm/sec)</th>
<th>Additional Tests Conducted (See Notes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>% Finer No. 4 Sieve</td>
<td>% Finer No. 200 Sieve</td>
<td>% Finer .005 mm</td>
<td>Maximum Dry Density (pcf)</td>
<td>Optimum Moisture %</td>
</tr>
<tr>
<td>B-5</td>
<td>Bulk</td>
<td>-</td>
<td>CH</td>
<td>24.1</td>
<td>52</td>
<td>25</td>
<td>27</td>
<td>-0.02</td>
<td>97.2</td>
<td>78.2</td>
</tr>
<tr>
<td>B-13</td>
<td>Bulk</td>
<td>-</td>
<td>Cl</td>
<td>26.8</td>
<td>48</td>
<td>24</td>
<td>24</td>
<td>0.13</td>
<td>99.8</td>
<td>95.7</td>
</tr>
<tr>
<td>B-18</td>
<td>Bulk</td>
<td>-</td>
<td>CH</td>
<td>28.6</td>
<td>58</td>
<td>27</td>
<td>31</td>
<td>0.04</td>
<td>100.0</td>
<td>97.2</td>
</tr>
</tbody>
</table>

**ABBREVIATIONS:**
- LIQUID LIMIT (LL)
- PLASTIC LIMIT (PL)
- PLASTICITY INDEX (PI)
- LIQUIDITY INDEX (LI)
- SPECIFIC GRAVITY (Gs)
- MOISTURE (Me)

**NOTES:**
- T = TRIAXIAL TEST
- U = UNCONFINED COMPRESSION TEST
- C = CONSOLIDATION TEST
- DS = DIRECT SHEAR TEST
- O = ORGANIC CONTENT
- P = pH

_Golder Associates Inc._
MOISTURE / DRY DENSITY CURVE
ASTM D 698 Method A

PROJECT NAME: SCS/SORD/OK
PROJECT NUMBER: 1652183
SAMPLE ID: B-18

DE çıktı: -
SAMPLE TYPE: Bulk

SAG AIR Voids CURVES
Gs=2.80
Gs=2.70
Gs=2.60

COMPACTATION POINTS

<table>
<thead>
<tr>
<th>Specimen Number</th>
<th>Dry Density (pcf)</th>
<th>Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>96.5</td>
<td>17.2%</td>
</tr>
<tr>
<td>2</td>
<td>99.0</td>
<td>19.6%</td>
</tr>
<tr>
<td>3</td>
<td>99.4</td>
<td>21.8%</td>
</tr>
<tr>
<td>4</td>
<td>97.5</td>
<td>25.3%</td>
</tr>
</tbody>
</table>

Maximum Dry Density (pcf) 99.5
Optimum Moisture (%) 21.3
Corrected Maximum Dry Density (pcf)  
Corrected Optimum Moisture (%)  
As-Received Moisture Content 28.6%
% Retained on #4 sieve  
% Retained on 3/8" sieve  
% Retained on 3/4" sieve  

DESCRIPTION
CLAY, trace fine to coarse sand; red.

USCS CH

Golder Associates Inc.
PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS
ASTM D421, D422, D4318

PROJECT NAME: SCS/SORD/OK
SAMPLE ID: B-18
TYPE: Bulk


description: CLAY, trace fine to coarse sand; red.
USCS: CH

Hydrometer Analysis
<table>
<thead>
<tr>
<th>Grain Size</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finer than</td>
<td>94.8</td>
</tr>
<tr>
<td>#010</td>
<td>94.7</td>
</tr>
<tr>
<td>#010</td>
<td>94.3</td>
</tr>
<tr>
<td>#0074</td>
<td>82.1</td>
</tr>
<tr>
<td>#0054</td>
<td>73.7</td>
</tr>
<tr>
<td>#0029</td>
<td>52.6</td>
</tr>
<tr>
<td>#0012</td>
<td>42.1</td>
</tr>
</tbody>
</table>

Finer than | 97.2

Plasticity Chart

Atterberg Limits
Method B (Dry preparation)
ML LL PI PL LL
28.6 58 27 31 0.04

Golder Associates Inc.
MOISTURE / DRY DENSITY CURVE
ASTM D 698    Method A

PROJECT NAME: SCS/SORD/OK
PROJECT NUMBER: 1652183
SAMPLE ID: B-13    DEPTH: -    SAMPLE TYPE: Bulk

<table>
<thead>
<tr>
<th>Mechanical</th>
<th>Standard</th>
<th>Dry Method</th>
</tr>
</thead>
</table>

![Graph showing moisture content vs. dry density with zero air voids curves for Gs=2.80, Gs=2.70, Gs=2.60.]

**Compaction Points**

<table>
<thead>
<tr>
<th>Specimen Number</th>
<th>Dry Density (pcf)</th>
<th>Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>104.8</td>
<td>12.3%</td>
</tr>
<tr>
<td>2</td>
<td>107.7</td>
<td>14.3%</td>
</tr>
<tr>
<td>3</td>
<td>108.2</td>
<td>16.5%</td>
</tr>
<tr>
<td>4</td>
<td>107.6</td>
<td>18.8%</td>
</tr>
<tr>
<td>5</td>
<td>105.8</td>
<td>21.1%</td>
</tr>
<tr>
<td>6</td>
<td>101.1</td>
<td>23.5%</td>
</tr>
</tbody>
</table>

**Maximum Dry Density (pcf):** 108.5

**Optimum Moisture (%):** 16.7

**Corrected Maximum Dry Density (pcf):**

**Corrected Optimum Moisture (%):**

**As-Received Moisture Content:** 26.8%

**% Retained on # 4 sieve:**

**% Retained on 3/8" sieve:**

**% Retained on 3/4" sieve:**

**Description:** SILTY CLAY, trace fine to coarse sand, trace gravel, red.

**USCS:** CL

Golder Associates Inc.
MOISTURE / DRY DENSITY CURVE
ASTM D 698  Method A

PROJECT NAME: SCS/SORD/OK
PROJECT NUMBER: 1652183
SAMPLE ID: B-5  DEPTH: -  SAMPLE TYPE: Bulk

**MOISTURE CONTENT (%)**

**DRY DENSITY (pcf)**

**ZERO AIR VOIDS CURVES**

\[ G_s = 2.80 \]
\[ G_s = 2.70 \]
\[ G_s = 2.60 \]

---

**COMPACtion POINTS**

<table>
<thead>
<tr>
<th>Specimen Number</th>
<th>Dry Density (pcf)</th>
<th>Moisture Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>102.0</td>
<td>14.7%</td>
</tr>
<tr>
<td>2</td>
<td>104.0</td>
<td>16.8%</td>
</tr>
<tr>
<td>3</td>
<td>105.6</td>
<td>18.4%</td>
</tr>
<tr>
<td>4</td>
<td>106.5</td>
<td>19.2%</td>
</tr>
<tr>
<td>5</td>
<td>101.8</td>
<td>21.9%</td>
</tr>
</tbody>
</table>

**Maximum Dry Density (pcf):** 106.5
**Optimum Moisture (%):** 19.4
**Corrected Maximum Dry Density (pcf):**
**Corrected Optimum Moisture (%):**

**As-Received Moisture Content: 24.1%**

- % Retained on # 4 sieve: 2.8%
- % Retained on 3/8" sieve:  
- % Retained on 3/4" sieve:  

**DESCRIPTION:** sandy CLAY, fine to coarse, trace fine to coarse gravel; red.

**USCS:** CH

Golder Associates Inc.
PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS
ASTM D421, D422, D4318

PROJECT NAME: SCS/SORD/OK
SAMPLE ID: B-5
TYPE: Bulk

Golder Associates Inc.
# SCS/SORD/OK

## SUMMARY OF SOIL DATA

<table>
<thead>
<tr>
<th>Sample Identification</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Soil Classification</th>
<th>Natural Moisture %</th>
<th>Atterberg Limits</th>
<th>Grain Size Distribution</th>
<th>Compaction</th>
<th>Unit Weight</th>
<th>Permeability (cm/sec)</th>
<th>Additional Tests Conducted (See Notes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-5</td>
<td>Bulk</td>
<td>-</td>
<td>CH</td>
<td>24.1</td>
<td>52 25 27 -0.02</td>
<td>97.2 78.2 53.0</td>
<td>106.5</td>
<td>19.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B-13</td>
<td>Bulk</td>
<td>-</td>
<td>CL</td>
<td>26.8</td>
<td>48 24 24 0.13</td>
<td>99.8 95.7 74.0</td>
<td>108.5</td>
<td>16.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B-18</td>
<td>Bulk</td>
<td>-</td>
<td>CH</td>
<td>28.6</td>
<td>58 27 31 0.04</td>
<td>100.0 97.2 70.5</td>
<td>99.5</td>
<td>21.3</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**ABBREVIATIONS:**
- LIQUID LIMIT (LL)
- PLASTIC LIMIT (PL)
- PLASTICITY INDEX (PI)
- LIQUIDITY INDEX (LI)
- SPECIFIC GRAVITY (Gs)
- MOISTURE (Mc)

**NOTES:**
- T = TRIAXIAL TEST
- U = UNCONFINED COMPRESSION TEST
- C = CONSOLIDATION TEST
- DS = DIRECT SHEAR TEST
- O = ORGANIC CONTENT
- P = pH

_Golder Associates Inc._
Appendix D

Geotechnical Laboratory Test Results
## GAMMA/NEUTRON

**Company:** SCS  
**Well:** B17  
**Field:** SORD LANDFILL  
**County:** CARTER  
**State:** OKLAHOMA

<table>
<thead>
<tr>
<th>Location: Permanent Datum</th>
<th>GL</th>
<th>RGE</th>
<th>API #</th>
<th>Other Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation</td>
<td>K.B.</td>
<td>D.F.</td>
<td>G.L.</td>
<td></td>
</tr>
<tr>
<td>Log Measured From</td>
<td>GL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drilling Measured From</td>
<td>GL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Date:
- **8/17/2016**

### Run Numbers:
- **1**

### Depth Information:
- **Depth Driller:** 40
- **Depth Logger:** 40
- **Bottom Logged Interval:** 40
- **Top Log Interval:** 0

### Casing Information:
- **Casing Driller:** 6 INCH
- **Casing Logger:** 6 INCH

### Fluid Information:
- **Type Fluid in Hole:** 6 INCH
- **Density / Viscosity:** 6 INCH
- **pH / Fluid Loss:** 6 INCH

### Source of Sample:
- **Rm @ Meas. Temp:** 6 INCH
- **Rmf @ Meas. Temp:** 6 INCH
- **Rmc @ Meas. Temp:** 6 INCH
- **Source of Rmf / Rmc:** 6 INCH
- **Rm @ BHT:** 6 INCH

### Additional Information:
- **Time Circulation Stopped:** 6 INCH
- **Time Logger on Bottom:** 6 INCH
- **Maximum Recorded Temperature:** 6 INCH
- **Equipment Number:** 107
- **Location:** PIEDMONT, OK
- **Recorded By:** M.MAYFIELD
- **Witnessed By:** MR FLOWLER

---

**All interpretations are opinions based on information from electrical, chemical, or other measurements and we cannot and do not guarantee the accuracy or completeness of any interpretation. We assume no responsibility for any interpretation made by any of our clients, agents or employees. These interpretation are also subject to our general terms and conditions set out in our current Price Schedule.**
<table>
<thead>
<tr>
<th>Company</th>
<th>SCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well</td>
<td>B16</td>
</tr>
<tr>
<td>Field</td>
<td>SORD LANDFILL</td>
</tr>
<tr>
<td>County</td>
<td>CARTER</td>
</tr>
<tr>
<td>State</td>
<td>OKLAHOMA</td>
</tr>
<tr>
<td>Location</td>
<td></td>
</tr>
<tr>
<td>API # :</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SEC</th>
<th>TWP</th>
<th>RGE</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL</td>
<td>GL</td>
<td>GL</td>
<td>K.B.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>D.F.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>G.L.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>8/17/2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run Number</td>
<td>1</td>
</tr>
<tr>
<td>Depth Driller</td>
<td>B16</td>
</tr>
<tr>
<td>Depth Logger</td>
<td>B16</td>
</tr>
<tr>
<td>Bottom Logged Interval</td>
<td>B16</td>
</tr>
<tr>
<td>Top Log Interval</td>
<td>0</td>
</tr>
<tr>
<td>Casing Driller</td>
<td></td>
</tr>
<tr>
<td>Casing Logger</td>
<td></td>
</tr>
<tr>
<td>Bit Size</td>
<td>6 INCH</td>
</tr>
<tr>
<td>Type Fluid in Hole</td>
<td></td>
</tr>
<tr>
<td>Density / Viscosity</td>
<td></td>
</tr>
<tr>
<td>pH / Fluid Loss</td>
<td></td>
</tr>
<tr>
<td>Source of Sample</td>
<td></td>
</tr>
<tr>
<td>Rm @ Meas. Temp</td>
<td></td>
</tr>
<tr>
<td>Rmf @ Meas. Temp</td>
<td></td>
</tr>
<tr>
<td>Rmc @ Meas. Temp</td>
<td></td>
</tr>
<tr>
<td>Source of Rmf / Rmc</td>
<td></td>
</tr>
<tr>
<td>Rm @ BHT</td>
<td></td>
</tr>
<tr>
<td>Time Circulation Stopped</td>
<td></td>
</tr>
<tr>
<td>Time Logger on Bottom</td>
<td></td>
</tr>
<tr>
<td>Maximum Recorded Temperature</td>
<td>107</td>
</tr>
<tr>
<td>Equipment Number</td>
<td>107</td>
</tr>
<tr>
<td>Location</td>
<td>PIEDMONT,OK</td>
</tr>
<tr>
<td>Recorded By</td>
<td>M.MAYFIELD</td>
</tr>
<tr>
<td>Witnessed By</td>
<td>MR.FLOWLER</td>
</tr>
</tbody>
</table>

All interpretations are opinions based on references from electrical or other measurements and we cannot and do not guarantee the accuracy of the interpretations or conclusions rendered hereon. The data, conclusions, and recommendations are also subject to our general terms and conditions set out in our current Price Schedule.
All interpretations are opinions based on experience. We cannot and do not guarantee the accuracy or correctness of any interpretation.
<table>
<thead>
<tr>
<th>Date</th>
<th>8/17/2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run Number</td>
<td>1</td>
</tr>
<tr>
<td>Depth Driller</td>
<td>30</td>
</tr>
<tr>
<td>Depth Logger</td>
<td>30</td>
</tr>
<tr>
<td>Bottom Logged Interval</td>
<td>30</td>
</tr>
<tr>
<td>Top Log Interval</td>
<td>0</td>
</tr>
<tr>
<td>Casing Driller</td>
<td></td>
</tr>
<tr>
<td>Casing Logger</td>
<td></td>
</tr>
<tr>
<td>Bit Size</td>
<td>6 INCH</td>
</tr>
<tr>
<td>Type Fluid in Hole</td>
<td></td>
</tr>
<tr>
<td>Density / Viscosity</td>
<td></td>
</tr>
<tr>
<td>pH / Fluid Loss</td>
<td></td>
</tr>
<tr>
<td>Source of Sample</td>
<td></td>
</tr>
<tr>
<td>Rm @ Meas. Temp</td>
<td></td>
</tr>
<tr>
<td>Rmf @ Meas. Temp</td>
<td></td>
</tr>
<tr>
<td>Rmc @ Meas. Temp</td>
<td></td>
</tr>
<tr>
<td>Source of Rmf / Rmc</td>
<td></td>
</tr>
<tr>
<td>Rm @ BHT</td>
<td></td>
</tr>
<tr>
<td>Time Circulation Stopped</td>
<td></td>
</tr>
<tr>
<td>Time Logger on Bottom</td>
<td></td>
</tr>
<tr>
<td>Maximum Recorded Temperature</td>
<td></td>
</tr>
<tr>
<td>Equipment Number</td>
<td>107</td>
</tr>
<tr>
<td>Location</td>
<td>PIEDMONT, OK</td>
</tr>
<tr>
<td>Recorded By</td>
<td>M.MAYFIELD</td>
</tr>
<tr>
<td>Witnessed By</td>
<td>MR.FLOWLER</td>
</tr>
</tbody>
</table>

All interpretations are opinions based on inferences from electrical or other measurements, and we cannot and do not guarantee the accuracy or correctness of any interpretation. We shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages, or expenses incurred or sustained by anyone relying on any interpretation made by any of our officers, agents or employees. These interpretations are also subject to our general terms and conditions set out in our current Price Schedule.

Comments:
**Company:** SCS  
**Well:** B5  
**Field:** SORD LANDFILL  
**County:** CARTER  
**State:** OKLAHOMA

<table>
<thead>
<tr>
<th>Field</th>
<th>Location</th>
<th>API #</th>
<th>County</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td>SORD LANDFILL</td>
<td>CARTER</td>
<td>API #</td>
<td>CARTER</td>
<td>OKLAHOMA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Run Number</th>
<th>Bottom Logged Interval</th>
<th>Depth Driller</th>
<th>Depth Casing Logger</th>
<th>Top Log Interval</th>
<th>Bottom Log Interval</th>
<th>Date 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>45</td>
<td>45</td>
<td>45</td>
<td>6 INCH</td>
<td>6 INCH</td>
<td>8/1/2016</td>
</tr>
</tbody>
</table>

---

All interpretations are opinions based on inferences from electrical or other measurements and we cannot and do not guarantee the accuracy or correctness of any interpretation, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages, or expenses incurred or sustained by anyone resulting from any interpretation made by any of our officers, agents or employees. These interpretations are also subject to our general terms and conditions set out in our current Price Schedule.

**Comments**

---

Database File: b5.db  
Dataset Pathname: pass4  
Presentation Format: gr-n-ccl  
Charted by: Depth in Feet scaled 1:240

---

0  
GR  
25  
0  
NEU (NAPI)  
2000
Appendix C

Geophysical Logs
<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGY DESCRIPTION</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>RECOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>Shale</td>
<td>brown, weathered, thinly bedded, friable</td>
<td>SS</td>
<td>65-66</td>
<td>100</td>
</tr>
</tbody>
</table>

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES; ACTUAL TRANSITIONS MAY BE GRADUAL.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (fmsl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Silty clay; brown to reddish brown, orange and gray matting, moist between 30-40, transitions to a gray to brown silty clay to claystone</td>
<td>SS</td>
<td>30-35</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>788</td>
</tr>
<tr>
<td>36</td>
<td>Silty Clay</td>
<td>SS</td>
<td>39-40</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>784</td>
</tr>
<tr>
<td>40</td>
<td>Silty Clay</td>
<td>SS</td>
<td>42-43</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>780</td>
</tr>
<tr>
<td>44</td>
<td>Clay; dark gray clay, some silty clay, high plasticity</td>
<td>SS</td>
<td>49-50</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>772</td>
</tr>
<tr>
<td>52</td>
<td>Clay</td>
<td>SS</td>
<td>51-52</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>768</td>
</tr>
<tr>
<td>56</td>
<td>Silty Clay</td>
<td>SS</td>
<td>52.5-53</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>764</td>
</tr>
<tr>
<td>60</td>
<td>Silty Clay; brown, some gray matting, hard, blocky, low plasticity</td>
<td>SS</td>
<td>59-60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>760</td>
</tr>
<tr>
<td>64</td>
<td>Shale; gray to</td>
<td>SS</td>
<td>61-62</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>760</td>
</tr>
</tbody>
</table>

The stratification lines represent approximate boundary lines between soil and rock types. Actual transitions may be gradual.
# Log of Boring B-18

**Client:** SORD, LLC  
**Location:** SORD Landfill, Ardmore, OK

**Project Name:** SORD Hydrogeologic Investigation  
**Number:** 27215136.00

**Driller:** Bill Graham  
**Drilling Rig:** 8150LS Sonic Rig  
**Drilling Method:** Rotary Sonic  
**Drilling Contractor:** Associated Environmental Industries

**Surface Elevation:** 822.00 ft MSL  
**TOC Elevation:** N/A ft MSL  
**Well Depth Completion:** 67.84 ft MSL  
**Location:**  
NORTHING: 318948.5600  
EASTING: 2258593.8300

**Sampling Method:** Continuous Core  
**Water Level:** fbgs  
**Stabilized Water Elevation:** N/A ft MSL  
**Water Level Date:** 9/7/2016

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (ft MSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Fill; sandstone conglomerate</td>
<td>ss 0-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>820</td>
</tr>
<tr>
<td>4</td>
<td>Silt; tan to gray, sandy, some clay, fine grained</td>
<td>ss 3-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>816</td>
</tr>
<tr>
<td>8</td>
<td>Sandstone; tan to light gray, fine grained, interbedded with silty clay (thin)</td>
<td>ss 9-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>812</td>
</tr>
<tr>
<td>12</td>
<td>Sand; light gray, moist</td>
<td>ss 10.5-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>808</td>
</tr>
<tr>
<td>12</td>
<td>Clay; light gray with orange motting, silty, high plasticity</td>
<td>ss 12-13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>804</td>
</tr>
<tr>
<td>16</td>
<td>Silty Clay; green</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>20</td>
<td>Clay; light gray with orange motting, silty, high plasticity transitions to a reddish brown clay, high plasticity, some gray motting</td>
<td>Geo Tech Bucket 15-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>796</td>
</tr>
<tr>
<td>24</td>
<td>Silty Clay; dark brown, orange and gray motting, high plasticity to medium plasticity at 27&quot;</td>
<td>ss 19-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>792</td>
</tr>
<tr>
<td>28</td>
<td>Limestone; tan to gray, fine grained</td>
<td>ss 28-29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>792</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>ss 30-31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The stratification lines represent approximate boundary lines between soil and rock types. Actual transitions may be gradual.
<table>
<thead>
<tr>
<th>Depth (FT)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (FMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>Silty Clay</td>
<td>Silty Clay; green, fine grained to 61.5' transitioning to reddish brown with yellow, orange, and gray matting, low to medium plasticity</td>
<td>SS</td>
<td>66-67</td>
<td>100</td>
<td></td>
<td></td>
<td>760</td>
</tr>
<tr>
<td>70</td>
<td>Clay</td>
<td>Clay, green, silty</td>
<td>SS</td>
<td>71-71.5</td>
<td>114</td>
<td></td>
<td></td>
<td>755</td>
</tr>
<tr>
<td></td>
<td>Sandstone</td>
<td>Sandstone; light gray, poorly sorted, some interbedded reddish clay</td>
<td>SS</td>
<td>71.5-72</td>
<td></td>
<td></td>
<td></td>
<td>750</td>
</tr>
<tr>
<td>75</td>
<td>Limestone</td>
<td>Limestone; light gray, some reddish brown clay layers</td>
<td>SS</td>
<td>74-75</td>
<td></td>
<td></td>
<td></td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
<td>Clay; reddish brown, gravel, dark gray and orange matting</td>
<td>SS</td>
<td>76-77</td>
<td></td>
<td></td>
<td></td>
<td>745</td>
</tr>
<tr>
<td></td>
<td>Limestone</td>
<td>Limestone; light gray</td>
<td>SS</td>
<td>77.5-78</td>
<td></td>
<td></td>
<td></td>
<td>745</td>
</tr>
<tr>
<td>80</td>
<td>Clay</td>
<td>Clay; reddish brown, some yellow-orange matting transitions to green to light gray with some gravels at 79'</td>
<td>SS</td>
<td>79-80</td>
<td></td>
<td></td>
<td></td>
<td>740</td>
</tr>
<tr>
<td></td>
<td>Silty Clay</td>
<td>Silty Clay; reddish brown, some orange matting, some grey, blocky-hard, low plasticity</td>
<td>SS</td>
<td>83-84</td>
<td>100</td>
<td></td>
<td></td>
<td>740</td>
</tr>
<tr>
<td>85</td>
<td>Clay</td>
<td>Clay; reddish, orange-yellow-gray matting, dry</td>
<td>SS</td>
<td>89-90</td>
<td>100</td>
<td></td>
<td></td>
<td>735</td>
</tr>
<tr>
<td>90</td>
<td>Sandy Clay</td>
<td>Sandy Clay; light gray, low plasticity</td>
<td>SS</td>
<td>90-91</td>
<td></td>
<td></td>
<td></td>
<td>735</td>
</tr>
<tr>
<td></td>
<td>Sand</td>
<td>Sand; light gray, sugary, wet</td>
<td>SS</td>
<td>93-94</td>
<td></td>
<td></td>
<td></td>
<td>730</td>
</tr>
<tr>
<td>95</td>
<td>Silty Clay</td>
<td>Silty Clay; light gray, low plasticity</td>
<td>SS</td>
<td>94.5-95</td>
<td></td>
<td></td>
<td></td>
<td>730</td>
</tr>
</tbody>
</table>

The stratification lines represent approximate boundary lines between soil and rock types; actual transitions may be gradual.
# SCS Engineers

**Log of Boring No.: B-15**  
**Sheet Number: 2 of 3**

**11219 Richardson Drive**  
**North Little Rock, AR**

**Client:** SORD, LLC  
**Project Name:** SORD Hydrogeologic Investigation  
**Project Number:** 27215136.00  
**Project Location:** SORD Landfill, Ardmore, OK  
**Geologist:** Robert Fowler  
**Sampling Method:** Continuous Core

**Driller:** Bill Graham  
**Drilling Rig:** 8150S Sonic Rig  
**Drilling Method:** Rotary Sonic  
**Drilling Contractor:** Associated Environmental Industries  
**Location:**  
- Northing: 319808.5100  
- Easting: 2258582.7900  
**Surface Elevation:** 825.00 ft amsl  
**TOC Elevation:** N/A ft amsl  
**Well Depth Completion:** 95.00 ft bgs  
**Stabilized Water Elevation:** N/A ft amsl

**Start Date:** 8/3/2016  
**Finish Date:** 8/8/2016  
**Boring Diameter:** 6"  
**Well Diameter:** N/A  
**Water Level Date:** 9/7/2016

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>Silty Clay</td>
<td>Gray matting, low plasticity</td>
<td>SS</td>
<td>34-35</td>
<td>100</td>
</tr>
<tr>
<td>40</td>
<td>Limestone</td>
<td>Light gray, interbedded with reddish brown silty clay</td>
<td>SS</td>
<td>37-38</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Silty Clay</td>
<td>Reddish brown, low plasticity, blocky</td>
<td>SS</td>
<td>39.5-40</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Shale</td>
<td>Brown, weathered, friable, wet @ 41'</td>
<td>SS</td>
<td>40-41</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Sandstone</td>
<td>Light grey</td>
<td>SS</td>
<td>43-44</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Sandstone</td>
<td>Reddish brown, some gravels, high plasticity</td>
<td>SS</td>
<td>45.5-46</td>
<td>100</td>
</tr>
<tr>
<td>50</td>
<td>Clay</td>
<td>Reddish grey</td>
<td>SS</td>
<td>46-47</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Sandstone</td>
<td>Poorly sorted, transitions to green clay</td>
<td>SS</td>
<td>47.5-48</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Clay</td>
<td>Green, high plasticity, some gravels</td>
<td>SS</td>
<td>48.5-49</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Silty Clay</td>
<td>Brown, low plasticity, transitions to claystone</td>
<td>SS</td>
<td>49-50</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Clay</td>
<td>Brown, gravel present, medium grained transitioning to green, high plasticity at 58.5'</td>
<td>SS</td>
<td>52-53</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Sandstone</td>
<td>Light grey</td>
<td>SS</td>
<td>55-58</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Sandy Clay</td>
<td>Brown, some gravel, wet</td>
<td>SS</td>
<td>58.5-59</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Sandstone</td>
<td>Light grey</td>
<td>SS</td>
<td>59-60</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Sandy Clay</td>
<td>Brown, some gravel, wet</td>
<td>SS</td>
<td>60-61</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Sandy Clay</td>
<td>Brown, some gravel, wet</td>
<td>SS</td>
<td>61-61.5</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Sandy Clay</td>
<td>Brown, some gravel, wet</td>
<td>SS</td>
<td>61.5-62</td>
<td></td>
</tr>
</tbody>
</table>

The stratification lines represent approximate boundary lines between soil and rock types. Actual transitions may be gradual.
**LOG OF BORING NO. B-15**

**CLIENT:** SORD, LLC  
**PROJECT NAME:** SORD Hydrogeologic Investigation  
**PROJECT NUMBER:** 27215136.00  
**PROJECT LOCATION:** SORD LANDFILL, Ardmore, OK  
**GEOLOGIST:** Robert Fowler  
**START DATE:** 8/3/2016  
**FINISH DATE:** 8/8/2016

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGY DESCRIPTION</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>RECOVERY (%)</th>
<th>MONITORING WELL CONSTRUCTION</th>
<th>MONITORING WELL DESCRIPTION</th>
<th>ELEVATION (FMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SSD</td>
<td>Silty Clay, tan-light grey, with orange mottling, transitions to dark brown at 1.5, then back to tan-light gray with interbedded green clay at 8.5</td>
<td>SS</td>
<td>0-1</td>
<td></td>
<td></td>
<td></td>
<td>825</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SS</td>
<td>1.5-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>SSD</td>
<td>Silty Clay</td>
<td>SS</td>
<td>4-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>SSD</td>
<td>Limestone; light-gray to gray</td>
<td>SS</td>
<td>8.5-9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9-10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>SSD</td>
<td>Sandy Clay; reddish-brown, some interbedded green clay, medium plasticity</td>
<td>SS</td>
<td>10.5-11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silty Clay; reddish-orange, with orange and gray mottling, high plasticity</td>
<td>SS</td>
<td>13-14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Geo Tech Bucket</td>
<td>15-20</td>
<td></td>
<td></td>
<td></td>
<td>810</td>
</tr>
<tr>
<td>20</td>
<td>SSD</td>
<td>Clay; brown, with gray mottling, dry/hard, some gray, orange and green mottling</td>
<td>SS</td>
<td>19-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24-25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td></td>
<td></td>
<td>SS</td>
<td>27-28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>Silty Clay; brown</td>
<td>SS</td>
<td>30-31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DRILLER:** Bill Graham  
**DRILLING RIG:** B150LS Sonic Rig  
**DRILLING METHOD:** Rotary Sonic  
**WELL DEPTH COMPLETION:** 95.00 ftgs

**TOC ELEVATION:** N/A ftmsl  
**LOCATION:**  
NORTHING: 319808.5100  
EASTING: 2258582.7900  
**SURFACE ELEVATION:** 825.00 ftmsl  
**WATER LEVEL:** fgbs  
**WATER LEVEL DATE:** 9/7/2016

*The stratification lines represent approximate boundary lines between soil and rock types; actual transitions may be gradual.*
**LOG OF BORING NO.: B-14**

**11219 Richardson Drive**

**North Little Rock, AR**

**DRILLER:** Bill Graham  
**DRILLING RIG:** 8150LS Sonic Rig  
**TOC ELEVATION:** N/A fmsl  
**WELL DEPTH COMPLETION:** 85.50 ft

**CLIENT:** SORD, LLC  
**PROJECT NAME:** SORD Hydrogeologic Investigation  
**PROJECT NUMBER:** 272151 36.00  
**PROJECT LOCATION:** SORD LANDFILL, Ardmore, OK  
**GEOLOGIST:** Robert Fowler  
**SAMPLING METHOD:** Continuous Core  
**START DATE:** 7/12/2016  
**FINISH DATE:** 7/12/2016  
**BORING DIAMETER:** 6\"  
**WELL DIAMETER:** N/A  
**LOCATION:**  
- Northing: 319604.0000  
- Easting: 2258152.8000  
**WATER LEVEL:** fbgs  
**STABILIZED WATER ELEVATION:** N/A fmsl  
**WATER LEVEL DATE:** 9/7/2016

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGY DESCRIPTION</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>RECOVERY (%)</th>
<th>MONITORING WELL CONSTRUCTION</th>
<th>MONITORING WELL DESCRIPTION</th>
<th>ELEVATION (FMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>Silty Clay</td>
<td>reddish brown, hard</td>
<td>SS</td>
<td>69-70</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>Sandstone</td>
<td>light gray, poorly sorted, conglomerate</td>
<td>SS</td>
<td>75.5-76</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>Clay</td>
<td>dark brown, hard, some gray mottling, some claystone present</td>
<td>SS</td>
<td>79-80</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth (ft)</td>
<td>Lithology</td>
<td>Lithology Description</td>
<td>Sample Type</td>
<td>Sample Depth</td>
<td>Recovery</td>
<td>Monitoring Well Construction</td>
<td>Monitoring Well Description</td>
<td>Elevation (fmsl)</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
<td>-----------------------</td>
<td>-------------</td>
<td>--------------</td>
<td>----------</td>
<td>------------------------------</td>
<td>-----------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>35</td>
<td>sorted, wet Silty Clay; gray-greenish</td>
<td>SS</td>
<td>32-33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>780</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>SS</td>
<td>33-34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>775</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>SS</td>
<td>39-40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>770</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>SS</td>
<td>41-42</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>770</td>
</tr>
<tr>
<td>50</td>
<td>Clay; reddish brown, some gray mottling, hard, low plasticity, CaCO3 inclusions noted at 57', some blue-green, yellow and dark brown lenses</td>
<td>SS</td>
<td>49-50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>765</td>
</tr>
<tr>
<td>55</td>
<td></td>
<td>SS</td>
<td>51-52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>765</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>SS</td>
<td>57-58</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>760</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>SS</td>
<td>59-60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>760</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>SS</td>
<td>61-62</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>755</td>
</tr>
</tbody>
</table>

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery (%)</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (ftmsl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Silty Clay</td>
<td>reddish brown, dark with some CaCO3 clasts, gray mottling</td>
<td>SS</td>
<td>0-1</td>
<td></td>
<td></td>
<td></td>
<td>810</td>
</tr>
<tr>
<td>5</td>
<td>Silty Clay</td>
<td></td>
<td>SS</td>
<td>2-3</td>
<td></td>
<td></td>
<td></td>
<td>805</td>
</tr>
<tr>
<td>10</td>
<td>Clay</td>
<td>reddish brown, blocky, fat</td>
<td>SS</td>
<td>9-10</td>
<td></td>
<td></td>
<td></td>
<td>800</td>
</tr>
<tr>
<td>15</td>
<td>Clay &amp; Silty Clay</td>
<td>light gray transitions to reddish brown with gray mottling, then greenish, CaCO3</td>
<td>SS</td>
<td>12-13</td>
<td></td>
<td></td>
<td></td>
<td>795</td>
</tr>
<tr>
<td>20</td>
<td>Sand</td>
<td>light gray, coarse, poorly sorted, wet</td>
<td>SS</td>
<td>15-16</td>
<td></td>
<td></td>
<td></td>
<td>790</td>
</tr>
<tr>
<td>25</td>
<td>Silty Clay</td>
<td>dark brown (reddish), some gray mottling, low plasticity</td>
<td>SS</td>
<td>17-18</td>
<td></td>
<td></td>
<td></td>
<td>785</td>
</tr>
<tr>
<td>30</td>
<td>Sandstone</td>
<td>light tan, coarse grained, poorly sorted</td>
<td>SS</td>
<td>20-21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand</td>
<td>Sand; light gray, some clay</td>
<td>SS</td>
<td>22-23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silty Clay</td>
<td>Sandstone; light tan, coarse grained, poorly sorted</td>
<td>SS</td>
<td>25-26</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand; tan, poorly</td>
<td>SS</td>
<td>28-29</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silt; light gray, some clay</td>
<td>SS</td>
<td>29.5-30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sand; tan, poorly</td>
<td>SS</td>
<td>30-31</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The stratification lines represent approximate boundary lines between soil and rock types. Actual transitions may be gradual.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Clay</td>
<td>some black mottling, high plasticity</td>
</tr>
<tr>
<td>34</td>
<td>Sand</td>
<td>Sand; light gray, poorly sorted, coarse grained, wet</td>
</tr>
<tr>
<td>36</td>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Log of Boring No.: B-12**

**Driller:** Bill Graham  
**Drilling Rig:** B1S0LS Sonic Rig  
**Surface Elevation:** 756.00 ft

**Well Completion:** 39.89 ft

**Drilling Method:** Rotary Sonic  
**Well Diameter:** N/A

**Drilling Contractor:** Associated Environmental Industries  
**Location:** Northing: 320225.8000  
**Easting:** 2257288.9500

**Sampling Method:** Continuous Core  
**Stabilized Water Elevation:** N/A

**Start Date:** 7/13/2016  
**Finish Date:** 7/13/2016

**Boring Diameter:** 6"  
**Water Level:** ft

**Well Diameter:** N/A  
**Water Level Date:** 9/7/2016

**RECOVERY:** 100

**Sample Type:** SS  
**Sample Depth:** 36-37

**Elevation (ft):**
- 724
- 722
- 720
- 718
- 716

---

*The stratification lines represent approximate boundaries between soil and rock types; actual transitions may be gradual.*
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery (%)</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (FV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Top Soil</td>
<td>reddish brown, clay, rootlets</td>
<td>SS</td>
<td>0-1</td>
<td></td>
<td></td>
<td></td>
<td>756</td>
</tr>
<tr>
<td>2</td>
<td>Top Soil</td>
<td>Silty Clay; brown, rootlets some gravel present (&lt;10%)</td>
<td>SS</td>
<td>3.5-4.1</td>
<td>100</td>
<td></td>
<td></td>
<td>754</td>
</tr>
<tr>
<td>6</td>
<td>Top Soil</td>
<td>Clay; reddish brown, silty, poorly sorted gravels presents</td>
<td>SS</td>
<td>9-10</td>
<td></td>
<td></td>
<td></td>
<td>752</td>
</tr>
<tr>
<td>12</td>
<td>Top Soil</td>
<td>Silty Clay; reddish brown, gravel present (30-40%) less gravel toward the base</td>
<td>SS</td>
<td>16-17</td>
<td></td>
<td></td>
<td></td>
<td>750</td>
</tr>
<tr>
<td>14</td>
<td>Top Soil</td>
<td>Clay; dark brown with light gray and orange motting, large gravels present</td>
<td>SS</td>
<td>21.8-22.8</td>
<td>100</td>
<td></td>
<td></td>
<td>748</td>
</tr>
<tr>
<td>22</td>
<td>Top Soil</td>
<td>Silty Clay; reddish brown with orange motting, gravel present (10%)</td>
<td>SS</td>
<td>23.24</td>
<td></td>
<td></td>
<td></td>
<td>746</td>
</tr>
<tr>
<td>24</td>
<td>Top Soil</td>
<td>Sandstone; light gray, weathered, poorly sorted, friable, wet</td>
<td>SS</td>
<td>29-30</td>
<td></td>
<td></td>
<td></td>
<td>744</td>
</tr>
<tr>
<td>30</td>
<td>Top Soil</td>
<td>Clay; reddish brown,</td>
<td>SS</td>
<td>30-31</td>
<td></td>
<td></td>
<td></td>
<td>742</td>
</tr>
<tr>
<td>Depth (ft)</td>
<td>Lithology</td>
<td>Lithology Description</td>
<td>Sample Type</td>
<td>Sample Depth</td>
<td>Recovery (M)</td>
<td>Monitoring Well Construction</td>
<td>Monitoring Well Description</td>
<td>Elevation (FMSL)</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------------</td>
<td>-------------------------------------------------------------</td>
<td>-------------</td>
<td>--------------</td>
<td>--------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>32</td>
<td>V</td>
<td>with some limestone gravels at 33'</td>
<td>SS</td>
<td>33-34</td>
<td>50</td>
<td></td>
<td></td>
<td>732</td>
</tr>
<tr>
<td>36</td>
<td>Sand</td>
<td>Sand; light gray, poorly sorted, wet</td>
<td>SS</td>
<td>35-36</td>
<td></td>
<td></td>
<td></td>
<td>728</td>
</tr>
<tr>
<td>40</td>
<td>Silty Clay</td>
<td>Silty Clay; green transitioning reddish brown with gray mottling</td>
<td></td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>724</td>
</tr>
<tr>
<td>44</td>
<td>Sandy Clay</td>
<td>Sandy Clay; reddish brown, coarse grained sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>720</td>
</tr>
<tr>
<td>48</td>
<td></td>
<td>Claystone; dark brown, blocky, grey mottling</td>
<td></td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>716</td>
</tr>
<tr>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>712</td>
</tr>
<tr>
<td>56</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>708</td>
</tr>
</tbody>
</table>
# SCS Engineers

**11219 Richardson Drive**  
**North Little Rock, AR**

**Project Name:** SORD Hydrogeologic Investigation  
**Project Number:** 27215136.00  
**Project Location:** SORD LANDFILL, Ardmore, OK  
**Geologist:** Robert Fowler  
**Start Date:** 7/14/2016  
**Finish Date:** 7/14/2016

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (ftmsl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Silty Clay</td>
<td>Dark brown; organic present</td>
<td>SS</td>
<td>0-1</td>
<td></td>
<td></td>
<td></td>
<td>764</td>
</tr>
<tr>
<td>4</td>
<td>Clay</td>
<td>Reddish brown, some silty layers, some small gravel</td>
<td>SS</td>
<td>4-5</td>
<td>90</td>
<td></td>
<td></td>
<td>760</td>
</tr>
<tr>
<td>8</td>
<td>Sandstone</td>
<td>Light gray, poorly sorted, friable</td>
<td>SS</td>
<td>9-10</td>
<td></td>
<td></td>
<td></td>
<td>756</td>
</tr>
<tr>
<td>12</td>
<td>Silty Clay</td>
<td>Light gray, high plasticity transitions to a reddish brown low to medium plasticity with some small gravels at 12'</td>
<td>SS</td>
<td>11-12</td>
<td>100</td>
<td></td>
<td></td>
<td>752</td>
</tr>
<tr>
<td>16</td>
<td>Silty Clay</td>
<td>Light gray, high plasticity transitions to a reddish brown low to medium plasticity with some small gravels at 12'</td>
<td>SS</td>
<td>14-15</td>
<td></td>
<td></td>
<td></td>
<td>748</td>
</tr>
<tr>
<td>20</td>
<td>Limestone</td>
<td></td>
<td>SS</td>
<td>19-20</td>
<td></td>
<td></td>
<td></td>
<td>744</td>
</tr>
<tr>
<td>24</td>
<td>Clay</td>
<td>Red-brown, limestone gravels (&lt;10%), orange motting</td>
<td>SS</td>
<td>22-23</td>
<td>100</td>
<td></td>
<td></td>
<td>740</td>
</tr>
<tr>
<td>28</td>
<td>Silty Clay</td>
<td>Dark brown, limestone gravels (&lt;30%), light gray motting, transitions to green</td>
<td>SS</td>
<td>26-27</td>
<td></td>
<td></td>
<td></td>
<td>736</td>
</tr>
<tr>
<td>32</td>
<td>Silty Clay</td>
<td></td>
<td>SS</td>
<td>29-30</td>
<td></td>
<td></td>
<td></td>
<td>732</td>
</tr>
</tbody>
</table>

*The stratification lines represent approximate boundary lines between soil and rock types. Actual transitions may be gradual.*
<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGY DESCRIPTION</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>RECOVERY (%)</th>
<th>MONITORING WELL CONSTRUCTION</th>
<th>MONITORING WELL DESCRIPTION</th>
<th>ELEVATION (FMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Silty Clay; reddish brown, some orange mottling, high plasticity, with weathered limestone and limestone gravels transitions to a greenish gray color slightly moist at 44.5'</td>
<td>SS</td>
<td>32-33</td>
<td></td>
<td></td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Silty Clay;</td>
<td>SS</td>
<td>34-35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Claystone; reddish brown, hard, silty, weathered shale, some grey and orange mottling</td>
<td>SS</td>
<td>38-39</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Sandstone; dark brown, hard, with some light grey to brown sands</td>
<td>SS</td>
<td>41-43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Sandstone; dark brown to grey, orange mottling</td>
<td>SS</td>
<td>45-46</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Shale; weathered</td>
<td></td>
<td>47-48</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td></td>
<td></td>
<td>49-50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**LOG OF BORING NO.: B-10**

**DRILLER:** Bill Graham  
**DRILLING RIG:** 8150LS Sonic Rig  
**TOC ELEVATION:** N/A fmsl  
**WELL DEPTH COMPLETION:** 53.75 fbgs  
**CLIENT:** SORD, LLC  
**PROJECT NAME:** SORD Hydrogeologic Investigation  
**PROJECT NUMBER:** 27215136.00  
**PROJECT LOCATION:** SORD LANDFILL, Ardmore, OK  
**GEOLOGIST:** Robert Fowler  
**SAMPLING METHOD:** Continuous Core  
**START DATE:** 7/14/2016  
**FINISH DATE:** 7/14/2016  
**BORING DIAMETER:** 6"  
**WELL DIAMETER:** N/A  
**WATER LEVEL:** fbgs  
**WATER LEVEL DATE:** 9/7/2016

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGY DESCRIPTION</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>RECOVERY</th>
<th>MONITORING WELL CONSTRUCTION</th>
<th>MONITORING WELL DESCRIPTION</th>
<th>ELEVATION (FMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Sandy Clay; reddish brown</td>
<td></td>
<td>SS</td>
<td>0-1</td>
<td>100</td>
<td></td>
<td></td>
<td>776</td>
</tr>
<tr>
<td>4</td>
<td>Silty Clay</td>
<td></td>
<td>SS</td>
<td>3-4</td>
<td></td>
<td></td>
<td></td>
<td>772</td>
</tr>
<tr>
<td>8</td>
<td>Clay; dark reddish brown, light gray mottling, medium plasticity, some silt</td>
<td></td>
<td>SS</td>
<td>9-10</td>
<td>100</td>
<td></td>
<td></td>
<td>768</td>
</tr>
<tr>
<td>12</td>
<td>Silty Clay; light gray, medium plasticity transitions to a reddish brown color with orange and black mottling at 10.5'</td>
<td></td>
<td>SS</td>
<td>10.5-11</td>
<td></td>
<td></td>
<td></td>
<td>764</td>
</tr>
<tr>
<td>16</td>
<td>Clay; green-light gray, high plasticity transitions to reddish brown with orange mottling at 15.5'</td>
<td></td>
<td>SS</td>
<td>15-15.5</td>
<td>100</td>
<td></td>
<td></td>
<td>760</td>
</tr>
<tr>
<td>20</td>
<td>Limestone; interbedded with thinly bedded reddish brown clay</td>
<td></td>
<td>SS</td>
<td>16-17</td>
<td></td>
<td></td>
<td></td>
<td>756</td>
</tr>
<tr>
<td>24</td>
<td>Silty Clay; reddish brown, medium plasticity, some weathered limestone and limestone gravels</td>
<td></td>
<td>SS</td>
<td>19-20</td>
<td>100</td>
<td></td>
<td></td>
<td>752</td>
</tr>
<tr>
<td>28</td>
<td>Limestone; interbedded with weathered limestone and limestone gravels</td>
<td></td>
<td>SS</td>
<td>24.5-24.8</td>
<td></td>
<td></td>
<td></td>
<td>748</td>
</tr>
<tr>
<td>32</td>
<td>Silty Clay; reddish brown, interbedded with weathered limestone and limestone gravels</td>
<td></td>
<td>SS</td>
<td>25-26</td>
<td></td>
<td></td>
<td></td>
<td>744</td>
</tr>
<tr>
<td></td>
<td>Limestone, gravel</td>
<td></td>
<td>SS</td>
<td>29-30</td>
<td></td>
<td></td>
<td></td>
<td>740</td>
</tr>
<tr>
<td></td>
<td>Limestone, gravel</td>
<td></td>
<td>SS</td>
<td>30-30.4</td>
<td></td>
<td></td>
<td></td>
<td>736</td>
</tr>
</tbody>
</table>

**THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES. ACTUAL TRANSITIONS MAY BE GRADUAL.**
**LOG OF BORING NO.: B-8**

**CLIENT:** SORD, LLC  
**PROJECT LOCATION:** SORD LANDFILL, Ardmore, OK  
**PROJECT NUMBER:** 27215136.00  
**PROJECT NAME:** SORD Hydrogeologic Investigation  
**GEOLOGIST:** Robert Fowler

**DRILLER:** Bill Graham  
**DRILLING RIG:** B150LS Sonic Rig  
**DRILLING METHOD:** Rotary Sonic  
**SURFACE ELEVATION:** 775.00 ftmsl  
**TOC ELEVATION:** N/A ftmsl  
**WELL DEPTH COMPLETION:** 55.00 ftbg

**START DATE:** 8/2/2016  
**FINISH DATE:** 8/2/2016  
**BORING DIAMETER:** 6”  
**WELL DIAMETER:** N/A  
**WATER LEVEL:** 650 ftbg

<table>
<thead>
<tr>
<th>Depth (FT)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (FTMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Sand</td>
<td>Sand; light gray, poorly sorted, wet ***</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>740</td>
</tr>
<tr>
<td>36</td>
<td>Silty Clay</td>
<td>Silty Clay; green, medium plasticity</td>
<td>ss</td>
<td>38-39</td>
<td>80</td>
<td></td>
<td></td>
<td>736</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td>ss</td>
<td>39-40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Clay</td>
<td>Clay; dark brown, blocky, hard, some gray mottling, some thin CoCO3 Layers</td>
<td>ss</td>
<td>42-43</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td></td>
<td></td>
<td>ss</td>
<td>48-49</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td></td>
<td></td>
<td>ss</td>
<td>52-53</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.**
## SCS Engineers

**Log of Boring No.: B-8**

### Project Information
- **Address:** 11219 Richardson Drive, North Little Rock, AR
- **Client:** SORD, LLC
- **Project Name:** SORD Hydrogeologic Investigation
- **Project Number:** 27215136.00
- **Project Location:** SORD Landfill, Ardmore, OK
- **GEOLOGIST:** Robert Fowler
- **DRILLER:** Bill Graham
- **DRILLING RIG:** 8150LS Sonic Rig
- **DRILLING METHOD:** Rotary Sonic
- **Surface Elevation:** 775.00 ft
- **TOC Elevation:** N/A ft
- **WELL DEPTH COMPLETION:** 55.00 ft
- **CONTRACTOR:** Associated Environmental industries
- **Location:**&emsp;NORTHING: 320663.9300
&emsp;EASTING: 2258141.7400
- **Sampling Method:** Continuous Core
- **Start Date:** 8/2/2016
- **Finish Date:** 8/2/2016
- **BoR Diameter:** 6"
- **WATER LEVEL:** N/A ft
- **Stabilized Water Elevation:** N/A ft
- **WATER LEVEL DATE:** 9/7/2016

### Lithology Table

<table>
<thead>
<tr>
<th>Depth (FT)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Top Soil</td>
<td>Topsoil; reddish brown, silty-clay, organics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Silty Clay</td>
<td>Silty Clay; reddish brown, with gray motting; medium to high plasticity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Clay</td>
<td>Clay; reddish brown, limestone gravels, coarse grained</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Silty Clay</td>
<td>Silty Clay; reddish brown, some weathered limestone, some orange and gray motting</td>
<td>SS</td>
<td>11-12</td>
</tr>
<tr>
<td>16</td>
<td>Silty Clay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Limestone</td>
<td>Limestone</td>
<td>SS</td>
<td>19-20</td>
</tr>
<tr>
<td>24</td>
<td>Clay</td>
<td>Clay; dark brown, orange and gray motting, organics present, limestone gravels,</td>
<td>SS</td>
<td>21-22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>transitions to a greenish gray clay at 27.5'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td>SS</td>
<td>27.5-28</td>
</tr>
<tr>
<td>29</td>
<td></td>
<td></td>
<td>SS</td>
<td>29-30</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td></td>
<td>SS</td>
<td>31-32</td>
</tr>
</tbody>
</table>

**Elevation (FMSL):**

- 772
- 768
- 764
- 760
- 756
- 752
- 748
- 744

---

The Stratification lines represent approximate boundary lines between soil and rock types. Actual transitions may be gradual.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery (%)</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (ftNGL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td>Clay</td>
<td>Clay, dark brown, with coarse grain</td>
<td>SS</td>
<td>32-33</td>
<td></td>
<td></td>
<td></td>
<td>728</td>
</tr>
<tr>
<td>36</td>
<td>Clay</td>
<td>limestone gravel</td>
<td>SS</td>
<td>35-36</td>
<td></td>
<td></td>
<td></td>
<td>724</td>
</tr>
<tr>
<td>40</td>
<td>Sandstone</td>
<td>Sandstone; gray, with thin layers of</td>
<td>SS</td>
<td>37-38</td>
<td>100</td>
<td></td>
<td></td>
<td>720</td>
</tr>
<tr>
<td></td>
<td></td>
<td>red clay interbedded, poorly sorted,</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>medium to coarse grained</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Log of Boring No. B-7

**Client:** SORD, LLC  
**Project Name:** SORD Hydrogeologic Investigation  
**Project Number:** 27215160  
**Project Location:** SORD LANDFILL, Ardmore, OK  
**Geologist:** Robert Fowler  
**Driller:** Bill Graham  
**Drilling Rig:** 8150LS Sonic Rig  
**Drilling Method:** Rotary Sonic  
**Drilling Contractor:** Associated Environmental Industries  
**Surface Elevation:** 762.00 fmns  
**TOC Elevation:** N/A fmns  
**WELL Depth Completion:** 43.00 ftbgns  
**Location:**  
- **NORTHING:** 320659.4400  
- **EASTING:** 2257711.7600  
**Sampling Method:** Continuous Core  
**Boring Diameter:** 6"  
**WATER LEVEL:** fbgs  
**Stabilized Water Elevation:** N/A fmns  
**Finish Date:** 8/2/2016  
**Drilling Date:** 8/2/2016  
**Water Level Date:** 9/7/2016

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery (%)</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (fmns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Silty Clay</td>
<td>Silty clay, reddish brown to brown, some orange and gray motting, rootlets present, some gravel present, low plasticity</td>
<td>SS</td>
<td>0-1</td>
<td></td>
<td></td>
<td></td>
<td>760</td>
</tr>
<tr>
<td>4</td>
<td>Silty Clay</td>
<td></td>
<td>SS</td>
<td>4-5</td>
<td>100</td>
<td></td>
<td></td>
<td>756</td>
</tr>
<tr>
<td>8</td>
<td>Silty Clay</td>
<td></td>
<td>SS</td>
<td>9-10</td>
<td></td>
<td></td>
<td></td>
<td>752</td>
</tr>
<tr>
<td>12</td>
<td>Silty Clay</td>
<td></td>
<td>SS</td>
<td>11-12</td>
<td>100</td>
<td></td>
<td></td>
<td>748</td>
</tr>
<tr>
<td>16</td>
<td>Sandstone</td>
<td>Sandstone, light gray, poorly sorted, coarse grain</td>
<td>SS</td>
<td>17-18</td>
<td></td>
<td></td>
<td></td>
<td>744</td>
</tr>
<tr>
<td>20</td>
<td>Silty Clay</td>
<td>Silty clay, gray, medium plasticity transitioning to reddish brown with orange and gray motting, blocky at 19.5&quot;</td>
<td>SS</td>
<td>19-19.5</td>
<td></td>
<td></td>
<td></td>
<td>740</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SS</td>
<td>19.5-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Limestone</td>
<td>Limestone, gray, with brown silty clay interbedded</td>
<td>SS</td>
<td>21-22</td>
<td>100</td>
<td></td>
<td></td>
<td>736</td>
</tr>
<tr>
<td>28</td>
<td>Silty Clay</td>
<td>Silty clay, dark brown, low plasticity</td>
<td>SS</td>
<td>25-26</td>
<td></td>
<td></td>
<td></td>
<td>732</td>
</tr>
<tr>
<td>32</td>
<td>Silty Clay</td>
<td></td>
<td>SS</td>
<td>29-30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The stratification lines represent approximate boundary lines between soil and rock types; actual transitions may be gradual.
<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGY DESCRIPTION</th>
<th>SAMPLE TYPE</th>
<th>SAMPLE DEPTH</th>
<th>RECOVERY (%)</th>
<th>MONITORING WELL CONSTRUCTION</th>
<th>MONITORING WELL DESCRIPTION</th>
<th>ELEVATION (FMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>32</td>
<td></td>
<td>32'</td>
<td></td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>722</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>720</td>
</tr>
<tr>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>718</td>
</tr>
<tr>
<td>DEPTH (FT)</td>
<td>LITHOLOGY</td>
<td>LITHOLOGY DESCRIPTION</td>
<td>Sample Type</td>
<td>Sample Depth</td>
<td>RECOVERY (%)</td>
<td>MONITORING WELL CONSTRUCTION</td>
<td>MONITORING WELL DESCRIPTION</td>
<td>ELEVATION (FMSL)</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
<td>------------------------</td>
<td>-------------</td>
<td>--------------</td>
<td>--------------</td>
<td>-----------------------------</td>
<td>----------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>60</td>
<td>Silty Clay</td>
<td>reddish brown motting, high plasticity</td>
<td>SS</td>
<td>61-62</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64</td>
<td></td>
<td>Silty Clay; brown to gray, low to medium plasticity</td>
<td>SS</td>
<td>64-65</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>68</td>
<td>Limestone</td>
<td>Limestone; light gray-white</td>
<td>SS</td>
<td>65-65.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>72</td>
<td>Clayey Sand</td>
<td>Clayey Sand; gray, fine grained, well sorted, some moisture</td>
<td>SS</td>
<td>74-75</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>76</td>
<td>Sand</td>
<td>Sand; gray, fine grained, some clay, moist</td>
<td>SS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL
**LOG OF BORING NO.: PZ-20**

**11219 Richardson Drive**  
North Little Rock, AR

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery (ft)</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (ft GND)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Top Soil</td>
<td>Topsoil; brown, silty clay, black organics</td>
<td>SS</td>
<td>0-1</td>
<td></td>
<td></td>
<td></td>
<td>832.86</td>
</tr>
<tr>
<td>4</td>
<td>Sandy Clay</td>
<td>Sandy Clay; orange, black organics, low-medium plasticity</td>
<td>SS</td>
<td>2-3</td>
<td>100</td>
<td></td>
<td></td>
<td>832.36</td>
</tr>
<tr>
<td>8</td>
<td>Sand</td>
<td>Sand; tan, fine grained, well sorted</td>
<td>SS</td>
<td>7-8</td>
<td></td>
<td></td>
<td></td>
<td>831.86</td>
</tr>
<tr>
<td>12</td>
<td>Clay</td>
<td>Clay; tan, orange mottling, fat, high plasticity, black organics</td>
<td>SS</td>
<td>9-10</td>
<td>100</td>
<td></td>
<td></td>
<td>831.36</td>
</tr>
<tr>
<td>16</td>
<td>Limestone</td>
<td>Limestone; light grey</td>
<td>SS</td>
<td>14-15</td>
<td></td>
<td></td>
<td></td>
<td>830.86</td>
</tr>
<tr>
<td>20</td>
<td>Silty Clay</td>
<td>Silty Clay; red-brown some gray mottling, medium plasticity</td>
<td>Geo Tech Bucket</td>
<td>24-25</td>
<td>100</td>
<td></td>
<td></td>
<td>830.36</td>
</tr>
<tr>
<td>24</td>
<td></td>
<td></td>
<td>SS</td>
<td>17.5-18</td>
<td></td>
<td></td>
<td></td>
<td>829.86</td>
</tr>
<tr>
<td>28</td>
<td></td>
<td></td>
<td>SS</td>
<td>17.5-18</td>
<td></td>
<td></td>
<td></td>
<td>829.36</td>
</tr>
</tbody>
</table>

**THE STRATIFICATION LINES REPRESENT APPROXIMATE**  
**BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL**  
**TRANSITIONS MAY BE GRADUAL**  

**Driller:** Bill Graham  
**Drilling Rig:** B150LS Sonic Rig  
**Surface Elevation:** 830.86 ft GND  
**Drilling Method:** Rotary Sonic  
**Toc Elevation:** 833.16 ft GND

**Drilling Contractor:** Associated Environmental Industries  
**Location:** Northing: 317377.8208  
**Easting:** 2258726.3740  
**WELL DEPTH COMPLETION:** 76.00 ft GND

**Start Date:** 8/15/2016  
**Finish Date:** 8/16/2016  
**Boring Diameter:** 6"  
**Stabilized Water Elevation:** 782.22 ft GND  
**WELL DIAMETER:** 2"  
**Water Level Date:** 9/7/2016
**LOG OF BORING NO.: PZ-19**

**CLIENT:** SORD, LLC  
**PROJECT NAME:** SORD Hydrogeologic Investigation  
**PROJECT NUMBER:** 27215136.00  
**PROJECT LOCATION:** SORD LANDFILL, Ardmore, OK  
**GEOLOGIST:** Robert Fowler  
**DRILLER:** Bill Graham  
**DRILLING RIG:** 81.50LS Sonic Rig  
**DRILLING METHOD:** Rotary Sonic  
**DRILLING CONTRACTOR:** Associated Environmental Industries  
**WELL DEPTH COMPLETION:** 92.50 ft bs  
**SURFACE ELEVATION:** 831.93 ftmsl  
**TOC ELEVATION:** 834.17 ftmsl  
**START DATE:** 8/11/2016  
**FINISH DATE:** 8/15/2016  
**BORING DIAMETER:** 6"  
**WELL DIAMETER:** 2"  
**SAMPLING METHOD:** Continuous Core  
**WATER LEVEL:** 44.71 ft bs  
**NORTHING:** 318953.5286  
**EASTING:** 2259009.6160  
**STABILIZED WATER ELEVATION:** 787.22 ftmsl  
**WATER LEVEL DATE:** 9/7/2016

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGY DESCRIPTION</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>RECOVERY (%)</th>
<th>MONITORING WELL CONSTRUCTION</th>
<th>MONITORING WELL DESCRIPTION</th>
<th>ELEVATION (FTMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td></td>
<td></td>
<td>SS</td>
<td>64-65</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>Silty Clay</td>
<td>Silty Clay; reddish brown, interbedded with dark gray silty clay, medium plasticity some orange and gray mottling, dark brown between 73' and 78' and gray limestone gravels noted at 78'</td>
<td>SS</td>
<td>68-69</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td></td>
<td></td>
<td>SS</td>
<td>73-74</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>80</td>
<td></td>
<td></td>
<td>SS</td>
<td>78-79</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>Limestone</td>
<td>Limestone; light gray, weathered</td>
<td>SS</td>
<td>82-83</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>86</td>
<td></td>
<td></td>
<td>SS</td>
<td>84-85</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>Silty Clay</td>
<td>Silty Clay; reddish brown, orange-yellowish and gray mottling, medium plasticity</td>
<td>SS</td>
<td>90-91</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The stratification lines represent approximate boundary lines between soil and rock types; actual transitions may be gradual.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Limestone</td>
<td></td>
<td>SS</td>
<td>27-28</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sand</td>
<td></td>
<td>SS</td>
<td>28-29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silty Clay;</td>
<td>light gray, orange, mottled, some thin sand layers</td>
<td>SS</td>
<td>29.5-30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limestone</td>
<td></td>
<td>SS</td>
<td>31-31.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SS</td>
<td>33-34</td>
<td>100</td>
</tr>
<tr>
<td>35</td>
<td>Sand</td>
<td></td>
<td>SS</td>
<td>39-40</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SS</td>
<td>40-41</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Clay</td>
<td>light gray-ton, high plasticity, orange mottling</td>
<td>SS</td>
<td>41-42</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>transitions to grayish green at 42'</td>
<td>SS</td>
<td>42-43</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SS</td>
<td>43-44</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Silty Clay;</td>
<td>reddish brown, orange and gray mottling, low-medium</td>
<td>SS</td>
<td>49-50</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>plasticity</td>
<td>SS</td>
<td>53-54</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Clay</td>
<td>reddish brown, high plasticity</td>
<td>SS</td>
<td>56-57</td>
<td>100</td>
</tr>
</tbody>
</table>

Bentonite pellet seal from 31’ to 33’ bgs
Sand filter pack from 33’ to 46’ bgs
Wet at 40’ bgs
10 ft of 2 in dia, 0.010 slot, Sch. 40 PVC green, 34.67’ - 44.67’ bgs
End Cap

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES. ACTUAL TRANSITIONS MAY BE GRADUAL.
### Log of Boring No.: PZ-19

**Client:** SORD, LLC  
**Project Name:** SORD Hydrogeologic Investigation  
**Project Number:** 27215136.00  
**Location:** SORD Landfill, Ardmore, OK  
**Geologist:** Robert Fowler  
**Sampling Method:** Continuous Core  
**Start Date:** 8/11/2016  
**Finish Date:** 8/15/2016  

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery (%)</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (FMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>Silty Clay</td>
<td>orange-tan</td>
<td>SS</td>
<td>0-1</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Sand</td>
<td></td>
<td>SS</td>
<td>6-7</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>Sand</td>
<td>SS</td>
<td>11-12</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Silty Clay</td>
<td>light grey, orange</td>
<td>SS</td>
<td>15-16</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>mottling, high</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>plasticity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Sand</td>
<td>gray to tan, fine</td>
<td>SS</td>
<td>19-20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>grained, some clay</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Clay</td>
<td>Clay; light grey,</td>
<td>SS</td>
<td>21-23</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>orange mottling, high</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>plasticity transitions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>to reddish brown at</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>23'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Silty Clay</td>
<td>reddish brown,</td>
<td>Shelby Tube</td>
<td>24-25</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>medium plasticity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The stratification lines represent approximate  
boundary lines between soil and rock types: actual  
transitions may be gradual.
### Log of Boring No. PZ-17

**Client:** SORD, LLC  
**Project Name:** SORD Hydrogeologic Investigation  
**Project Number:** 27215136.00  
**Location:** SORD Landfill, Ardmore, OK  
**Geologist:** Robert Fowler  
**Sampling Method:** Continuous Core  
**Driller:** Bill Graham  
**Drilling Rig:** 8150LS Sonic Rig  
**Drilling Method:** Rotary Sonic  
**Well Depth Completion:** 58.00 ft

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery</th>
<th>Monitoring Well Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Clay</td>
<td>Clay; greenish-grey</td>
<td>SS</td>
<td>28-28.5</td>
<td>100</td>
<td>Wet at 32' bgs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>greenish, poorly</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sorted, low plasticity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Sand</td>
<td>Sand; light grey,</td>
<td>SS</td>
<td>33-34</td>
<td>100</td>
<td>Sand filter pack from 28' to 41' bgs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>medium grained,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>some clay seams,</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>wet @ 32'</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Limestone</td>
<td>Limestone; weathered</td>
<td>SS</td>
<td>35.5-36.5</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SS</td>
<td>36.5-37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Sand</td>
<td>Sand; light grey,</td>
<td>SS</td>
<td>39-40</td>
<td>100</td>
<td>End Cap</td>
</tr>
<tr>
<td></td>
<td></td>
<td>well sorted, medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>grained</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Clayey Sand</td>
<td>Clayey Sand; some</td>
<td>SS</td>
<td>44-45</td>
<td>100</td>
<td>Portland/Bentonite grout</td>
</tr>
<tr>
<td></td>
<td></td>
<td>limestone gravels</td>
<td></td>
<td></td>
<td></td>
<td>from 41' to 58' bgs</td>
</tr>
<tr>
<td>48</td>
<td>Silty Clay</td>
<td>Silty Clay; reddish</td>
<td>SS</td>
<td>46-47</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>brown, orange and</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>gray motting, medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>plasticity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Sandy Clay</td>
<td>Sandy Clay; light</td>
<td>SS</td>
<td>49-50</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>grey-green, some</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>orange clay, low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>plasticity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Sand</td>
<td>Sand; light grey,</td>
<td>SS</td>
<td>51-52</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>some clay, well</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sorted, medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>grained</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Silty Clay</td>
<td>Silty Clay; brown,</td>
<td>SS</td>
<td>53-54</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>medium plasticity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Clay</td>
<td>Clay; greenish, some</td>
<td>SS</td>
<td>54-55</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>gravels</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Sandy Clay</td>
<td>Sandy Clay; light</td>
<td>SS</td>
<td>56-57</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>grey, low plasticity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Surface Elevation:** 792.05 fmsl  
**10C Elevation:** 794.35 fmsl  
**Location:** Northing: 319338.2632  
**Easting:** 2258160.2930  
**Water Level:** 25.09 ft

*The stratification lines represent approximate boundary lines between soil and rock types; actual transitions may be gradual.*
**LOG OF BORING NO.: PZ-17**

**CLIENT:** SORD, LLC  
**PROJECT NAME:** SORD Hydrogeologic Investigation  
**PROJECT NUMBER:** 27215136.00  
**PROJECT LOCATION:** SORD LANDFILL, Ardmore, OK  
**GEOLOGIST:** Robert Fowler

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGY DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>SS</td>
<td>0-1</td>
</tr>
<tr>
<td>4</td>
<td>SS</td>
<td>3-4</td>
</tr>
<tr>
<td>8</td>
<td>SS</td>
<td>9-10</td>
</tr>
<tr>
<td>12</td>
<td>SS</td>
<td>14-15</td>
</tr>
<tr>
<td>16</td>
<td>SS</td>
<td>15-16</td>
</tr>
<tr>
<td>20</td>
<td>SS</td>
<td>19-20</td>
</tr>
<tr>
<td>24</td>
<td>SS</td>
<td>21-22</td>
</tr>
<tr>
<td>28</td>
<td>SS</td>
<td>22-23</td>
</tr>
</tbody>
</table>

-4

**Sample Type** | **Sample Depth** | **Recovery** |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SS</td>
<td>0-1</td>
<td>100</td>
</tr>
<tr>
<td>SS</td>
<td>3-4</td>
<td>100</td>
</tr>
<tr>
<td>SS</td>
<td>9-10</td>
<td>100</td>
</tr>
<tr>
<td>SS</td>
<td>14-15</td>
<td>100</td>
</tr>
<tr>
<td>SS</td>
<td>15-16</td>
<td>100</td>
</tr>
<tr>
<td>SS</td>
<td>19-20</td>
<td>100</td>
</tr>
<tr>
<td>SS</td>
<td>21-22</td>
<td>100</td>
</tr>
<tr>
<td>SS</td>
<td>22-23</td>
<td>100</td>
</tr>
</tbody>
</table>

-4

**THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL**

- Stick Up (2.30')
- Concrete Pod (Approximately 6')
- Portland/Bentonite grout from ground surface to 26' bgs
- 2 in dia. Sch. 40 PVC solid riser from 0' - 29.67' bgs
- 10 ft of 2 in dia, 0.010 slot, Sch. 40 PVC screen, 29.67' - 39.67' bgs
- Bentonite pellet seal from 26' to 28' bgs
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery</th>
<th>Monitoring Well Construction</th>
<th>Monitoring Well Description</th>
<th>Elevation (fmsl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>95</td>
<td>Sand</td>
<td>Sand; light gray, wet</td>
<td>SS</td>
<td>94-95</td>
<td>80</td>
<td></td>
<td></td>
<td>735</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SS</td>
<td>95-96</td>
<td></td>
<td></td>
<td></td>
<td>730</td>
</tr>
</tbody>
</table>

The stratification lines represent approximate boundary lines between soil and rock types; actual transitions may be gradual.
**LOG OF BORING NO.: PZ-16**

**CLIENT:** SORD, LLC
**PROJECT NAME:** SORD Hydrogeologic Investigation
**PROJECT NUMBER:** 27215136.00
**PROJECT LOCATION:** SORD LANDFILL, Ardmore, OK
**GEOLOGIST:** Robert Fowler
**START DATE:** 8/11/2016
**FINISH DATE:** 8/11/2016

**DRILLER:** Bill Graham
**DRILLING RIG:** B150LS Sonic Rig
**DRILLING METHOD:** Rotary Sonic
**DRILLING CONTRACTOR:** Associated Environmental Industries
**LOCATION:**
  - Northing: 319794.9712
  - Easting: 2258999.7060
**WATER LEVEL:** 62.39 ft bgs
**STABILIZED WATER ELEVATION:** 766.28 ft msl

**SURFACE ELEVATION:** 828.67 ft msl
**TOC ELEVATION:** 830.94 ft msl
**WELL DEPTH COMPLETION:** 100.00 ft bgs

**DEPTH (FT)** | **LITHOLOGY** | **LITHOLOGY DESCRIPTION** | **Sample Type** | **Sample Depth** | **RECOVERY** | **MONITORING WELL CONSTRUCTION** | **MONITORING WELL DESCRIPTION** | **ELEVATION (FT msl)**
--- | --- | --- | --- | --- | --- | --- | --- | ---
60 | Clayey Sand | greenish, transitions to light gray, wet | SS | 58.5-59.5 | 100 | Wet at 62' bgs | Sand filter pack from 58' to 71' bgs | 765
65 | Sand | light gray-fan, wet at 62' bgs | SS | 64-65 | 100 | 10 ft of 2 in dia, 0.010 slot, Sch. 40 PVC green, 59.67' - 69.67' bgs | End Cap | 760
70 | Clay | greenish transitioning to reddish brown with high plasticity at 71' | SS | 70-71 | 100 | Portland/Bentonite grout from 71' to 100' bgs | | 755
75 | Silty Clay | reddish brown, grey motting, thin seams of gray clay, medium plasticity, dry with some limestone gravels between 87'-94' and Gray to green at 94' | SS | 79-80 | 100 | | | 750
80 | Silty Clay | | SS | 84-85 | | | | 745
85 | | | SS | 87-88 | | | | 740

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.
Silty Clay; reddish brown, orange motting, light gray seams, low to medium plasticity, transitioning to dark gray with low plasticity at 35'

Limestone; light gray, weathered

Clay; reddish brown, orange and gray motting, limestone gravel, medium plasticity

Silty Clay; reddish brown, light gray motting, medium plasticity

Silty Clay; green, high plasticity

Clayey Sand, light gray sand, green clay

Sand; light gray, some competent layers, limestone seam at 52.5' bgs

Silty clay; green to dark brown with medium plasticity
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>-5</td>
<td>Silty Clay</td>
<td>tan, high plasticity transitions to reddish brown with orange mottling, medium plasticity at 3'</td>
</tr>
<tr>
<td>0</td>
<td>SS</td>
<td>0-1</td>
</tr>
<tr>
<td>5</td>
<td>Silty Clay</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>SS</td>
<td>9-10</td>
</tr>
<tr>
<td>15</td>
<td>Limestone</td>
<td></td>
</tr>
<tr>
<td>15-16</td>
<td>Shelby Tube</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>SS</td>
<td>14-15</td>
</tr>
<tr>
<td>20-20.5</td>
<td>Silty Clay</td>
<td>green, some gravel transitioning to reddish brown with orange and gray mottling at 20.5</td>
</tr>
<tr>
<td>20.5-21</td>
<td>SS</td>
<td>20.5-21</td>
</tr>
<tr>
<td>25</td>
<td>Clay</td>
<td></td>
</tr>
<tr>
<td>23-24</td>
<td>SS</td>
<td>23-24</td>
</tr>
</tbody>
</table>

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL
<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>LITHOLOGY DESCRIPTION</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>MONITORING WELL CONSTRUCTION</th>
<th>MONITORING WELL DESCRIPTION</th>
<th>ELEVATION (FMSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>716</td>
</tr>
<tr>
<td>64</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Lithology</th>
<th>Lithology Description</th>
<th>Sample Type</th>
<th>Sample Depth</th>
<th>Recovery (%)</th>
<th>Monitoring Well Description</th>
<th>Elevation (FMS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>Silty Clay</td>
<td>Sand; light gray, fine to medium grained, moist</td>
<td>SS</td>
<td>29-30</td>
<td>100</td>
<td>Monitoring Well 1</td>
<td>748</td>
</tr>
<tr>
<td>32</td>
<td>Sandy Clay</td>
<td>Silty Clay; green, low plasticity, moist transitions to brown to dark gray dry.</td>
<td>SS</td>
<td>34-35</td>
<td>100</td>
<td></td>
<td>744</td>
</tr>
<tr>
<td>36</td>
<td>Sandy Clay</td>
<td>Sandy Clay; brown, dark gray mottling, organics</td>
<td>SS</td>
<td>36-37</td>
<td>100</td>
<td></td>
<td>740</td>
</tr>
<tr>
<td>40</td>
<td>Silty Clay</td>
<td>Silty Clay; brown, dark gray and orange mottling, dry, medium plasticity, transitions to reddish brown with gray mottling at 45'</td>
<td>SS</td>
<td>41-42</td>
<td>100</td>
<td></td>
<td>736</td>
</tr>
<tr>
<td>44</td>
<td>Silty Clay</td>
<td>Silty Clay; brown, dark gray and orange mottling, dry, medium plasticity, transitions to reddish brown with gray mottling at 45'</td>
<td>SS</td>
<td>46-47</td>
<td>100</td>
<td></td>
<td>732</td>
</tr>
<tr>
<td>48</td>
<td>Limestone</td>
<td>Limestone</td>
<td>SS</td>
<td>51-51.1</td>
<td>100</td>
<td></td>
<td>728</td>
</tr>
<tr>
<td>52</td>
<td>Silty Clay</td>
<td>Silty Clay; brown, gray mottling, high plasticity</td>
<td>SS</td>
<td>52-53</td>
<td>100</td>
<td>Portland/Bentonite grout from 31' to 61' ftgs</td>
<td>724</td>
</tr>
<tr>
<td>56</td>
<td>Clay</td>
<td>Clay; dark gray, high plasticity</td>
<td>SS</td>
<td>54-55</td>
<td>100</td>
<td></td>
<td>720</td>
</tr>
<tr>
<td>56</td>
<td>Silty Clay</td>
<td>Silty Clay; dark brown, gray mottling, high plasticity, transitions to gray to tan at 60'</td>
<td>SS</td>
<td>55-56</td>
<td>100</td>
<td></td>
<td>720</td>
</tr>
</tbody>
</table>

The stratification lines represent approximate boundary lines between soil and rock types, actual transitions may be gradual.
**LOG OF BORING NO.: PZ-5**

**CLIENT:** SORD, LLC  
**PROJECT NAME:** SORD Hydrogeologic Investigation  
**PROJECT NUMBER:** 27215136.00  
**PROJECT LOCATION:** SORD LANDFILL, Aramore, OK  
**GEOLOGIST:** Robert Fowler  
**START DATE:** 8/1/2016  
**FINISH DATE:** 8/1/2016  

<table>
<thead>
<tr>
<th>DEPTH (FT)</th>
<th>LITHOLOGY</th>
<th>SAMPLE TYPE</th>
<th>SAMPLE DEPTH</th>
<th>MONITORING WELL CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td></td>
<td>SS</td>
<td>28-29</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>SS</td>
<td>31-32</td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>Clay; green, gravel present (50%)</td>
<td>SS</td>
<td>36-37</td>
<td>10' of 2&quot; dia, 0.010 slot, Sch. 40 PVC screen, 35.17 - 45.17' bgs</td>
</tr>
<tr>
<td>40</td>
<td>Silty Clay; dark brown, some dark gray motting, low plasticity</td>
<td>SS</td>
<td>38-39</td>
<td>100</td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>SS</td>
<td>42-44</td>
<td>Wet at 40' bgs</td>
</tr>
<tr>
<td>48</td>
<td></td>
<td>SS</td>
<td>44-45</td>
<td>TD - 45.5 ft bgs End Cap</td>
</tr>
</tbody>
</table>

**DRILLER:** Bill Graham  
**DRILLING RIG:** 8150LS Sonic Rig  
**DRILLING METHOD:** Rotary Sonic  
**SURFACE ELEVATION:** 759.84 ftmsl  
**TOC ELEVATION:** 762.27 ftmsl  
**WELL DEPTH COMPLETION:** 45.50 ft bgs  
**LOCATION:** Northing: 320638.7605  
Easting: 2256853.5040  
**WATER LEVEL:** 36.02 ft bgs  
**STABILIZED WATER ELEVATION:** 723.82 ftmsl  

**THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.**
Appendix B

Boring/Lithologic Logs and Construction Diagrams
Two-percent probability of exceedance in 50 years map of peak ground acceleration
APPENDIX D

USGS Seismic Hazards
APPENDIX C

USGS Topography 7.5 Minute Quadrangle
<table>
<thead>
<tr>
<th>Sampler Type</th>
<th>Sample Depth (Ft)</th>
<th>PPM</th>
<th>Recovery</th>
<th>Depth (Ft)</th>
<th>USCS Class</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>95-100</td>
<td>n/a</td>
<td></td>
<td>5</td>
<td>CL</td>
<td>Brn. Hard Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>CaCO3 gravel throughout.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Low Plasticity</td>
<td></td>
</tr>
</tbody>
</table>

Bottom of Borehole*******
<table>
<thead>
<tr>
<th>SAMPLER TYPE</th>
<th>SAMPLE DEPTH (FT)</th>
<th>PID (PPM)</th>
<th>RECOVERY (%)</th>
<th>DEPTH IN FEET</th>
<th>USCSCS CLASS</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Coarse CaCO3 w/ 1&quot; lenses of Coarse</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Sand that are Wet and Loose at 72' and 74'</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Moist - Wet Non Plastic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Blue-Green Clay. ~100% Clay. SL Moist Low plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Hard Brn Clay. ~100% Clay Slightly Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Low Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>V-Lt. Green, Coarse, CaCO3 Slightly Moist Non Plastic - Low Plasticity</td>
</tr>
<tr>
<td></td>
<td>80-90</td>
<td>n/a</td>
<td></td>
<td>10</td>
<td>CL</td>
<td>Blue-Green Clay. ~100% Clay. SL Moist Low plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Brn. Hard Clay with occasional CaCO3 Gravel Slightly Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Low Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Becomes soft from 90° - 91°</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Lt. Green CaCO3 Effervesces in HCl</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>Brn. Hard Clay. Slightly Moist Low Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td></td>
</tr>
</tbody>
</table>

**LEGEND:**
- PID - Photoionization Detector
- HA - Hand Auger
- SS - Split Spoon
- PP - Pocket Penetrometer
- WB - Wash Bore
- CS - 5 foot CME Sampler
- CC - Continuous Core
- ST - Shelby Tube
- RX - Rock Core
- THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.
<table>
<thead>
<tr>
<th>SAMPLER TYPE</th>
<th>SAMPLE DEPTH</th>
<th>PID (PPM)</th>
<th>RECOVERY</th>
<th>DEPTH (FT)</th>
<th>USCS CLASS</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>45-55</td>
<td>n/a</td>
<td>10</td>
<td>CL</td>
<td></td>
<td>Med. Brn. Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Hard</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>CL</td>
<td>Interbedded Blue Grey Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>CL</td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50</td>
<td>CL</td>
<td>Minor Fine Gravel from 52'-53'</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>51</td>
<td>CL</td>
<td>Med. Brn. Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
<td>CL</td>
<td>Hard</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
<td>CL</td>
<td>Interbedded Blue Grey Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
<td>CL</td>
<td>Sparse Cobble size clasts of CaCO3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55</td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>56</td>
<td>CL</td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>58</td>
<td>CL</td>
<td>Mostly fine Gravel w/ Sparse coarse Gravel</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>59</td>
<td>CL</td>
<td>~20% Gravel, ~80% Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>CL</td>
<td>Slightly Moist - Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>61</td>
<td>CL</td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>62</td>
<td>CL</td>
<td>Light Grey-White CaCO3 Indurated</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>63</td>
<td>CL</td>
<td>Dry, non Plastic</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>64</td>
<td>CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>65</td>
<td>CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>66</td>
<td>CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>67</td>
<td>CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>68</td>
<td>CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69</td>
<td>CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70</td>
<td>CL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**LEGEND:**
- PID - Photoionization Detector
- SS - Split Spoon
- PP - Pocket Penetrometer
- CS - 5 foot CME Sampler
- CC - Continuous Core
- ST - Shelby Tube
- WA - Wash Bore
- RB - Rock Bit
- NX - Rock Core

**THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.**
<table>
<thead>
<tr>
<th>Sampler</th>
<th>Sample</th>
<th>PID</th>
<th>Recovery</th>
<th>Depth</th>
<th>USCS Class</th>
<th>C</th>
<th>Soil Description and Drilling Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>20-30</td>
<td>10</td>
<td>n/a</td>
<td>21</td>
<td>CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>30-40</td>
<td>10</td>
<td>n/a</td>
<td>31</td>
<td>CL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>40-45</td>
<td>n/a</td>
<td>5.0</td>
<td>41</td>
<td>CL</td>
<td></td>
<td>Interbedded Blue-Grey Clay From 20' - 36'</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>42</td>
<td>CL</td>
<td></td>
<td>Brn. Hard Clay Slightly Moist. Low Plasticity</td>
</tr>
</tbody>
</table>

**Legend:**
- PID: Photolization Detector
- SS: Split Spoon
- CS: 5-foot CME Sampler
- ST: Shelby Tube
- PP: Pocket Penetrometer
- CC: Continuous Core
- HA: Hand Auger
- WB: Wash Bore
- RB: Rock Bit
- NX: Rock Core

**Notes:**
- The stratification lines represent approximate boundary lines between soil and rock types. Actual transitions may be gradual.
**LOG OF BORING NO.: PZ-4 (B-4)**

**DRILLING CONTRACTOR:** AEI  
**DRILLER:** Chuck Clarks  
**DRILLING RIG:** TS 1500 (Rotary Sonic)  
**DRILLING METHOD:** Rotary Sonic  
**SAMPLING METHOD:** 10' Continuous Core  
**BORING DIAMETER:** 6"  
**WELL DIAMETER:** 2"  
**WELL COMPLETION:** Stick Up Well Cover  
**SURFACE ELEVATION:** 809.92' above MSL  
**WATER LEVEL:** 78.25' from TOC  
**WATER ELEVATION:** 735' from TOC  
**TOC ELEVATION:** to be surveyed  
**WELL TOTAL DEPTH:** 80'  
**RISER LENGTH:** 3'  
**TSC ELEVATION:** to be surveyed  
**TOP OF SCREEN:** 69.66' BGS  
**BOTTOM OF SCREEN:** 79.66' BGS  
**SCREEN SLOT:** 0.010 in top  
**OF FILTER PACK:** 67.66' BGS  
**TOP OF SEAL:** 65.66' BGS  
**TYPE OF SEAL:** Bentonite 3/8" chips  

**DATE FORM COMPLETED:** 2/15/2016  
**TYPE OF FILTER PACK:** Sand 20/40

**SOIL DESCRIPTION AND DRILLING CONDITIONS**

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>DEPTH (FT)</th>
<th>USCS CLASS</th>
<th>C I</th>
<th>SOIL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 10</td>
<td>Cong</td>
<td></td>
<td>Calcareous Micro Conglomerate.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Contains clasts up to 1/2cm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cemented by CaCO3</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>Dry</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>Non Plastic</td>
</tr>
<tr>
<td>4</td>
<td>0 - 10</td>
<td>ML</td>
<td></td>
<td>Lt. Greenish-Grey Silt.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Friable Siltstone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>~100%Silt</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>Dry - Slightly Moist</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**NOTES AND WELL CONSTRUCTION**

- Fine Gravel
- approx 10% from 10' - 17.5'
- Blue-Green Hard Clay. SL Moist. Low Plastic
- Brn. Hard Clay
- Slightly Moist
- Low Plasticity

**LEGEND:**
- PID - Photoionization Detector
- SS - Split Spoon
- PP - Pocket Penetrometer
- CS - 5 foot CME Sampler
- CC - Continuous Core
- ST - Shelby Tube
- HA - Hard Auger
- WB - Wash Bore
- RB - Rock Bit
- NX - Rock Core

**THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES. ACTUAL TRANSITIONS MAY BE GRADUAL.**
<table>
<thead>
<tr>
<th>Sample Depth</th>
<th>Soil Description and Drilling Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>95-105</td>
<td>Brn. Hard Clay with occasional 1&quot; lens of soft Moist Clay at 92' and 96'</td>
</tr>
<tr>
<td>96</td>
<td>Slightly Moist</td>
</tr>
<tr>
<td>97</td>
<td>CaCO3</td>
</tr>
<tr>
<td>98</td>
<td>Cl</td>
</tr>
<tr>
<td>n/a</td>
<td>Low Plasticity</td>
</tr>
<tr>
<td>99</td>
<td>Off White. CaCO3 vein. Friable and Dry</td>
</tr>
<tr>
<td>100</td>
<td>Effervesces strongly in HCl.</td>
</tr>
<tr>
<td>101</td>
<td>Non Plastic</td>
</tr>
<tr>
<td>102</td>
<td>CaCO3</td>
</tr>
<tr>
<td>103</td>
<td>CaCO3</td>
</tr>
<tr>
<td>104</td>
<td>Alternating Layers of Dark Brn. Hard Clay (&lt;3&quot; thick) and Off White, Friable CaCO3 (2&quot; thick).</td>
</tr>
<tr>
<td>105</td>
<td>Dry - Slightly Moist</td>
</tr>
<tr>
<td>106</td>
<td>Non Plastic - Low Plasticity</td>
</tr>
<tr>
<td>107</td>
<td>CaCO3</td>
</tr>
<tr>
<td>108</td>
<td>CaCO3</td>
</tr>
<tr>
<td>109</td>
<td>CaCO3</td>
</tr>
<tr>
<td>110</td>
<td>CaCO3</td>
</tr>
<tr>
<td>n/a</td>
<td>Bottom of Borehole******</td>
</tr>
</tbody>
</table>

**Legend:**
- PID - PhotoIonization Detector
- HA - Hand Auger
- SS - Split Spoon
- WB - Wash Bore
- CS - 5 foot CME Sampler
- RB - Rock Bit
- CC - Continuous Core
- ST - Shelby Tube
- NX - Rock Core

**Notes:**
- THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.
<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Depth (Ft)</th>
<th>Depth (Ft)</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>n/a</td>
<td>10</td>
<td>Reddish Brn. Clay</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>70-80</td>
<td>10</td>
<td>Reddish Brn. Clay w Inclusions of Yellow and Dark Brn. Clay (thin)</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>n/a</td>
<td>10</td>
<td>Lt. Green Silty, Gravely, Clay, ~40% Silt, ~10% Gravel, ~50% Clay</td>
<td>Slightly Moist</td>
</tr>
<tr>
<td>CC</td>
<td>80-90</td>
<td>10</td>
<td>Mixed. Brn, Yellow, Blue-Green Clay</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>n/a</td>
<td>10</td>
<td>Lt Green Coarse Gravely Sand. Wet</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>90-95</td>
<td>5.0</td>
<td>Brn. Hard Clay with occasional 1&quot; lens of soft Clay at 92' and 96'</td>
<td>Bottom of Casing*******</td>
</tr>
</tbody>
</table>

**Legend:**
- PID - Photoionization Detector
- SS - Split Spoon
- PP - Pocket Penetrometer
- CS - 5 foot CME Sampler
- CC - Continuous Core
- ST - Shelby Tube
- HA - Hand Auger
- WB - Wash Bore
- RB - Rock Bit
- NX - Rock Core

**Notes:**
- The stratification lines represent approximate boundary lines between soil and rock types. Actual transitions may be gradual.
<table>
<thead>
<tr>
<th>SAMPLER TYPE</th>
<th>SAMPLE DEPTH (FT)</th>
<th>PID (PPM)</th>
<th>RECOVERY (%)</th>
<th>DEPTH IN FEET</th>
<th>USGS CLASS</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>45-55</td>
<td>10</td>
<td>n/a</td>
<td>46</td>
<td>CL</td>
<td>Med. Brn. Clay w/ minor Silt</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>47</td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>48</td>
<td>CL</td>
<td>Med. Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>49</td>
<td>CL</td>
<td>Layered Blue Clay and CaCO3</td>
<td>Slightly Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50</td>
<td>CL</td>
<td>CaCO3 is sugary in texture and friable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>52</td>
<td>CL</td>
<td>Reddish Brn. Gravely, Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53</td>
<td>CL</td>
<td>Minor Gravel</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>54</td>
<td>CL</td>
<td>Interbedded w/ Drk Brn and Yellow Clays</td>
<td>probably weathered clays</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55</td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>56</td>
<td>CL</td>
<td>Low to Med. Plasticity</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>55-65</td>
<td>10</td>
<td>n/a</td>
<td>57</td>
<td>CL</td>
<td>Off white/ Indurated CaCO3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>58</td>
<td>CL</td>
<td>CaCO3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>59</td>
<td>CL</td>
<td>CaCO3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>CL</td>
<td>CaCO3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>61</td>
<td>CL</td>
<td>CaCO3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>62</td>
<td>CL</td>
<td>~Limestone</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>64</td>
<td>CaCO3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>65</td>
<td>CaCO3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>65-70</td>
<td>n/a</td>
<td>5.0</td>
<td>66</td>
<td>CL</td>
<td>Reddish Brn. Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>67</td>
<td>CL</td>
<td>Minor Blue-Green Lenses.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>68</td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69</td>
<td>CL</td>
<td>Low Plasticity</td>
<td></td>
</tr>
</tbody>
</table>

**LEGEND:**
- PID - Photolization Detector
- SS - Split Spoon
- PP - Pocket Penetrometer
- CS - 5 foot CME Sampler
- CC - Continuous Core
- ST - Shelby Tube
- HA - Hand Auger
- WB - Wash Bore
- RB - Rock Bit
- NX - Rock Core

**THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.**
<table>
<thead>
<tr>
<th>SAMPLER TYPE</th>
<th>SAMPLE DEPTH (FT)</th>
<th>PID (PPM)</th>
<th>RECOVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>20-30</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>30-40</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>40-45</td>
<td>n/a</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DEPTH IN FEET</th>
<th>USGS CLASS</th>
<th>C</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
<th>NOTES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>CL</td>
<td></td>
<td>Lt. Brownish Grey, Clay w/ minor Silt</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>CL</td>
<td></td>
<td>Med. Stiff - Stiff</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>CL</td>
<td></td>
<td>Slightly Moist.</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>CL</td>
<td></td>
<td>Low - Med. Plasticity</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>CL</td>
<td></td>
<td>Thin laminations of Bluish-Grey Clay</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>CL</td>
<td></td>
<td>Friable CaCO3 vein</td>
<td>Effervescence in HCL</td>
</tr>
<tr>
<td>33</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>CL</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| CC | CaCO3 | 45 | Sugary CaCO3 zone. Grades to Clay at last 4" | Effervescence in HCL |

**LEGEND:**
- PID - Photolization Detector
- SS - Split Spoon
- PP - Pocket Penetrometer
- CS - 5 foot CME Sampler
- CC - Continuous Core
- ST - Shelby Tube
- HA - Hand Auger
- WB - Wash Bore
- RB - Rock Bit
- NX - Rock Core

**NOTES:**
- THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES. ACTUAL TRANSITIONS MAY BE GRADUAL.
<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>DEPTH (FT)</th>
<th>PID</th>
<th>RECOVERY</th>
<th>USCS CLASS</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>0-10</td>
<td>n/a</td>
<td>10</td>
<td>CL</td>
<td>L1. Reddish Brn. Silty Clay. Grey Clay lenses interbedded ~3mm thick. Hard Clay Slightly Moist Low Plasticity</td>
</tr>
<tr>
<td>CC</td>
<td>10-20</td>
<td>n/a</td>
<td>10</td>
<td>CL</td>
<td>Reddish Brn. Silty Clay. Hard Slightly Moist Low Plasticity Contains Clasts of Bluish-Grey, Hard Clay ~1&quot; in diameter</td>
</tr>
</tbody>
</table>

**Legend:**
- PID - Photolization Detector
- SS - Spat Spoon
- PP - Pocket Penetrometer
- CC - Continuous Core
- ST - Shelby Tube
- HA - Hand Auger
- WB - Wash Bore
- RB - Rock Bit
- NX - Rock Core

**Log of Boring No:** PZ-3 (B-3)  
**Drilling Contractor:** AEI  
**Driller:** Chuck Clarks  
**Drilling Rig:** TS 1500 (Rotary Sonic)  
**Sampling Method:** 10" Continuous Core  
**Material:** PVC  
**Diameter:** 2 IN  
**Total Depth:** 90 FT TOT  
**Screen Length:** 10 FT  
**Riser Length:** 3 FT  
**Top of Screen:** 79.66 FT BGS  
**Bottom of Screen:** 89.66 FT BGS  
**Screen Slot:** 0.010 IN TOP  
**Filter Pack:** Bentonite 3/8" chips  
**Well Completion:** Stick Up Well Cover  
**Surface Elevation:** 799.36' above MSL  
**Date Form Completed:** 2/15/2016  
**Type of Filter Pack:** Sand 2040  

**Notes and Well Construction:**
- Becomes drier and soft from 7.5'-10'
<table>
<thead>
<tr>
<th>SAMPLER TYPE</th>
<th>SAMPLE DEPTH</th>
<th>PID (PPM)</th>
<th>RECOVERY (FT)</th>
<th>DEPTH IN FEET</th>
<th>USCS CLASS</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
<th>NOTES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC 70-80</td>
<td>n/a</td>
<td></td>
<td>10</td>
<td></td>
<td>CL</td>
<td>Brn. Gravely Clay.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stiff</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td>CC 80-6</td>
<td>n/a</td>
<td></td>
<td>6</td>
<td></td>
<td>CL</td>
<td>Bottom of Borehole</td>
<td></td>
</tr>
</tbody>
</table>

LEGEND:
- PID - Photoionization Detector
- HA - Hand Auger
- SS - Split Spoon
- PP - Pocket Penetrometer
- WB - Wash Bore
- CS - 5 foot CME Sampler
- RB - Rock Bit
- ST - Shelby Tube
- NX - Rock Core

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.
<table>
<thead>
<tr>
<th>Sampler</th>
<th>Sample Depth</th>
<th>PID</th>
<th>Recovery</th>
<th>Depth (ft)</th>
<th>USCS Class</th>
<th>Soil Description and Drilling Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>45-55</td>
<td>n/a</td>
<td></td>
<td>10</td>
<td>CL</td>
<td>Brn. Clay mixed w/ grey-green Gravely Clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stiff</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Moist - V-Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity</td>
</tr>
<tr>
<td>CC</td>
<td>55-65</td>
<td>n/a</td>
<td></td>
<td>10</td>
<td>CL</td>
<td>Teal Clay. Minor Gravel, grads to more gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>at 58'</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stiff</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Slightly Moist - Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GM</td>
<td>Greenish White, V-Coarse Sand and Fine Gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wet.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non-Plastic</td>
</tr>
<tr>
<td>CC</td>
<td>65-70</td>
<td>n/a</td>
<td></td>
<td>5.0</td>
<td>CL</td>
<td>Teal Clay, V-Gravely</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gradates to Brn Clay at last 2&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Slightly Moist, Low Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bottom of Well Casing***</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brn. Gravely Clay.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stiff</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Slightly Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity</td>
</tr>
</tbody>
</table>

**Legend:**
- PID - Photoionization Detector
- SS - Split Spoon
- PP - Pocket Penetrometer
- CS - 5 foot CME Sampler
- CC - Continuous Core
- ST - Shelby Tube
- HA - Hand Auger
- WB - Wash Bore
- RB - Rock Bit
- NX - Rock Core

**Notes:**
- THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.
<table>
<thead>
<tr>
<th>SAMPLER</th>
<th>SAMPLE DEPTH</th>
<th>PID (PPM)</th>
<th>recovery USES CLASS</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>20-30</td>
<td>n/a</td>
<td>10</td>
<td>Reddish Brn. Silty Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Med. Stiff</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Reddish Brn. Gravely Clay</td>
<td>Fine and Coarse Gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Soft</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V-Moist - Wet</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>30-40</td>
<td>n/a</td>
<td>10</td>
<td>Reddish Brn. Gravely Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stiff</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Slightly Moist - Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Off white, Clayey Sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V- Coarse Sand. ~80%Sand, ~20% Clay</td>
<td>Cemented w/ CaCO3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Non Plastic</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brn. Clay mixed w/ grey-green Gravely Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stiff</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Moist - V-Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>40-45</td>
<td>n/a</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- PID = Photoionization Detector
- HA = Hand Auger
- SS = Split Spoon
- PP = Pocket Penetrometer
- WB = Wash Bore
- CS = 5 foot CME Sampler
- CC = Continuous Core
- ST = Shelby Tube
- NX = Rock Core

**Boundary Lines:**
- The stratification lines represent approximate boundaries between soil and rock types. Actual transitions may be gradual.
## LOG OF BORING NO. PZ-2 (B-2)

### WELL CONSTRUCTION DETAILS
- **LOG OF BORING NO.**: PZ-2 (B-2)
- **SHEET NUMBER**: 1 of 4
- **DRILLING CONTRACTOR**: AEI
- **DRILLER**: Chuck Clarks
- **DRILLING RIG**: TS 1500 (Rotary Sonic)
- **DRILLING METHOD**: Rotary Sonic
- **MATERIAL**: PVC
- **DIAMETER**: 2 in
- **WELL TOTAL DEPTH**: 66 ft TOC
- **SCREEN LENGTH**: 10 ft
- **RISER LENGTH**: 3 ft
- **TOP OF SCREEN**: 55.66 ft BGS
- **BOTTOM OF SCREEN**: 65.66 ft BGS
- **SCREEN SLOT**: 0.010 in TOP
- **OF FILTER PACK**: 53.66 ft BGS
- **WATER LEVEL**: 58.59' from TOC
- **WATER ELEVATION**: 751' from TOC
- **TOC ELEVATION**: to be surveyed
- **WELL COMPLETION**: Stick Up Well Cover
- **SURFACE ELEVATION**: 806.64' above MSL
- **DATE FORM COMPLETED**: 2/10/2016
- **TYPE OF FILTER PACK**: Bentonite 3/8" chips
- **TYPE OF SEAL**: Sand 2040
- **START DATE**: 02/03/16
- **FINISHED DATE**: 02/03/16
- **START TIME**: 0900
- **FINISH TIME**: 1435

### SOIL DESCRIPTION AND DRILLING CONDITIONS

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>PID</th>
<th>RECOVERY</th>
<th>DEPTH (FT)</th>
<th>USCS CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>0-10</td>
<td>n/a</td>
<td>10</td>
<td>CL</td>
</tr>
<tr>
<td>CC</td>
<td>10-20</td>
<td>n/a</td>
<td>10</td>
<td>CL</td>
</tr>
</tbody>
</table>

- **Slighty Moist - Moist**
- **Low Plasticity**
- **Off White w/ Burnt Orange Staining**
- **Conglomerate, Coarse Sandy, Gravely, Silty, Clayey Mix.**
- **Slightly Moist**
- **Non- Plastic - V-Low Plasticity**
- **White Sandy, Silt w/ Green and Greyish-Brn. Clasts of Clay**
- **Dry, Non Plastic**
- **Grey Green Silty Clay, Stiff, SL moist, Low PI**
- **Reddish Brn. Silty Clay**
- **Med. Stiff**
- **Slighty Moist**
- **Low Plasticity**

### LEGEND:
- **PID - Photoionization Detector**
- **CL - Clay**
- **GC - Gravel**
- **GM - Mud**
- **HA - Hand Auger**
- **PP - Pocket Penetrometer**
- **WB - Wash Bone**
- **CS - 5 foot CME Sampler**
- **CC - Continuous Core**
- **RB - Rock Bit**
- **ST - Shelby Tube**
- **Nx - Rock Core**

**THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES. ACTUAL TRANSITIONS MAY BE GRADUAL.**
<table>
<thead>
<tr>
<th>Sampler</th>
<th>Sample</th>
<th>PID (PPM)</th>
<th>Recovery (FT)</th>
<th>Depth in Feet</th>
<th>USCS Class</th>
<th>Soil Description and Drilling Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>70-80</td>
<td>10</td>
<td>n/a</td>
<td>71</td>
<td>CL</td>
<td>Brn. Gravely Clay. Med. Stiff</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>72</td>
<td>CL</td>
<td>Slightly Moist - Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>73</td>
<td>CL</td>
<td>Low Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>74</td>
<td>CaCO3</td>
<td>Greenish White, Coarse CaCO3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75</td>
<td>CaCO3</td>
<td>Dry, Non Plastic</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>76</td>
<td>CL</td>
<td>Brn. Gravely Clay. Stiff - V-Stiff</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>77</td>
<td>CL</td>
<td>Slightly Moist - Stiff</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>78</td>
<td>CL</td>
<td>Low Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>79</td>
<td>CL</td>
<td>Yellow and Red clays</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80</td>
<td>CL</td>
<td>Interbedded</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>81</td>
<td>CL</td>
<td>Bottom of Borehole****</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>83</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>85</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>86</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>87</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>88</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>89</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>91</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>92</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>93</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>94</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>95</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- PID - Photorization Detector
- PP - Pocket Penetrometer
- CS - 5 foot CME Sampler
- CC - Continuous Core
- SS - Split Spoon
- ST - Shelby Tube
- HA - Hand Auger
- WB - Wash Bore
- RB - Rock Bit
- NX - Rock Core

**Notes:**
- The stratification lines represent approximate boundary lines between soil and rock types. Actual transitions may be gradual.
<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>SAMPLE DEPTH</th>
<th>PID (PPM)</th>
<th>RECOVERY (FT)</th>
<th>DEPTH IN FEET</th>
<th>SOIL DESCRIPTION AND DRILLING CONDITIONS</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>45-55</td>
<td>n/a</td>
<td></td>
<td>10</td>
<td>Places Gravel, Soft Clay, Moist, Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Places Yellow, and Blue-Green, Med. Stiff Clay, Slightly Moist, Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Blue-Green, Med. Stiff Clay, Slightly Moist, Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lt. Green, Diatomaceous Silt, Very Fine Grained</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V-Moist - Wet</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity-Non Plastic, Becomes less wet - Moist - V-Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td>55-65</td>
<td>n/a</td>
<td></td>
<td>10</td>
<td>Blue-Green, Med. Stiff - Stiff Clay, Slightly Moist, Low Plasticity</td>
<td>approx 100% clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Brn. Gravely, Clay, Med. Stiff, Slightly Moist - Moist, Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65-70</td>
<td>n/a</td>
<td></td>
<td>5.0</td>
<td>Brn. Gravely, Soft Clay, Slightly Moist - Moist, Low Plasticity</td>
<td></td>
</tr>
</tbody>
</table>

**LEGEND:**
- PID - Photoionization Detector
- HA - Hand Auger
- SS - Split Spoon
- PP - Pocket Penetrometer
- CS - 5 foot CME Sampler
- CC - Continuous Core
- ST - Shelby Tube

**THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES. ACTUAL TRANSITIONS MAY BE GRADUAL.**
<table>
<thead>
<tr>
<th>Sampler</th>
<th>Sample</th>
<th>PID</th>
<th>Recovery</th>
<th>Depth (ft)</th>
<th>USCS Class</th>
<th>Soil Description and Drilling Conditions</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>20-30</td>
<td>n/a</td>
<td>10</td>
<td></td>
<td>CL</td>
<td>Brn. Gravelly, Clay. CaCO3 clasts throughout</td>
<td>CaCO3 Gravel sized</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Moist</td>
<td>Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Low Plasticity</td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Brn., Yellow, and Red Gravelly, Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Low - Med. Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>~100% CaCO3, Lt. Green/White, Friable</td>
<td>Dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Brn., Yellow, and Red, Stiff, Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Slightly Moist - Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Slightly Moist, Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>CaCO3, Friable, Off White</td>
<td>Dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>CaCO3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MUC/CL</td>
<td>Brn. Clay, Med-Stiff</td>
<td>approx 100% clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MUC/CL</td>
<td>Slightly Moist, Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>CaCO3, Friable, Off White</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CaCO3</td>
<td>CaCO3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Brn. Stiff, Gravelly, Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>~100% CaCO3, Friable, off white/beige</td>
<td>Dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>CaCO3</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Brn. Gravelly, Clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Low Plasticity</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>~100% CaCO3, Friable, off white/beige</td>
<td>Dry</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Brn., Yellow, and Green, Stiff Clay</td>
<td>Sparse Gravel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Slightly Moist</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td>Low Plasticity</td>
<td></td>
</tr>
</tbody>
</table>

**Legend:**
- PID - Photoionization Detector
- HA - Hand Auger
- SS - Split Spoon
- PP - Pocket Penetrometer
- WB - Wash Bore
- CS - 5 foot CME Sampler
- CC - Continuous Core
- ST - Shelby Tube
- RB - Rock Bit
- NX - Rock Core

**Notes:**
- THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.
LOG OF BORING NO.: PZ-1 (B-1)

DRILLING CONTRACTOR: AEI
WELL CONSTRUCTION DETAILS

CLIENT: SORD
DRILLER: Chuck Clarks
PROJECT NAME: SORD Landfill Expansion
MATERIAL: PVC
PROJECT NUMBER: 27215136.00, Task 4
DIAMETER: 2 IN
PROJECT LOCATION: SORD
DRILLING METHOD: Rotary Sonic
WELL TOTAL DEPTH: 64 FT TOC
BORING LOCATION: Ardmore, OK
SCREEN LENGTH: 10 FT
GEOLOGIST: Peter Price
BORING DIAMETER: 6”
TOC ELEVATION: to be surveyed
SAMPLE METHOD: 10” Continuous Core
WELL DIAMETER: 2”
WELL COMPLETION: Stick Up Well Cover
SURFACE ELEVATION: 779.64’ above MSL
START DATE: 02/02/16
IN TOP OF FILTER PACK: 48.66
FINISH DATE: 02/02/16
FT BGS TOP OF SEAL: 46.66
START TIME: 1044
TOP OF SCREEN: 50.66 FT BGS
FINISH TIME: 1700
WATER LEVEL: 31.41’ from TOC
WATER ELEVATION: 751’ from TOC
DATE FORM COMPLETED: 2/10/2016
TYPE OF SEAL: 3/8” Bentonite chips

SAND: 2040

SOIL DESCRIPTION AND DRILLING CONDITIONS

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>SAMPLE PID</th>
<th>RECOVERY DEPTH (FT)</th>
<th>USCS CLASS</th>
<th>NOTES AND WELL CONSTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC 0-10</td>
<td>n/a</td>
<td>1</td>
<td>CL</td>
<td>V-Stiff to Hard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>CL</td>
<td>Slightly Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>CL</td>
<td>Low - Med. Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>CL</td>
<td>Brn. Gravely, Clay (Fine Gravel)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>CL</td>
<td>Moist, Med. Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>CL</td>
<td>Brn. Gravely, Clay (Soft)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>CL</td>
<td>Moist, Med. Plasticity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>CL</td>
<td>CaCO3 appears in veins</td>
</tr>
<tr>
<td></td>
<td></td>
<td>9</td>
<td>CL</td>
<td>Slightly Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>CL</td>
<td>Strong effervescence in HCl</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11</td>
<td>CL</td>
<td>Reddish Brn. Med. Stiff, Clay w/ off white and Greenish CaCO3 mixed throughout</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12</td>
<td>CL</td>
<td>Moist</td>
</tr>
<tr>
<td></td>
<td></td>
<td>13</td>
<td>CL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>CL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>15</td>
<td>CL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>CL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>17</td>
<td>CL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>CL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>19</td>
<td>CL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>CL</td>
<td></td>
</tr>
</tbody>
</table>

LEGEND:
PID - Photoionization Detector
HA - Hard Auger
SS - Split Spoon
PP - Pocket Penetrometer
CS - 5 foot CME Sampler
CC - Continuous Core
ST - Shelby Tube
WBP - Wash Bore
RB - Rock Bit
NX - Rock Core

THE STRATIFICATION LINES REPRESENT APPROXIMATE BOUNDARY LINES BETWEEN SOIL AND ROCK TYPES: ACTUAL TRANSITIONS MAY BE GRADUAL.
APPENDIX B

Well Logs from Initial Subsurface Investigation
SOIL SAMPLING FOR GEOTECHNICAL ANALYSES

Soil samples collected from the borings or excavations may be retained for selected physical analyses that can be performed on disturbed soil samples. Representative samples for grain size analyses (ASTM International (ASTM) D-6913) can be obtained from the interval in which the screen for the monitoring well will be placed (if well is screened in unconsolidated materials).

Disturbed soil samples collected for physical/geotechnical analysis will be placed in sealable plastic bags if moisture content analysis (ASTM D-2216) is requested. Remaining sample material will be placed in sealable plastic bags or buckets and labeled with the date, boring number, and depth of sample for Atterberg limits (ASTM D-4318) or grain size analysis.

In the event that undisturbed soil samples are collected, a thin-walled sample of “Shelby Tube” will be used to obtain these samples (ASTM D-1587). These samples can be taken in cohesive or granular material for laboratory classification and limited testing purposes. The sampling procedures when using a drilling rig are as follows:

1. Advance the borehole to the required depth, taking care not to disturb material to be sampled.

2. Examine the thin-walled tube to determine that it is free of rust, dents or scratches. The cutting edge should be beveled and drawn-in slightly less than the outside diameter of the tube.

3. Attach the thin-walled sampler to the head assembly and drill rods.

4. Lower the sampler assembly to the required depth and press the sampler 2 feet into the soil.

5. To insure good recovery, leave the assembly in the borehole for 10 to 15 minutes, to allow buildup of skin friction within the thin-wall sampler. Then rotate entire assembly 1 or 2 revolutions to shear off sample from soil below withdraw assembly from the borehole and disassemble.

6. Remove any disturbed material from the tube ends and measure the recovery.

7. Seal, mark, and store the tube in an upright position during storage and shipment to testing laboratory.
APPENDIX A

Soil Sampling for Geotechnical Analysis
FIGURE 5

Site Specific Alluvium and Terrace Deposits
FIGURE 4
Site Specific Flood Plain Extent
FIGURE 3

Proposed Additional Boring Locations
FIGURE 2

Initial Boring Locations
FIGURE 1

Site Location Map
<table>
<thead>
<tr>
<th>Proposed Boring</th>
<th>Northing</th>
<th>Easting</th>
<th>Approx. Ground Elevation (ft)</th>
<th>Proposed Bottom of Landfill (ft) msl</th>
<th>Proposed TD Elevation (ft) msl</th>
<th>Proposed Drilling Depth (ft)</th>
<th>Proposed Screen Elevation (ft) msl</th>
<th>Proposed Screen Length (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-5</td>
<td>320650.45</td>
<td>2256851.81</td>
<td>760</td>
<td>745</td>
<td>715</td>
<td>45</td>
<td>745-735</td>
<td>10</td>
</tr>
<tr>
<td>B-6</td>
<td>320654.94</td>
<td>2257261.78</td>
<td>754</td>
<td>750</td>
<td>720</td>
<td>34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-7</td>
<td>320659.44</td>
<td>2257711.76</td>
<td>762</td>
<td>750</td>
<td>720</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-8</td>
<td>320663.93</td>
<td>2258141.74</td>
<td>775</td>
<td>750</td>
<td>720</td>
<td>55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-9</td>
<td>320670.31</td>
<td>2258569.51</td>
<td>773</td>
<td>745</td>
<td>715</td>
<td>58</td>
<td>745-735</td>
<td>10</td>
</tr>
<tr>
<td>B-10</td>
<td>320215.99</td>
<td>2256427.36</td>
<td>778</td>
<td>755</td>
<td>725</td>
<td>53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-11</td>
<td>320220.49</td>
<td>2256857.34</td>
<td>764</td>
<td>750</td>
<td>720</td>
<td>44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-12</td>
<td>320225.80</td>
<td>2257288.95</td>
<td>756</td>
<td>755</td>
<td>725</td>
<td>31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-13</td>
<td>320235.40</td>
<td>2258144.43</td>
<td>798</td>
<td>755</td>
<td>725</td>
<td>73</td>
<td>745-735</td>
<td>10</td>
</tr>
<tr>
<td>B-14</td>
<td>319604.00</td>
<td>2258152.80</td>
<td>814</td>
<td>760</td>
<td>730</td>
<td>84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-15</td>
<td>319806.51</td>
<td>2258582.79</td>
<td>825</td>
<td>760</td>
<td>730</td>
<td>95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-16</td>
<td>319813.00</td>
<td>2259012.77</td>
<td>832</td>
<td>760</td>
<td>730</td>
<td>102</td>
<td>760-750</td>
<td>10</td>
</tr>
<tr>
<td>B-17</td>
<td>319374.05</td>
<td>2258158.35</td>
<td>791</td>
<td>765</td>
<td>735</td>
<td>56</td>
<td>765-755</td>
<td>10</td>
</tr>
<tr>
<td>B-18</td>
<td>318948.56</td>
<td>2258593.83</td>
<td>822</td>
<td>770</td>
<td>740</td>
<td>82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B-19</td>
<td>318953.07</td>
<td>2259023.83</td>
<td>829</td>
<td>770</td>
<td>740</td>
<td>89</td>
<td>770-760</td>
<td>10</td>
</tr>
<tr>
<td>B-20</td>
<td>317372.95</td>
<td>2258725.74</td>
<td>832</td>
<td>785</td>
<td>755</td>
<td>77</td>
<td>785-775</td>
<td>10</td>
</tr>
</tbody>
</table>
TABLE 3

Proposed Additional Borings
<table>
<thead>
<tr>
<th>Well ID</th>
<th>Date Gauged</th>
<th>Time Gauged (24hr clock)</th>
<th>Approx. Elevation (ft MSL) at TOC</th>
<th>Water Level (ft) from TOC</th>
<th>Approx. Location (Northing)</th>
<th>Approx. Location (Easting)</th>
<th>Water Level Elevation (ft MSL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>2/25/2016</td>
<td>1644</td>
<td>782.64</td>
<td>31.11</td>
<td>320229.49</td>
<td>2257717.31</td>
<td>751.53</td>
</tr>
<tr>
<td>B-2</td>
<td>2/25/2016</td>
<td>1655</td>
<td>809.64</td>
<td>46.61</td>
<td>320238.48</td>
<td>2258577.26</td>
<td>763.03</td>
</tr>
<tr>
<td>B-3</td>
<td>2/25/2016</td>
<td>1703</td>
<td>802.36</td>
<td>43.37</td>
<td>319378.55</td>
<td>2258588.32</td>
<td>758.99</td>
</tr>
<tr>
<td>B-4</td>
<td>2/25/2016</td>
<td>1710</td>
<td>812.92</td>
<td>56.57</td>
<td>318944.09</td>
<td>2258163.88</td>
<td>756.35</td>
</tr>
</tbody>
</table>
# TABLE 2

**Groundwater Levels for Initial Borings**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Level (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>Boring</td>
<td>Northing</td>
</tr>
<tr>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>B-1</td>
<td>320229.49</td>
</tr>
<tr>
<td>B-2</td>
<td>320238.48</td>
</tr>
<tr>
<td>B-3</td>
<td>319378.55</td>
</tr>
<tr>
<td>B-4</td>
<td>318944.09</td>
</tr>
</tbody>
</table>

All units - feet
Elevations - feet above mean sea level
<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Borings</td>
</tr>
</tbody>
</table>

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

9.0 REFERENCES


Hvorslev, M.J. 1951. *Time Lag and Soil Permeability in Ground-water Observations (Bulletin No. 36, Waterways Experiment Station)*. U.S. Army Corps of Engineers, Vicksburg, MS.


7.0 SURVEYING

Following the completion of field activities, a surveyor will determine the positions of all unsurveyed sample locations, including subsurface sampling locations with piezometers and other discrete sampling points.

All sample locations will be surveyed horizontally to the nearest 0.1 foot and tied to the State Plane Coordinate System. The ground surface elevation of the sampling locations will be measured to the nearest 0.1 foot relative to mean sea level (MSL). For all piezometers, the top of the riser pipe will be used as a reference point and surveyed to the nearest 0.01 foot relative to MSL.
6.3 PHOTOGRAPHS

Photographs taken to document sampling point locations should include two or more reference points to facilitate relocating the sample location at a later date. The following information should be noted in the field logbook:

- Date
- Time
- General direction faced and description of subject
- Sequential number of the photograph and roll number (if not digital)
- Type of film used (if not digital)

A photograph location sketch may also be drawn in the field book.
11. The amount of water used during drilling will be noted and recorded on the form. Any water gains or losses estimated rates and depths will be noted in the “Remarks” column.

12. The depth and type of temporary casing used will be noted in the “Remarks” column.

13. Depth intervals of borehole instability that are encountered during drilling will be recorded on the drilling log. In addition, difficulties during drilling (e.g., drilling speed, rates or downhole torque) and special sampling problems will be noted, along with problem resolution.

14. Samples retained for lithologic or chemical analyses will be noted in the “Sample No.” column.

15. Any changes or corrections to the drilling log descriptions will be lined through and initialed with corrected notation adjacent to it.

6.2.1.1 Logging Soils (Unconsolidated Materials)

1. Unconsolidated materials will be visually classified in accordance with the Unified Soil Classification System (USCS) and ASTM D2488. The visual field classification will provide principal and minor soil constituents along with approximate proportions.

2. The moisture content will be described in relative terms (e.g., dry, damp, moist, wet) and noted in the description. In addition, relative plasticity and consistency (cohesive soils), relative gradation and density (cohesionless soils), grain size, angularity, depositional environment, and structure will be recorded in the description column.

3. Color will be defined using standardized color for unconsolidated materials using a Munsell Color Chart.

4. Bedding characteristics and evidence of bioturbation, root holes, or fractures will be recorded.

6.2.1.2 Logging Rock (Consolidated Materials)

1. Bedrock will be described based on visual observations, in accordance with standard geologic nomenclature.

2. This nomenclature includes, but is not limited to: formation name (if known); relative hardness; density; texture; grain size; weathering; bedding; fractures, joints, and cavities; and other descriptive features, such as fossils.

3. The standardized color of consolidated materials will be logged using the Munsell Rock Color Chart.

4. The moisture content will be described in relative terms (e.g., dry, damp, moist, wet) and noted in description.
6.2.1 General Requirements

The following are the general requirements for logging consolidated and unconsolidated geologic materials.

1. For each borehole, a geologic log will be prepared in the field by a qualified groundwater scientist. The logs will be hand-printed utilizing an appropriate scale. Logs will be of such quality that revisions will not be necessary prior to inclusion within a report. Logs will be prepared on forms specified by the client or on the SCS Drilling Log.

2. The drilling logs will be filled out as completely as possible, where appropriate information is available. At entry points on the form that are not applicable, write “N/A” (e.g., “N/A” is written in the bedrock footage section if bedrock is not encountered in the borehole).

3. Stratigraphic or lithologic changes will be identified under the description of material column as a solid horizontal line which corresponds to a measured borehole depth where the changes occur. Gradational changes in stratigraphy and lithology or changes identified from cuttings or methods other than direct observation will be represented as a horizontal dashed line at appropriate depth based upon the best judgment of the logger.

4. Borehole measurements (i.e., run depths and water levels) will be recorded to the nearest 0.1 foot.

5. The logs will show total depth of penetration and sampling. The bottom of the borehole will be represented as a double line from margin to margin with notation of “T.D. = ___ ft. bgs” written below the double lines.

6. Any evidence of contamination will be noted in “Remarks,” including color, odor, etc.

7. The depth to groundwater will be recorded in the header box labeled “Depth Groundwater Encountered.” After drilling is completed and the water level has stabilized, a second water depth measurement will be recorded in the box labeled “Depth to Water and Elapsed time after Drilling Completed.”

8. The length of core or soil sample (recovery) will be measured with a tape measure to the nearest 0.1 foot and recorded in the “Recovery” column.

9. The size and type of sampler or coring bit and barrel will be recorded on the form in the header. Logs will show borehole and sample diameters and depths at which sampling method or equipment changes.

10. Logs will show the drilling fluid used, including, as appropriate: source of makeup water; drilling fluid additives by brand and product name; mixture proportions; and type of filter for compressed air.
6.0 DOCUMENTATION, SAMPLE CUSTODY, PACKAGING AND SHIPPING

Each sample, field measurement, and field activity will be documented to facilitate timely, correct, and complete analyses, and support actions concerning the site. The documentation system should provide a means to identify, track, and monitor sampling activities.

6.1 FIELD LOGBOOK PROCEDURES

Information pertinent to the investigation will be recorded in a bound logbook with consecutively numbered, water-resistant pages. The field personnel responsible for the entries will sign and date each entry or page. All logbook entries will be made in indelible ink. The time and date of each entry will be noted in the logbook.

General rules cannot specify the exact information that must be entered in a logbook for a particular site. However, the logbook should contain sufficient information so that sampling activities can be reconstructed. Logbooks will be kept in the field personnel's possession or a secure place during the investigation. Following the investigation, logbooks will become part of the project file. The following list contains typical field logbook entries.

- Date
- Weather conditions
- Names of field personnel
- Calibration record of field equipment
- Location of sample
- Type of sample (soil, groundwater, sediment, etc.)
- Time of sample collection
- Sample identification number
- Interval and depth of sample
- Field screening results
- Field measurements
- Duplicate sample information
- Water level and total depth measurements
- Well purging volume and technique

6.2 LOGGING CRITERIA

The logging of borings is one of the fundamental activities in a subsurface investigation. The main elements of the logging process are accurately locating the boring horizontally and vertically, elevations, accurately measuring the depths of observations relative to the surface, and consistently describing soils, consolidated materials, and groundwater occurrence.
5.0 SAMPLE NUMBERING SYSTEM

A numbering system will be used to identify each boring and well. The purpose of this numbering system is to provide a tracking system for data retrieval. The sample identification allocated for the investigation will be used on drilling logs, sample labels, chain of custody records, and all other applicable documentation used during the sampling activities. An SCS site representative will maintain a listing of sample identification numbers in the field logbook.

5.1 SAMPLE IDENTIFICATION

All samples will be identified with a unique sample number. The sample will be comprised of the sampling point, sample designator, and depth interval, as appropriate.

The sampling point indicates the location of sampling; e.g., B1, where “B” indicates a boring and “1” is the first boring.

The sample designator will be comprised of a matrix abbreviation followed by a consecutive sample number. The matrix abbreviations are as follows:

<table>
<thead>
<tr>
<th>SS</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT</td>
<td>Rock / Soil Cuttings</td>
</tr>
<tr>
<td>RC</td>
<td>Rock Core</td>
</tr>
<tr>
<td>GW</td>
<td>Groundwater</td>
</tr>
</tbody>
</table>

Subsurface soil and rock samples will be further identified according to location and depth. Samples collected from each boring will be consecutively numbered by depth. The actual sample depth will be recorded in the field logbook and on the chain of custody record.

In summary, the sample numbering system will consist of the sampling point, sample designator, and depth interval (if necessary). The following are examples of the sample numbering systems:

<table>
<thead>
<tr>
<th>Sampling Point</th>
<th>Sample Designator</th>
<th>Depth Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>SS1</td>
<td>0-4 ft</td>
</tr>
<tr>
<td>B1</td>
<td>SS2</td>
<td>8-10 ft</td>
</tr>
<tr>
<td>B1</td>
<td>GW1</td>
<td>10 ft</td>
</tr>
</tbody>
</table>

If piezometers are installed in a boring, the identifier “B” will be converted to “P” for piezometer.
• every 30 seconds for 3-5 minutes into the test
• every minute thereafter

6. Review data in the field logbook for completeness.

Analysis of slug test data will be performed using the Hvorslev (1951) or the Bouwer and Rice (1976) method.
5. Install the transducer and cable in the well to a depth below the target drawdown estimated for the test, but at a minimum of 2 feet from the bottom of the well. Check that the depth of submergence is within the design range stamped on the transducer.

6. Tape the transducer cable to the well to keep the transducer at a constant depth.

7. Connect the transducer cable to the electronic data logger.

8. Enter the initial water level and transducer design range into the recording device according to the manufacturer's instructions. The transducer design range will be stamped on the side of the transducer.

9. Introduce a solid cylinder of known volume to displace and raise the water level or use a bailer to remove a volume of water from the well. Allow the water level to stabilize to static and quickly remove the cylinder.

10. Consider the moment of removal as time zero and starting point of test.

11. Continue measuring and recording depth/time measurements until the water level returns to equilibrium conditions or a sufficient number of readings have been made to clearly show a trend on a semi-logarithmic plot of time versus depth.

12. If the aquifer is coarse-grained with a short recovery period, repeat the test to check initial recovery rates.

13. Stop the logging sequence.

14. Review the field forms for completeness.

A slug test conducted using manual methods will proceed in the following manner:

1. Decontaminate the water level indicator.

2. Measure and record the static water level in the well.

3. Bail water from the well using a clean, large, disposable polyethylene bailer such that a measurable drop in water depth is noted (1 to 2 feet) after extraction of the bailer volume. An alternative to using a bailer is utilizing a clean (decontaminated) mechanical slug.

4. Record the time the bailer volume is removed. Measure the water level and record the time in the field logbook.

5. Measure and record the water level at the following intervals (or until 95 percent recovery is achieved) as water rises or lowers:
   - every 15 seconds for the first 3 minutes of the test
length of the cable extended from the tip of the probe to the reference point. Add the length of the distance between the end of the probe and the fluid sensor to the total depth measurement. Record the depth to the nearest 0.01 foot in the field logbook.

6. Decontaminate the probe prior to gauging the next boring or well.

4.6 IN-SITU HYDRAULIC CONDUCTIVITY TESTING

4.6.1 Overview

Determination of the in-situ hydraulic conductivity of a formation is an aspect in the characterization of a site. The usage of slug tests can provide data that will aid in understanding the dynamics of the geology and hydrogeology of the site.

4.6.2 Procedures

4.6.2.1 Slug Test

Slug tests will be used to determine the hydraulic conductivity of distinct water bearing geologic horizons under in-situ conditions. Slug tests will be conducted on selected piezometers.

Water will not be added to any of the piezometers. All equipment to be used in piezometers will be decontaminated prior to the slug test to avoid cross-contamination. Slug tests will be conducted only on piezometers at which development has been completed. If a test is conducted on a well recently purged for water sampling, the measured water level must be within 0.1 foot of the static water level prior to testing.

The slug test may be conducted using an electronic data-logger and pressure transducer or by manually measuring well recovery. All data collected with the data-logger will be stored electronically. The information will be directly transferred to a computer and analyzed. A computer printout of the data will be kept in the project files for documentation. Manual readings will be recorded in the field logbook.

The slug test utilizing an electronic data logger will be conducted in the following manner:

1. Decontaminate the transducer and cable.

2. Record pertinent information into the electronic data logger before beginning the slug test.

3. Determine the static water level in the well by periodically measuring the depth to water for several minutes and calculating the average of the readings.

4. Cover sharp edges of the well casing with duct tape to protect the transducer cables.
- Mechanical surge block
- Electronic water level indicator, water level popper, or Teflon®-coated woven tape
- Field file
- Specific conductivity meter
- pH meter and calibration buffer solutions
- Thermometer
- Sample containers and preservatives
- Calculator
- Generator
- Bladder pump capable of pumping 150 mL per minute or less
- Applicable decontamination equipment (refer to Section 5.0)
- Applicable safety equipment (refer to Section 4.1)

4.4.2.2 Methodologies

Newly installed piezometers will be developed no sooner than 24 hours after the installation of grout. Wells can be developed by bailing, air lifting, pumping, and/or surging and pumping. If surging and pumping is used, a surge block will be used to force the groundwater in and out of the filter pack and surrounding native material. Water will be removed using a submersible pump or bailer. Water will be removed from the entire water column in the well by periodically raising and lowering the pump. Surging and pumping will be repeated in cycles until the well development parameters are met.

4.5 FIELD MEASUREMENTS

4.5.1 WATER LEVEL MEASUREMENTS

An electronic water level meter will be used to gauge the piezometers. The following procedure will be used to measure to measure the water levels:

1. Decontaminate the cable and probe. Wipe the cable with paper towels as the cable is rewound onto the reel.

2. Turn on the water level indicator and press the instrument test button to check the batteries.

3. Lower the probe into the borehole or well by pulling the cable from the hand-held reel until the indicator light illuminates or the audible signal sounds.

4. Move the cable up and down to determine the upper groundwater surface. Note the exact length of the cable extended from the probe fluid sensor to the reference point at the top of the well casing. Record the measurement to the nearest 0.01 foot, the boring or well designation, and the date the measurement was taken.

5. Measure the total depth by gently lowering the probe or weighted tape to the bottom of the boring or well until the cable becomes slack. Reel in the slack cable and note the
The surface pad will be sloped in a manner to ensure that all surface water flows away from the piezometer.

All protective casings will be free of extraneous openings, and devoid of any asphalitic, bituminous, encrusting, and/or coating except the paint or primer applied by the manufacturer.

A steel surface casing will be set a minimum of 12 inches through the cement or concrete surface pad and will extend a minimum of 24 inches above the pad or ground. The top of the protective casing will be fitted with a locking cap and will be marked to clearly identify the well as a piezometer or site assessment observation well.

Surveying
Upon completion of the drilling activities and installation of piezometers, the locations and casing elevations of each piezometer will be surveyed in accordance with criteria described in Section 7.0.

4.4 PIEZOMETER WELL DEVELOPMENT

4.4.1 Overview

The purpose of well development is to remove fines (clay, silt, fine sand, rock flour) and drilling fluid residue from the filter pack and the natural formation in the vicinity of the screened interval in the monitoring well. Additionally, well development results in the settlement and stabilization of the material adjacent to the well screen.

4.4.1.1 Methods

Following well completion, well development will be performed to remove fluids used during drilling and to remove fines from the natural formation. This will provide a particulate-free discharge for sampling. When possible, development will be done by reversing flow direction or surging the well. If possible, no fluids other than natural formation water will be added during development. There are a number of different methods to develop a monitoring well. Bailing, air lifting, pumping, and pumping and surging are all adequate methods for well development. The appropriate method that is actually utilized for a particular well is highly dependent upon hydrogeologic conditions, volume of groundwater produced by the formation, and the drilling method used for the installation.

4.4.2 Procedures

4.4.2.1 Equipment

The equipment to be used for piezometer well development consists of:

- Stainless steel submersible pump with backflow check valve and Teflon® tubing capable of pumping from the depth of the wells
- Disposable bailers
- Polypropylene rope
approximately three inches of annular space between the borehole wall on all sides of the well (centered riser and screen). The depth of each borehole will be based on the results of drilling activities.

Screen and Casing Placement
Well screens and well casings will be clean and free of foreign matter prior to use. Pre-washing will not be necessary if the materials have been packaged by the manufacturer and the packaging is intact up to the time of installation. Well casing will bear the manufacturer's markings that identify the material as that specified. Washed screens and casings will be stored in clean plastic sheeting or the manufacturer's packaging until insertion into the borehole. Screen bottoms will be securely fitted with a threaded cap or plug of the same composition as the screen. No solvents or glues will be used for attachment.

In general, monitoring well screens will be no more than five feet in length. However, situations may arise where a greater length of well screen may be needed to fully monitor a specific zone.

Filter Pack Placement
The annular space between the screen and borehole will be filled with a filter pack, and aggregates used for the filter pack will consist of uncontaminated quartz sand, silica or other material that will not affect the groundwater quality. The filter pack will be selected to prevent or minimize infiltration of the formation fines. The filter pack will extend two feet above the top of the screen, and will be placed in the well annulus in such a manner that bridging of the filter pack material will not occur.

Bentonite Seal
A minimum of two feet of bentonite pellets, chips or granules between 0.25 and 0.75 inches in size will be placed immediately above the filter pack in the annular space between the well casing and borehole and properly hydrated.

Cement/Bentonite Grout Placement
Above the bentonite seal, a cement/bentonite grout mixture or other suitable backfill material will be placed from the top of the bentonite seal to approximately two feet below grade level. The backfill material will be mixed in accordance with the ratio requirements set forth in OAC 785:35-7-2(b)(6)(C).

When the placement of grout will exceed 20 feet, the grout will be placed using a tremie pipe and filled or pumped from the bottom upward.

Surface Seal
A concrete or cement grout surface seal will be placed around the casing immediately above the annular seal, from a depth of two feet to land surface.

Protective Cover and Concrete Pad
When the grout has cured to the proper depth below ground surface (bgs), a 3-foot diameter concrete pad with a minimum thickness of 3.5 inches will be placed around the piezometers.
4.3 PIEZOMETER INSTALLATION

4.3.1 Overview

4.3.1.1 Drilling Methods

Installation methods will include the use of hollow stem auger, air rotary or sonic drilling techniques with minimal introduction of drilling fluid into the borehole. All groundwater piezometers will be installed to yield representative water level and groundwater quality data.

4.3.1.2 Piezometer Materials

Piezometers installed for long term monitoring will be two inches or larger in diameter and constructed of PVC. All joints will be flush-threaded without the use of cementing compounds. Piezometer and monitor well completion will be in accordance with OAC 785:35-7-2.

4.3.2 Procedures

4.3.2.1 Equipment

Other equipment needed for sampling, drilling and installation of piezometers includes the following:

- One-quart resealable plastic bags
- Munsell Soil and Rock Color Charts
- Boring logs and data forms
- Field file
- Indelible marking pen
- Garbage bags
- Hand lens
- Caution tape
- Lath and flagging
- Utility knife
- Stainless steel sampling knife and/or spoon
- Keyed-alike locks
- Fiberglass tape
- Electronic water level indicator
- Sampling containers
- Applicable decontamination equipment (refer to Section 5.0)
- Applicable safety equipment (refer to Section 4.1)

4.3.2.2 Installation

Borehole Diameter and Depth

The nominal borehole diameter for piezometer installation will be determined as per subsurface conditions and potential use. The borehole will provide sufficient diameter to permit
that is circulating down through the drill pipe and up through the annular space. When there is no water entering the borehole from the formation, penetration and removal of cuttings may be enhanced by adding small quantities of water.

4.2.1.3 Sonic Drilling

Sonic drilling advances a borehole using resonant high frequency vibrations to fluidize the formation at the drill bit. Vibrations created in the sonic head at the top of the drill string move rapidly up and down the drill string with intense vibration at the drill bit. Resonant frequencies of around 150 Hertz, which are audible and thus “sonic,” can be controlled to suit the type of formation. Rotation can be added when drilling in harder geologic formations. The primary benefits of this technology are that very rapid drilling rates are possible, combined with reduced volumes of derived waste.

4.2 Procedures

4.2.2 Logging Criteria

For specifics on logging criteria, refer to Section 7.2.

4.2.2.2 Soil Sampling

Geotechnical samples will be collected continuously on 5-foot intervals to total depth within the overburden using split spoon samplers, continuous split barrel samplers, and/or thin walled sampling tubes (Shelby Tubes). Soil samples will be collected for chemical or geotechnical analysis using the following procedure:

1. For split spoon or continuous split barrel samplers, remove the sub and shoe and split open the two halves of the sampler. Samples collected using Shelby Tubes will be capped and extruded at the testing laboratory.

2. Visually examine and log the remaining geologic material.

3. Geotechnical samples will be collected as described in Appendix A.

4. Transfer the soil into the appropriate sample containers.

4.2.3 Borehole Abandonment

A temporary borehole not converted into a monitoring well or piezometer will be plugged in accordance with OAC 785:35-11.

4.2.4 Decontamination Procedures

For specific details on decontamination procedures, refer to Section 5.0.
4.0 PROCEDURES

This chapter presents the details regarding specific types of field investigation procedures. These procedures include drilling, piezometer installation, aquifer testing, sample collection, and decontamination. In addition, health and safety measures, methods for managing investigation-derived waste, and sample-handling/chain of custody procedures are provided.

4.1 HEALTH AND SAFETY

Drilling and sampling personnel will conduct operations in accordance with promulgated Occupational Safety and Health Administration (OSHA) regulations. Upon arrival at the site work location, field personnel will record the time, location, and weather conditions in the field logbook. Field personnel will be suited in Modified Level D personal protective equipment (PPE), which consists of:

- Steel-toed boots
- Hard hat
- High-visibility vest or shirt
- Safety glasses, splash goggles, or face shield
- Hearing protection

4.2 DRILLING AND SAMPLING

4.2.1 Overview

Drilling and sampling procedures can be conducted by using a number of different methods. The variability of geologic and topographic conditions, in addition to the engineering or protocol requirements will dictate the type of equipment and methodologies to be employed on any specific project.

4.2.1.1 Auger Drilling

Auger drilling utilizes a spiral tool form to convey dug material to the surface. An auger is essentially a conveyor which has a drill head, or cutting bit, or combination head and bit at its bottom end to cut the formation, which is then conveyed upward. There are four basic types of auger in use: bucket auger, digger auger, solid-stem continuous flight auger, and hollow-stem continuous flight auger. Auger drilling does not normally require the use of drilling fluids.

4.2.1.2 Rotary Drilling

Rotary drilling is a drilling method in which drill pipe with an attached bit is continuously rotated against the face of the borehole while drilling fluid (i.e., drilling mud or air), is pumped through the pipe and bit to flush the cuttings to the surface. In air rotary drilling, air is compressed and circulated down through the drill rods and up the open hole. The rotary drill bit is attached to the lower end of the drill pipe, and as the bit cuts into the formation, cuttings are immediately removed from the bottom of the borehole and transported to the surface by the air.
3.4.4 Comparability

The objective of comparability is to establish that the data developed during the investigation are comparable with applicable criteria and with data available from other scientific studies in the area.

3.5 REPORTING

Per OAC 252:515-7-37, SCS will prepare a soils report detailing the characteristics of soil and rock material proposed for liner, intermediate, or final cover material. The report will be stamped or sealed by the licensed professional engineer directing the soils laboratory; and will include all test results, type of test used, method of testing and the condition, preparation, and orientation of each sample.

Per OAC 252:515-7-38, SCS will complete a regional hydrogeologic study of the proposed expansion area and the results included with the permit application. SCS will collect the following information to be included:

- The formation underlying the deepest formation penetrated by the boreholes and/or piezometers
- All formations exposed in the outcrop on or within 1/4 mile of the proposed permitted boundary
- A geologic column and structural information of all rock formations occurring from surface to a depth of 500 feet
- A regional surface geological map
- Illustrations of the regional stratigraphic column and geologic or hydrogeologic cross sections
- A description of regional groundwater quality
- References indicating the sources of information.
approximately the same date each month. If significant changes in the water level in the continuous monitor are identified following heavy rainfall events, ODEQ may require additional measurements in other piezometers to further define the level of highest groundwater elevation. In the event that trends in the data indicate that groundwater characteristics are similar to previously collected data, a shortened piezometric measurement period may be requested.

SCS will obtain daily and monthly precipitation data from the climatological station closest to the expansion area, for the months in which the on-site measurements were taken and for the preceding 12 months. CLIMOCs will be used to obtain the 30-year mean precipitation from the climatological station. The precipitation data will be used to interpret any fluctuations in the piezometric surface throughout the site characterization period.

3.4 QUALITY ASSURANCE/QUALITY CONTROL

The quality assurance (QA) objective for analytical data is to collect environmental monitoring data of known and acceptable quality. To meet this objective, the following quality control (QC) parameters must be addressed:

- Precision
- Accuracy
- Representativeness
- Completeness
- Comparability

Each of these parameters will be briefly discussed in the following subsections.

3.4.1 Precision and Accuracy

The primary objective of field measurements is to obtain reproducible measurements to a degree of accuracy with the limits imposed by the intended use of the data. Thus, quality control procedures for field measurements will be limited to checking the reproducibility of field measurements by taking readings and by calibration of the instruments.

3.4.2 Representativeness

The objective in addressing representativeness is to assess whether the information obtained during the investigation accurately represents the actual site conditions. Representativeness will be assessed after initial data validation and reduction and will be based only on validated data.

3.4.3 Completeness

The objective for completeness is to provide sufficient valid data to meet the goals of the investigation. Completeness will be assessed by comparing the number of the valid sample results to the number of samples collected.
Soil/rock samples will be collected at a rate of 1 sample per 5 feet of soil/rock drilled and at soil and rock changes from the surface to the total depth drilled. The samples will be stored until directed by SORD to dispose of them. Specific details concerning subsurface investigative methodologies and procedures are provided in Section 4.0 of this Plan.

3.2.2 Groundwater

Borings will be advanced into the uppermost water-bearing geologic unit beneath the Site while seven borings will be completed as piezometers. Proposed borings B-5, B-9, B-13, B-16, B-17, and B-19 will be completed as piezometers and logged with geophysical methods. Boring B-20 will also be converted to a piezometer and is located within the existing permit boundary. See Figure 3 for approximate locations and surface elevations. Note that Figure 3 also denotes which borings will be completed as piezometers.

The water-bearing unit will need to yield sufficient quantities of groundwater for regular sampling events. Aquifer testing and/or field hydraulic conductivity (slug) tests will be performed on selected piezometers.

Details describing the specific procedures for installation and completion of the piezometers and performance of field testing are presented in Section 4.0.

3.3 Sampling and Groundwater Elevations

3.3.1 Soil Sampling

To aid in the characterization and determination of the site as a suitable location for a horizontal landfill expansion, soil samples will be collected for testing (see Appendix A). The samples will be shipped to a geotechnical laboratory and tested under the direction of a licensed professional engineer. The following tests will be conducted on each type of soil sampled:

- Soil classification according to the specifications of ASTM D2487
- Particle-size analysis of soil according to the specifications of ASTM D422
- Sieve analysis for the following screen sizes: #4, #10, #40, #200
- Percent fines (#200 sieve) according to the specifications of ASTM D1140
- Atterberg limits according to the specifications of ASTM D4318
- Moisture content according to the specifications of either the oven drying method of ASTM D2216 or the microwave drying method of ASTM D4643
- Moisture-density relationship according to the specifications of the standard proctor test of ASTM D698 or the modified proctor test of ASTM D1557
- Hydraulic conductivity according to the specifications of ASTM D5084

3.3.2 Groundwater Elevations

Groundwater elevations will be collected monthly for one year, to aid in establishment of groundwater flow direction and aquifer geometry underlying the proposed horizontal expansion. SCS will install a continuous water level monitoring system in one piezometer, and will monitor the water levels in all other piezometers once each month for 12 consecutive months on...
3.0 TECHNICAL APPROACH

3.1 PLAN STRATEGY

This Plan will utilize a strategy that will allow for flexibility in approach while meeting the regulatory criteria for the proposed landfill expansion. This will allow the detail of information collected to be increased or decreased in order to accommodate specific situations encountered during the work.

3.2 SUBSURFACE INVESTIGATION

3.2.1 Soil and Bedrock

Initially, a subsurface investigation to determine the subsurface conditions beneath the site and obtain data to assist in development of this Plan was conducted by installing four borings across the area of planned expansion (Figure 2). Table 1 lists the four borings with approximate locations and depths.

Data collected from these borings was utilized in determining placement of approximately 16 additional borings, which will be drilled to aid in the characterization of the hydrogeologic and soil conditions underlying the proposed expansion site. Table 3 lists the 16 borings with approximate locations and depths. However, if complex hydrogeology exists, such as groundwater divides, shallow saturated zones, or hydraulic barriers, additional borings may be required. Data from previously completed four borings (B-1 through B-4) and existing wells will also be used to aid in the characterization at the Site. These locations will be advanced using a combination of one or more of the following dry drilling methods:

- Hollow stem auger
- Air rotary
- Cable tool
- Sonic

Per OAC 252:515-7-4(b)(4): all borings will be drilled a minimum of thirty feet below the deepest proposed placement of waste, the elevation of which shall be reported in relation to mean sea level; and at least six borings will be drilled a minimum of ten feet into the uppermost saturated zone.

B-3 and B-4 were both drilled to a minimum depth 100 feet or more, which meets the requirements of OAC: 252:515-7-4(4)(c), having at least one boring shall drilled to a depth of 100 feet, regardless of the depth at which groundwater is encountered.

Geophysical logging will be completed on six of the boreholes converted to piezometers. The geophysical logs will be obtained using gamma ray/neutron logs or an alternative method approved by ODEQ from the total depth to the surface, in either open hole or behind casing.
2.4 GEOLOGY AND HYDROGEOLOGY

According to the Oklahoma Geological Survey, the local geology consists of the Permain-age concretionary mudstone known as the Stillwater Formation, and the Antlers Sandstone from the Mesozoic period. The Stillwater Formation is typified by mudstone with local interbeds of reddish-orange, friable, fine-grained sandstone, with dolomite- and siltstone-pebble conglomerates common at base of sandstone intervals. The base of the formation is mapped at the base of the Hart Limestone. The Stillwater Formation grades laterally into the Stratford Formation near the Arbuckle Mountains. Its total thickness varies from 300 to 500 feet.

The Antlers Sandstone is a Lower Cretaceous, white to light brownish-yellow, medium-grained, poorly indurated sandstone. It is commonly interbedded with varicolored clays, and red to maroon, arkosic conglomerates occur in the project area. It has been known to contain fossil wood and dinosaurs. Thickness of the sandstone ranges between 80 and 900 feet; the unit becomes thicker in the subsurface in a southeasterly direction.

According to the Oklahoma Water Resources Board, the nearest aquifer is the Antlers Aquifer. The Antlers Aquifer is located approximately one mile south of the SORD landfill, and extends generally along an east/west path where, according to Hart and Davis (1981), the aquifer crops out in an area of 1,860 m² and underlies about 4,400 m² in southeast Oklahoma. The large outcrop area combined with precipitation of up to 50 inches per year is conducive to high infiltration rates. The average saturated sand thickness of the aquifer is 250 feet, and it is estimated to contain 31,600,000 acre-feet of water having less than 1,000 ppm total dissolved solids.

2.5 SEISMICITY

Based on the USGS U.S. Seismic Hazard Map, Peak Horizontal Acceleration with 2% Probability of Exceedance in 50 Years (2014), the location of the Site is depicted as exhibiting a maximum horizontal acceleration (or effective peak ground acceleration) in rock of between 1.4 and 2 percent of gravity with a 98 percent probability of not exceeding the horizontal acceleration within a 50-year recurrence. This acceleration factor may be utilized during seismic analysis of soil performance to liquefaction and during design of structural elements to resist earthquake forces.

Based on the USGS report, One-year seismic hazard forecast for the Central and Eastern United States from induced and natural earthquakes (2016), a 1-year seismic hazard forecast for 2016 for the United States that includes contributions from both induced and natural earthquakes. Pages 37 and 38 from this report are appended to show the chance of damage from an earthquake in 2016.
2.0 BACKGROUND INFORMATION

2.1 PHYSICAL SETTING

The proposed landfill expansion site (Site) consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore in Carter County, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian (Ardmore East USGS Topographic Quadrangle). Refer to Figure 1 for the property location map.

Site specific maps have been generated and/or appended in accordance with OAC 252:515-7-4(b)(2) for the following:
- Figure 1 – Site Location Map
- Figure 4 – Flood Plain Map
- Figure 5 – Alluvium and Terrace Deposits and Recharge Areas
- Appendix D – Seismic Hazard Map

2.2 CLIMATE

The climate for Carter County, Oklahoma is humid and temperate, and is characterized by warm summers and cold, dry winters. Average temperatures range between 52 °F and 75 °F. Mean annual precipitation is approximately 38.53 inches, with approximately 223 days in the growing season (OCS).

2.3 PHYSIOGRAPHY

The proposed Site is located within the Osage Plains, a section of the Central Lowland province, which in turn is part of the larger Interior Plains physiographic province. Three subregions make up the Osage Plains; the subregion that stretches across central Oklahoma is known as the Cross Timbers region. The woodland and savanna portions of the Cross Timbers are mainly post oak and blackjack oak on coarse, sandy soils, while the prairie portions are chiefly tallgrass on finer, dry soils.

Surface elevations at the Site range from approximately 750 to 850 feet above mean sea level. Surface water drains primarily to the north to an intermittent stream that flows to the northeast approximately 1.75 miles and into the Sand Branch of Caddo Creek.

2.4 SOILS

Soils on the Site are primarily comprised of the Windthorst-Weatherford complex (approximately 38%), Tamford-Grainola complex (approximately 28%), Weatherford fine sandy loam (approximately 20%), Pulaski and Bunyan soils (approximately 8%) and Konsil and Weatherford soils (approximately 7%).
1.3.2 Piezometer Installation Activities

B-1 was drilled to a total depth of 699 feet Mean Sea Level (MSL), B-2 drilled to a total depth of 721 feet MSL, B-3 drilled to a total depth of 689 feet MSL, and B-4 was drilled to a total depth of 710 feet MSL. B-3 and B-4 were both drilled to a minimum depth 100 feet or more, which meets the requirements of OAC: 252:515-7-4(4)(c), having at least one boring shall be drilled to a depth of 100 feet, regardless of the depth at which groundwater is encountered.

Each boring was converted to a piezometer and was constructed with two inch diameter schedule 40 PVC flush-threaded pipe riser and a 10-foot, 0.010 inch machine-slotted screen. 20-40 silica sand was gravity placed from the bottom of the well to a minimum of 2 feet above the top of screen. A 2-foot or greater bentonite seal consisting of 3/8-inch Bentonite chips was gravity placed on top of the filter pack. The remainder of the annulus was backfilled with a Portland cement and bentonite slurry grout. The wells were completed with 4-inch by 4-inch aboveground locking protective casings at approximately 3 feet above grade set into a 3-foot by 3-foot concrete pad.

1.3.3 Groundwater Evaluation

The four piezometers were given ample time to recover from development on February 3, 2016 and water levels were gauged again on February 25, 2016 (Table 2). The water levels indicate a gradual groundwater gradient to the north with the greatest difference in water levels for the four piezometers at 11.5 feet. A Northward trending slope of decreasing groundwater elevation is expected for the expansion site. The expansion site sits to the North of the Antlers Aquifer by approximately one mile.

The four initial borings completed as piezometers, indicate water levels above the screens ranging from ~12' to 39' and are therefore considered to be screened in a lower confined aquifer. B-1, B-2, B-3, and B-4 are screened at 730-720’ MSL, 751-741’ MSL, 720-710’ MSL, and 740-730’ MSL, respectively. The corresponding water levels on February 25, 2016 were 751.50’ MSL, 763.00’ MSL, 759.00’ MSL, and 756.40’ MSL, respectively.

The well logs for the four initial piezometers show evidence of water above the screened intervals in the form of moist to very moist and occasionally wet clayey sediments. The upper saturated zone will be the target screened zone for the additional 16 borings, seven of which will be converted to piezometers. Of the seven proposed piezometers, six of them will be logged with the addition of geophysical methods (See Section 3.2.1 and 3.2.2 for more information).
1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this report is to provide guidance and rationale for activities being conducted in association with the Drilling Plan for the proposed 80-acre horizontal expansion and modification of base grades and final cover for the Southern Oklahoma Regional Disposal Landfill near Ardmore, which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). This Work Plan (Plan) has been developed and prepared in accordance with the Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code (OAC) 252:515.

1.2 SCOPE AND OBJECTIVES

The Plan will involve obtaining geologic and hydrogeologic data to aid in the design and construction of the proposed landfill expansion. The work will entail drilling, piezometer installation, aquifer testing, sampling, and analysis of the conditions and materials present at the proposed landfill expansion site. Initially, a subsurface investigation to determine the subsurface conditions beneath the site and obtain data to assist in development of this Plan was conducted by completing four initial borings across the area of planned expansion. Data collected from these borings was utilized in determining placement of 16 (15 within proposed expansion and 1 within existing permit boundary) additional borings, which will be drilled to determine the subsurface conditions beneath the site. Select borings will be completed as piezometers, dependent upon hydrogeologic conditions and spatial location. Existing data from borings and piezometers will be utilized to aid in characterizing the hydrogeologic and soil conditions at the site. Aquifer testing will be performed to evaluate the hydraulic properties of the materials that underlie the site. Groundwater levels and precipitation measurements will be collected to determine seasonal potentiometric surface variations and the effect of surficial recharge on the uppermost continuous aquifer beneath the site.

1.3 INITIAL SUBSURFACE INVESTIGATION

1.3.1 Drilling

The initial subsurface investigation was performed from January 27, 2016 to February 3, 2016 in efforts to obtain data and develop this Plan. A total of four initial borings (B-1, B-2, B-3, and B-4) across the area of planned expansion (Figure 2) were completed in accordance with OAC 252:515-7. Drilling was conducted by Associated Environmental Industries, Corp. (AEI) using a TS-1500 Rotary Sonic drilling rig creating a nominal six inch borehole. Lithology samples and cuttings were visually screened for the presence of moisture, and a lithological log was created for each borehole. A copy of each boring log is included in Appendix B. The initial four borings were converted to piezometers and were screened in a lower confining zone and gauged for water levels to help develop the Plan for the additional 16 borings.
CONTENTS (Continued)

LIST OF TABLES

Table 1: Proposed Initial Borings
Table 2: Groundwater Levels for Initial Borings, Gauged on 2/25/2016
Table 3: Proposed Additional Borings

LIST OF FIGURES

Figure 1: Site Location Map
Figure 2: Initial Boring Locations
Figure 3: Proposed Additional Boring Locations
Figure 4: Site Specific Flood Plain Extent
Figure 5: Site Specific Alluvium and Terrace Deposits

APPENDICES

Appendix A: Soil Sampling for Geotechnical Analyses
Appendix B: Initial Boring Logs
Appendix C: USGS Topography 7.5 Minute Quadrangle
Appendix D: USGS Seismic Hazards
<table>
<thead>
<tr>
<th>CONTENTS (Continued)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4.3 Piezometer Installation</td>
<td>11</td>
</tr>
<tr>
<td>4.3.1 Overview</td>
<td>11</td>
</tr>
<tr>
<td>4.3.1.1 Drilling Methods</td>
<td>11</td>
</tr>
<tr>
<td>4.3.1.2 Piezometer Materials</td>
<td>11</td>
</tr>
<tr>
<td>4.3.2 Procedures</td>
<td>11</td>
</tr>
<tr>
<td>4.3.2.1 Equipment</td>
<td>11</td>
</tr>
<tr>
<td>4.3.2.2 Installation</td>
<td>11</td>
</tr>
<tr>
<td>4.4 Piezometer Well Development</td>
<td>13</td>
</tr>
<tr>
<td>4.4.1 Overview</td>
<td>13</td>
</tr>
<tr>
<td>4.4.1.1 Methods</td>
<td>13</td>
</tr>
<tr>
<td>4.4.2 Procedures</td>
<td>13</td>
</tr>
<tr>
<td>4.4.2.1 Equipment</td>
<td>13</td>
</tr>
<tr>
<td>4.4.2.2 Methodologies</td>
<td>14</td>
</tr>
<tr>
<td>4.5 Field Measurements</td>
<td>14</td>
</tr>
<tr>
<td>4.5.1 Water Level Measurements</td>
<td>14</td>
</tr>
<tr>
<td>4.6 In-Situ Hydraulic Conductivity Testing</td>
<td>15</td>
</tr>
<tr>
<td>4.6.1 Overview</td>
<td>15</td>
</tr>
<tr>
<td>4.6.2 Procedures</td>
<td>15</td>
</tr>
<tr>
<td>4.6.2.1 Slug Test</td>
<td>15</td>
</tr>
<tr>
<td>5.0 Sample Numbering System</td>
<td>18</td>
</tr>
<tr>
<td>5.1 Sample Identification</td>
<td>18</td>
</tr>
<tr>
<td>6.0 Documentation, Sample Custody, Packaging and Shipping</td>
<td>19</td>
</tr>
<tr>
<td>6.1 Field Logbook Procedures</td>
<td>19</td>
</tr>
<tr>
<td>6.2 Logging Criteria</td>
<td>19</td>
</tr>
<tr>
<td>6.2.1 General Requirements</td>
<td>20</td>
</tr>
<tr>
<td>6.2.1.1 Logging Soils (Unconsolidated Materials)</td>
<td>21</td>
</tr>
<tr>
<td>6.2.1.2 Logging Rock (Consolidated Materials)</td>
<td>21</td>
</tr>
<tr>
<td>6.3 Photographs</td>
<td>22</td>
</tr>
<tr>
<td>7.0 Surveying</td>
<td>23</td>
</tr>
<tr>
<td>9.0 References</td>
<td>24</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Purpose</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Scope and Objectives</td>
<td>1</td>
</tr>
<tr>
<td>1.3 Initial Subsurface...</td>
<td>1</td>
</tr>
<tr>
<td>1.3.1 Drilling</td>
<td>1</td>
</tr>
<tr>
<td>1.3.2 Piezometer Installation Activities</td>
<td>2</td>
</tr>
<tr>
<td>1.3.3 Groundwater Evaluation</td>
<td>2</td>
</tr>
<tr>
<td>2.0 Background Information</td>
<td>3</td>
</tr>
<tr>
<td>2.1 Physical Setting</td>
<td>3</td>
</tr>
<tr>
<td>2.2 Climate</td>
<td>3</td>
</tr>
<tr>
<td>2.3 Physiography</td>
<td>3</td>
</tr>
<tr>
<td>2.4 Soils</td>
<td>3</td>
</tr>
<tr>
<td>2.4 Geology and Hydrogeology</td>
<td>4</td>
</tr>
<tr>
<td>2.5 Seismicity</td>
<td>4</td>
</tr>
<tr>
<td>3.0 Technical Approach</td>
<td>5</td>
</tr>
<tr>
<td>3.1 Plan Strategy</td>
<td>5</td>
</tr>
<tr>
<td>3.2 Subsurface Investigation</td>
<td>5</td>
</tr>
<tr>
<td>3.2.1 Soil and Bedrock</td>
<td>5</td>
</tr>
<tr>
<td>3.2.2 Groundwater</td>
<td>6</td>
</tr>
<tr>
<td>3.3 Sampling and Groundwater Elevation</td>
<td>6</td>
</tr>
<tr>
<td>3.3.1 Soil Sampling</td>
<td>6</td>
</tr>
<tr>
<td>3.3.2 Groundwater Elevation</td>
<td>6</td>
</tr>
<tr>
<td>3.4 Quality Assurance/Quality Control</td>
<td>7</td>
</tr>
<tr>
<td>3.4.1 Precision and Accuracy</td>
<td>7</td>
</tr>
<tr>
<td>3.4.2 Representativeness</td>
<td>7</td>
</tr>
<tr>
<td>3.4.3 Completeness</td>
<td>7</td>
</tr>
<tr>
<td>3.4.4 Comparability</td>
<td>8</td>
</tr>
<tr>
<td>3.5 Reporting</td>
<td>8</td>
</tr>
<tr>
<td>4.0 Procedures</td>
<td>9</td>
</tr>
<tr>
<td>4.1 Health and Safety</td>
<td>9</td>
</tr>
<tr>
<td>4.2 Drilling and Sampling</td>
<td>9</td>
</tr>
<tr>
<td>4.2.1 Overview</td>
<td>9</td>
</tr>
<tr>
<td>4.2.1.1 Auger Drilling</td>
<td>9</td>
</tr>
<tr>
<td>4.2.1.2 Rotary Drilling</td>
<td>9</td>
</tr>
<tr>
<td>4.2.1.3 Sonic Drilling</td>
<td>10</td>
</tr>
<tr>
<td>4.2.2 Procedures</td>
<td>10</td>
</tr>
<tr>
<td>4.2.2.1 Logging Criteria</td>
<td>10</td>
</tr>
<tr>
<td>4.2.2.2 Soil Sampling</td>
<td>10</td>
</tr>
<tr>
<td>4.2.2.3 Borehole Abandonment</td>
<td>10</td>
</tr>
<tr>
<td>4.2.2.4 Decontamination Procedures</td>
<td>10</td>
</tr>
</tbody>
</table>
DRILLING PLAN
FOR THE
PROPOSED 80-ACRE EXPANSION
OF THE
SOUTHERN OKLAHOMA REGIONAL DISPOSAL LANDFILL
CARTER COUNTY, OKLAHOMA

Prepared for:
Southern Oklahoma Regional Disposal, Inc.
PO Box 1088
Ardmore, Oklahoma 73402

Prepared By:
SCS ENGINEERS
1817 Commons Circle, Suite 1
Yukon, Oklahoma 73099
405.265.3960

April 2016
File No. 27215136.00
DRILLING PLAN
FOR THE
PROPOSED 80-ACRE EXPANSION
OF THE
SOUTHERN OKLAHOMA REGIONAL
DISPOSAL LANDFILL

Carter County, Oklahoma

Prepared for:
Southern Oklahoma Regional Disposal, Inc.
PO Box 1088
Ardmore, Oklahoma 73402

Prepared by:
SCS ENGINEERS
1817 Commons Circle, Suite 1
Yukon, Oklahoma 73099
405.265.3960

April 2016
File No. 27215136.00

Offices Nationwide
www.scsengineers.com
April 20, 2016
File No. 27215136.00

Ms. Martha Grafton
Land Protection Division
Oklahoma Department of Environmental Quality
707 North Robinson
Oklahoma City, Oklahoma 73101

Subject: Drilling Plan
Southern Oklahoma Regional Disposal

Dear Ms. Grafton:

On behalf of Southern Oklahoma Regional Disposal, Inc., SCS Engineers is submitting the Drilling Plan associated with the proposed 80-acre horizontal expansion at the Southern Oklahoma Regional Disposal Landfill. The proposed expansion is more specifically described as the northeast quarter of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian.

Initially, a subsurface investigation to determine the subsurface conditions beneath the site and obtain data to assist in development of this Plan was conducted by completing four initial borings across the area of planned expansion. Data collected from these borings was utilized in determining placement of 16 (15 within proposed expansion and 1 within existing permit boundary) additional borings. A total of 19 borings (initial 4 borings and 15 additional borings) will be utilized to determine the subsurface conditions beneath the site which complies with the requirements of OAC 252:515-7-4(b)(3)(C).

Proposed borings B-5, B-9, B-13, B-16, B-17, and B-19 will be completed as piezometers and logged with the additional of geophysical methods. Boring B-20 will also be converted to a piezometer and is located within the existing permit boundary.

Should you have any questions or require additional information, please feel free to contact us at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade J. Miller
Project Director
SCS ENGINEERS

cc: Mr. Troy Duke – Southern Oklahoma Regional Disposal, Inc.

Enclosures
May 23, 2016

Mr. Troy Duke, Director, Solid Waste Services
SORD Landfill
P.O. Box 1088
Ardmore, Oklahoma 73402

Re: Drilling Plan, Southern Oklahoma Regional Disposal (SORD) Landfill, Carter County, Permit Number 3510007

Dear Mr. Duke:

The Oklahoma Department of Environmental Quality (DEQ) is in receipt of the above referenced Plan for SORD Landfill dated April 20, 2016, submitted by SCS Engineers.

The Drilling Plan encompasses an expansion area of 80 acres outside of the current permit boundary. The Drilling Plan and subsurface investigation results will be submitted as part of a Tier III permit application to expand the permit boundary.

The Drilling Plan has been reviewed and is accepted by DEQ. Per OAC 252:515-7-5(a), please notify DEQ at least two (2) weeks prior to initiating drilling.

If you have any questions, please contact Martha Grafton at (405) 702-5144.

Sincerely,

[Signature]

Hillary Young, P.E.
Chief Engineer
Land Protection Division

HY/mg

cc: Wade Miller, SCS Engineers
Appendix A

Work Plan and Approval
### Table 4.4

**Proposed Monitoring Well Details**

<table>
<thead>
<tr>
<th>Proposed Monitoring Well</th>
<th>Approximate Surface Elevation (fmsl)</th>
<th>Proposed Depth (ft bgs)</th>
<th>Approximate Screened Interval (fmsl)</th>
<th>Geologic Unit Monitored</th>
<th>Up gradient/Down gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW-1</td>
<td>832</td>
<td>52</td>
<td>NA</td>
<td>Stillwater</td>
<td>Up gradient</td>
</tr>
<tr>
<td>MW-3</td>
<td>808</td>
<td>45</td>
<td>NA</td>
<td>Stillwater</td>
<td>Down gradient</td>
</tr>
<tr>
<td>MW-6</td>
<td>834</td>
<td>57</td>
<td>777-782</td>
<td>Stillwater</td>
<td>Up gradient</td>
</tr>
<tr>
<td>MW-7</td>
<td>807</td>
<td>41</td>
<td>765-770</td>
<td>Stillwater</td>
<td>Down gradient</td>
</tr>
<tr>
<td>MW-8</td>
<td>830</td>
<td>69</td>
<td>761-766</td>
<td>Stillwater</td>
<td>Down gradient</td>
</tr>
<tr>
<td>MW-9</td>
<td>775</td>
<td>61</td>
<td>745-755</td>
<td>Stillwater</td>
<td>Down gradient</td>
</tr>
<tr>
<td>MW-10</td>
<td>768</td>
<td>23</td>
<td>745-750</td>
<td>Stillwater</td>
<td>Down gradient</td>
</tr>
<tr>
<td>MW-11</td>
<td>759</td>
<td>45</td>
<td>714-724</td>
<td>Stillwater</td>
<td>Down gradient</td>
</tr>
</tbody>
</table>

*Note: target depths are based off of exploratory piezometers/borings actual depth may vary based on field observations*
<table>
<thead>
<tr>
<th>Well</th>
<th>Geologic Formation</th>
<th>Solution Method</th>
<th>K ft/sec</th>
<th>K cm/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ-5 (IN)</td>
<td>Stillwater</td>
<td>Bouwer-Rice</td>
<td>1.94E-06</td>
<td>5.97E-05</td>
</tr>
<tr>
<td>PZ-5 (OUT)</td>
<td>Stillwater</td>
<td>Bouwer-Rice</td>
<td>3.63E-06</td>
<td>1.11E-04</td>
</tr>
<tr>
<td>PZ-13 (IN)</td>
<td>Stillwater</td>
<td>Bouwer-Rice</td>
<td>5.99E-08</td>
<td>1.88E-06</td>
</tr>
<tr>
<td>PZ-13 (OUT)</td>
<td>Stillwater</td>
<td>Bouwer-Rice</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>PZ-16 (IN)</td>
<td>Stillwater</td>
<td>Bouwer-Rice</td>
<td>5.35E-06</td>
<td>1.68E-04</td>
</tr>
<tr>
<td>PZ-16 (OUT)</td>
<td>Stillwater</td>
<td>Bouwer-Rice</td>
<td>4.76E-06</td>
<td>1.45E-04</td>
</tr>
<tr>
<td>PZ-17 (IN)</td>
<td>Stillwater</td>
<td>Bouwer-Rice</td>
<td>3.38E-06</td>
<td>1.03E-04</td>
</tr>
<tr>
<td>PZ-17 (OUT)</td>
<td>Stillwater</td>
<td>Bouwer-Rice</td>
<td>1.1E-05</td>
<td>3.36E-04</td>
</tr>
<tr>
<td>Year</td>
<td>Jan</td>
<td>Feb</td>
<td>Mar</td>
<td>Apr</td>
</tr>
<tr>
<td>------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>1981-2010 Normal</td>
<td>1.96</td>
<td>2.34</td>
<td>3.09</td>
<td>3.39</td>
</tr>
<tr>
<td>Mesonet Average</td>
<td>1.85</td>
<td>1.51</td>
<td>2.67</td>
<td>3.51</td>
</tr>
<tr>
<td>1994</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>1995</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>1996</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>1997</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>1998</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>1999</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2000</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2001</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2002</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2003</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2004</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2005</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2006</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2007</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2008</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2009</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2010</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2011</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2012</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2013</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2014</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2015</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2016</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
<tr>
<td>2017</td>
<td>1.38</td>
<td>0.26</td>
<td>3.41</td>
<td>3.96</td>
</tr>
</tbody>
</table>

Note: Measurement recorded in inches.

Source: Mesonet (www.mesonet.org/index.php/weather/monthly_rainfall_table)

Station Information: (ARD2) Ardmore
County: Carter
Commissioned: 3/1/2004
Lat: 34° 11' 33" N
Lon: 97° 05' 08" W
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>PZ-1</td>
<td>320227.43</td>
<td>225771.00</td>
<td>781.49</td>
<td>31.23</td>
<td>31.75</td>
<td>31.60</td>
<td>31.45</td>
<td>31.50</td>
<td>31.35</td>
<td>31.65</td>
<td>31.50</td>
<td>31.45</td>
<td>31.50</td>
<td>31.40</td>
<td>31.50</td>
<td>750.2644</td>
<td></td>
</tr>
<tr>
<td>PZ-2</td>
<td>320237.57</td>
<td>225858.99</td>
<td>800.72</td>
<td>48.39</td>
<td>48.80</td>
<td>48.80</td>
<td>48.80</td>
<td>48.85</td>
<td>48.70</td>
<td>49.00</td>
<td>49.05</td>
<td>49.00</td>
<td>49.00</td>
<td>48.90</td>
<td>48.75</td>
<td>761.3274</td>
<td></td>
</tr>
<tr>
<td>PZ-3</td>
<td>319378.02</td>
<td>225858.02</td>
<td>802.61</td>
<td>44.36</td>
<td>44.65</td>
<td>44.70</td>
<td>44.75</td>
<td>44.80</td>
<td>44.50</td>
<td>45.10</td>
<td>45.05</td>
<td>45.00</td>
<td>44.90</td>
<td>44.85</td>
<td>44.90</td>
<td>758.2490</td>
<td></td>
</tr>
<tr>
<td>PZ-4</td>
<td>318943.98</td>
<td>225816.29</td>
<td>813.13</td>
<td>53.92</td>
<td>53.75</td>
<td>53.40</td>
<td>53.20</td>
<td>53.30</td>
<td>53.15</td>
<td>53.85</td>
<td>53.25</td>
<td>53.20</td>
<td>53.40</td>
<td>53.35</td>
<td>53.50</td>
<td>759.9752</td>
<td></td>
</tr>
<tr>
<td>PZ-5</td>
<td>320638.76</td>
<td>225685.50</td>
<td>762.27</td>
<td>36.61</td>
<td>36.15</td>
<td>35.40</td>
<td>34.50</td>
<td>35.20</td>
<td>35.00</td>
<td>34.75</td>
<td>35.40</td>
<td>35.25</td>
<td>35.10</td>
<td>35.20</td>
<td>35.10</td>
<td>737.7693</td>
<td></td>
</tr>
<tr>
<td>PZ-9</td>
<td>320652.70</td>
<td>225856.70</td>
<td>778.26</td>
<td>30.64</td>
<td>30.75</td>
<td>30.85</td>
<td>30.90</td>
<td>30.70</td>
<td>30.65</td>
<td>30.90</td>
<td>31.05</td>
<td>31.00</td>
<td>31.00</td>
<td>31.00</td>
<td>31.10</td>
<td>747.6212</td>
<td></td>
</tr>
<tr>
<td>PZ-16</td>
<td>319794.97</td>
<td>225999.71</td>
<td>830.94</td>
<td>65.22</td>
<td>65.35</td>
<td>65.10</td>
<td>64.90</td>
<td>65.00</td>
<td>64.70</td>
<td>65.00</td>
<td>65.10</td>
<td>65.10</td>
<td>65.00</td>
<td>65.05</td>
<td>65.00</td>
<td>766.2392</td>
<td></td>
</tr>
<tr>
<td>PZ-17</td>
<td>319338.26</td>
<td>225816.29</td>
<td>794.35</td>
<td>27.31</td>
<td>27.70</td>
<td>27.15</td>
<td>26.95</td>
<td>27.10</td>
<td>26.90</td>
<td>26.40</td>
<td>26.70</td>
<td>27.10</td>
<td>27.10</td>
<td>27.10</td>
<td>27.10</td>
<td>768.1514</td>
<td></td>
</tr>
<tr>
<td>PZ-19</td>
<td>318953.53</td>
<td>225900.62</td>
<td>834.17</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>Dry</td>
<td>N/A</td>
<td>782.7632</td>
<td></td>
</tr>
<tr>
<td>PZ-20</td>
<td>317377.82</td>
<td>225872.67</td>
<td>833.16</td>
<td>51.40</td>
<td>51.60</td>
<td>50.45</td>
<td>50.55</td>
<td>50.70</td>
<td>50.40</td>
<td>51.65</td>
<td>50.95</td>
<td>51.00</td>
<td>50.90</td>
<td>51.00</td>
<td>50.95</td>
<td>782.7632</td>
<td></td>
</tr>
<tr>
<td>Boring</td>
<td>Northing</td>
<td>Easting</td>
<td>Drilled Depth (ft. bgs)</td>
<td>Completed Depth (ft. bgs)</td>
<td>TOC ELEV (fmsl)</td>
<td>GS ELEV (fmsl)</td>
<td>Stick up (ft)</td>
<td>Bottom of Borehole Elev. (fmsl)</td>
<td>Top of Screen Elev. (fmsl)</td>
<td>Bottom of Screen Elev. (fmsl)</td>
<td>Top of Sandpack (fmsl)</td>
<td>Bottom of Sandpack (fmsl)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
<td>-------------</td>
<td>-------------------------</td>
<td>--------------------------</td>
<td>-----------------</td>
<td>---------------</td>
<td>---------------</td>
<td>---------------------------------</td>
<td>---------------------------</td>
<td>----------------------------</td>
<td>---------------------</td>
<td>----------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-1</td>
<td>320227.4272</td>
<td>225771.1004</td>
<td>81</td>
<td>64</td>
<td>781.4944</td>
<td>777.64</td>
<td>3.8544</td>
<td>696.64</td>
<td>726.98</td>
<td>716.98</td>
<td>728.98</td>
<td>716.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-2</td>
<td>320237.571</td>
<td>2258588.991</td>
<td>86</td>
<td>66</td>
<td>809.7174</td>
<td>806.64</td>
<td>3.0774</td>
<td>720.64</td>
<td>750.98</td>
<td>740.98</td>
<td>752.98</td>
<td>740.98</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-3</td>
<td>319378.0193</td>
<td>2258588.024</td>
<td>110</td>
<td>90</td>
<td>802.609</td>
<td>799.36</td>
<td>3.2499</td>
<td>689.36</td>
<td>719.72</td>
<td>709.72</td>
<td>721.72</td>
<td>709.72</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-4</td>
<td>318943.9837</td>
<td>2258164.289</td>
<td>100</td>
<td>80</td>
<td>813.1252</td>
<td>809.92</td>
<td>3.2052</td>
<td>709.92</td>
<td>740.26</td>
<td>730.26</td>
<td>744.26</td>
<td>730.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-5</td>
<td>320638.7605</td>
<td>2256853.504</td>
<td>45.5</td>
<td>45.5</td>
<td>762.2693</td>
<td>759.84</td>
<td>2.4333</td>
<td>714.3363</td>
<td>724.6663</td>
<td>714.6663</td>
<td>726.8363</td>
<td>714.3363</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-9</td>
<td>320652.7012</td>
<td>2258567.696</td>
<td>61</td>
<td>31</td>
<td>778.2612</td>
<td>776.06</td>
<td>2.1992</td>
<td>715.062</td>
<td>755.392</td>
<td>745.392</td>
<td>758.062</td>
<td>745.392</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-13</td>
<td>320235.7173</td>
<td>2258145.242</td>
<td>35</td>
<td>35</td>
<td>800.1394</td>
<td>797.92</td>
<td>2.2235</td>
<td>762.9159</td>
<td>773.2459</td>
<td>763.2459</td>
<td>774.9159</td>
<td>763.2459</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-16</td>
<td>319794.9712</td>
<td>2258999.706</td>
<td>70</td>
<td>100</td>
<td>830.9392</td>
<td>828.67</td>
<td>2.2733</td>
<td>758.6659</td>
<td>768.9959</td>
<td>758.9959</td>
<td>770.6659</td>
<td>757.6659</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-17</td>
<td>319338.2632</td>
<td>2258160.293</td>
<td>68</td>
<td>68</td>
<td>794.3514</td>
<td>792.05</td>
<td>2.3019</td>
<td>734.0495</td>
<td>762.3795</td>
<td>752.3795</td>
<td>764.0495</td>
<td>751.0495</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-19</td>
<td>318953.5286</td>
<td>2259009.616</td>
<td>92.5</td>
<td>45</td>
<td>834.167</td>
<td>831.93</td>
<td>2.2328</td>
<td>739.4342</td>
<td>797.2642</td>
<td>787.2642</td>
<td>798.9342</td>
<td>785.9342</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PZ-20</td>
<td>317377.8208</td>
<td>2258726.374</td>
<td>76</td>
<td>50</td>
<td>833.1632</td>
<td>830.86</td>
<td>2.3045</td>
<td>754.8587</td>
<td>791.1887</td>
<td>781.1887</td>
<td>792.8587</td>
<td>779.8587</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Era</td>
<td>Period</td>
<td>Epoch</td>
<td>APPROX DEPTH</td>
<td>FORMATION</td>
<td>DESCRIPTION</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>--------</td>
<td>-------</td>
<td>--------------</td>
<td>-----------</td>
<td>-------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CENOZOIC</td>
<td>QUaternary</td>
<td>Holocene</td>
<td>25</td>
<td>Alluvium</td>
<td>Unconsolidated sand, silt, clay, and gravel in stream and river channels on modern flood plains. Thickness ranges from 25 to 100 ft.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MESOZOIC</td>
<td>CRETACEOUS</td>
<td>Lower Cretaceous</td>
<td>225</td>
<td>Antlers Sandstone</td>
<td>White to light brownish yellow, medium-grained, poorly indurated sandstone. Red to maroon, arkosic conglomerates occur locally. Thickness ranges from 200 to 700 ft.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PALEOZOIC</td>
<td>PERMIAN</td>
<td>Lower Permian</td>
<td>325</td>
<td>Wellington Formation</td>
<td>Reddish-brown shale with interbedded very fine-grained sandstone and limestone-pebble conglomerate. The base of formation is mapped at the base of the Fallis Sandstone, which is more of a fine to locally medium-grained sandstone interval. Thickness ranges from 100 to 200 ft.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Upper Permian</td>
<td>625</td>
<td>Stillwater Formation</td>
<td>Predominantly a reddish-brown concretionary mudstone, with local interbeds of reddish-orange, friable, fine grained, micaceous channel sandstones, dolomite and silstone pebble conglomerates common at base of sandstone intervals. The base of the formation is mapped at the Hart Limestone in the area south of the Arbuckles. Thickness ranges from 300 to 500 feet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tables
NOT TO SCALE

GROUND SURFACE

PROTECTIVE COVER: LOCKABLE STEEL COVER.

STICK UP: RISER PIPE EXTENDED TO APPROXIMATELY 3-FT ABOVE GROUND SURFACE.

CONCRETE APRON: 2-FT X 2FT X 4-IN THICK EXTENDING TO CASING SEAL

RISER PIPE: 2-IN PVC SCHEDULE 40 PIPE WITH FLUSH THREADED JOINTS

SCREEN: 2-IN PVC SCHEDULE 40 PIPE WITH FACTORY SLOTTED SCREEN (0.010-IN).

END CAP: 4-IN SCHEDULE 40 PVC THREADED ENDCAP

CASING SEAL: Bentonite chips, cement/bentonite grout, or bentonite grout placed from annular seal to within 2-ft of ground surface

ANNULAR SEAL: At least 2-ft of hydrated bentonite placed on top of sand.

SAND FILTER: Silica sand; placed to 2-ft above the top of screen.

SCS ENGINEERS
8575 W 110th Street, Suite 100
Overland Park, Kansas 66210
Ph. (913) 681-0030 Fax. (913) 681-0012

TYPICAL MONITORING WELL CONSTRUCTION LAYOUT
SORD LANDFILL
31 SORD DRIVE, ARDMORE, OK

CHK. BY: KV
DWN. BY: RCW
DSN. BY: RCW
PROJ. NO.: 27215136.00

PROJ. MGR.: WM
DATE: 12/10/18
CADD FILE: 5.2 - TYPICAL MONITORING WELL CONSTRUCTION LAYOUT
DRAWING NO.: 5.2

12-10-18
FIGURE 4.1A - HYDROGRAPH FOR PZ-1*
SORD LANDFILL
FIGURE 4.1B - HYDROGRAPH FOR PZ-2
SORD LANDFILL
FIGURE 4.1D - HYDROGRAPH FOR PZ-4
SORD LANDFILL

WATER ELEVATION

DATE

NOV-16
DEC-16
JAN-17
FEB-17
MAR-17
APR-17
MAY-17
JUN-17
JUL-17
AUG-17
SEP-17

PZ-4
FIGURE 4.1E - HYDROGRAPH FOR PZ-5
SORD LANDFILL

WATER ELEVATION

DATE

Nov-16 Dec-16 Jan-17 Feb-17 Mar-17 Apr-17 May-17 Jun-17 Jul-17 Aug-17 Sep-17

PZ-5
FIGURE 4.1F - HYDROGRAPH FOR PZ-9
SORD LANDFILL
FIGURE 4.1G - HYDROGRAPH FOR PZ-13
SORD LANDFILL
FIGURE 4.1H - HYDROGRAPH FOR PZ-16
SORD LANDFILL
FIGURE 4.11 - HYDROGRAPH FOR PZ-17
SORD LANDFILL
FIGURE 4.1J - HYDROGRAPH FOR PZ-20
SORD LANDFILL
Figure 4.2 - PZ-9 Hydrograph (Annual Data Set)
NOTE:
1. BACKGROUND IMAGERY IS THE HYDROLOGIC ATLAS RECONNAISSANCE OF THE WATER RESOURCES OF THE ARDMORE AND SHERMAN QUADRANGLES.

- **Psw**
  - Stillwater Formation - Yields only limited amounts of water of poor to fair quality.

- **Qal**
  - Alluvium - Yields moderate to large amounts of water of poor to good quality along major rivers.

- **Kan**
  - Antlers Sand - Yields moderate to large amounts of water of good quality.

*Scale: 2000 0 2000 4000*
NOTE:
1. BACKGROUND IMAGERY RETRIEVED FROM GOOGLE MAPS.

SCS ENGINEERS
8575 W. 110th Street, Suite 100
Overland Park, Kansas 66210
PH. (913) 681-0030 FAX. (913) 681-0012

FIGURE 1.1 - GENERAL LOCATION OF LANDFILL
SOUTHERN OKLAHOMA REGIONAL DISPOSAL, INC.
SORD LANDFILL
31 SORD DRIVE, ARDMORE, OKLAHOMA, 73402

CHK. BY: RF DWN. BY: RCW DSN. BY: RCW PROJ. NO. 27215136.00
PROJ. MGR: WM DATE: 12/10/18 CADD FILE: FL-1.1 - GENERAL LOCATION OF LANDFILL DRAWING NO. 1.1
Figures
6.0 PROPOSED GROUNDWATER MONITORING SYSTEM

As provided in OAC 252:515-9, a groundwater monitoring system must be installed that consists of a sufficient number of wells, installed at appropriate locations and depths, to yield groundwater samples from the uppermost aquifer that: 1) represent the quality of background groundwater that has not been affected by the disposal unit and 2) represent the quality of groundwater that has passed underneath the disposal facility.

The current groundwater monitoring system for the SORD consists of five (5) monitoring wells designated as MW-1, MW-2R, MW-3, MW-4, and MW-5 (FIGURE 5.1). The proposed groundwater monitoring system to be utilized for both the existing and the proposed lateral expansion will consist of a series of existing and new groundwater monitoring wells designed to address the current site comprehensive hydrogeologic model.

Specific details of the proposed groundwater monitoring system were designed to monitor the proposed expansion area and to add to the site-wide monitoring program and are shown on Figure 5.1 and are described as follows:

The proposed monitoring system would therefore consist of existing monitoring wells MW-1, and MW-3, with additional wells MW-6, MW-7, MW-8, MW-9, MW-10, and MW-11. It should be noted that MW-1 and MW-6 are considered up gradient monitoring wells. Monitoring wells MW-3, MW-7, MW-8, MW-9, MW-10, and MW-11 are considered down gradient monitoring wells. Each of the wells that are proposed to be installed (MW-6, MW-7, MW-8 and MW-10) will be screened within the uppermost water-bearing unit. See Table 4.4 for the Proposed Monitoring Well Details. All monitoring wells will be installed in accordance with OAC 252:515-7-3 and OWRB 785:35-7-2. Existing piezometer PZ-9 will become MW-9 and existing piezometer PZ-5 will become MW-11. Boring logs and construction details for these piezometers\monitoring wells can be found in Appendix B.

The groundwater samples will be collected according to the approved Groundwater Monitoring Plan for the facility.

The permanent groundwater monitoring wells will be subject to the strict sampling, testing and reporting requirements of OAC 252:515-9 and the final permit. Four rounds of background data will be collected for groundwater quality constituents listed in OAC 252:515-9-31(d)(1)(A) as well as Appendix A parameters in accordance with OAC 252:515-9-31(d)(1)(B). Additional sampling events may be required prior to the first statistical evaluation.

The groundwater monitoring system will follow all aspects of ODEQ OAC 252:515-9. A typical monitoring well construction diagram is included as Figure 5.2.
Borehole geophysical logging was performed within the 7 boreholes that were converted to piezometers. The results of these logs indicated that the majority of the wells do not show a clear defined change in neutron counts which makes it difficult to determine the change to a saturated zone. The natural gamma logs for the site indicate alternating layers of clays, shales and sands.

During this investigation eleven (11) piezometers were installed and water levels were obtained on a monthly basis (November 2016 – October 2017) at these piezometers and continuously at PZ-9 (September 2016 – December 2017).

The highest recorded water level measurement from PZ-9 was taken on February 21, 2017 at 748.79 ftmsl. The lowest water level recorded was on October 16, 2017 at 746.79 ftmsl. It should be noted that over the course of a year the water level showed very little variation with only 2 ft between the highest recorded water level and the lowest recorded water level.

During this investigation, the highest groundwater elevation was measured in piezometer PZ-20 (782.76 ftmsl). PZ-20 is located on the southeastern portion of the proposed expansion area. The lowest groundwater elevation recorded, with the exception of a piezometer (PZ-19) that was dry throughout the investigation period, occurred in piezometer PZ-5, located along the northwestern portion of the expansion area.

The highest groundwater surface map was utilized to show separation between highest groundwater elevation and the deepest excavation of the landfill bottom. The deepest placement of waste would therefore be 5 feet above this elevation which would be the top of the liner. The highest groundwater surface and the deepest elevation depth (landfill bottom) are presented on the cross sections.

During the period from November 2016 through October 2017, August 2017 (6.58 inches) had the highest rainfall and December 2016 (0.85 inches) had the least rainfall. No significant increases or decreases were recorded in the water level data from those months at any of the piezometers.

A falling head (slug-in) and raising head (slug out) tests was performed at each of the four piezometers locations. Hydraulic conductivity values ranged from 5.99x10^-8 ft/sec to 1.10x10^-5 ft/sec. An average hydraulic conductivity of 4.30x10^-6 was calculated for this site, which corresponds to typical representative value for unconsolidated sedimentary materials.
5.0 CONCLUSIONS

The soils in the vicinity of the SORD Landfill can be classified as seven distinct soil units:

1. Konsil and Weatherford soils (1 to 8% slopes)
2. Pulaski and Bunyan soils (0 to 1% slopes)
3. Tamford-Grainola complex (5 to 12% slopes)
4. Weatherford fine sandy loam (1 to 5% slopes)
5. Windthorst fine sandy loam (3 to 5% slopes)
6. Windthorst fine sandy loam (3 to 8% slopes, eroded)
7. Windthorst-Weatherford complex (5 to 12% slopes)

The SORD is located specifically in the Ardmore Basin, which is characterized by lowlands of folded Mississippian and Pennsylvanian shales and sandstones. The Geology of Carter County consists of outcropping sandstones, shales, and conglomerate that were deposited near the shores of shallow seas that covered much of what is now western Oklahoma. In many places, these sedimentary rocks are mantled by unconsolidated alluvium laid down by present day rivers and streams. Three geologic units are present at the SORD, the Quaternary aged Alluvium, the Cretaceous aged Antlers Sandstone, and the Permian aged Stillwater Formation.

The facility is located in “areas least favorable for development of ground water supplies.” Lithologically, these areas are comprised mainly of shale, siltstone, and tightly cemented sandstone, all of which have low permeability.

The site can be characterized by three hydrogeologic units; Hoxbar Group, Oscar Group, and Antlers Sand. The Hoxbar Group yields only limited amounts of water of poor to fair quality, the Oscar Group yields small to moderate amounts of water of poor to fair quality, and the Antlers Sand yields moderate to large amounts of water of good quality.

A total of four (4) exploratory borings, B-1/PZ-1, B-2/PZ-2, B-3/PZ-3 and B-4/PZ-4 were drilled at the facility from January 27, 2016 to February 3, 2016.

In July-August 2016, a characterization of the subsurface and groundwater condition in the area of the proposed 80-acre expansion was conducted. A total of sixteen (16) additional borings were drilled and piezometers were installed in seven (7) of these borings. The boreholes ranged in depth from approximately 35 feet below ground surface (bgs) to a maximum depth of approximately 100 feet bgs.

The site geology and hydrogeologic conditions were defined by the twenty (20) borings drilled within the proposed expansion area. The Stillwater Formation was encountered across the entire site. The Stillwater Formation can be associated throughout the site through the alternating layers of clays, silty clays, sandy clays, sands and limstones across the site.
4.3 AQUIFER TESTING

During 2016, slug tests were performed in four piezometers PZ-5, PZ-13, PZ-16 and PZ-17 located within the proposed expansion area. Falling head test, lowering a slug into the well and measuring the initial rise in water level followed by the gradual fall in water level to pre-slug conditions and rising head tests, removing the slug and measuring the initial fall in water level followed by the gradual rise in water level to pre-slug conditions were performed on the four piezometers above. The slug test data were analyzed using the Bower and Rice method for unconfined aquifers. Data analysis was performed using the computer program AQTESOLV and analysis graphs are included in Appendix E.

As described above, a falling head (slug-in) and raising head (slug out) tests was performed at each of the four piezometers locations. Field equipment malfunctioned during the PZ-13 raising head test and therefore no results are presented for PZ-13. As presented on Table 4.3 hydraulic conductivity values ranged from 5.99X10-8 ft/sec to 1.10x10-5 ft/sec. An average hydraulic conductivity of 4.30 x 10-6 ft/sec or 0.3715 ft/day was calculated for this site, which corresponds to typical representative value for unconsolidated sedimentary materials.

November 2016 groundwater elevations, as shown in Table 4.1, were used to calculate horizontal gradients across the proposed landfill expansion. The horizontal hydraulic gradient beneath the expansion area was calculated by taking the hydraulic head difference between PZ-20 and PZ-9 (34.14 feet) and dividing by the distance between the wells perpendicular to the groundwater elevation contour lines (3,275 feet). This calculation indicates a hydraulic gradient of 0.0104 for the expansion area. The calculated average flow rate based on a hydraulic conductivity 0.3715 ft/day and an effective porosity of 0.20 was calculated to be 0.019 ft/day. This calculation is based on an assumed effective porosity. The actual effective porosity may vary.
4.2.2 Highest Groundwater Elevations and Groundwater Flow Direction

During this investigation the highest groundwater elevation was measured in piezometer PZ-20 (782.76 fmsl). PZ-20 is located on the southeastern portion of the proposed expansion area. The lowest groundwater elevation recorded, with the exception of a piezometer (PZ-19) that was dry throughout the investigation period, occurred in piezometer PZ-5, located along the northwestern portion of the expansion area. A groundwater surface map as Figure 4.3 was constructed utilizing the highest recorded elevation during the investigation. This groundwater surface was utilized to show separation between highest groundwater elevation and the deepest excavation of the landfill bottom. The deepest placement of waste would therefore be 5 feet above this elevation which would be the top of the liner. The groundwater surface and the deepest elevation depth (landfill bottom) are presented on cross section (Figures 3.3 through 3.6).

A potentiometric surface map utilizing the water levels taken at all of the piezometers in November 2016 was produced to show the groundwater flow across the site. The November 2016 potentiometric surface is depicted on Figure 4.4. As you can see in the figure groundwater flows from south to north across the expansion area.

4.2.3 Continuous Measurements

In accordance with OAC 252:515-7-54(b) and the approved work plan, an in-situ water level troll was installed in PZ-9 and allowed to monitor water levels for a 12-month period beginning in November 2016 through October 2017. All groundwater elevations were measured in accordance to the specifications outlined in ASTM D4750. A Hydrograph depicting the data from the continuous water level monitoring system is included as Figure 4.2. As you can see on the figure, the highest recorded water level measurement was taken on February 21, 2017 at 748.79 fmsl. The lowest water level recorded was on October 16, 2017 at 746.79 fmsl. It should be noted that over the course of a year the water level showed very little variation with only 2 ft between the highest recorded water level and the lowest recorded water level.

4.2.4 Area Rainfall

The climate for Carter County, Oklahoma is humid and temperate, and is characterized by warm summers and cold, dry winters. Average temperatures range between 52 °F and 75 °F. Mean annual precipitation is approximately 38.53 inches, with approximately 223 days in the growing season (OCS). As per OAC 252:515-7-55 daily and monthly precipitation data was obtained from the climatological station closest to the proposed 80-acre expansion area for the months of November 2016 through October 2017 along with the preceding 12 months. Table 4.2 shows the precipitation for Ardmore, Oklahoma. During the period from November 2016 through October 2017, August 2017 (6.58 inches) had the highest rainfall and December 2016 (0.85 inches) had the least rainfall. No significant increases or decreases were recorded in the water level data from those months at any of the piezometers.
4.0 GROUNDWATER

4.1 PIEZOMETERS INSTALLED

As per OAC regulation 252:515-7-52&53 the piezometers were installed in the uppermost saturated zone at locations that were approved by ODEQ so that data collected is representative of the expansion area. The horizontal expansion area is 80-acres, therefore a minimum of 6 piezometers were required by OAC 252:515-7-53(a)&(b). During the current and previous investigations within the expansion area, 11 piezometers were installed and water levels were obtained on a monthly basis.

The piezometer construction consisted of a 2-inch diameter Schedule 40 PVC solid riser and five feet of 0.010" slotted screen. The sand filter pack extends to a minimum of two (2) feet above the screened interval. A minimum three (3) foot bentonite pellet seal was placed immediately above the filter pack. After placement of the entire bentonite seal, the pellets were allowed to hydrate prior to the placement of the remaining bentonite chip seal to the surface. The depth of sand or bentonite was measured as the material was added to the borehole with a cloth tape to insure that bridging did not occur within any portion of the borehole. All piezometers were surveyed after completion. The piezometer installation diagrams are included in Appendix B. The monthly groundwater elevations measured in the piezometers are included on Table 4.1.

4.2 GROUNDWATER ELEVATIONS

During the current investigation, piezometers were installed within 7 of the boreholes to allow the gathering of additional information relative to the groundwater flow in the expansion area (PZ-5, PZ-9, PZ-13, PZ-16, PZ-17, PZ-19, and PZ-20). Attributes for each of these piezometers are listed in Table 3.1. The well construction diagrams are presented in Appendix B. At each of the piezometers, groundwater depths were noted when they were encountered during drilling. Stabilized water levels were also obtained at least 24 hours after completion.

Stabilized groundwater elevations in the piezometers ranged from 787.22 fmsl (PZ-19) to 723.82 fmsl (PZ-5). Following the collection of the stabilized water levels PZ-19 was reported as dry throughout the remainder of the investigation.

4.2.1 Monthly Measurements

In accordance with OAC 252:515-7-54, a groundwater elevation survey was conducted to determine the relationship between the highest water table and the lowest waste placement elevations. Groundwater measurements were taken monthly at piezometers (PZ-1, PZ-2, PZ-3, PZ-4, PZ-5, PZ-9, PZ-13, PZ-16, PZ-17, PZ-19, and PZ-20). Monthly groundwater levels were taken at these piezometers/wells between November 2016 and October 2017. Groundwater measurements were recorded on approximately the same date each month. See Table 4.1 and Figures 4.1A through 4.1K for the recorded monthly groundwater data.
Decreasing counts to the left of the scale show higher water content or more clay or shale type formations. The borehole geophysical logs are included in Appendix C.

3.3 SOIL TESTS

In order to characterize the proposed expansion area in terms of geotechnical properties, samples were collected from boreholes drilled during this investigation. A total of 9 samples were collected from 8 boreholes. These 9 samples were taken at various depths and locations at the site and submitted to Golder Associates, Inc. for geotechnical analysis. The purpose of these analyses was to gain information on the geotechnical properties of the samples and to properly characterize each individual soil type found on site. The results of the geotechnical tests can be found in Appendix D.
- Geotechnical information about drilling, such as penetration rates, hydraulic conductivity test intervals and results, and drill bit changes,

- Identification of all soil and rock layers encountered during drilling describing color, texture, thickness, degree of compaction or consolidation and amount of moisture present in each layer

In accordance with OAC 252:515-35, soil samples were collected continuously at five-foot intervals utilizing continuous sampling. Samples were placed in plastic Ziploc baggies to preserve the sample. Samples will be stored until final action has been taken by the ODEQ.

The site geology and hydrogeologic conditions were defined by the 19 borings drilled within the proposed expansion area as well as one addition boring drilled within the existing permit boundary. The Stillwater Formation was encountered across the entire site. The Stillwater Formation can be associated throughout the site through the alternating layers of clays, silty clays, sandy clays, sands and limestones across the site. The soil boring/lithologic logs are presented in Appendix B of this report. In addition, a series of cross sections were prepared to provide a visual presentation of the lithology beneath the proposed 80-acre expansion area. The cross sections were produced with two figures for each section. The “A” cross section depicts the lithology across the section, and the “B” cross section shows the water levels and bottom of the containment structure. The cross section location map is Figure 3.2. The eight cross sections are Figures 3.3 to 3.6.

As the boring logs and cross section present, the lithology beneath the site is quite varied and consistent with the geology as discussed in Section 2.2 of this report. The site geology consists of clay, silty clay, sandy clay, silty sand, sand, shale, siltstone, and sandstone.

### 3.2 Downhole Geophysical Logs

OAC 252:515-7-34 states that for waste disposal areas of 20-acres or less, at least three boreholes shall be logged by geophysical tools, one of which must be run on the deepest drilled borehole. In addition, one additional borehole shall be logged for each additional 20 acres of waste disposal. Gamma ray/neutron logs from total depth to the surface was logged within the casing of 7 of the boreholes during this investigation. Geophysical Logs are included in Appendix C of this report.

In accordance with OAC 252:515-7-32(a) and OAC 252:515-7-34(a), borehole geophysical logging was performed within boreholes that were converted to piezometers including the 100-foot deep boring (PZ-16) per OAC 252:515-7-34(a). The geophysical logs were performed by Enviro-Log and include natural gamma, resistivity, and conductivity.

The natural gamma log is the recording of a scintillation counter or detector to the natural gamma radiation emitted by a naturally occurring formations, or materials placed in the well bore annulus. Higher gamma readings occur in the presence of clay and shale. The neutron log uses a 1.0 Ci, Americium Beryllium neutron emitting radioactive source to measure the relative porosity of the formation. In cased hole applications, raw counts are recorded and scaled proportionally with increasing counts to the right, which indication of sands or limestone.
3.0 BORING PROGRAM

Prior to preparation of the Drilling Plan a preliminary subsurface exploratory investigation was completed for the site to provide basic information. A total of four (4) exploratory borings, B-1, B-2, B-3, and B-4) were drilled across the area of planned expansion at the facility in January and February 2016 (see Table 3.1). A boring location map is included as Figure 3.1 and boring logs are provided in Appendix B. Each of the exploratory borings was converted to a piezometer (PZ-1- through PZ-4) and was continued to be monitored through this investigation. The exploratory borings for these initial piezometers show evidence of water above the screened intervals in the form of moist to very moist and occasionally wet clayey sediments. The upper saturated zone was the target screened zone for the newly installed piezometers of this investigation. Stabilized water levels in the initial piezometers (indicate a gradual groundwater gradient to the north. A Northward trending slope of decreasing groundwater elevation was expected for the expansion site. Further discussion of the lithology encountered in the exploratory borings and groundwater elevations can be found in Sections 3.1 and 4.2 respectively.

In July-August 2016, a characterization of the subsurface and groundwater condition in the area of the proposed 80-acre expansion was conducted. The field work was conducted in accordance with OAC 252:515-7-4, and the ODEQ approved Drilling Plan prepared by SCS dated April 20, 2016 (see Appendix A).

A total of sixteen (16) additional borings were drilled and piezometers were installed in seven (7) of these borings. Borings that were not converted to piezometers were decommissioned by utilizing 2" tremie pipe to fill the annulus from the total depth to ground surface with a bentonite/Portland grout. The boreholes ranged in depth from approximately 35 feet below ground surface (bgs) to a maximum depth of approximately 100 feet bgs. Further discussion of the lithology encountered in these borings and groundwater elevations measured over time can be found in Sections 3.1 and 4.2 respectively. Construction details for each boring drilled can be found on Table 3.1 and boring logs in Appendix B. The location of each boring can be found on Figure 3.1.

The drilling contractor for all drilling activities was Associated Environmental Industries, Corp of Norman, Oklahoma. A Geoprobe® 8150LS Rotary Sonic rig was utilized to advance a nominal eight inch borehole for each of the borings. The soil borings were advanced utilizing an 8 inch OD hollow barrel and continuous sampling was conducted. Samples were collected at five-foot interval and/or at any major changes in the lithology. A SCS Field Geologist logged each boring and a detailed field boring log for each soil boring is presented in Appendix B.

3.1 BORING LOGS

In accordance with OAC 252:515-7-32 and 33, boring and lithologic logs were completed for each borehole for its entire depth. Each log includes the following information:

- All pertinent information, such as the depth at which water was encountered,
- Depth of water at the time of drilling and again at least 24 hours later,
The Windthorst-Weatherford complex soils are comprised of 35% Windthorst soils which are moderately well drained and moderately slowly permeable, and 30% Weatherford soils which are well drained and moderately permeable. These soils are sloping or strongly sloping which occur on ridge crests and side slopes of uplands. A Windthorst soil profile presents as the following. A 3 inch grayish brown, medium acid fine sandy loam surface layer, 3 inch pale brown medium acid fine sandy loam subsurface layer, then 36 inches of subsoil. The upper 26 inches being yellowish red and reddish yellow medium acid sandy clay and the lower 10 inches being reddish yellow neutral sandy clay. This is underlain by coarsely mottled moderately alkaline soft shale. This soil has a moderate to high shrink-swell potential. A Weatherford soil profile presents as the following. A 5 inch grayish brown slightly acid fine sandy loam surface layer, 9 inch pale brown slightly acid fine sandy loam subsurface layer, then 31 inches of subsoil. The upper 16 inches being reddish yellow medium acid sandy clay and the lower 15 inches being reddish yellow distinctly mottled slightly acid sandy clay loam. This is underlain by weakly consolidated sandstone. This soil has a low or moderate shrink-swell potential.

2.2 REGIONAL GEOLOGY

The physiographic provinces Central Red-Bed Plains, Ardmore Basin, Dissected Coastal Plain, and Arbuckle Mountains Province Arbuckle Hills are all represented in Carter County Oklahoma. The SORD is located specifically in the Ardmore Basin, which is characterized by lowlands of folded Mississippian and Pennsylvanian shales and sandstones. The Geology of Carter County consists of outcropping sandstones, shales, and conglomerate that were deposited near the shores of shallow seas that covered much of what is now western Oklahoma. In many places, these sedimentary rocks are mantled by unconsolidated alluvium laid down by present day rivers and streams. Three geologic units are present at the SORD, the Quaternary aged Alluvium, the Cretaceous aged Antlers Sandstone, and the Permian aged Stillwater Formation.

The Stillwater Formation underlies the Wellington Formation and is comprised of red brown gray shale with arkosic sandstones and the Hart limestone at the base. The majority of the site is comprised of the Stillwater Formation (OGS 2012). The Stillwater Formation ranges in thickness of 300 to 500 feet. The Antlers Sandstone is characterized as white to light brownish yellow, medium-grained, poorly indurated sandstone, with some red to maroon, arkosic conglomerates occurring in some locals. Alluvial deposition of gravel, sand, silt and clay with a thickness of 25 to 100 feet are associated with the Caddo Creek and are located to the north of the site near Sand Branch Creek (OGS 2012). Figure 2.2 depicts a Regional Geologic Map. These formations generally dip gently to the west. Table 2.1 shows the Geologic Column from surface to approximately 500 feet in depth per OAC 252:515-7-38(3). The SORD is generally bordered east and west by Sand Creek a tributary of Caddo Creek. The topography naturally slopes to the north from approximately 850 feet mean sea level (fmsl) along the southern property boundary to approximately 770 fmsl along the northern property boundary.
The Pulaski and Bunyan soils are nearly level to very gently sloping flood plains that are frequently flooded. A typical Pulaski soil profile includes light brown, medium acid fine sandy loam surface layer 20 inches thick. This surface section is followed by 10 inches of light reddish brown, slightly acid fine sandy loam. The bottom section of the profile is reddish brown, slightly acid loam. The Pulaski soil has a moderate water capacity and organic matter content. The Bunyan soil profile consists of a yellowish brown, neutral fine sandy loam surface layer 24 inches thick. The following layer of the profile of is brown, moderately alkaline clay loam and is 9 inch thick. The bottom layer of the profile is brown, moderately alkaline clay loam stratified with fine sandy loam.

The Tamford-Grainola complex soils are sloping to strongly sloping soils which occur on crests and sides of ridges upland. The soil is slowly well drained and permeable. The complex is approximately 40% Tamford soil, 30% Grainola soil, 20% is a Tamford like soil which has a darker colored surface layer and the remaining 5% is a Grainola like soil that had a thicker dark brown surface layer. A Tamford soil profile includes a reddish gray, slightly acid clay loam 6 inches thick surface layer, followed by a 54 inch thick reddish brown, moderately alkaline clay (Noted as calcareous in the lower portion) layer. The base of the profile is red, moderately alkaline, massive clay. Tamford profiles are typically 40 to 60 inches thick and available water capacity is high. A Grainola soil profile is described as 3 inches of reddish brown, moderately alkaline clay loam at the surface. Followed by 32 inches of reddish brown and week red moderately alkaline clay. There is a massive, calcareous clay underlying the profile. The soil is typically 20 to 40 inches deep and has a moderate water capacity. This soil had a high shrink-swell potential.

The Weatherford fine sandy loam soils are gently to very gently sloping eroded soils presents on smooth convex ridgetop and hillsides. The soil is deep, well drained, moderately permeable, and has medium available water capacity. The plow layer of the soil is reddish brown, slightly acid fine sandy loam about 4 inches thick. The subsoil extends to about 58 inches and is red, slightly acid and neutral sandy clay loam. This all is underlain by a poorly cemented sandstone.

The Windthorst fine sandy loam (3 to 5 % slopes) soils are deep, gently sloping, moderately well drained, moderately slowly permeable, and have a high available water capacity. These are present on upland hillside. A Windthorst fine sandy loam soil profile presents as the following. A 3 inch thick brown medium acid fine sandy loam surface layer then a 4 inch light brown medium acid fine sandy loam subsurface layer. The subsoil presents as 13 inches reddish brown, medium acid sandy clay, 19 inches light yellowish brown neutral clay, 15 inches of pale brown moderately alkaline sandy clay with brownish gray mottles. This is underlain by soft sale interbedded with sandstone. These soils have a moderate to high shrink-swell potential.

The Windthorst fine sandy loam (3 to 8 % slopes, eroded) soils are deep, very gently sloping to gently sloping, moderately well drained, moderately slowly permeable, moderately eroded, and have a high available water capacity. These are present on upland areas. A Windthorst fine sandy loam soil profile presents as the following. A 5 inch pale brown slightly acid fine sandy loam plow layer, 21 inches of yellowish red medium acid sandy clay in the upper subsoil then, 12 inches of reddish yellow moderately alkaline sandy clay with brownish and grayish mottles. This is underlain by a massive alkaline sandy clay interbedded with soft sandstone. These soils have a moderate to high shrink-swell potential.
2.0 REGIONAL CHARACTERIZATION

In accordance with OAC 252:515-7-38, this section discusses the regional climate, soils, hydrology, geology, hydrogeology, and water quality of the area surrounding the SORD. The information contained in these sections was compiled from published literature, previous studies conducted at the site, and from the borings that were advanced during the current investigation.

2.1 REGIONAL SOILS

According to the Soil Survey of Carter County, Oklahoma published by the U.S. Soil Conservation Service (USDA, 1979) and the review of information provided by the Web Soil Survey website (August 30, 2017), the soils in the vicinity of the landfill can be classified as seven distinct soil units:

1. Konsil and Weatherford soils (1 to 8% slopes)
2. Pulaski and Bunyan soils (0 to 1% slopes)
3. Tamford-Grainola complex (5 to 12% slopes)
4. Weatherford fine sandy loam (1 to 5% slopes)
5. Windthorst fine sandy loam (3 to 5% slopes)
6. Windthorst fine sandy loam (3 to 8% slopes, eroded)
7. Windthorst-Weatherford complex (5 to 12% slopes)

Figure 2.1 displays the locations of the soil units from USDA 1985 Soil Survey and the Web Soil Survey website (August 30, 2017) in relation to the landfill property boundary. The soils were mapped prior to landfill activities within the expansion area. Note the Windthorst-Weatherford complex is the most abundant soil type onsite. A portion of these soils have been excavated and utilized in the landfiling operations. The soil information described below is from the Soil Survey of Carter County, Oklahoma USDA (1979) and Web Soil Survey Site (August 30, 2017).

The Konsil and Weatherford soils unit typically occurs on uplands that have been gullied by water erosion. These soils are well drained, moderately permeable and gently sloping. A typical Konsil soil profile includes pale brown, slightly acid loamy fine sand 5 inches thick, followed by yellowish red, medium acid sandy clay loam for 45 inches, ending with reddish yellow, medium acid fine sandy loam with pink mottles for 25 inches. The Konsil soil has a moderate water capacity and bedrock depth is typically greater than 60 inches. A typical Weatherford soil profile includes a pale brown, slightly acid fine sandy loam surface layer 5 inches thick, followed by a reddish yellow, medium acid sandy clay loam with mottling in the lower sections that is 43 inches thick. The Weatherford soil has a moderate water capacity for the first 40 inches and bedrock depth is typically ranges from 40 to 60 inches. These are low strength soils that in most areas are sandy.
As outlined in the Drilling Work Plan the locations and depths of the borings were completed in accordance with OAC 252:515-7-4(b)(3)&(4). The Drilling Work Plan along with the ODEQ approval letter are included as Appendix A of this report.

As per OAC 252:515-7-5 once approval was granted for each drilling plan, a Notice of Intent to Drill was prepared and submitted to ODEQ prior to initiating drilling activities. All subsurface drilling activities were conducted in accordance with the approved Drilling Work Plans and were supervised by a qualified groundwater scientist.
1.0 INTRODUCTION

This hydrogeological report documents the investigation conducted for the permit modification application to expand the permit boundary at the Southern Oklahoma Regional Disposal Landfill (SORD). The investigation was designed to meet the requirements of Title 252 Oklahoma Department of Environmental Quality (ODEQ) Chapter 515, “Management of Solid Waste.” The investigation followed the ODEQ approved workplan (SCS April, 2016) and the specific references to ODEQ Regulation 252:515 are included within applicable subsection titles of this report.

1.1 BACKGROUND

The SORD is owned and operated by Southern Oklahoma Regional Disposal, Inc. and is located in the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma, approximately 4 miles east of Ardmore, Oklahoma. Figure 1.1 shows the general location of the landfill while Figure 1.2 shows the layout of the landfill facility. The SORD permit boundary contains approximately 120 acres. Approximately 65.84 acres have been developed for municipal solid waste disposal, of which 43.20 acres have been developed with a Pre-Subtitle D liner, and the remaining 22.64 acres have been developed with a Subtitle D composite liner system. This horizontal expansion proposes to increase the permit boundary to 200 acres.

1.2 WORKPLANS AND APPROVALS

As per ODEQ regulation 252:515-7-4 a Drilling Work Plan was prepared and submitted to ODEQ for approval by SCS on behalf of SORD. The Drilling Work Plan was submitted to ODEQ in April 2016. ODEQ approved the Drilling Work Plan on May 23, 2016. This Drilling Work Plan included the name, address, and telephone number of the owner/operator, the consulting firm, and the person in charge of the project. In addition, the following maps were included in the Drilling Work Plan as per regulation OAC 252:515-7-4:

- General location map, flood plan map, and quadrangle topographic map in accordance with OAC 252:515-3-52;
- Existing contour map in accordance with OAC 252:515-3-55, showing the locations, estimated elevations and total depths of any proposed or existing borings on site;
- Site specific maps showing any wetlands, fault areas, seismic impact zones, and alluvium or terrace deposits and their recharge areas; and
- Drawings of proposed piezometers and/or monitoring wells to demonstrate their construction will be in accordance with the requirements of the OWRB (OAC 252:515-7-3).
List of Figures

No.
1.1 General Location of Landfill
1.2 Site Layout
2.1 Location of Soil Units
2.2 Regional Geologic Map
2.3 Hydrologic Atlas Map
2.4 Groundwater Resource Map
3.1 Boring Location Map
3.2 Cross Section Location Map
3.3 Cross Section A-A'
3.4 Cross Section B-B'
3.5 Cross Section C-C'
3.6 Cross Section D-D'
4.1(A-J) Hydrograph (PZ-1*, PZ-2, PZ-3, PZ-4, PZ-5, PZ-9, PZ-13, PZ-16, PZ-17, PZ-20)
4.2 Hydrograph for PZ-9 (Annual Data Set)
4.3 Highest Recorded Groundwater Elevation Map
4.4 Potentiometric Flow Map (November 2016)
5.1 Proposed Groundwater Monitoring System
5.2 Typical Monitoring Well Construction Diagram

List of Tables

No.
Table 2.1 Geologic Column and Structural Information
Table 3.1 Boring Information
Table 4.1 Monthly Groundwater Elevations
Table 4.2 Ardmore Precipitation
Table 4.3 Slug Test Results
Table 4.4 Proposed Monitoring Well Details

Appendices

Appendix A Work Plan and Approval
Appendix B Boring/Lithologic Logs and Construction Diagrams
Appendix C Geophysical Logs
Appendix D Geotechnical Laboratory Test Results
Appendix E AQTESOLV Analysis Graphs
Appendix F 193+44
# Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 Introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.1 Background</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Workplans and Approvals</td>
<td>1</td>
</tr>
<tr>
<td>2.0 Regional Characterization</td>
<td>3</td>
</tr>
<tr>
<td>2.1 Regional Soils</td>
<td>3</td>
</tr>
<tr>
<td>2.2 Regional Geology</td>
<td>5</td>
</tr>
<tr>
<td>3.0 Boring Program</td>
<td>6</td>
</tr>
<tr>
<td>3.1 Boring Logs</td>
<td>6</td>
</tr>
<tr>
<td>3.2 Downhole Geophysical Logs</td>
<td>7</td>
</tr>
<tr>
<td>3.3 Soil Tests</td>
<td>8</td>
</tr>
<tr>
<td>4.0 Groundwater</td>
<td>9</td>
</tr>
<tr>
<td>4.1 Piezometers Installed</td>
<td>9</td>
</tr>
<tr>
<td>4.2 Groundwater Elevations</td>
<td>9</td>
</tr>
<tr>
<td>4.2.1 Monthly Measurements</td>
<td>9</td>
</tr>
<tr>
<td>4.2.2 Highest Groundwater Elevations and Groundwater Flow Direction</td>
<td>10</td>
</tr>
<tr>
<td>4.2.3 Continuous Measurements</td>
<td>10</td>
</tr>
<tr>
<td>4.2.4 Area Rainfall</td>
<td>10</td>
</tr>
<tr>
<td>4.3 Aquifer Testing</td>
<td>11</td>
</tr>
<tr>
<td>5.0 Conclusions</td>
<td>12</td>
</tr>
<tr>
<td>6.0 Proposed Groundwater Monitoring System</td>
<td>14</td>
</tr>
</tbody>
</table>
INDEX AND CERTIFICATION PAGE

REPORT INDEX

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Number of Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>Introduction</td>
<td>2</td>
</tr>
<tr>
<td>2.0</td>
<td>Regional Characterization</td>
<td>3</td>
</tr>
<tr>
<td>3.0</td>
<td>Boring Program</td>
<td>3</td>
</tr>
<tr>
<td>4.0</td>
<td>Groundwater</td>
<td>3</td>
</tr>
<tr>
<td>5.0</td>
<td>Conclusions</td>
<td>2</td>
</tr>
<tr>
<td>6.0</td>
<td>Proposed Groundwater Monitoring System</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Appendices</td>
<td>236</td>
</tr>
</tbody>
</table>

Certification

This Hydrogeologic and Geotechnical Investigation Report has been prepared in accordance with good engineering practice including consideration of industry standards and the requirements of the Oklahoma Department of Environmental Quality.

Prepared by:

Floyd Cotter, P.E.
Vice President
SCS Engineers
Hydrogeologic and Geotechnical Investigation

Presented To:
Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented From:
SCS Engineers
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00
Hydrogeologic and Geotechnical Investigation

Southern Oklahoma Regional Disposal Landfill

Presented to:
Southern Oklahoma Regional Disposal, Inc.

Southern Oklahoma Regional Disposal, Inc.
P.O. Box 1088
Ardmore, Oklahoma 73402
(580) 226-1276

Presented by:

SCS ENGINEERS
8575 West 110th Street, Suite 100
Overland Park, Kansas
(913) 681-0030

April 2018
Revised December 2018
File No. 27215136.00

Offices Nationwide
www.scsengineers.com
Appendix B

Subsurface Investigation
Certified Mail Receipts
<table>
<thead>
<tr>
<th>YEAR</th>
<th>MONTH</th>
<th>DAY</th>
<th>STID</th>
<th>TR05</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>7</td>
<td>30</td>
<td>ARD2</td>
<td>3.4916</td>
</tr>
<tr>
<td>2017</td>
<td>7</td>
<td>31</td>
<td>ARD2</td>
<td>3.4599</td>
</tr>
<tr>
<td>2017</td>
<td>8</td>
<td>1</td>
<td>ARD2</td>
<td>3.4838</td>
</tr>
<tr>
<td>2017</td>
<td>8</td>
<td>2</td>
<td>ARD2</td>
<td>3.5061</td>
</tr>
<tr>
<td>2017</td>
<td>8</td>
<td>3</td>
<td>ARD2</td>
<td>3.4832</td>
</tr>
<tr>
<td>2017</td>
<td>8</td>
<td>4</td>
<td>ARD2</td>
<td>3.4640</td>
</tr>
</tbody>
</table>
American Burying Beetle *Nicrophorus americanus* Presence/Absence Live-trapping Survey Guidance

**AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM**

**S.O.R.D.**

Project Name: ____________________________ Project Description: Landfill Expansion

Action Agency/Proponent: US Army Corp of Engineers

Time Checked: 8:19  Date Checked: July 31, 2017  Transect #: 1  Survey Night: 1

Survey Company: SCS Engineers  Permitee: Vaughn Weaver  Permittee#: TE 50643B-0

State: OK  County: Carter  Legal Description: 13, 4S, 3E (township range section)  Gen. Location: SORD Landfill

Decimal Degrees: 34.202125, -97.042455  Type of Transect: 5-gal above ground  Trap size: 18/24/ in. (circle one)

Vegetation Type: Prairie  Primary Soil Type: Tamford-Granola complex, 5 to 12 percent slopes  Soil Moisture: 3.4599

Daily Temp (°F): Max 89  Min 69  Period Temp: Max 77  Min 70  Humidity%: Max 83  Min 27

Heavy Rainfall? Yes [ ] No [x]  Wind>10mph? Yes [ ] No [x]  Trap Disturbed? Yes [ ] No [x]

Additional survey night required because of wind, temperature, rain or disturbance? Yes [ ] No [x]

<table>
<thead>
<tr>
<th>Trap</th>
<th><em>americanus</em></th>
<th>orbicollis</th>
<th>tomentosus</th>
<th>pustulatus</th>
<th>marginatus</th>
<th>carolinus</th>
<th>sayi</th>
<th>Necrodes</th>
<th>Necrophila</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

List each individual American burying beetle captured below and complete the appropriate columns.

<table>
<thead>
<tr>
<th>ABB</th>
<th>Male</th>
<th>Female</th>
<th>Old°</th>
<th>New°</th>
<th>Age Unknown°</th>
<th>Recapture 10°</th>
<th>Newly Marked</th>
<th>Dead</th>
<th>Pronotum Width (mm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:

 Transect location near top of slope between wooded area.

1. Date and time refer to when trap is checked
2. Check that legal description fits decimal degrees location. Lat/long MUST be in decimal degrees, NAD 83
4. Max/Min temp from 9 pm to 4 am prior to checking traps, must use data from [www.wunderground.com](http://www.wunderground.com) or [www.mesonet.org](http://www.mesonet.org). **Heavy Rain** is defined by the World Meteorological Organization ([http://scverc.worldweather.org/raindoc.html](http://scverc.worldweather.org/raindoc.html)) as "Rainfall greater than or equal to 50 mm [1.9685 inches] in the past 24 hours."
5. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am
6. Additional trapping required if any metrics exceed the allowable thresholds.
7. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
8. OLD = breeding adult; NEW = newly enclosed adult; UNK = age cannot be determined.
9. Recaptures refer to mark on beetles that have been previously marked.
10. Newly marked males and females refers mark and age of beetle (e.g. R54 [old]).

Last updated May 17, 2017
AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM

S.O.R.D. Project Description: Landfill Expansion

Action Agency/Proponent: US Army Corp of Engineers

Time Checked: 8:19 Date Checked: July 31, 2017 Transect #: 1 Survey Night: 1

Survey Company: SCS Engineers Permittee: Vaughn Weaver Permitte#: TE 50643B-0

State: OK County: Carter Legal Description: 13, 4S, 3E Gen. Location: SORD Landfill

Decimal Degrees: 34.202125/-97.042455 Type of Transect: 5-gal above ground Trap size: 18/24/ in. (circle one)

Vegetation Type: Prairie Primary Soil Type: tamford-Grainola complex, 5 to 12 percent slopes Soil Moisture: 3.4599

Daily Temp (°F): Max 89 Min 69 Period Temp: Max 77 Min 70 Humidity%: Max 83 Min 27

Heavy Rainfall?: Yes □ No ✔ Wind > 10 mph?: Yes □ No ✔ Trap Disturbed?: Yes □ No ✔

Additional survey night required because of wind, temperature, rain or disturbance?: Yes □ No ✔

<table>
<thead>
<tr>
<th>Trap</th>
<th>americanus</th>
<th>orbicollis</th>
<th>tomentosus</th>
<th>pustulatus</th>
<th>marginatus</th>
<th>carolinus</th>
<th>sayi</th>
<th>Necrodes</th>
<th>Necrophila</th>
<th>Other carrion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List each individual American burying beetle captured below and complete the appropriate columns.

<table>
<thead>
<tr>
<th>ABB</th>
<th>Male</th>
<th>Female</th>
<th>Old</th>
<th>New</th>
<th>Age Unknown</th>
<th>Recapture</th>
<th>Newly Marked</th>
<th>Dead</th>
<th>Pronotum Width (mm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Transect location near top of slope between wooded area.

Comments:

1. Date and time refer to when trap is checked.
2. Check that legal description fits decimal degrees location. Lat/long MUST be in decimal degrees, NAD 83.
4. Max/Min temp from 9 pm to 4 am prior to checking traps, must use data from www.wunderground.com or www.mesonet.org.
5. Rain from 9 pm to 4 am, must use data from www.wunderground.com or www.mesonet.org. **Heavy Rain** is defined by the World Meteorological Organization (http://severe.worldweather.org/raindoc.html) as "Rainfall greater than or equal to 50 mm \(1.9685 \text{ inches}\) in the past 24 hours."
6. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am.
7. Additional trapping required if any metrics exceed the allowable thresholds.
8. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
9. OLD = breeding adult; NEW = newly enclosed adult; UNK = age cannot be determined.
10. Recaptures refer to mark on beetles that have been previously marked.
11. Newly marked males and females refers mark and age of beetle (e.g. R54[old]).

Last updated May 17, 2017
Appendix A: Data Collection Form
American Burying Beetle *Nicrophorus americanus* Presence/Absence Live-trapping Survey Guidance

**AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM**

**S.O.R.D.**

**Project Description:** Landfill Expansion

**Action Agency/Proponent:** US Army Corp of Engineers

**Time Checked:** 8:19  **Date Checked:** July 31, 2017  **Transect #:** 1  **Survey Night:** 1

**Survey Company:** SCS Engineers  **Permittee:** Vaughn Weaver  **Permittee#:** TE 50643B-0

**State:** OK  **County:** Carter  **Legal Description:** 13, 4S, 3E Gen. Location: SORD Landfill (township range section)

**Decimal Degrees:** 34.202125/-97.042455  **Type of Transect:** 5-gal above ground  **Trap size:** 18/24/ in. (circle one)

**Vegetation Type:** Prairie  **Primary Soil Type:** Tamfoord-Grassland complex, 5 to 12 percent slopes  **Soil Moisture:** 3.4599

**Daily Temp (°F):** Max 89  **Min 69**  **Period Temp:** Max 77  **Min 70**  **Humidity%:** Max 83  **Min 27**

**Heavy Rainfall:** Yes ☑ No ❌  **Wind>10mph?:** Yes ☑ No ❌  **Trap Disturbed:** Yes ☑ No ❌

**Additional survey night required because of wind, temperature, rain or disturbance?** Yes ☑ No ❌

<table>
<thead>
<tr>
<th>Trap</th>
<th>americanus</th>
<th>orbicollis</th>
<th>tomentosus</th>
<th>pustulatus</th>
<th>marginatus</th>
<th>carolinus</th>
<th>sayi</th>
<th>Necrodes</th>
<th>Necrophila</th>
<th>Other carrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List each individual American burying beetle captured below and complete the appropriate columns.

<table>
<thead>
<tr>
<th>ABB</th>
<th>Male</th>
<th>Female</th>
<th>Old</th>
<th>New</th>
<th>Age Unknown</th>
<th>Recapture</th>
<th>Newly Marked</th>
<th>Dead</th>
<th>Pronotum Width (mm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments:** Transect location near top of slope between wooded area.

1. Date and time refer to when trap is checked
2. Check that legal description fits decimal degrees location. Lat/long MUST be in decimal degrees, NAD 83
4. Max/Min temp from 9 pm to 4 am prior to checking traps, must use data from [www.wunderground.com](http://www.wunderground.com) or [www.mesonet.org](http://www.mesonet.org)
5. Rain from 9 pm to 4 am, must use data from [www.wunderground.com](http://www.wunderground.com) or [www.mesonet.org]. Heavy Rain is defined by the World Meteorological Organization ([http://severe.worldweather.org/raindoc.html](http://severe.worldweather.org/raindoc.html)) as "Rainfall greater than or equal to 50 mm [1.9685 inches] in the past 24 hours."
6. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am
7. Additional trapping required if any metrics exceed the allowable thresholds.
8. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
9. OLD=breeding adult; NEW=newly enclosed adult; UNK=age cannot be determined.
10. Recaptures refer to mark on beetles that have been previously marked.
11. Newly marked males and females refers mark and age of beetle (e.g. R54[old]).

_Last updated May 17, 2017_
AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM

Project Name: S.O.R.D. Project Description: Landfill Expansion

Action Agency/Proponent: US Army Corp of Engineers

Time Checked: 8:19 Date Checked: July 31, 2017 Transect #: 1 Survey Night: 1

Survey Company: SCS Engineers Permittee: Vaughn Weaver Permittee #: 50643B-0

State: OK County: Carter Legal Description: 13, 4S, 3E Gen. Location: SORD Landfill

Decimal Degrees: 34.202125, -97.042455 Type of Transect: 5-gal above ground Trap size: 18/24/ in. (circle one)

Vegetation Type: Prairie Primary Soil Type: samford-graino complex, 5 to 12 percent slopes Soil Moisture: 3.4599

Daily Temp (°F): Max 89 Min 69 Period Temp: Max 77 Min 70 Humidity %: Max 83 Min 27

Heavy Rainfall? Yes No Wind >10 mph? Yes No Trap Disturbed? Yes No

Additional survey night required because of wind, temperature, rain or disturbance? Yes No

List each individual American burying beetle captured below and complete the appropriate columns.

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ABB</td>
<td>Male</td>
<td>Female</td>
<td>Old</td>
<td>New</td>
<td>Age Unknown</td>
<td>Recapture</td>
<td>Newly Marked</td>
<td>Dead</td>
<td>Pronotum Width (mm)</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:

Transect location near top of slope between wooded area.

1. Date and time refer to when trap is checked
2. Check that legal description fits decimal degrees location. Lat/long MUST be in decimal degrees, NAD 83
3. Soil moisture must be obtained by obtaining the TR-05 report from http://www.mesonet.org/index.php/weather/daily_data_retrieval
4. Max/Min temp from 9 pm to 4 am prior to checking traps, must use data from www.wunderground.com or www.mesonet.org
5. Rain from 9 pm to 4 am, must use data from www.wunderground.com or www.mesonet.org. Heavy Rain is defined by the World Meteorological Organization (http://severe.worldweather.org/raindoc.html) as "Rainfall greater than or equal to 50 mm [1.9685 inches] in the past 24 hours."
6. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am
7. Additional trapping required if any metrics exceed the allowable thresholds.
8. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
9. OLD=breeding adult; NEW=newly enclosed adult; UNK=age cannot be determined.
10. Recaptures refer to mark on beetles that have been previously marked.
11. Newly marked males and females refers mark and age of beetle (e.g. R54[old]).

Last updated May 17, 2017
Appendix A: Data Collection Form
American Burying Beetle Nicrophorus americanus Presence/Absence Live-trapping Survey Guidance

AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM

S.O.R.D. Project Name: Project Description: Landfill Expansion

Action Agency/Proponent: US Army Corp of Engineers

Time Checked: 8:19 Date Checked: July 31, 2017 Transect #: 1 Survey Night: 1

Survey Company: SCS Engineers Permitee: Vaughn Weaver Permittee#: 50643B-0

State: OK County: Carter Legal Description: 13, 4S, 3E Gen. Location: SORD Landfill (township range section)

Decimal Degrees: 34.202125/ -97.042455 Type of Transect: 5-gal above ground Trap size: 18/24/ _ in. (circle one)

Vegetation Type: Prairie Primary Soil Type: sandbur-Grassland complex, 5 to 12 percent slopes Soil Moisture: 3.4599

Daily Temp (°F): Max 89 Min 69 Period Temp: Max 77 Min 70 Humidity%: Max 83 Min 27

Heavy Rainfall? Yes ☐ No ☑ Wind>10mph? Yes ☐ No ☑ Trap Disturbed? Yes ☐ No ☑

Additional survey night required because of wind, temperature, rain or disturbance? Yes ☐ No ☑

<table>
<thead>
<tr>
<th>Trap</th>
<th>americanus</th>
<th>orbicollis</th>
<th>tomentosus</th>
<th>pustulatus</th>
<th>marginatus</th>
<th>carolinus</th>
<th>sayi</th>
<th>Necrodes</th>
<th>Necrophila</th>
<th>Other carrion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List each individual American burying beetle captured below and complete the appropriate columns.

<table>
<thead>
<tr>
<th>ABB</th>
<th>Male</th>
<th>Female</th>
<th>Old</th>
<th>New</th>
<th>Age Unknown</th>
<th>Recapture10</th>
<th>Newly Marked</th>
<th>Dead</th>
<th>Pronotum Width (mm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Transect location near top of slope between wooded area.**

Comments:
1. Date and time refer to when trap is checked
2. Check that legal description fits decimal degrees location. Lat/lon MUST be in decimal degrees, NAD 83
4. Max/Min temp from 9 pm to 4 am prior to checking traps, must use data from [www.wunderground.com](http://www.wunderground.com) or [www.mesonet.org](http://www.mesonet.org). Rain from 9 pm to 4 am, must use data from [www.wunderground.com](http://www.wunderground.com) or [www.mesonet.org]. Heavy Rain is defined by the World Meteorological Organization (http://severe.worldweather.org/raindoc.html) as "Rainfall greater than or equal to 50 mm [1.9685 inches] in the past 24 hours."
5. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am
6. Additional trapping required if any metrics exceed the allowable thresholds.
7. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
8. OLD=breeding adult; NEW=newly enclosed adult; UNK=age cannot be determined.
9. Recaptures refer to mark on beetles that have been previously marked.
10. Newly marked males and females refers mark and age of beetle (e.g. R54(old)).

Last updated May 17, 2017
Appendix A: Data Collection Form
American Burying Beetle *Nicrophorus americanus* Presence/Absence Live-trapping Survey Guidance

**AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM**

Project Name: __________________________ Project Description: Landfill Expansion

Action Agency/Proponent: US Army Corp of Engineers

Time Checked: 8:19

Date Checked: July 31, 2017

Transact #: 1

Survey Night: 1

Survey Company: SCS Engineers

Permittee: Vaughn Weaver

Permittee#: 50643B-0

State: OK

County: Carter

Legal Description: 13, 4S, 3E (township range section)

Decimal Degrees: 34.202125, -97.042455

Type of Transect: 5-gal above ground

Trap size: 18/24/____in. (circle one)

Vegetation Type: Prairie

Primary Soil Type: Stanford-Granola complex, 5 to 12 percent slopes

Soil Moisture: 3.4599

Daily Temp (°F): Max 89 Min 69

Period Temp: Max 77 Min 70

Humidity %: Max 83 Min 27

Heavy Rainfall?: Yes [ ] No [ ]

Wind > 10 mph?: Yes [ ] No [ ]

Trap Disturbed?: Yes [ ] No [ ]

Additional survey night required because of wind, temperature, rain or disturbance?: Yes [ ] No [ ]

<table>
<thead>
<tr>
<th>Trap</th>
<th>americanus</th>
<th>orbicollis</th>
<th>tomentosus</th>
<th>pasteatus</th>
<th>marginatus</th>
<th>carolinus</th>
<th>sayi</th>
<th>Necrodes</th>
<th>Necrophila</th>
<th>Other carrion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List each individual American burying beetle captured below and complete the appropriate columns.

<table>
<thead>
<tr>
<th>ABB</th>
<th>Male</th>
<th>Female</th>
<th>Old</th>
<th>New</th>
<th>Age Unknown</th>
<th>Recapture</th>
<th>Newly Marked</th>
<th>Dead</th>
<th>Pronotum Width (mm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:

Transact location near top of slope between wooded area.

1. Date and time refer to when trap is checked
2. Check that legal description fits decimal degrees location. Lat/Long MUST be in decimal degrees, NAD83
4. Max/Min temp from 9 pm to 4 am prior to checking traps, must use data from [www.wunderground.com](http://www.wunderground.com) or [www.mesonet.org](http://www.mesonet.org)
5. Rain from 9 pm to 4 am, must use data from [www.wunderground.com](http://www.wunderground.com) or [www.mesonet.org]. **Heavy Rain** is defined by the World Meteorological Organization (http://severe.worldweather.org/raindoc.html) as "Rainfall greater than or equal to 50 mm [1.9685 inches] in the past 24 hours."
6. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am
7. Additional trapping required if any metrics exceed the allowable thresholds.
8. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
9. OLD = breeding adult, NEW = newly enclosed adult; UNK = age cannot be determined.
10. Recaptures refer to mark on beetles that have been previously marked.
11. Newly marked males and females refers mark and age of beetle (e.g. R54[old]).

Last updated May 17, 2017
Appendix A: Data Collection Form
American Burying Beetle *Nicrophorus americanus* Presence/Absence Live-trapping Survey Guidance

**AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM**

Project Name: S.O.R.D.  
Project Description: Landfill Expansion

Action Agency/Proponent: US Army Corp of Engineers

Time Checked: 8:19  
Date Checked: July 31, 2017  
Transect #: 1  
Survey Night: 1

Survey Company: SCS Engineers  
Permittee: Vaughn Weaver  
Permittee#: TE 50643B-0

State: OK  
County: Carter  
Legal Description: 13, 4S, 3E (township range section)  
Gen. Location: SORD Landfill

Decimal Degrees: **34.202125, -97.042455**  
Type of Transect: 5-gal above ground  
Trap size: 18/24/ in.

Vegetation Type: Prairie  
Primary Soil Type: Cambisols-Grassland complex, 5 to 12 percent slopes  
Soil Moisture: 3.4599

Daily Temp (°F): Max 89, Min 69  
Period Temp: Max 77, Min 70  
Humidity%: Max 83, Min 27

Heavy Rainfall: Yes ☑  
Wind>10mph: Yes ☑  
Trap Disturbed: Yes ☑

Additional survey night required because of wind, temperature, rain or disturbance: Yes ☑

<table>
<thead>
<tr>
<th>Trap</th>
<th><em>americanus</em></th>
<th><em>orbicollis</em></th>
<th><em>tomentosus</em></th>
<th><em>pustulatus</em></th>
<th><em>marginatus</em></th>
<th><em>carolinus</em></th>
<th><em>sayi</em></th>
<th><em>Necrodes</em></th>
<th><em>Necrophila</em></th>
<th>Other carrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

List each individual American burying beetle captured below and complete the appropriate columns.

<table>
<thead>
<tr>
<th>ABB</th>
<th>Male</th>
<th>Female</th>
<th>Old*</th>
<th>New*</th>
<th>Age Unknown*</th>
<th>Recapture*</th>
<th>Newly Marked</th>
<th>Dead</th>
<th>Pronotum Width (mm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:

Transect location near top of slope between wooded area.

1. Date and time refer to when trap is checked
2. Check that legal description fits decimal degrees location. Lat/long MUST be in decimal degrees, NAD 83
4. Max/Min temp from 9 pm to 4 am prior to checking traps, must use data from [www.wunderground.com](http://www.wunderground.com) or [www.mesonet.org](http://www.mesonet.org)
5. Rain from 9 pm to 4 am, must use data from [www.wunderground.com](http://www.wunderground.com) or [www.mesonet.org](http://www.mesonet.org). Heavy Rain is defined by the World Meteorological Organization ([http://severe.worldweather.org/raindoc.html](http://severe.worldweather.org/raindoc.html)) as "Rainfall greater than or equal to 50 mm [1.9685 inches] in the past 24 hours."
6. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am
7. Additional trapping required if any metrics exceed the allowable thresholds.
8. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
9. OLD=breeding adult; NEW=newly enclosed adult; UNK=age cannot be determined.
10. Recaptures refer to mark on beetles that have been previously marked.
11. Newly marked males and females refers mark and age of beetle (e.g., R54[old]).

Last updated May 17, 2017
AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM

Project Name: S.O.R.D. Project Description: Landfill Expansion

Action Agency/Proponent: US Army Corp of Engineers

Time Checked: 8:19 Date Checked: July 31, 2017 Transect #: 1 Survey Night: 1

Survey Company: SCS Engineers Permittee: Vaughn Weaver Permittee#: TE 50643B-0

State: OK County: Carter Legal Description: 13, 4S, 3E Gen. Location: SORD Landfill (township range section)

Decimal Degrees: 34.202125, -97.042455 Type of Transect: 5-gal above ground Trap size: 18/24/ in.

(circle one)

Vegetation Type: Prairie Primary Soil Type: tamford-Granite complex, 5 to 12 percent slopes Soil Moisture: 3.4599

Daily Temp (°F): Max 89 Min 69 Period Temp*: Max 77 Min 70 Humidity%: Max 83 Min 27

Heavy Rainfall?* Yes ☐ No ☑ Wind>10mph?* Yes ☐ No ☑ Trap Disturbed? Yes ☐ No ☑

Additional survey night required because of wind, temperature, rain or disturbance? Yes ☐ No ☑

<table>
<thead>
<tr>
<th>Trap</th>
<th>americanus</th>
<th>orbicollis</th>
<th>tomentosus</th>
<th>pustulatus</th>
<th>marginatus</th>
<th>carolinus</th>
<th>sayi</th>
<th>Necrodes</th>
<th>Necrophila</th>
<th>Other</th>
<th>carriage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Totals

List each individual American burying beetle captured below and complete the appropriate columns.

<table>
<thead>
<tr>
<th>ABB</th>
<th>Male</th>
<th>Female</th>
<th>Old9</th>
<th>New9</th>
<th>Age Unknown9</th>
<th>Recapture10</th>
<th>Newly Marked</th>
<th>Dead</th>
<th>Pronotum Width (mm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:

1. Date and time refer to when trap is checked
2. Check that legal description fits decimal degrees location. Lat/long MUST be in decimal degrees, NAD 83
4. Max/Min temp from 9 pm to 4 am prior to checking traps, must use data from www.wunderground.com or www.mesonet.org
5. Rain from 9 pm to 4 am, must use data from www.wunderground.com or www.mesonet.org. Heavy Rain is defined by the World Meteorological Organization (http://severe.worldweather.org/raindoc.html) as "Rainfall greater than or equal to 50 mm [1.9685 inches] in the last 24 hours."
6. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am
7. Additional trapping required if any metrics exceed the allowable thresholds.
8. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
9. OLD = breeding adult; NEW = newly enclosed adult; UNK = age cannot be determined.
10. Recaptures refer to mark on beetles that have been previously marked.
11. Newly marked males and females refers mark and age of beetle (e.g. R54[old]).

Last updated May 17, 2017
AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM

S.O.R.D.                                                  Project Description: Landfill Expansion

Action Agency/Proponent: US Army Corp of Engineers

Time Checked: 8:19                                      Date Checked: July 31, 2017                                    Transect #: 1                                    Survey Night: 1

Survey Company: SCS Engineers                              Permittee: Vaughn Weaver                              Permittee#: TE 50643B-0

State: OK                                                County: Carter                                      Legal Description: 13, 4S, 3E
(township range section)

Decimal Degrees: 34.202125/-97.042455                        Type of Transect: 5-gal above ground

Vegetation Type: Prairie                                   Trap size: 18/24/___ in.

Daily Temp (°F): Max 89 Min 69                              Soil Moisture: 3.4599

Period Temp: Max 77 Min 70                                

Humidity%: Max 83 Min 27

Heavy Rainfall? Yes ☒ No ☐ Wind>10mph? Yes ☐ No ☒

Trap Disturbed? Yes ☐ No ☒

Additional survey night required because of wind, temperature, rain or disturbance? Yes ☐ No ☒

<table>
<thead>
<tr>
<th>Trap</th>
<th>americanus</th>
<th>orbicollis</th>
<th>tomentosus</th>
<th>pustulatus</th>
<th>marginatus</th>
<th>carolinus</th>
<th>sayi</th>
<th>Necrones</th>
<th>Necrophila</th>
<th>Other carrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

List each individual American burying beetle captured below and complete the appropriate columns.

<table>
<thead>
<tr>
<th>ABB</th>
<th>Male</th>
<th>Female</th>
<th>Old</th>
<th>New</th>
<th>Age Unknown</th>
<th>Recapture</th>
<th>Newly Marked</th>
<th>Dead</th>
<th>Pronotum Width (mm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments:
1. Date and time refer to when trap is checked
2. Check that legal description fits decimal degrees location. Lat/long MUST be in decimal degrees, NAD83
4. Max/Min temp from 9 pm to 4 am prior to checking traps. Must use data from www.wunderground.com or www.mesonet.org.
5. Rain from 9 pm to 4 am, must use data from www.wunderground.com or www.mesonet.org. Heavy Rain is defined by the World Meteorological Organization (http://severe.worldweather.org/raindoc.html) as "Rainfall greater than or equal to 50 mm [1.9685 inches] in the past 24 hours."
6. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am
7. Additional trapping required if any metrics exceed the allowable thresholds.
8. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
9. OLD = breeding adult; NEW = newly enclosed adult; UNK = age cannot be determined.
10. Recaptures refer to mark on beetles that have been previously marked.
11. Newly marked males and females refers mark and age of beetle (e.g. R54[old]).

Last updated May 17, 2017
Appendix A: Data Collection Form
American Burying Beetle *Nicrophorus americanus* Presence/Absence Live-trapping Survey Guidance

**AMERICAN BURYING BEETLE SURVEY DATA COLLECTION FORM**

- **S.O.R.D.**
- **Project Description:** Landfill Expansion

- **Project Name:**
- **Action Agency/Proponent:** US Army Corp of Engineers

- **Time Checked:** 8:19
- **Date Checked:** July 31, 2017
- **Survey Night:** 1
- **Transect #:** 1

- **Survey Company:** SCS Engineers
- **Permittee:** Vaughn Weaver
- **Permittee #:** 50643B-0
- **State:** OK
- **County:** Carter
- **Legal Description:**
  - 13, 4S, 3E
  - Gen. Location: SORD Landfill
  - Township Range Section

- **Decimal Degrees:** 34.202125, -97.042455
- **Type of Transect:** 5-gal above ground
- **Trap size:** 18/24/ in.

- **Vegetation Type:** Prairie
- **Primary Soil Type:** sandy-sandstone complex; 5 to 12 percent slopes
- **Soil Moisture:** 3.4599

- **Daily Temp (**F): Max**
  - **Min**
  - 89
  - 69

- **Period Temp:**
  - **Max**
  - **Min**
  - 77
  - 70

- **Humidity:**
  - **% Max**
  - **% Min**
  - 83
  - 27

- **Heavy Rainfall:** Yes [ ] No [ ]
- **Wind >10mph:** Yes [ ] No [ ]
- **Trap Disturbed:** Yes [ ] No [ ]

- **Additional survey night required because of wind, temperature, rain or disturbance?** Yes [ ] No [ ]

<table>
<thead>
<tr>
<th>Trap</th>
<th>americanus</th>
<th>orbicollis</th>
<th>tomentosus</th>
<th>postulatus</th>
<th>marginatus</th>
<th>carolinus</th>
<th>sayi</th>
<th>Necronex</th>
<th>Necrophilia</th>
<th>Other carrion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Totals**

List each individual American burying beetle captured below and complete the appropriate columns.

<table>
<thead>
<tr>
<th>ABB</th>
<th>Male</th>
<th>Female</th>
<th>Old</th>
<th>New</th>
<th>Old*</th>
<th>New*</th>
<th>Age Unknown</th>
<th>Recapture</th>
<th>Newly Marked</th>
<th>Dead</th>
<th>Pronotum Width (mm)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Comments:**

1. Date and time refer to when trap is checked
2. Check that legal description fits decimal degrees. Lat/long MUST be in decimal degrees, NAD 83
4. Max/Min temp: Prior to checking traps, must use data from www.wunderground.com or www.mesonet.org
5. Rain from 9 pm to 4 am, must use data from www.wunderground.com or www.mesonet.org. **Heavy Rain** is defined by the World Meteorological Organization (http://severe.worldweather.org/raindoc.html) as "Rainfall greater than or equal to 50 mm [1.9685 inches] in the past 24 hours.
6. Wind exceeds 10 mph > than 20% of time between 9 pm to 4 am
7. Additional trapping required if any metrics exceed the allowable thresholds.
8. Determine total number of disturbed traps over all 5 survey nights. Any disturbance to 5-gallon traps requires an additional night of survey effort.
9. OLD = breeding adult; NEW = newly enclosed adult; UNK = age cannot be determined.
10. Recaptures refer to mark on beetles that have been previously marked.
11. Newly marked males and females refers mark and age of beetle (e.g. R54[old]).

** Transect location near top of slope between wooded area.**

Last updated May 17, 2017
Appendix C

Data Forms
Transect 2.

Trap placement and setup west of the southeast critical habitat area and a retention pond.

Direction of photograph is east.

Photograph by Vaughn Weaver
Date: July 30, 2017
Transect 1.
Trap placement and setup in the north potential critical habitat area.

Direction of photograph is northeast.

Photograph by Vaughn Weaver
Date: July 30, 2017

Transect 1.
 Trap placement in relation to surrounding terrain features.

Direction of photograph is east.

Photograph by Vaughn Weaver
Date: July 30, 2017
Appendix B

Site Photographs
Figure 1.

SORD ABB Survey Area
Transect Location and Coverage
July 30 through August 4, 2017
Figure 1.
SORD ABB Survey Area
Project Area Boundary with Potential ABB Habitat
July 30 through August 4, 2017
Appendix A

Figures
7.0 REFERENCES


https://www.fws.gov/southwest/es/Oklahoma/ABB_Add_Info.htm
Vaughn Weaver  
Staff Biologist/Project Manager  
SCS ENGINEERS

Wade Miller  
Office Manager/Project Director  
SCS ENGINEERS

Reviewed by CRM.
night of sampling. A total of zero Silphid beetles were collected during the five night sample event. Completed data sheets for transect 1 can be found in Appendix C, Datasheets.

3.2 TRANSECT 2

Transect 2 was established for five consecutive nights starting on July 30 through August 4, 2017. Transect 2 was a 5-gallon above ground trap baited with an 8 ounce frozen rat and set up in the northern undeveloped area located at:
- Latitude 34.197115
- Longitude -97.040103

Transect 2 was set in a prairie grass cover terrain close to the top of the existing slope. The soil type is Konsil and Weatherford soils, 1 to 8 percent slopes, gullied. There is a retention pond located east of transect 2 location. The lowest night temperature was 68°F. Four of the five nights had no precipitation with one night receiving 0.05 inches. Winds were calm with only onetime winds reaching 10 miles per hour (mph) for less than an hour. The TR05 soil moisture values ranged from 3.4599 to 3.5061, Appendix C, TR05 Soil Moisture. The transect was not disturbed during the five nights sampled. During the evening setup for the third night, ants had infested the trap so the trap was moved to the south approximately 30 feet. No ants were observed in the trap the next morning. New bait was added for the forth night of sampling. A total of zero Silphid beetles were collected during the five night sample event. Completed data sheets for transect 1 can be found in Appendix C, Datasheets.

6.0 CONCLUSION

SCS was retained by SORD to conduct an ABB presence/absence survey and summary report as part of an ecological compliance for potential impacts to federally and state listed threatened and endangered (T&E) species habitat impacts. This survey was completed as part of the permitting process for ODEQ for the proposed SORD facility expansion. Two transects were established that provided one-hundred percent coverage of the project area. A total of five consecutive survey nights were completed from July 30 through August 4, 2017.

No ABB individuals were collected during the survey period. In addition, no other Silphid species were collected. Based on the results of this survey, the project area does not appear to be inhabited by the ABB. Impact to the existing potential ABB habitat should not have a deleterious impact to the continual survival of the ABB species. The results of this report should be valid until May 26, 2018. After that date, the project area would be subject to an ABB habitat assessment if new ground is to be disturbed. Although SCS does not have the authority to make a final determination of impact to critical habitat, this report is being provided to the USFWS to better help in their determination of impacts to potential critical habitat for the ABB from the proposed expansion of the SORD landfill facility.
trap’s two all-thread rods were driven into the ground on opposite sides of the traps to help hold the trap in place. A large rock was then placed on top to minimize scavengers from disturbing the trap setup. A global position system (GPS) location was taken for each trap. A photograph of each trap set up can be reviewed in Appendix B, Photographs 1-2.

2.5 PROCESS CAPTURES

USFWS states that all traps are to be processed before 10 a.m. so as to minimize stress and mortalities on captured ABB specimens. The SORD facility opens at 8 a.m. each weekday which allowed for two hours to process the traps. Every morning traps were checked and captured beetles identified and recorded. After a trap was processed, it was re-assembled and allowed to remain in the field where it was set up. Each night, before the SORD facility closed, the sponges were re-dampened and the baits were examined. If ants were present within the trap, the soil was dumped out and the trap was moved at least seven meters away. New soil was placed within the bucket and the sponge was re-damped prior to re-assembling of the trap for the night.

Each night sampled, an ABB survey data collection form was completed. The information included:

1. Location information
2. Daily weather
3. Captured individuals

Each transect was identified by a number and each night results were recorded on individual data forms (Appendix C, Datasheets). Five consecutive survey nights were completed for the SORD facility.

3 SURVEY RESULTS

3.1 TRANSECT 1

Transect 1 was established for five consecutive nights starting on July 30 through August 4, 2017. Transect 1 was a 5-gallon above ground trap baited with an 8 ounce frozen rat and set up in the northern undeveloped area located at:

- Latitude 34.202125
- Longitude -97.043455

Transect 1 was set in a prairie grass cover terrain close to the top of the existing slope. The soil type is Tanford-Grainola complex, 5 to 12 percent slopes. There is a retention pond located directly north and stands of trees are located east and west of the transect 1 location. The lowest night temperature was 68°F. Four of the five nights had no precipitation with one night receiving 0.05 inches. Winds were calm with only one time winds reaching 10 miles per hour (mph) for less than an hour. The TR05 soil moisture values ranged from 3.4599 to 3.5061, Appendix C, TR05 Soil Moisture. The transect was not disturbed during the five nights sampled. During the evening setup for the third night, ants had infested the trap so the trap was moved to the south approximately 30 feet. No ants were observed in the trap the next morning. New bait was added for the fourth...
in Appendix A, Figure 1 as the borrow area. The borrow area is designated as developed without topsoil and vegetation and unfavorable habitat for ABB. Two separate areas of undeveloped terrain within the project area are located north and southeast of the borrow area. The north undeveloped terrain identified in Appendix A, Figure 1 is the largest potential ABB habitat within the project area and is approximately 33 acres, the southeastern undeveloped terrain is approximately four acres of potential ABB habitat.

2.2 SURVEY SEASON

Acceptable survey periods are based on when the night temperatures are at and above 60 degrees Fahrenheit (°F). This period is typically between May 26 and September 14. There are two designated survey periods during the summer survey time. The first period includes the spring emergent where adults emerge, find a mate and help raise their young underground. This first period is from May 26 to July 28. Surveys completed during this time are good until July 28. The second survey period is from July 29 until the first night temperature is below 60 °F after August 31. The second survey period is valid until May 26 of the following year. The SORD survey started July 31 for this year’s tenderals. The second period survey results will be valid until May 26, 2018.

2.3 TRAP

The USFWS has approved an above ground five-gallon pitfall trap. The above ground bucket trap used during this survey was constructed according to the specifications indicated in the 2015 ABB sampling protocol (USFWS, 2015). The SORD survey utilized two above ground five-gallon bucket traps (trap). Each trap represents one transect as identified in Figure 2.

2.4 TRAP DEPLOYMENT

Each trap is one transect which effectively samples a 0.5 mile radius. Identified potential ABB habitat requires that a minimum of 75% of the habitat be within the sampling area of a transect (USFWS, 2015). Two traps were used to provide 100 percent coverage of the project area and provide a redundancy within the sampling activity (Appendix A, Figure 2). The trap for Transect 1 was placed close to the center of the northern undeveloped terrain providing complete sampling coverage for this northern area. The trap bucket for Transect 2 was placed west of the southeastern undeveloped terrain and a nearby retention pond. The area that the second transect was set up had a sparse vegetative cover and moist soils. Although the center of the second transect was setup within the developed area, the scent trail to the southeast and north undeveloped terrain areas was clear and bait odor should carry in all directions. The general topography of the second transect was effectively flat.

The initial trap setup was completed prior to sunset on Sunday July 30 for the initial night survey. Each trap was baited with a frozen rat that had been placed in individual zip-lock bags and allowed to be outside for 24 hours prior to being placed within the bait-cup of each trap. Each rat was “ripe” with odor. Soil was placed in the bottom of each bucket, then a damp 3.5 x 5.5 x ¾ inch sponge was placed on top of the soil in the bottom of each bucket trap. The
1 PROJECT OVERVIEW

Southern Oklahoma Regional Disposal Landfill (SORD) is expanding their current facility operations. As part of the process to expand the current landfill a new operation permit from the Oklahoma Department of Environmental Quality (ODEQ) is needed before the project area can be developed. As part of the permitting process, an ecological review was completed to evaluate potential ecological constraints that may constrain expansion activities. This ecological review identified that the SORD facility was within the potential range of the American Burying Beetle (ABB). Potential ABB habitat was identified within the project area. To determine if impacts to ABB habitat may occur, with the development of the project area, an ABB absence/presence survey would need to be completed (USFWS, 2017). This report is the summary of a completed absence/presence ABB survey within the proposed project area.

SORD has retained SCS Engineers (SCS) to complete an ABB survey and summary report as part of an ecological compliance for potential impacts to federally listed threatened and endangered (T&E) species habitat impacts. The SORD facility is located approximately 4 miles east of the City of Ardmore in Carter County, Oklahoma in Sections 13 and 24, Township 4 South, Range 3 East. The proposed expansion area (project area) comprises the eastern half of the SORD property (Figure 1).

2 SURVEY CONDITIONS

SCS followed the US Fish and Wildlife Service (USFWS) ABB Oklahoma Presence/Absence Live-trapping Survey Guidance, May 2015 (USFWS, 2015). The survey followed the parameters for:

1. Favorable and unfavorable terrain habitat
2. Seasonal parameters
3. Trap design
4. Trap deployment
5. Processing captures

A qualified ABB survey must be completed based on these parameters to demonstrate a viable survey. Surveys that do not adhere to these parameters may not be acceptable to the USFWS.

2.1 HABITAT

Favorable terrain used by the ABB consists of a wide variety of habitats. The assessment of unfavorable habitat is easier to identify. Land that has been:

1. Tilled and planted in monoculture
2. Pasture or grassland that have been maintained through mowing, grazing, or herbicide at a height of 8 inches or less
3. Already been developed or no longer exhibits surficial topsoil, leaf litter, or vegetation
4. Urban areas
5. Stockpiled soil without vegetation
6. Wetlands with standing water

The project area consisted of two distinct areas. SORD is currently using much of the project area as a source for soil to cover the daily placed waste in the active cell. This area is identified
EXECUTIVE SUMMARY

Southern Oklahoma Regional Disposal Landfill (SORD) is expanding their current facility operations. As part of the process to expand the current landfill a new operation permit from the Oklahoma Department of Environmental Quality (ODEQ) is needed before the proposed expansion area (project area) can be developed. As part of the permitting process, an ecological review was completed to evaluate potential ecological constraints that may constrain expansion activities. This ecological review identified that the SORD facility was within the potential range of the American Burying Beetle (ABB) and potential ABB habitat was identified within the project area. To determine if impacts to ABB habitat may occur, with the development of the project area, an ABB survey would need to be completed (USFWS, 2017).

SORD has retained SCS Engineers (SCS) to complete an ABB survey and summary report as part of an ecological compliance for potential impacts to federally listed threatened and endangered (T&E) species habitat impacts. The SORD facility is located approximately 4 miles east of the City of Ardmore in Carter County, Oklahoma in Sections 13 and 24, Township 4 South, Range 3 East. The project area comprises the eastern half of the SORD property, approximately 82 acres (Figure 1).

SCS completed a five consecutive night ABB field survey from July 30 through August 4, 2017. Sampling was conducted using the US Fish and Wildlife Service (USFWS) ABB Oklahoma Presence/Absence Live-trapping Survey Guidance, May 2015 (USFWS, 2015). Two transects were setup that provided 100 percent sample coverage of the project area. Each transect data included:

1. Location information
2. Daily weather
3. Individuals collected

There were no ABB individuals collected during the survey period. In addition, no other Silphid species were collected. Based on the results of this survey, the project area does not appear to be inhabited by the ABB. Impact to the existing potential ABB habitat should not have a deleterious impact to the continual survival of the ABB species. The results of this report should be valid until May 26, 2018. The survey season is discussed in more detail below. After that date, the project area would be re-assessed to determine if potential critical habitat is present. If critical habitat were present, these areas would be subject to an additional ABB absence/presence survey before the ground could be disturbed. Although SCS does not have the authority to make a final determination of impact to critical habitat, this report is being provided to the USFWS to better help in their determination of impacts of potential critical habitat for the ABB from the proposed expansion of the SORD landfill facility.
## Table of Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXECUTIVE SUMMARY</td>
<td>1</td>
</tr>
<tr>
<td>1 PROJECT OVERVIEW</td>
<td>2</td>
</tr>
<tr>
<td>2 SURVEY CONDITIONS</td>
<td>2</td>
</tr>
<tr>
<td>2.1 HABITAT</td>
<td>2</td>
</tr>
<tr>
<td>2.2 SURVEY SEASON</td>
<td>3</td>
</tr>
<tr>
<td>2.3 TRAP</td>
<td>3</td>
</tr>
<tr>
<td>2.4 TRAP DEPLOYMENT</td>
<td>3</td>
</tr>
<tr>
<td>2.5 PROCESS CAPTURES</td>
<td>4</td>
</tr>
<tr>
<td>3 SURVEY RESULTS</td>
<td>4</td>
</tr>
<tr>
<td>3.1 TRANSECT 1</td>
<td>4</td>
</tr>
<tr>
<td>3.2 TRANSECT 2</td>
<td>5</td>
</tr>
<tr>
<td>6.0 CONCLUSION</td>
<td>5</td>
</tr>
<tr>
<td>7.0 REFERENCES</td>
<td>7</td>
</tr>
</tbody>
</table>

### Appendices

- **Appendix A**  Figures
  - Figure 1 - Aerial Photograph of Project Area
  - Figure 2 - Transect Location and Coverage Area
- **Appendix B**  Site Photographs
- **Appendix C**  Datasheets
  - TR05 Soil Moisture
Southern Oklahoma Regional Disposal Landfill
American Burying Beetle Survey

Presented to:
Southern Oklahoma Regional Disposal, Inc.

P.O. Box 1088
Ardmore, Oklahoma 73402

Presented by:

SCS ENGINEERS
11120 E. 26th St. North
Wichita, KS 67226
(316) 315-4505

Date
August 22, 2017

File No. 27216227.00
Southern Oklahoma Regional Disposal
Landfill
American Burying Beetle Survey

Presented to:
Southern Oklahoma Regional Disposal, Inc.

P.O. Box 1088
Ardmore, Oklahoma 73402

Presented by:

SCS ENGINEERS
11120 E. 26th St. North
Wichita, KS 67226
(316) 315-4505

Date
September 11, 2017
File No. 27216227.00

Offices Nationwide
www.scsengineers.com
Permanent impacts are those that eliminate ABB habitat (e.g., buildings, roads, quarries, strip mines), as well as any impact to habitat that takes more than 5 years to re-establish as suitable for ABB use.

Please see the *American Burying Beetle Conservation Strategy for the Establishment, Management, and Operations of Mitigation Lands* document for additional information about implementing appropriate mitigation ratios. This is available on our webpage at [http://www.fws.gov/southwest/es/oklahoma/ConsBank.htm](http://www.fws.gov/southwest/es/oklahoma/ConsBank.htm).

**Literature Cited**


The ABB CPAs have a higher proportion of positive ABB surveys; consequently these areas will contribute more towards ABB conservation and recovery than areas within the ABB's range but outside the CPAs. Factors such as availability of habitat, food resources, and environmental variables likely contribute to higher density of ABB present within the CPAs. Therefore, impacts that could cause take and that occur within the CPAs have a greater effect on ABB and thus have a higher mitigation ratio than impacts in areas outside of CPAs.

Conservation easements are required for mitigation lands to protect the land from various potential impacts. However, it may not be possible to avoid all impacts, such as sub-surface mineral exploration. In cases where impacts to mitigation lands cannot be avoided, the Service expects a higher mitigation ratio. For temporary impacts the ratio is 1:1.5 and for permanent impacts 1:3. Mitigation lands are usually within ABB CPAs, have additional conservation value for the ABB through permanent protection by a conservation easement, and have a management plan specifically for the ABB.

Temporary impacts are those that impact ABB habitat for 5 years or less (areas impacted by the project are restored to a condition suitable for ABB use within 5 years of the original impact). Based on the climate and vegetation types of eastern Oklahoma, the Service expects that most grass and shrub-dominated cover types can be re-established to their pre-impact condition within 5 years. When considering precipitation, vegetation regrowth time, etc. in ABB range in Oklahoma, 5 years after the impacts occur is a reasonable timeframe for habitat to be restored to a condition suitable for ABB use.

Permanent cover change impacts are defined as impacts that change the successional stage of an area to a different stage (e.g., forest or shrubland to grassland; grassland to forest), resulting in habitat that is possibly less preferable for ABB use. Similar to temporary impacts, these areas will be restored to a condition suitable for ABB use within 5 years. However, if these areas will be permanently maintained at a different successional stage (through vegetation control, tree planting, or suppression of natural vegetation), the Service considers the vegetation cover of the area to have been permanently changed. Anthropogenic changes in cover type create intense, sudden contrast between patches (e.g., a grassland ROW fragmenting a contiguous stand of forest habitat or a forest stand fragmenting a contiguous grassland), compared to the natural patchy landscapes in Oklahoma, which have less contrast between adjacent patches. Evidence suggests that permanent change in cover, even if the types are native to the area, can increase threats to ABBs (Trumbo and Bloch 2000) by increasing invasive plant and animal species (Marvier et al. 2004), reducing the carrion prey base of the appropriate size for ABB reproduction (Oxley et al. 1974), or increasing the vertebrate scavenger competition for carrion (Kozol 1995, Ratcliffe 1996, Amaral et al. 1997, Bedick et al. 1999) necessary for ABB reproduction.
APPENDIX B:

Mitigation Recommendations for the American burying beetle (ABB) in Oklahoma

_Oklahoma Ecological Services Office_

The Service recommends that each project proponent conserve an amount of land proportional to the impacts to ABB habitat resulting from the project. The Service’s proportions, or ratios, are based on proximity of the impacts to areas of importance to ABB conservation (location) and duration of habitat impacts (Table 1).

<table>
<thead>
<tr>
<th>Impact Duration</th>
<th>Location of impact</th>
<th>Mitigation Land</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ABB Range (but not within CPA)</td>
<td>Conservation Priority Area (CPA)</td>
</tr>
<tr>
<td>Temporary</td>
<td>1:0.25</td>
<td>1:0.5</td>
</tr>
<tr>
<td>Permanent Cover Change</td>
<td>1:0.5</td>
<td>1:1</td>
</tr>
<tr>
<td>Permanent</td>
<td>1:1</td>
<td>1:2</td>
</tr>
</tbody>
</table>

*Mitigation Land ratio = CPA ratio plus replacement of lost mitigation value.

Areas where impacts may result in a greater magnitude of take, and thus a larger effect on ABB, have higher mitigation ratios. For example, for permanent impacts occurring within the ABB range but outside of a CPA, for each acre of impact, 1 acre of mitigation is required (1:1 ratio). For permanent impacts occurring within an ABB CPA, for each acre of impact, 2 acres of mitigation is required (1:2 ratio). For impacts occurring within an established mitigation area, 3 acres of mitigation is expected for each acre of impact (1:3 ratio); this is the same as the ratio for impacts in a CPA, plus replacement for the acre of mitigation from prior projects that would be impacted by the action. Mitigation ratios start at 1:0.25 for temporary impacts and increase as duration of impacts increase. Greater duration of impacts likely results in greater adverse impacts to the ABB.
7. Install appropriate erosion controls, including such items as straw bales, biologs, silt fence, and similar materials.

8. Implement Pollution Prevention Requirements as required in section 3.3.3 of the Oklahoma Department of Environmental Quality General Permit OKR10 for Storm Water Discharges. Additionally, fuel all equipment outside of ABB habitat (that is, outside of undisturbed native vegetation) and store all fuel and motor vehicle oil outside of ABB habitat.
APPENDIX A:

Best Management Practices for American burying beetle (ABB) in Oklahoma

_Oklahoma Ecological Services Office_  
October 29, 2013

1. To decrease habitat loss, minimize clearing of temporary work areas and use small equipment or hand cutting techniques that leave the root zone intact. In general, using hand cutting techniques is likely to result in a smaller area of impact and reduce soil compaction relative to heavy equipment.

2. Minimize construction requiring artificial lighting. In situations where night construction work is necessary, shield direct light to the work area and prevent light from projecting upwards, thus minimizing the potential to attract insects, including ABBs.

3. In areas where ABBs are present (determined by valid surveys) or where ABB presence is assumed (when no ABB surveys were completed), return surface soils to approximate pre-construction conditions.

4. Restore areas in native range using approved native seed mixes developed for the applicable ecozone.

5. Prior to the topsoil replacement, rip (i.e., mechanically turn soil with a plow or rippling device) the impacted area. Rip and disk at a time when the soil is dry enough for normal tillage operations to occur on undisturbed farmlands adjacent to the areas to be ripped. This soil de-compaction treatment should be beneficial to the ABB by reducing the extent of soil compaction.

6. Educate all workers operating in the project areas about ABB habitat, biology, reasons for ABB decline, and the responsibility of all workers to protect the ABB. Require all workers to report any ABB sightings to the project manager or environmental inspector, remove all food wastes from the ROW each day, and prohibit dogs or cats on the ROW. Provide each worker a full color Endangered Species Card with a picture of the ABB and all information summarized on the card before they are allowed to conduct soil disturbing activities. Post signs at all access points to the project area highlighting the areas as ABB habitat and reminding workers to follow special restrictions in the area.


LITERATURE CITED


For projects that cannot avoid take of the ABB, the Service recommends mitigating the effects of the take through conservation (protection, preservation, and management) of occupied ABB habitat in perpetuity (referred to as “mitigation lands”) to assist in recovery efforts for the ABB (Appendix B). The Service strongly encourages habitat offsets to Federal agencies conducting formal Section 7 consultations, and the Service requires them of private entities developing HCPs (pursuant to section 10(a)(1)(B) of the ESA). Additionally see the American Burying Beetle Conservation Strategy for the Establishment, Management, and Operations of Mitigation Lands document on our webpage at http://www.fws.gov/southwest/es/oklahoma/ConsBank.htm.
9. a. Project actions do not include soil disturbance, use of vehicles or heavy equipment, artificial lighting, vegetation removal, use of herbicides, pesticides, other hazardous chemicals, **OR** any activity that may cause take of ABBs. **Activity causes “No take” of ABB, Incidental Take Permit for the ABB is not needed.**

9. b. Project actions include soil disturbance, use of vehicles or heavy equipment, artificial lighting, vegetation removal, use of herbicides, pesticides, other hazardous chemicals, **OR** any action that could cause take of ABBs. **The Service recommends obtaining an ESA Section 10(a)(1)(B) permit through the development of a Habitat Conservation Plan (either individually or as part of an applicable General Conservation Plan). Incorporate the Service’s BMPs for the ABB (Appendix A) as minimization measures in the HCP. Contact the Service for more information on how to prepare a Habitat Conservation Plan or permit application.**

Surveys results should only be used in the decision-making process if they are current and valid (as defined in the latest **ABB Oklahoma Presence/Absence Live-trapping Survey Guidance – http://www.fws.gov/southwest/es/Oklahoma/**). Project proponents should re-evaluate impacts if survey results have expired prior to project implementation. For example, a project proponent expects to start construction in September. Therefore, ABB presence/absence surveys are conducted in August. Due to unexpected delays, the project does not end up starting construction until the following June. In this situation, the surveys conducted in August are no longer valid or current. Therefore, additional surveys should be conducted, or if ABB presence is likely, occupancy could be assumed in order to avoid further project delays. See the latest **ABB Oklahoma Presence/Absence Live-trapping Survey Guidance** for more information; this document can be found on the OKESFO webpage **http://www.fws.gov/southwest/es/oklahoma/ABB_Add_Info.htm.**

Additionally, see Appendix A for the Service’s BMPs for American burying beetle in Oklahoma. These BMPs should be incorporated as conservation measures in Federal project Biological Assessments and as minimization measures in non-Federal project HCPs. The list of BMPs is not exhaustive and is subject to change at any time. To ensure you have the most recent version, visit our webpage at **http://www.fws.gov/southwest/es/oklahoma/ABB_Add_Info.htm.**
6. a. Entire Action Area (all areas to be affected directly or indirectly by the action and not merely the immediate area involved in the action [50 CFR §402.02]) occurs outside of ABB range (as defined by the Service). Activity causes “No Take” of ABB, Incidental Take Permit not needed.

6. b. All or portions of the Action Area occur within ABB range. Cont. to Step 7

7. a. Entire Action Area considered unfavorable for use by ABBs (see list in “Areas unfavorable for the ABB” section above). Activity causes “No Take” of ABB, Incidental Take Permit not needed.

7. b. All or portions of the action area may be favorable for use by the ABB (ABB habitat; areas not excluded by list of “Areas unfavorable for the ABB”). Cont. to Step 8

8. a. Valid and current ABB presence/absence survey conducted for the portion(s) of the action area with ABB habitat did not find any ABBs (according to the latest ABB Oklahoma Presence/Absence Survey Guidance – http://www.fws.gov/southwest/es/Oklahoma/) AND the entire action area is farther than 0.8 km (0.5 miles) from any valid positive survey (the effective radius of an ABB survey, as described in ABB Oklahoma Presence/Absence Survey Guidance) Activity causes “No Take” of ABBs, Incidental Take Permit not needed.

8. b. Presence/absence surveys conducted for the action area find ABBs (according to the latest ABB Oklahoma Presence/Absence Survey Guidance), OR no presence/absence surveys are conducted, OR any portion of the Action Area is within 0.8 km (0.5 miles) of a valid positive ABB survey (the effective radius of an ABB survey, as described in ABB Oklahoma Presence/Absence Survey Guidance). Cont. to Step 9
4. a. Valid and current ABB presence/absence survey conducted for portion(s) of action area with ABB habitat did not find any ABBs (according to the latest ABB Oklahoma Presence/Absence Survey Guidance – http://www.fws.gov/southwest/es/Oklahoma/). AND the entire action area is farther than 0.8 km (0.5 miles) from any valid positive survey (the effective radius of an ABB survey, as described in ABB Oklahoma Presence/Absence Survey Guidance). Activity “May Affect, Not Likely to Adversely Affect” the ABB. Federal agency requests concurrence from the Service through informal Section 7 consultation.

4. b. Presence/absence surveys conducted for the action area find ABBs (according to the latest ABB Oklahoma Presence/Absence Survey Guidance), OR no presence/absence surveys are conducted, OR any portion of the Action Area is within 0.8 km (0.5 miles) of a valid positive ABB survey (the effective radius of an ABB survey, as described in ABB Oklahoma Presence/Absence Survey Guidance). Cont. to Step 5

5. a. Project actions do not include soil disturbance, use of vehicles or heavy equipment, artificial lighting, vegetation removal, use of herbicides, pesticides, other hazardous chemicals, OR any activity that may impact soil or vegetation or otherwise harm ABBs. Activity will have “No Effect” on the ABB. No concurrence from the Service required. Document your decision in your project files.

5. b. Project actions include soil disturbance, use of vehicles or heavy equipment, artificial lighting, vegetation removal, use of herbicides, pesticides, other hazardous chemicals, OR any activity that may impact soil or vegetation or otherwise harm ABBs. Activity “May Affect, Likely to Adversely Affect” ABBs. Submit a Biological Assessment (BA) to the Service and initiate formal consultation through Section 7(a)(2) of the ESA. Incorporate the Service’s best management practices (BMPs) for the ABB (Appendix A) into the proposed project description as conservation measures in the BA. Additionally, the Service encourages Federal agencies to improve the status of the species and reduce the relative impacts of their actions by including conservation measures as part of their project, through acquisition of mitigation lands (described below in Appendix B).
The Service anticipates re-analyzing and updating the CPAs in Oklahoma every three years using the most recent 10 years of ABB occurrence data. The Service will also use the best available scientific information to determine whether a new method for identifying CPAs should be used in the future.

**IMPACTS ANALYSIS**

The Service's recommended *step-wise process* for determining the potential for take of the ABB resulting from a proposed activity is described below. The Service provides a step-wise process to assist project proponents in evaluating their action's risk of taking ABBs. However, the responsibility for this determination is ultimately that of each Federal agency or project proponent, as applicable. These recommendations are based on the best available information and are subject to change at any time.

1. a. Project has a Federal nexus (Federal agency is undertaking, funding, permitting, or authorizing actions) .................................................................Cont. to Step 2

1. b. Project does not have a Federal nexus (no Federal agency is undertaking, funding, permitting, or authorizing actions) .................................................................Cont. to Step 6

2. a. Entire Action Area (all areas to be affected directly or indirectly by the action and not merely the immediate area involved in the action [50 CFR §402.02]) occurs outside of ABB range (as defined by the Service) ............... *Activity will have "No Effect" on the ABB. No concurrence from the Service required. Document your decision in your project files.*

2. b. All or portions of the Action Area occur within ABB range .............. Cont. to Step 3

3. a. Entire Action Area considered unfavorable for use by ABBs (see list in “Areas unfavorable for the ABB” section above) ...................... *Activity "May Affect, Not Likely to Adversely Affect" the ABB. Federal agency requests concurrence from the Service through informal Section 7 consultation.*

3. b. All or portions of the action area may be favorable for use by the ABB (ABB habitat; areas not excluded by list of “Areas unfavorable for the ABB”) .................................................................................................. Cont. to Step 4
McClain, McCurtain, McIntosh, Murray, Muskogee, Nowata, Okfuskee, Okmulgee, Osage, Ottawa, Pawnee, Payne, Pittsburg, Pontotoc, Pottawatomie, Pushmataha, Rogers, Seminole, Sequoyah, Tulsa, Wagoner, and Washington. If a project is located within the ABB range, the Service recommends that the project proponent consider impacts to ABB. In several counties on the western edge, only the eastern portion of that county is included in the ABB range (see Figure 2). Within the ABB range, the Service recommends ABB presence/absence surveys for any proposed projects with potential impacts to suitable habitat.

**ABB Conservation Priority Areas in Oklahoma**

The Service has identified areas where conservation of the ABB should be targeted in Oklahoma (Figure 3.) The ABB Conservation Priority Areas (CPA) will serve as areas where conservation efforts should be focused and where higher ratios of mitigation for impacts to ABBs should occur. CPAs include areas with recent (within 10 years) documented ABB presence that the Service believes are likely to contain important elements for ABB conservation, such as documented presence over multiple years, relatively high density populations, suitable breeding, feeding, and sheltering habitat, and carrion resources.

![American Burying Beetle Conservation Priority Areas for Oklahoma](image)

*Figure 3. American burying beetle Conservation Priority Areas in Oklahoma.*
surveys conducted by Service-permitted biologists. The ABB range in Oklahoma includes all areas within 30 km (18.6 miles) (maximum ABB movement recorded by Jurzenki et al. 2011) of all documented ABB occurrences. The Service also considers portions of counties on the eastern edge of Oklahoma that are not within 30 km of a documented ABB occurrence as potential ABB range, due to the potential for ABB habitat in these areas and previously documented ABB locations in adjacent states. These areas are identified at the Information, Planning, and Conservation System (IPaC) website at http://ecos.fws.gov/ipac/.

The ABB range will be updated as new occurrence data are gathered using the above delineation methods unless the best available science identifies a better technique for identifying ABB range. Updated ABB range information will be available through our website http://www.fws.gov/southwest/es/Oklahoma/ABB_Add_Info.htm and the IPaC website (http://ecos.fws.gov/ipac/).

![American Burying Beetle Range in Oklahoma](image.png)

Figure 2. Range of ABB within Oklahoma. Portions of several counties on the Eastern edge of the ABB range in Oklahoma are not within 30 km of a recent survey (identified within IPaC, http://ecos.fws.gov/ipac/). However, these areas may contain ABB habitat.

Part or all of the following counties are currently included in the ABB range in Oklahoma (Figure 2): Adair, Atoka, Bryan, Carter, Cherokee, Choctaw, Coal, Craig, Creek, Delaware, Garvin, Haskell, Hughes, Johnston, Kay, Latimer, Le Flore, Lincoln, Love, Marshall, Mayes,
forest, scrub forest, forest edge, grassland prairie, riparian areas, mountain slopes, and maritime scrub communities (Ratcliffe 1996; USFWS 1991).

The ABB readily moves between different habitats (Creighton and Schnell 1998, Lomolino et al. 1995) and are considered to be habitat generalists. However, they are believed to have more selective breeding habitat (suitable soils and vegetation layer) compared to their feeding habitat (Anderson 1982).

Areas Unfavorable for the ABB

While the ABB uses a wide variety of habitats, the Service currently believes that areas exhibiting the following characteristics are unfavorable for use by ABBs based on disturbance regime, vegetation structure, unsuitable soil conditions and carrion availability:

1. Land that is tilled on a regular basis, planted in monoculture, and does not contain native vegetation.
2. Pasture or grassland that have been maintained through frequent mowing, grazing, or herbicide application at a height of 20 cm (8 inches) or less.
3. Land that has already been developed and no longer exhibits surficial topsoil, leaf litter, or vegetation.
4. Urban areas with maintained lawns, paved surfaces, or roadways.
5. Stockpiled soil without vegetation.
6. Wetlands with standing water or saturated soils (defined as sites exhibiting hydric-soils, and vegetation typical of saturated soils, and/or wetland hydrology).

**NOTE: Areas adjacent to wetlands and/or riparian areas may be used by the ABB (and are therefore not considered unfavorable for the ABB). These areas may be important for ABBs seeking moist soils during dry conditions.**

Additional information regarding ABB biology and habitat can be found on the Oklahoma Ecological Field Service’s website at:
http://www.fws.gov/southwest/es/Oklahoma/Documents/TE_Species/Species%20Profiles/American%20Burying%20Beetle.pdf and

**ABB RANGE IN OKLAHOMA**

The Service has delineated the range of the ABB in Oklahoma based on locations of known ABB occurrences. The primary source for documented ABB occurrences is ABB presence/absence
rearing and overwintering (personal communication with Bob Mertz, St. Louis Zoo, May 30, 2013).

**Life History**

The ABB is a nocturnal species. Individuals usually live for only one year. Adults and larvae are dependent on carrion (flesh of dead animals) for food and reproduction. The ABB competes with other invertebrate species, as well as vertebrate species, for carrion. They are active in the summer months (active season) and bury themselves in the soil during the winter months (inactive season). The length of the inactive season can fluctuate depending on temperature. (Once nighttime temperatures are below 60 degrees Fahrenheit (°F), the ABB retreat underground and become inactive until the temperatures are above 60 °F.) In Oklahoma the inactive season is typically from October to April or May. The ABB begins reproduction soon after emergence from the inactive season, finding and securing a mate and carcass for reproduction. Adults bury a small vertebrate carcass (35-250 grams; 1-9 ounces) and lay eggs beside it. Resulting ABB larvae use the carcass as a food source until they emerge. The entire reproductive process takes approximately 48-65 days (Kozol et al. 1988). Following metamorphosis from larva to adult, tenerals (adult ABBs newly emerged from the pupal case) typically emerge from underground in late summer; although timing can vary based on latitude and weather conditions and some presence/absence surveys in Oklahoma have documented tenerals in early summer (USFWS species files). Typically, tenerals over-winter as adults and comprise the breeding population the following spring and summer (Kozol 1990).

**Movement**

ABBs fly and have been reported moving nightly distances ranging from 0.16 to 30 kilometers (km) (0.10 to 18.6 miles) in various parts of their range (Bedick et al. 1999, Creighton and Schnell 1998, Jurzenksi et al. 2011, Schnell et al 1997-2006). In Oklahoma, ABBs have been recorded to move approximately 10 km (6.2 miles) in 6 nights (Creighton and Schnell 1998). In Nebraska, one ABB was reported to move, wind-aided, approximately 30 km (18.6 miles) in one night (Jurzenksi et al. 2011).

**Habitat**

ABBs have been successfully live-trapped in several vegetation types including native grassland, grazed pasture, riparian zone, coniferous forest, mature forest, and oak-hickory forest, as well as on a variety of soil types (Creighton et al. 1993; Lomolino and Creighton 1996; Lomolino et al. 1995; USFWS 1991). Ecosystems supporting ABB populations are diverse and include primary
segment of the body that lies between the head and the abdomen), a feature shared with no other members of the genus in North America (USFWS 1991). Gender can be determined from markings on the elytra (a shield-like plate on the front of the head of an insect); males have a large, rectangular, red marking and females have a smaller, triangular, red marking.

![Female and Male American burying beetles. The female (left) has a smaller, triangular, red marking, while the male (right) has a larger, rectangular marking. Photo credit: Saint Louis Zoo, St. Louis, Missouri.](image)

**Figure 1.** Female and Male American burying beetles. The female (left) has a smaller, triangular, red marking, while the male (right) has a larger, rectangular marking. Photo credit: Saint Louis Zoo, St. Louis, Missouri.

**Geographic Distribution**

The ABB once occurred throughout much of temperate eastern North America, including 35 U.S. states (USFWS 1991). Its absence throughout much of its former range became apparent in the 1980s, and by 1989 the ABB was thought to occur only on Block Island, Rhode Island, and at one location in Oklahoma (Davis 1980; Kozol et al. 1988; USFWS 1991). Currently, the ABB can be found in less than 10% of its historic range, with localized, extant populations discovered in six states (Backlund and Marrone 1997, Bedick et al. 1993, Godwin 2003, Lomolino et al. 1995, Miller and McDonald 1997, Ratcliffe 1996, Sikes and Raithel 2002, USFWS 2008). These locations include Block Island off the coast of Rhode Island, eastern Oklahoma, western Arkansas, the Sand Hills and Loess Hills regions in Nebraska, the Chautauqua Hills region of southeastern Kansas, south-central South Dakota, and northeastern Texas. Additionally, a reintroduced population on Nantucket Island off the coast of Massachusetts is thought to be stable and a recent reintroduction attempt in Missouri in 2012 has reported successful brood
Section 7(a)(1) of the ESA directs Federal agencies, in consultation with the Service, to use their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of endangered and threatened species. Additionally, Section 7(a)(2) of the ESA requires Federal agencies to ensure that any action they authorize, fund, or carry out (Federal nexus) is not likely to jeopardize the continued existence of any federally listed threatened or endangered species or result in the destruction or adverse modification of designated critical habitat. Jeopardy is defined as an appreciable reduction in the likelihood of survival and recovery in the wild. This includes actions that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR §402.02). In the event that a Federal agency determines that their authorized, funded, or carried out action “may affect” a listed threatened or endangered species or designated critical habitat, the agency is required to consult with the Service regarding the degree of impact and measures available to avoid or minimize the adverse effects.

Section 10 provides a mechanism for take authorization for private entities where no Federal nexus exists. This provision authorizes the Service, under some circumstances, to permit the taking of federally listed fish and wildlife if such taking is “incidental to, and not the purpose of carrying out otherwise lawful activities.” This process is also intended to be used to reduce conflicts between listed species and private development and to provide a framework that would encourage “creative partnerships” between the private sector and local, state, and Federal agencies in the interest of endangered and threatened species and habitat conservation. Applications for such permits include habitat conservation plans (HCP). When an HCP meets issuance criteria (50 CFR §§ 17.22(b) and 17.32(b)) and is approved by the Service, an incidental take permit is issued for the anticipated incidental take. The HCP must include appropriate conservation measures that, to the maximum extent practicable, minimize and mitigate the effects of the authorized take of the species.

**SPECIES DESCRIPTION**

**Physical Characteristics**

The ABB is the largest species of its genus (*Nicrophorus*) in North America, measuring 25-46 mm (1 – 1.8 inches) long (Wilson 1971, Anderson 1982). Species in the genus *Nicrophorus* are generally referred to as burying or undertaker beetles due to their unique behavior of burying carrion to provide a source of nutrition for developing young.

ABBs are black with orange-red markings (Figure 1). The most diagnostic feature of the ABB is the large orange-red marking on the raised portion of the pronotum (the upper surface of the first
ABB Impacts Assessment for Project Review – March 24, 2015

INTRODUCTION

The American burying beetle (*Nicrophorus americanus* Olivier, ABB) was federally listed as endangered in 1989 (54 FR 29652) by the U.S. Fish and Wildlife Service (Service) in accordance with the Endangered Species Act of 1973, as amended; 16 U.S.C. 1531 *et seq.*, (ESA). The ABB Recovery Plan was finalized in 1991 and a 5-year Review was completed in 2008 that recommended the ABB’s status remain as endangered. Due to its Federal listing as endangered, activities that may affect ABB, whether adverse or completely beneficial, are regulated to ensure conservation and persistence of the species.

The Service recommends that project proponents use this document to determine whether their project may affect the ABB for section 7 consultation for Federal projects or may result in take of the ABB for non-Federal projects. This document describes how to assess the potential impacts of your project. Additional information regarding the recommended level of offsets or mitigation based on project location and type of impacts can be found in the ABB Conservation Strategy and Mitigation Guidance document, found on our webpage: http://www.fws.gov/southwest/es/oklahoma/ABB_Add_Info.htm. The Service anticipates that with the accumulation of more detailed information, management strategies and priorities may change.

One of the goals of the ESA is to conserve ecosystems upon which listed threatened and endangered species of fish, wildlife, and plants depend. Section 9 of the ESA makes it illegal for any person subject to the jurisdiction of the United States to “take” any federally listed endangered or threatened species of fish or wildlife without a special exemption. “Person” is defined under the ESA to include individuals, corporations, partnerships, trusts, associations, or any other private entity; local, state, and Federal agencies; or any other entity subject to the jurisdiction of the United States. Under the ESA, “take” means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or to attempt to engage in any such conduct. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns such as breeding, feeding, or sheltering (50 CFR § 17.3). Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering(50 CFR § 17.3). Consequently, it is a violation of Federal law to take endangered species without appropriate permits. Take of federally-listed species incidental to an otherwise lawful activity may be authorized through section 7 or 10 of the ESA.
American Burying Beetle Impact Assessment for Project Reviews

U.S. Fish and Wildlife Service
Southwest Region

Oklahoma Ecological Services Field Office

March 24, 2015
Thank you,

Kris

Kris Wright Mutz

SCS AQUATERRA

1817 Commons Circle, Suite 1

Yukon, OK 73099

405.265.3960 office

405.708.1029 cell

www.scsengineers.com

--

Daniel Fenner
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
Oklahoma Ecological Services Field Office
9014 East 21st Street
Tulsa, Oklahoma 74129
(918) 382-4524 (voice)
(918) 581-7467 (fax)

This Email is covered by the Electronic Communications Privacy Act and may be legally privileged. The information contained in this Email is intended for the use of the individual or entity named above. If the reader of this message is not the intended recipient, you are hereby notified that any dissemination, distribution or copying of this communication is strictly prohibited. If you have received this communication in error, please immediately notify the sender and destroy the original message.
Hi Kris,

Thank you for your June 18, 2015 project review request for the SORD Landfill Expansion Project in Carter, County, OK. Unfortunately information provided in your request is not adequate for our review. More specifically, you identify American burying beetle habitat in the species conclusion table, but then suggest that habitat is not suitable for the ABB. We request that you provide additional justification regarding your ABB habitat assessment, for our review. Please utilize guidance we have developed to determine potential impacts to the ABB, in particular page 5 of the document which discusses unsuitable habitat for the ABB. If the habitat within your project area meets these conditions, then please details as to how you came to that conclusion. A link to the guidance is provided below:

American Burying Beetle Impact Assessment for Project Reviews (March 2015) - PDF

Sincerely,

Daniel Fenner

---------- Forwarded message ----------
From: FW2 Ok Project Review <okprojectreview@fws.gov>
Date: Wed, Aug 5, 2015 at 9:23 AM
Subject: FW: Project Review Request for Consultation 02EKOK00-2015-SLI-1168, Southern Oklahoma Regional Disposal (SORD) Landfill Expansion, Carter County
To: daniel_fenner@fws.gov

From: Mutz, Kris [mailto:KMutz@scsengineers.com]
Sent: Thursday, June 18, 2015 10:54 AM
To: OKProjectReview@fws.gov
Subject: Project Review Request for Consultation 02EKOK00-2015-SLI-1168, Southern Oklahoma Regional Disposal (SORD) Landfill Expansion, Carter County

Attached please find a project review package for the subject project. If you need additional information, please do not hesitate to contact me.
this inventory, to define the limits of proprietary jurisdiction of any Federal, state, or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate federal, state, or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities.

The following NWI Wetland types intersect your project area in one or more locations. To understand the NWI Classification Code, see http://wetlandsfws.usgs.gov/Data/interpreters/wetlands.aspx.

<table>
<thead>
<tr>
<th>Wetland Types</th>
<th>NWI Classification Code</th>
<th>Total Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater Pond</td>
<td>PUBFh</td>
<td>0.502517</td>
</tr>
</tbody>
</table>
Appendix C: NWI Wetlands

The U.S. Fish and Wildlife Service is the principal Federal agency that provides information on the extent and status of wetlands in the U.S., via the National Wetlands Inventory Program (NWI). In addition to impacts to wetlands within your immediate project area, wetlands outside of your project area may need to be considered in any evaluation of project impacts, due to the hydrologic nature of wetlands (for example, project activities may affect local hydrology within, and outside of, your immediate project area). It may be helpful to refer to the USFWS National Wetland Inventory website. The designated FWS office can also assist you. Impacts to wetlands and other aquatic habitats from your project may be subject to regulation under Section 404 of the Clean Water Act, or other State/Federal Statutes. Project Proponents should discuss the relationship of these requirements to their project with the Regulatory Program of the appropriate U.S. Army Corps of Engineers District.

The Service's objective of mapping wetlands and deepwater habitats is to produce reconnaissance level information on the location, type and size of these resources. The maps are prepared from the analysis of high altitude imagery. Wetlands are identified based on vegetation, visible hydrology and geography. A margin of error is inherent in the use of imagery; thus, detailed on-the-ground inspection of any particular site may result in revision of the wetland boundaries or classification established through image analysis.

The accuracy of image interpretation depends on the quality of the imagery, the experience of the image analysts, the amount and quality of the collateral data and the amount of ground truth verification work conducted. Metadata should be consulted to determine the date of the source imagery used and any mapping problems.

Wetlands or other mapped features may have changed since the date of the imagery and/or field work. There may be occasional differences in polygon boundaries or classifications between the information depicted on the map and the actual conditions on site.

Exclusions - Certain wetland habitats are excluded from the National mapping program because of the limitations of aerial imagery as the primary data source used to detect wetlands. These habitats include seagrasses or submerged aquatic vegetation that are found in the intertidal and subtidal zones of estuaries and nearshore coastal waters. Some deepwater reef communities (coral or tubercid worm reefs) have also been excluded from the inventory. These habitats, because of their depth, go undetected by aerial imagery.

Precautions - Federal, state, and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of

http://ecos.fws.gov/ipac, 06/17/2015 02:11 PM - Appendix C
<table>
<thead>
<tr>
<th>Bird Species</th>
<th>Status</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Painted Bunting (<em>Passerina ciris</em>)</td>
<td>Yes</td>
<td>Breeding</td>
</tr>
<tr>
<td>Prothonotary Warbler (<em>Protonotaria citrea</em>)</td>
<td>Yes</td>
<td>Breeding</td>
</tr>
<tr>
<td>Fox Sparrow (<em>Passerella iliaca</em>)</td>
<td>Yes</td>
<td>Wintering</td>
</tr>
<tr>
<td>Sprague's Pipit (<em>Anthus spragueii</em>)</td>
<td>Yes</td>
<td>Wintering</td>
</tr>
<tr>
<td>Red-headed Woodpecker (<em>Melanerpes erythrocephalus</em>)</td>
<td>Yes</td>
<td>Year-round</td>
</tr>
<tr>
<td>Short-eared Owl (<em>Asio flammeus</em>)</td>
<td>Yes</td>
<td>Wintering</td>
</tr>
<tr>
<td>Bird Species</td>
<td>Status</td>
<td></td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>Least Bittern (<em>Ixobrychus exilis</em>)</td>
<td>Breeding</td>
<td></td>
</tr>
<tr>
<td>Mississippi Kite (<em>Ictinia mississippiensis</em>)</td>
<td>Breeding</td>
<td></td>
</tr>
<tr>
<td>Rusty Blackbird (<em>Euphagus carolinus</em>)</td>
<td>Wintering</td>
<td></td>
</tr>
<tr>
<td>Harris's Sparrow (<em>Zonotrichia querula</em>)</td>
<td>Wintering</td>
<td></td>
</tr>
<tr>
<td>Scissor-tailed Flycatcher (<em>Tyrannus forficatus</em>)</td>
<td>Breeding</td>
<td></td>
</tr>
<tr>
<td>Lark Bunting (<em>Calamospiza melanocorys</em>)</td>
<td>Wintering</td>
<td></td>
</tr>
<tr>
<td>Bald eagle (<em>Haliaeetus leucocephalus</em>)</td>
<td>Wintering</td>
<td></td>
</tr>
<tr>
<td>Golden eagle (<em>Aquila chrysaetos</em>)</td>
<td>Wintering</td>
<td></td>
</tr>
<tr>
<td>Le Conte's Sparrow (<em>Ammordamus lecontei</em>)</td>
<td>Wintering</td>
<td></td>
</tr>
<tr>
<td>Orchard Oriole (<em>Icterus sparrius</em>)</td>
<td>Breeding</td>
<td></td>
</tr>
<tr>
<td>Little Blue Heron (<em>Egretta caerulea</em>)</td>
<td>Breeding</td>
<td></td>
</tr>
<tr>
<td>Dickcissel (<em>Spiza americana</em>)</td>
<td>Breeding</td>
<td></td>
</tr>
<tr>
<td>Hudsonian Godwit (<em>Limosa haemastica</em>)</td>
<td>Migrating</td>
<td></td>
</tr>
<tr>
<td>Loggerhead Shrike (<em>Lanius ludovicianus</em>)</td>
<td>Year-round</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B: FWS Migratory Birds

The protection of birds is regulated by the Migratory Bird Treaty Act (MBTA) and the Bald and Golden Eagle Protection Act (BGEPA). Any activity, intentional or unintentional, resulting in take of migratory birds, including eagles, is prohibited unless otherwise permitted by the U.S. Fish and Wildlife Service (50 C.F.R. Sec. 10.12 and 16 U.S.C. Sec. 668(a)). The MBTA has no otherwise lawful activities. For more information regarding these Acts see: http://www.fws.gov/migratorybirds/RegulationsandPolicies.html.

All project proponents are responsible for complying with the appropriate regulations protecting birds when planning and developing a project. To meet these conservation obligations, proponents should identify potential or existing project-related impacts to migratory birds and their habitat and develop and implement conservation measures that avoid, minimize, or compensate for these impacts. The Service’s Birds of Conservation Concern (2008) report identifies species, subspecies, and populations of all migratory nongame birds that, without additional conservation actions, are likely to become listed under the Endangered Species Act as amended (16 U.S.C 1531 et seq.).

For information about Birds of Conservation Concern, go to:

To search and view summaries of year-round bird occurrence data within your project area, go to the Avian Knowledge Network Histogram Tool links in the Bird Conservation Tools section at:

For information about conservation measures that help avoid or minimize impacts to birds, please visit:

Migratory birds of concern that may be affected by your project:
There are 22 birds on your Migratory birds of concern list.

<table>
<thead>
<tr>
<th>Species Name</th>
<th>Bird of Conservation Concern (BCC)</th>
<th>Seasonal Occurrence in Project Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bell's Vireo (Vireo bellii)</td>
<td>Yes</td>
<td>Breeding</td>
</tr>
<tr>
<td>Chestnut-collared Longspur (Calcarius ornatus)</td>
<td>Yes</td>
<td>Wintering</td>
</tr>
</tbody>
</table>

http://ecos.fws.gov/ipac 06/17/2015 02:11 PM - Appendix B
Appendix A: FWS National Wildlife Refuges

There are no refuges within your project area.
Critical habitats that lie within your project area

There are no critical habitats within your project area.
Endangered Species Act Species List

There are a total of 5 threatened or endangered species on your species list. Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species. Note that 1 of these species should be considered only under certain conditions. Critical habitats listed under the Has Critical Habitat column may or may not lie within your project area. See the Critical habitats within your project area section further below for critical habitat that lies within your project. Please contact the designated FWS office if you have questions.

<table>
<thead>
<tr>
<th>Birds</th>
<th>Status</th>
<th>Has Critical Habitat</th>
<th>Condition(s)</th>
</tr>
</thead>
</table>
| Least tern (*Sterna antillarum*)  
Population: interior pop. | Endangered | | Wind Turbines and Wind FarmsTowers (i.e. radio, television, cellular, microwave, meteorological) |
| Piping Plover (*Charadrius melodus*)  
Population: except Great Lakes watershed | Threatened | Final designated | |
| Red Knot (*Calidris canutus rufa*) | Threatened | | |
| Whooping crane (*Grus americana*)  
Population: except where EXPN | Endangered | Final designated | |
| Insects | | | |
| American Burying beetle  
(*Nicrophorus americanus*)  
Population: Entire | Endangered | | |
Project Location Map:

**Project Coordinates:** MULTIPOLYGON (((-97.03833575185854 34.198058269151424, -97.03830120663042 34.20355861360944, -97.04698984685818 34.203596768412986, -97.04702214010467 34.20173469978447, -97.04248545269365 34.20168137037083, -97.0425283667282 34.198097847099234, -97.03833575185854 34.198058269151424))

**Project Counties:** Carter, OK
Official Species List

Provided by:
Oklahoma Ecological Services Field Office
9014 EAST 21ST STREET
TULSA, OK 74129
(918) 581-7458
http://www.fws.gov/southwest/es/Oklahoma/

Consultation Code: 02EKOK00-2015-SLI-1168
Event Code: 02EKOK00-2015-E-01250

Project Type: LAND - DISPOSAL / TRANSFER

Project Name: Southern Oklahoma Regional Disposal (SORD) Landfill Expansio
Project Description: The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma.

Please Note: The FWS office may have modified the Project Name and/or Project Description, so it may be different from what was submitted in your previous request. If the Consultation Code matches, the FWS considers this to be the same project. Contact the office in the 'Provided by' section of your previous Official Species list if you have any questions or concerns.
A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2) (c)). For projects other than major construction activities, the Service suggests that a biological evaluation similar to a Biological Assessment be prepared to determine whether the project may affect listed or proposed species and/or designated or proposed critical habitat. Recommended contents of a Biological Assessment are described at 50 CFR 402.12.

If a Federal agency determines, based on the Biological Assessment or biological evaluation, that listed species and/or designated critical habitat may be affected by the proposed project, the agency is required to consult with the Service pursuant to 50 CFR 402. In addition, the Service recommends that candidate species, proposed species and proposed critical habitat be addressed within the consultation. More information on the regulations and procedures for section 7 consultation, including the role of permit or license applicants, can be found in the "Endangered Species Consultation Handbook" at:

http://www.fws.gov/endangered/esa-library/pdf/TOC-GLOS.PDF

Non-federal entities conducting activities that may result in take of listed species should consider seeking coverage under section 10 of the ESA, either through development of a Habitat Conservation Plan (HCP) or, by becoming a signatory to the General Conservation Plan (GCP) currently under development for the American burying beetle. Each of these mechanisms provides the means for obtaining a permit and coverage for incidental take of listed species during otherwise lawful activities.

Please be aware that bald and golden eagles are protected under the Bald and Golden Eagle Protection Act (16 U.S.C. 668 et seq.), and projects affecting these species may require development of an eagle conservation plan (http://www.fws.gov/windenergy/eagle_guidance.html). Additionally, wind energy projects should follow the wind energy guidelines (http://www.fws.gov/windenergy/) for minimizing impacts to migratory birds and bats.

Guidance for minimizing impacts to migratory birds for projects including communications towers (e.g., cellular, digital television, radio, and emergency broadcast) can be found at:
http://www.fws.gov/migratorybirds/CurrentBirdIssues/Hazards/towers/towers.htm;
http://www.towerkill.com; and

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit through our Project Review step-wise process http://www.fws.gov/southwest/es/oklahoma/OKESFO%20Permit%20Home.htm.

Attachment
United States Department of the Interior
FISH AND WILDLIFE SERVICE
Oklahoma Ecological Services Field Office
9014 EAST 21ST STREET
TULSA, OK 74129
PHONE: (918)581-7458 FAX: (918)581-7467
URL: www.fws.gov/southwest/es/Oklahoma/

Consultation Code: 02EKOK00-2015-SLI-1168  
Event Code: 02EKOK00-2015-E-01250  
Project Name: Southern Oklahoma Regional Disposal (SORD) Landfill Expansio

Subject: List of threatened and endangered species that may occur in your proposed project location, and/or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, proposed and candidate species, as well as proposed and final designated critical habitat, that may occur within the boundary of your proposed project and/or may be affected by your proposed project. The species list fulfills the requirements of the U.S. Fish and Wildlife Service (Service) under section 7(c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.).

New information based on updated surveys, changes in the abundance and distribution of species, changed habitat conditions, or other factors could change this list. Please feel free to contact us if you need more current information or assistance regarding the potential impacts to federally proposed, listed, and candidate species and federally designated and proposed critical habitat. Please note that under 50 CFR 402.12(e) of the regulations implementing section 7 of the Act, the accuracy of this species list should be verified after 90 days. This verification can be completed formally or informally as desired. The Service recommends that verification be completed by visiting the ECOS-IPaC website at regular intervals during project planning and implementation for updates to species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the ecosystems upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 et seq.), Federal agencies are required to utilize their authorities to carry out programs for the conservation of threatened and endangered species and to determine whether projects may affect threatened and endangered species and/or designated critical habitat.
# SPECIES CONCLUSIONS TABLE

**Project Name:** Southern Oklahoma Regional Disposal (SORD) Landfill Expansion Project

**Date:** June 18, 2015

<table>
<thead>
<tr>
<th>Species / Critical Habitat</th>
<th>Habitat Determination</th>
<th>Notes / Documentation</th>
<th>ESA Determination</th>
</tr>
</thead>
</table>
This project review is needed for

Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515:5-31(c).

No federal nexus.

The enclosed project review package provides the information about the species and critical habitat considered in our review, and the species conclusions table included in the package identifies our determinations for the resources that may be affected by the project.

For additional information, please contact Kris Mutz at the address listed above.

Sincerely,

Kris Mutz
Project Professional

Enclosures:

1) ENTIRE PROJECT REVIEW PACKAGE:
   -Species Conclusion Table
   -IPaC Species List and Action Area map
   -This form (Online Project Review Request)
   -(Optional) Additional maps

2) Other relevant project data/documents

   Aerial photo with project area outlined USGS Topographic Quadrangle (Arden)
OKESFO Online Project Review Request

From: Kris Mutz, SCS Aquaterra
1817 Commons Circle, Suite 1
Yukon, OK 73099
(405) 265-3960
kmutz@scsengineers.com

To: U.S. Fish and Wildlife Service
Oklahoma Ecological Services Field Office
9014 E 21st Street
Tulsa, Oklahoma 74129

June 18, 2005

Re: Online Project Review Request

Southern Oklahoma Regional Disposal (SORD) Landfill Expansion Project
Carter County, Oklahoma

We have reviewed the referenced project using the Oklahoma Ecological Services Field Office’s online project review process and have followed all guidance and instructions in completing the review. We completed our review on June 18, 2015 and are submitting our project review package in accordance with the instructions for further review.

Our proposed action consists of:

The proposed action is the expansion of the existing municipal solid waste landfill onto an adjacent parcel. The expansion would include lined cell creation and standard monitoring and transportation features. The expansion would accept municipal solid waste and receive daily and periodic cover. Design, construction, and operational aspects of the landfill expansion will be compliant with all applicable federal, state, and local regulations.

The location of the project and the action area are identified on the enclosed map.

The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

The project is expected to be completed

Construction of the expansion would commence upon receipt of any necessary permits.
United States Department of the Interior – Fish and Wildlife Service
Mr. Wade Miller
Project Director
SCS Aquaterra
1817 Commons Circle, Suite 1
Yukon, OK 73099

Subject: Southern Oklahoma Regional Disposal Landfill, Proposed Landfill Expansion Notification, ODEQ Permit No. 3510007

Dear Mr. Miller:

Thank you for the opportunity for our office to respond to your June 19, 2015 letter. Our office reviewed the maps for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill located on Red Cedar Road, four miles east of Ardmore. Your letter also describes this location as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

The Bureau of Reclamation does not currently have any projects, facilities, or areas dedicated for public recreation/preservation within one-half mile of the proposed landfill expansion described in your letter. As a result, we have no comments at this time.

Please contact me at 405-470-4830 if you have any questions or need additional information.

Sincerely,

Matt Warren, P.E.
Supervisor, Facility Operations Group
June 19, 2015

Mr. Matt Warren
Bureau of Reclamation
Oklahoma City Field Office
5924 NW 2nd Street, Suite 200
Oklahoma City, OK 73127

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Warren:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-31(b), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: no area within the permit boundary of a new solid waste disposal facility, or expansion of the permit boundary of an existing solid waste disposal facility, shall be located within one-half mile of any area formally dedicated and managed for public recreation or natural preservation by a federal, state, or local government agency, unless the appropriate management agency provides a statement that the proposed facility is not expected to adversely affect the existing recreation or natural preservation area.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
United States Department of the Interior – Bureau of Reclamation
June 30, 2015

James Williams, District Conservationist
USDA Natural Resources Conservation Service
Ardmore Field Service Center
39 N. Washington, Suite 109
Ardmore, OK 73401-7056

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Williams:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-32(d), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: *no new waste management or disposal areas of a solid waste disposal facility shall be located in wetland areas designated by the appropriate agency.*

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
United States Department of Agriculture – Natural Resources Conservation Service
Sincerely,

Vaughn Weaver  
Staff Biologist  
**SCS ENGINEERS**

Wade Miller  
Project Director  
**SCS ENGINEERS**
February 7, 2017
File No. 27216227.00

Mr. Marcus Ware
Regulatory Project Manager
1645 South 101st East Avenue
Tulsa, OK 74128-4629

Subject: SORD Permit Review Request

Dear Mr. Ware

This letter is a request for review to determine if US Army Corp of Engineers would require a 404 permit for a proposed operational expansion of the Southern Oklahoma Regional Disposal (SORD) facility east of Ardmore OK. This letter is a supplement document to a previously requested jurisdictional determination (JD) permit review submitted on June 19, 2015. Additional information regarding the management and operation of the storm water treatment system is being provided below.

The existing storm water treatment system located in the northwest corner of the proposed expansion was engineered and constructed with a clay liner and associated engineered conveyance channel. The constructed channel is solely for the release of treated storm water effluent from a manually operated release valve located on the northeast corner of the sedimentation basin. This treatment system is operating under an Oklahoma Department of Environmental Quality (ODEQ) approved Storm Water Industrial General Permit (SWIGP) OKR05 (Authorization No. OKR050819). The permitted discharge point, identified in the permit, is located at the property line at the north end of the conveyance channel. The channel and sedimentation basin have a maintenance schedule that allows for the SORD facility to maintain and operate this storm water treatment system. Maintenance on the storm water treatment system may include the removal of collected sediment within the basin, repairs of the basin and channel’s earthen structures to maintain design capacity and clay liner and/or channel integrity. Water released from the storm water sedimentation basin must meet minimum water quality standards that are outlined within the permit.

Under the proposed expansion plan, the existing storm water treatment system will be maintained and operated to comply with ODEQ storm water requirements. Repairs and general maintenance of the approved storm water treatment system will continue to occur as needed by SORD.
justifying this JD are not supported by the features that are actually present on site. This new JD could add undue burden for the exiting normal operations of the SORD facility and restrict expansion in the future by requiring unnecessary USACE permits for regular and unscheduled work.

SORD has been in operation for 38 years and has had a consistent local, state and federal agency consultation practice that has maintained compliance with applicable regulations. The constructed landfill cells would have been reviewed for potential 404/401 permits as part of the State of Oklahoma’s landfill permitting process. The Tulsa USACE office is not aware of any active permits. SORD has provided SCS with not only their current ODEQ approved permit, but the two previous approved permits dating back to 2002. With approved state landfill operating permits, SORD has been working in good faith and within the conditions of the approved permits.

SCS wants to thank you for reviewing this additional information as it relates to the proposed SORD expansion. If there is any questions regarding the additional information, please feel free to contact Vaughn Weaver at 316-494-7518 or vweaver@scsengineers.com.

Sincerely,

Vaughn Weaver
Staff Biologist
SCS ENGINEERS

Wade Miller
Project Director
SCS ENGINEERS
Mr. Marcus Ware, Army Corp of Engineers  
October 4, 2016  
Page 6

**SWT-2015-412 Section III, B (1)(iii) – Chemical Characteristics:** This section identifies surface water. Surface flow was reported with “water color was clear and the water quality was good. The general watershed characteristics are good with a dense riparian corridor.” We dispute the accuracy of this assessment as site conditions do not match the noted interpretations. Discharge from the storm water retention pond is controlled and managed by the landfill and releases are after the clarity of the water is approved by facility staff. Both the leachate and storm water retention ponds are identified within the SWT-2015-412 JD as “within the indicated non-RPW channel area” for the proposed project area. Both of these ponds are identified in the ODEQ industrial and storm water permit and are managed for controlled discharge accordingly. Understanding that the leachate pond typically has a wide variety of contaminants and the SWRP is managed for suspended solid removal, the existing water quality is not consistent with the noted JD water quality. The JD’s stated surface water quality aerial photograph assessment is not consistent with actual site conditions.

**Significant Nexus Determination**

**SWT-2015-412 Section III, D.(3) states that the non-RPW’s has 600 linear feet 3 width (ft) and the “stream channel” was “converted into a borrow area which expanded the jurisdictional area for WOUS by approximately 3.9 acres.” As discussed previously, the described “borrow area” in this section is an approved engineered clay lined SWRP with a permitted discharge point. In a conversation with Ed Tarisopto, he indicated that this “borrow area” is considered WOUS because prior alteration of an area would not alter the nexus of the water feature. Asked if there was a USACE 404 permit for the 2012 storm water pond expansion, Ed indicated that there was none on record, but a verbal approval may have been give through a phone call because the activity would increase the WOUS. During this conversation Ed stated that a natural channel connected to the southeast corner of the “borrow area” from the south and indicated this feature was part of the natural channel. This identified “natural channel” is an access road as identified in Figure 2. The misidentified “borrow area” does not accurately identify the SWRP or considered the engineered function. A 2012 approved constructed clay lined expansion of a prior existing constructed storm water retention pond does not meet the conditions for expansion of WOUS. Under the current ODEQ permit, management and discharge of storm water from this SWRP is approved provided SORD follows the permit guidelines.

**Summary**

The SORD Landfill has been in operation since the City of Ardmore opened the facility in 1978. SORD took over operations in 1994. This facility has over 38 years of operation within the majority of the identified non-RPW watershed. Prior agency reviews do not acknowledge potential JD WOUS features within the proposed project area. No prior 404 permits have been issued and this JD identified non-RPW drainage features do not have a prior JD. SORD has been operating under ODEQ issued solid waste permits. So for more than 38 years, the landfill has been actively operating in the upper reaches of the non-RPW watershed with approved permits that have been reviewed and updated by state and federal agencies. After a discussion with Ed Tarisopto, the justification for the current JD was that because the water feature has been modified does not change the nexus that the stream channel has as waters of the U.S connection/function. SCS understand this reasoning, but the stream channel features identified to
particles before the water is released in compliance with their existing storm water permit. The JD describing intermittent flow with discrete surface flows is not consistent with historic observation, soil profile, and topography.

**SWT-2015-412 Section III, B(1)(ii)(c) Flow, Tributary features that were identified included “Bed and Banks” and “OHWM”. OHWM features that were interpreted included “clear and natural line impressed on the bank”, “shelving”, “vegetation matted down, bent, or absent”, “leaf litter disturbed or washed away” and “the presence of litter and debris”. It is not possible to define the noted features without a site visit. During the SCS site visit, no defined bed and bank was observed within the proposed project area. OHWM features were not identified for: vegetation matted down, bent or absent, leaf litter disturbed or washed away, the presence of litter and debris. Bank shelving was observed along the constructed drainage channel between the SWRP and the edge of property, but the constructed channel lacked all other OHWM identified features. A constructed and maintained shelving of an engineered storm water diversion feature does not constitute a OHWM. The “substrate” in the bottom of the channel was clay and was consistent with the clay lining within the channel “banks”. No Tributary features were observed upgradient of the SWRP. According to Ed Tarisopto from the USACE Tulsa Office, he stated that the natural channel can be seen in an aerial photograph entering a “borrow pit” from the southeast in a 2016 aerial photograph identified in Figure 2. What he identified is an access road that is maintained by the landfill so as to access and provide maintenance to the constructed SWRP and a geosynthetic and clay lined leachate pond.

Figure 2.
described stream features noted weren’t present. Additionally, no thick riparian cover is present at the SORD facility.

**SWT-2015-412 Section III, B(1)(ii)(b)** “Tributary Condition/Stability” describes the channel as a “stream segment is relatively stable - Presence of run/riffle/pool complexes.” with an explanation that “There are no riffle and pool complexes within the segment of stream channel”. Additional JD comments indicate that “the stream channel has been manipulated upstream from the landfill operation (borrow area and redirecting the flows into drainage ditch.” The reported “Tributary geometry: Meandering” with reported “Tributary gradient (approximate average slope): 2%”. The SCS site visit previously discussed was unable to verify the described “Tributary Condition/Stability” described in this JD. With an existing straight storm water diversion ditch approximately 115 feet long with vegetative bottom and slopes, the described run/riffle/pool complex is not present. The JD noted that upstream of the proposed project area was modified, this would indicate that a natural channel was receiving storm water runoff with limited modification. This assumption is not consistent with the landfills storm water permit or approved solid waste facility operating practices. Normal operation of landfills is to place “fill” (trash) in protected areas (cells) that keep water from entering into the ground or flowing into nearby surface waters. As cells fill up, water runoff from the covered and closed waste disposal area is directed to a storm water retention pond. Modifying existing channels or redirecting channel flows through active landfills do not occur and are not allowed as part of the ODEQ solid waste permit to protect surface water quality. Additionally, the existence of a natural channel upgradient, as incorrectly interpreted in the JD, is not consistent with the landfills storm water permit or operating practices. The completed SCS site visit disputes the accuracy of the aerial photograph interpretation of the tributary conditions and stability as noted within the JD.

**SWT-2015-412 Section III, B(1)(ii)(c)** Flow - it was indicated that “Tributary provides for: flow was intermittent but not seasonal flow”. This section indicates that the tributary provides intermittent flow with greater than 20 flow events annually. The surface flow is described as “Discrete” with no subsurface flows. The interpretation of this data would indicate that flow through the non-RPW channel would be present for extended periods of time after rain events.

SCS reviewed the soil types that are within the water shed to evaluate the probability of sustainable surface water flow. A review of the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soils mapper indicated that the drainage feature is within “36-Pulaski and Bunyan Soils, 0 to 1 percent slopes frequently flooded” soils. NRCS identifies this soil in hydrologic groups A and B with a low potential for runoff with high to moderate rates of infiltration when thoroughly wet. The Pulaski and Bunyan Soils are not identified as hydric soils by the 2015 NRCS Hydric Soils list. From the soil description of the drainage feature, these soils would have relatively short surface flow durations and intermittent flow not associated with storm water runoff would not be probable.

The infiltration of runoff after a rain event would probably stop within 24 hours based on the transmittal rate of this soil complex. Discussion with Terry Lewis (Landfill Manager) and Troy Duke (Site Executive Director) about current and historic flow patterns revealed that the old drainage feature would be dry within 24 hours after a rain. The current SWRP holds storm water allowing for settlement of suspended
that a “stream segment” or the noted channel features exist at this facility. The presence of an engineered storm water management system in a drainage feature does not constitute a channel feature or stream channel.

Tributary Features

The SWT-2015-412 JD Section III, B (1)(i)(a) states that the watershed size has a drainage area of 1,000 acres in a watershed of 2,301 acres. Using a topographic map, SCS determined the drainage of the JD “stream channel” watershed at approximate 200 acres. Much lower than the stated 2,301 watershed area and the 1,000 acre drained area. The USACE identified USGS topographic maps used indicate that the water shed has an elevation ranging from approximately 860 to 750 feet above sea level for the entire watershed. Storm water drainage from within this relatively small watershed with more than 110 feet in elevation change would be quick with short durations under natural conditions. These watershed characteristics are consistent with drainage ways with short but intense flow periods. The SORD Facility occupies approximately 85 percent the watershed’s southern drainage areas. These watershed characteristics are consistent with drainage features with short duration flow periods. With more than 30 years of waste placed within this watershed, natural flows no longer prevail. SCS disputes the drainage area indicated and suggests that this over estimate of watershed size could imply a greater flow period than what actually exists.

SWT-2015-412 Section III, B (1)(ii)(b) General Tributary Characteristics have described the non-RPW as having “Natural” and “Manipulated” features. The “Tributary properties with respect to top of bank” included “Average width: 3 feet”, “Average depth: 2 feet”, and “Average side slopes: 3:1” with the “Primary tributary substrate composition” consisting of “Silts” and “Sands”. These general tributary characteristics are typically determined from a site visit which was not completed for this JD. Without a site visit by the USACE, we dispute the ability to accurately identify and interpret such features with this level of specificity.

SCS completed a site visit on August 3, 2016 to assess the current non-RPW drainage features. SCS was unable to verify a “natural” stream channel that was 3 feet wide, 2 feet deep, and had a 3:1 slope within the proposed project area. A constructed, storm water diversion ditch from the north edge of the SWRP to the north property boundary was the only drainage feature observed. Substrate within the drainage ditch was clay with clay sides. No sand was present and only a thin layer of silt was observed. A release valve is located at the southern end of this channel and controls the release from the SWRP. The SORD storm water permit notes the approved discharge point is the north end of two culvert pipes that are located under the fence along the north property boundary at the north end of the ditch. SORD has constructed drainage ditches to collect storm water flowing from the permitted solid waste facility. These ditches are located between the access road and the permitted solid waste facility area capturing approximately 100% of the storm water shed from the landfill facility. This water flows along the road toward the north center of the waste disposal area where the water is allowed to sheet flow over the road and into the southeastern edge of the SWRP. No channel is present between the waste disposal area and the SWRP. During the August 3, 2016 site visit, this low area between the waste disposal area and the SWRP was observed as a maintained access road and a heavily vegetated ground cover area, but the JD
monitoring and release of facility storm water. This permit allows for the management of storm water drainage features and retention basins for the primary treatment of storm water (settlement of suspended particles) before discharge at an approved location. The storm water retention pond (SWRP) that is identified in SWT-2015-412 JD as an “expanded borrow pit” (which is in reality part of an approved engineered storm water collection system) has a permitted discharge point located at the north edge of the SORD property. The JD non-relative permanent water (non-RPW) of “600 feet 3 width (ft.)” identified “tributary” is currently part of the ODEQ approved storm water management system for the facility.

SCS also reviewed the available public data sources that the USACE had identified and were able to find similar results on watershed size, location, and generalized regional information that is consistent with what is presented in the SWT-2015-412 JD. A review of the most detailed available hydrological data base, from the U.S. Geological Survey (USGS) National Geospatial Program (NGP), identified several adjacent watersheds with intermittent streams, but didn’t indicate that the subject area or adjacent areas has a defined stream channel. Figure 1 is from the USGS NGP and shows that there are no identified stream channel segments upgradient or downgradient from the proposed project area and that the FEMA flood plain is outside the facility area. The only supporting desktop resource that identifies a potential stream channel is a topographic map. Many of the small first order streams on topographic maps do not meet the criteria for waters of the United States (WOUS) and therefore site visits typically provide the necessary field verification to more accurately determine if sufficient channel features exist. Without the USACE completing a site visit, field verification was not completed for this JD. SCS does not concur

The National Map

NOTES: Data available from U.S. Geological Survey, National Geospatial Program.
October 4, 2016
File No. 27216227.00

Mr. Marcus Ware
U.S. Army Corp of Engineers, Tulsa District
1645 South 101st East Avenue
Tulsa, Oklahoma 74158-4609
918-669-7403

Dear Mr. Ware

SCS Engineers (SCS) is submitting this letter to provide additional information on the U.S. Army Corp of Engineers (USACE) jurisdictional determination (JD) identified in No. SWT-2015-412 was made. SCS was retained by Southern Oklahoma Regional Disposal (SORD) to review this JD. Based on our review of the site conditions and the JD, there are several inconsistencies about the applicability of the information that supports portions of the JD. Inconsistencies have been identified between actual and historic site conditions; current and JD channel descriptions; and desktop interpretations versus actual site conditions. The extent of these inconsistencies is a concern for SORD’s continued operation of the landfill facility and the proposed landfill expansion. Specific examples of these inconsistencies are outlined below. This information is being submitted in addition to previously submitted information so as to provide a more complete representation of the subject area. The additional information provided in this document discusses information from the previously identified JD and compares it with information that SCS Engineers has gathered from a site visit, document review, and interviews with SORD staff.

Desktop Review

SCS reviewed the USACE JD No. SWT-2015-412 Approved Jurisdictional Determination Form. In Section I (D) “Review Performed for Site Evaluation was an office (Desk) Determination” which was completed on April 6, 2016. The SWT-2015-412 JD form did not indicate a site visit was conducted by the USACE. Information SCS provided the USACE on June 19, 2015 also did not include any site visit data. The data sources that the USACE indicated it used included “Maps, plans, plots or plates submitted by or on behalf of the applicant/consultant”, “Corp’s navigable waters’ study: Washita River”, U.S. Geological Survey Hydrological Atlas ORM2 Map – USGS 8 and 12 digit HUC maps”, “U.S. Geological Survey map(s)”, “USDA Natural Resources Conservation Service Soil Survey”, and the “National Wetlands Inventory map(s)”. According to Ed Tarisopto of the Tulsa Office, no prior JD or 404/401 permits have been reviewed or issued for the project area or for the indicated drainage channel segment.

SORD provided SCS with their March 13, 2012 Oklahoma Department of Environmental Quality (ODEQ) Storm Water Industrial General Permit OKR05 (Authorization No. OKR050819) for industrial storm water management. It is SCS understanding that the state of Oklahoma, operating under the jurisdiction of the Environmental Protection Agency (EPA) and the USACE, issues and manages facilities that require 401 National Pollutant Discharge Emission System (NPDES) discharge permits. SORD has been operating with an approved NPDES storm water permit that includes collection,
B. ADDITIONAL COMMENTS TO SUPPORT JD: The 200 lf stream channel, within the project boundary, is a jurisdictional stream channel based on flow characteristics and the biological, physical, and chemical effects to the Washita River, a TNW.
which are or could be used by interstate or foreign travelers for recreational or other purposes.
- from which fish or shellfish are or could be taken and sold in interstate or foreign commerce.
- which are or could be used for industrial purposes by industries in interstate commerce.
- Interstate isolated waters. Explain: 
- Other factors. Explain: 

Identify water body and summarize rationale supporting determination: 

Provide estimates for jurisdictional waters in the review area (check all that apply):
- Tributary waters: linear feet width (ft).
- Other non-wetland waters: acres.
- Identify type(s) of waters: 
- Wetlands: acres.

F. NON-JURISDICTIONAL WATERS, INCLUDING WETLANDS (CHECK ALL THAT APPLY):
- If potential wetlands were assessed within the review area, these areas did not meet the criteria in the 1987 Corps of Engineers Wetland Delineation Manual and/or appropriate Regional Supplements.
- Review area included isolated waters with no substantial nexus to interstate (or foreign) commerce.
- Prior to the Jan 2001 Supreme Court decision in "SWANCC," the review area would have been regulated based solely on the "Migratory Bird Rule" (MBR).
- Waters do not meet the "Significant Nexus" standard, where such a finding is required for jurisdiction. Explain: 
- Other: (explain, if not covered above): There are 2 ponds that are considered stock tanks that are not regulated under Section 404 of the Clean Water Act.

Provide acreage estimates for non-jurisdictional waters in the review area, where the sole potential basis of jurisdiction is the MBR factors (i.e., presence of migratory birds, presence of endangered species, use of water for irrigated agriculture), using best professional judgment (check all that apply):
- Non-wetland waters (i.e., rivers, streams): linear feet width (ft).
- Lakes/ponds: Pond 1 is 0.77 acre, Pond 2 is 0.31 acres.
- Other non-wetland waters: acres. List type of aquatic resource: 
- Wetlands: acres.

Provide acreage estimates for non-jurisdictional waters in the review area that do not meet the "Significant Nexus" standard, where such a finding is required for jurisdiction (check all that apply):
- Non-wetland waters (i.e., rivers, streams): linear feet width (ft).
- Lakes/ponds: acres.
- Other non-wetland waters: acres. List type of aquatic resource: 
- Wetlands: acres.

SECTION IV: DATA SOURCES.

A. SUPPORTING DATA. Data reviewed for JD (check all that apply - checked items shall be included in case file and, where checked and requested, appropriately reference sources below):
- Maps, plans, plots or plat submitted by or on behalf of the applicant/consultant.
- Data sheets prepared/submitted by or on behalf of the applicant/consultant.
- Office concurs with data sheets/delineation report.
- Office does not concur with data sheets/delineation report.
- Data sheets prepared by the Corps.
- Corps navigable waters' study: Washita River.
- USGS NHD data.
- USGS 8 and 12 digit HUC maps.
- U.S. Geological Survey map(s). Cite scale & quad name: Ardmore East, OK - 11130303.
- USDA Natural Resources Conservation Service Soil Survey. Citation: Carter County.
- National wetlands inventory map(s). Cite name: Ardmore East, OK NWI Map.
- State/Local wetland inventory map(s): 
- FEMA FIRMs maps: 
- 100-year Floodplain Elevation is: (National Geodetic Vertical Datum of 1929)
- Photographs: Aerial (Name & Date): 
- or Other (Name & Date): 
- Previous determination(s). File no. and date of response letter: 
- Applicable/supporting case law: 

Tributaries of TNW where tributaries have continuous flow "seasonally" (e.g., typically three months each year) are jurisdictional. Data supporting this conclusion is provided at Section III.B. Provide rationale indicating that tributary flows seasonally:

Provide estimates for jurisdictional waters in the review area (check all that apply):
- Tributary waters: linear feet width (ft).
- Other non-wetland waters: acres.
Identify type(s) of waters:

3. Non-RPWs that flow directly or indirectly into TNWs.
- Waterbody that is not a TNW or an RPW, but flows directly or indirectly into a TNW, and it has a significant nexus with a TNW is jurisdictional. Data supporting this conclusion is provided at Section III.C.

Provide estimates for jurisdictional waters within the review area (check all that apply):
- Tributary waters: 600 linear feet 3 width (ft).
- Other non-wetland waters: The stream channel was converted into a borrow area which expanded the jurisdictional area for water of the U.S. by approximately 3.9 acres.
Identify type(s) of waters:

4. Wetlands directly abutting an RPW that flow directly or indirectly into TNWs.
- Wetlands directly abut RPW and thus are jurisdictional as adjacent wetlands.
- Wetlands directly abutting an RPW where tributaries typically flow year-round. Provide data and rationale indicating that tributary is perennial in Section III.D.2, above. Provide rationale indicating that wetland is directly abutting an RPW:
- Wetlands directly abutting an RPW where tributaries typically flow "seasonally." Provide data indicating that tributary is seasonal in Section III.B and rationale in Section III.D.2, above. Provide rationale indicating that wetland is directly abutting an RPW:

Provide acreage estimates for jurisdictional wetlands in the review area: acres.

5. Wetlands adjacent to but not directly abutting an RPW that flow directly or indirectly into TNWs.
- Wetlands that do not directly abut an RPW, but when considered in combination with the tributary to which they are adjacent and with similarly situated adjacent wetlands, have a significant nexus with a TNW are jurisdictional. Data supporting this conclusion is provided at Section III.C.

Provide acreage estimates for jurisdictional wetlands in the review area: acres.

6. Wetlands adjacent to non-RPWs that flow directly or indirectly into TNWs.
- Wetlands adjacent to such waters, and have when considered in combination with the tributary to which they are adjacent and with similarly situated adjacent wetlands, have a significant nexus with a TNW are jurisdictional. Data supporting this conclusion is provided at Section III.C.

Provide estimates for jurisdictional wetlands in the review area: acres.

7. Impoundments of jurisdictional waters.
- As a general rule, the impoundment of a jurisdictional tributary remains jurisdictional.
- Demonstrate that impoundment was created from "waters of the U.S.)," or
- Demonstrate that water meets the criteria for one of the categories presented above (1-6), or
- Demonstrate that water is isolated with a nexus to commerce (see E below).

E. ISOLATED {INTERSTATE OR INTRA-STATE) WATERS, INCLUDING ISOLATED WETLANDS, THE USE, DEGRADATION OR DESTRUCTION OF WHICH COULD AFFECT INTERSTATE COMMERCE, INCLUDING ANY SUCH WATERS (CHECK ALL THAT APPLY):

---

8See Footnote # 3.
9To complete the analysis refer to the key in Section III.D.6 of the Instructional Guidebook.
10Prior to asserting or declining CWA jurisdiction based solely on this category, Corps Districts will elevate the action to Corps and EPA HQ for review consistent with the process described in the Corps/EPA Memorandum Regarding CWA Act Jurisdiction Following Reymond.
For each wetland, specify the following:

Directly abuts? (Y/N)  Size (in acres)  Directly abuts? (Y/N)  Size (in acres)

Summarize overall biological, chemical and physical functions being performed:

C. SIGNIFICANT NEXUS DETERMINATION

A significant nexus analysis will assess the flow characteristics and functions of the tributary itself and the functions performed by any wetlands adjacent to the tributary to determine if they significantly affect the chemical, physical, and biological integrity of a TNW. For each of the following situations, a significant nexus exists if the tributary, in combination with all of its adjacent wetlands, has more than a speculative or insubstantial effect on the chemical, physical and/or biological integrity of a TNW. Considerations when evaluating significant nexus include, but are not limited to the volume, duration, and frequency of the flow of water in the tributary and its proximity to a TNW, and the functions performed by the tributary and all its adjacent wetlands. It is not appropriate to determine significant nexus based solely on any specific threshold of distance (e.g. between a tributary and its adjacent wetland or between a tributary and the TNW). Similarly, the fact an adjacent wetland lies within or outside of a floodplain is not solely determinative of significant nexus.

Draw connections between the features documented and the effects on the TNW, as identified in the Rapanos Guidance and discussed in the Instructional Guidebook. Factors to consider include, for example:

- Does the tributary, in combination with its adjacent wetlands (if any), have the capacity to carry pollutants or flood waters to TNWs, or to reduce the amount of pollutants or flood waters reaching a TNW?
- Does the tributary, in combination with its adjacent wetlands (if any), provide habitat and lifecycle support functions for fish and other species, such as feeding, nesting, spawning, or rearing young for species that are present in the TNW?
- Does the tributary, in combination with its adjacent wetlands (if any), have the capacity to transfer nutrients and organic carbon that support downstream foodwebs?
- Does the tributary, in combination with its adjacent wetlands (if any), have other relationships to the physical, chemical, or biological integrity of the TNW?

Note: the above list of considerations is not inclusive and other functions observed or known to occur should be documented below:

1. Significant nexus findings for non-RPW that has no adjacent wetlands and flows directly or indirectly into TNWs. Explain findings of presence or absence of significant nexus below, based on the tributary itself, then go to Section III.D: The unnamed tributary flows into Sand Branch, which flows into the Caddo Creek, a RPW. Caddo Creek flows into the Washita River, ultimately a TNW. The unnamed tributary through this property has been partially converted to open water using the one-step removal method for a borrow area. The stream channel has been diverted upstream into a drainage ditch. The borrow area discharges into the intermittent stream channel during storm events. During rain events water is collected and flows to carry water and sediment, pollutants and organic carbons downstream to the food web. This stream channel provides nutrient cycling, sediment retention, filtration which would improve water quality due to proximity to Washita River, a TNW.

2. Significant nexus findings for non-RPW and its adjacent wetlands, where the non-RPW flows directly or indirectly into TNWs. Explain findings of presence or absence of significant nexus below, based on the tributary in combination with all of its adjacent wetlands, then go to Section III.D:

3. Significant nexus findings for wetlands adjacent to an RPW but that do not directly abut the RPW. Explain findings of presence or absence of significant nexus below, based on the tributary in combination with all of its adjacent wetlands, then go to Section III.D:

D. DETERMINATIONS OF JURISDICTIONAL FINDINGS. THE SUBJECT WATERS/WETLANDS ARE (CHECK ALL THAT APPLY):

1. TNWs and Adjacent Wetlands. Check all that apply and provide size estimates in review area:
   - TNWs: linear feet  width (ft), or  acres.
   - Wetlands adjacent to TNWs:  acres.

2. RPWs that flow directly or indirectly into TNWs.
   - Tributaries of TNWs where tributaries typically flow year-round are jurisdictional. Provide data and rationale indicating that tributary is perennial:
(iv) Biological Characteristics. Channel supports (check all that apply):
- Riparian corridor. Characteristics (type, average width): The riparian area has been removed from construction of a
- Wetland fringe. Characteristics:
- Habitat for:
  - Federally Listed species. Explain findings: American burying beetle.
  - Fish/spawn areas. Explain findings:
  - Other environmentally-sensitive species. Explain findings:
  - Aquatic/wildlife diversity. Explain findings:

2. Characteristics of wetlands adjacent to non-TNW that flow directly or indirectly into TNW

(i) Physical Characteristics:
(a) General Wetland Characteristics:
   Properties:
   - Wetland size: acres
   - Wetland type. Explain:
   - Wetland quality. Explain:
   - Project wetlands cross or serve as state boundaries. Explain:

(b) General Flow Relationship with Non-TNW:
   Flow is: Pick List. Explain:
   - Surface flow is: Pick List
   - Characteristics:
   - Subsurface flow: Pick List. Explain findings:
     - Dye (or other) test performed:

(c) Wetland Adjacency Determination with Non-TNW:
   - Directly abutting
   - Not directly abutting
   - Discrete wetland hydrologic connection. Explain:
   - Ecological connection. Explain:
   - Separated by berm/barrier. Explain:

(d) Proximity (Relationship) to TNW
   - Project wetlands are Pick List river miles from TNW.
   - Project waters are Pick List aerial (straight) miles from TNW.
   - Flow is from: Pick List.
   - Estimate approximate location of wetland as within the Pick List floodplain.

(ii) Chemical Characteristics:
   Characterize wetland system (e.g., water color is clear, brown, oil film on surface; water quality; general watershed characteristics; etc.). Explain:
   Identify specific pollutants, if known:

(iii) Biological Characteristics. Wetland supports (check all that apply):
- Riparian buffer. Characteristics (type, average width):
- Vegetation type/percent cover. Explain:
- Habitat for:
  - Federally Listed species. Explain findings:
  - Fish/spawn areas. Explain findings:
  - Other environmentally-sensitive species. Explain findings:
  - Aquatic/wildlife diversity. Explain findings:

3. Characteristics of all wetlands adjacent to the tributary (if any)
   All wetland(s) being considered in the cumulative analysis. Pick List
   Approximately ( ) acres in total are being considered in the cumulative analysis.
(iii) Chemical Characteristics:
Characterize tributary (e.g., water color is clear, discolored, oily film; water quality; general watershed characteristics, etc.).

Explain: The water color was clear and the water quality was good. The general watershed characteristics are good with a dense riparian corridor.

Identify specific pollutants, if known: None identified.
Identify flow route to TNW: The unnamed tributary flows into the Sand Branch, flow to Caddo Creek, before discharging into the Washita River, a TNW.

Tributary stream order, if known:

(b) General Tributary Characteristics (check all that apply):

Tributary is:  
- ☑ Natural
- ☐ Artificial (man-made). Explain:
- ☑ Manipulated (man-altered). Explain: The stream channel has been manipulated by excavation using the one-step removal method.

Tributary properties with respect to top of bank (estimate):
- Average width: 3 feet
- Average depth: 2 feet
- Average side slopes: 3:1.

Primary tributary substrate composition (check all that apply):
- ☑ Silts
- ☑ Sands
- ☐ Cobbles
- ☐ Gravel
- ☐ Bedrock
- ☐ Vegetation. Type: % cover: 50
- ☐ Concrete
- ☐ Muck
- ☐ Other. Explain:

Tributary condition/stability [e.g., highly eroding, sloughing banks]. Explain: This stream segment is relatively stable. Presence of run/riffle/pool complexes. Explain: There are no riffle and pool complexes within the segment of stream channel. The stream channel has been manipulated upstream from the landfill operation (borrow area and redirecting the flows into a drainage ditch).

Tributary geometry: Meandering
Tributary gradient (approximate average slope): 2 %

(c) Flow:

Tributary provides for: Intermittent but not seasonal flow
Estimate average number of flow events in review area/year: 20 (or greater)
Describe flow regime:
Other information on duration and volume: Mesonet, Carter County, OK.

Surface flow is: Discrete. Characteristics:

Subsurface flow: No. Explain findings:
- Dye (or other) test performed:

Tributary has (check all that apply):
- ☑ Bed and banks
- ☑ OHWM (check all indicators that apply):
  - ☑ clear, natural line impressed on the bank
  - ☑ changes in the character of soil
  - ☑ shelving
  - ☑ vegetation matted down, bent, or absent
  - ☑ leaf litter disturbed or washed away
  - ☑ sediment deposition
  - ☑ water staining
  - ☐ other (list):
- ☑ Discontinuous OHWM. Explain:

If factors other than the OHWM were used to determine lateral extent of CWA jurisdiction (check all that apply):
- ☐ High Tide Line indicated by:
  - ☐ oil or scum line along shore objects
  - ☐ fine shell or debris deposits (foreshore)
  - ☐ physical markings/characteristics
  - ☐ tidal gauges
  - ☐ other (list):
- ☐ Mean High Water Mark indicated by:
  - ☐ survey to available datum;
  - ☐ physical markings;
  - ☐ vegetation lines/changes in vegetation types.

---

5 Flow route can be described by identifying, e.g., tributary a, which flows through the review area, to flow into tributary b, which then flows into TNW.

6 A natural or man-made discontinuity in the OHWM does not necessarily sever jurisdiction (e.g., where the stream temporarily flows underground, or where the OHWM has been removed by development or agricultural practices). Where there is a break in the OHWM that is unrelated to the waterbody’s flow regime (e.g., flow over a rock outcrop or through a culvert), the agencies will look for indicators of flow above and below the break.

7 Ibid.
SECTION III: CWA ANALYSIS

A. TNWs AND WETLANDS ADJACENT TO TNWs

The agencies will assert jurisdiction over TNWs and wetlands adjacent to TNWs. If the aquatic resource is a TNW, complete Section III.A.1 and Section III.D.1. only; if the aquatic resource is a wetland adjacent to a TNW, complete Sections III.A.2 and Section III.D.1.; otherwise, see Section III.B below.

1. TNW

   Identify TNW: The Washita River is the TNW.

   Summarize rationale supporting determination: The Washita River flow into Lake Texhoma and is part of the Red River Navigation Study. This section of the river historically sustains commercial barge traffic and offer passenger and recreational use.

2. Wetland adjacent to TNW

   Summarize rationale supporting conclusion that wetland is "adjacent":

B. CHARACTERISTICS OF TRIBUTARY (THAT IS NOT A TNW) AND ITS ADJACENT WETLANDS (IF ANY):

   This section summarizes information regarding characteristics of the tributary and its adjacent wetlands, if any, and it helps determine whether or not the standards for jurisdiction established under Rapanos have been met.

   The agencies will assert jurisdiction over non-navigable tributaries of TNWs where the tributaries are “relatively permanent waters” (RPWs), i.e. tributaries that typically flow year-round or have continuous flow at least seasonally (e.g., typically 3 months). A wetland that directly abuts an RPW is also jurisdictional. If the aquatic resource is not a TNW, but has year-round (perennial) flow, skip to Section III.D.2. If the aquatic resource is a wetland directly abutting a tributary with perennial flow, skip to Section III.D.4.

   A wetland that is adjacent to but that does not directly abut an RPW requires a significant nexus evaluation. Corps districts and EPA regions will include in the record any available information that documents the existence of a significant nexus between a relatively permanent tributary that is not perennial (and its adjacent wetlands if any) and a traditional navigable water, even though a significant nexus finding is not required as a matter of law.

   If the waterbody is not an RPW, or a wetland directly abutting an RPW, a JD will require additional data to determine if the waterbody has a significant nexus with a TNW. If the tributary has adjacent wetlands, the significant nexus evaluation must consider the tributary in combination with all of its adjacent wetlands. This significant nexus evaluation that combines, for analytical purposes, the tributary and all of its adjacent wetlands is used whether the review area identified in the JD request is the tributary, or its adjacent wetlands, or both. If the JD covers a tributary with adjacent wetlands, complete Section III.B.1 for the tributary, Section III.B.2 for any onsite wetlands, and Section III.B.3 for all wetlands adjacent to that tributary, both onsite and offsite. The determination whether a significant nexus exists is determined in Section III.C below.

1. Characteristics of non-TNWs that flow directly or indirectly into TNW

   (i) General Area Conditions:

   Watershed size: 2301 acres

   Drainage area: 1000 acres

   Average annual rainfall: 38.53 inches

   Average annual snowfall: 3.8 inches

   (ii) Physical Characteristics:

   (a) Relationship with TNW:

   ☐ Tributary flows directly into TNW.

   ☑ Tributary flows through 2 tributaries before entering TNW.

   Project waters are (or more) river miles from TNW.

   Project waters are 2-5 river miles from RPW.

   Project waters are 1-5 aerial (straight) miles from TNW.

   Project waters are 1-3 aerial (straight) miles from RPW.

   Project waters cross or serve as state boundaries. Explain:

---

*Note that the Instructional Guidebook contains additional information regarding swales, ditches, washes, and erosional features generally and in the arid West.*
APPROVED JURISDICTIONAL DETERMINATION FORM
U.S. Army Corps of Engineers

This form should be completed by following the instructions provided in Section IV of the JD Form Instructional Guidebook.

SECTION I: BACKGROUND INFORMATION
A. REPORT COMPLETION DATE FOR APPROVED JURISDICTIONAL DETERMINATION (JD): April 15, 2016

B. DISTRICT OFFICE, FILE NAME, AND NUMBER: Tulsa District, SWT-2015-412

C. PROJECT LOCATION AND BACKGROUND INFORMATION:
   State: Oklahoma  County/parish/borough: Carter  City: 
   Center coordinates of site (lat/long in degree decimal format): Lat. 34.1995° N, Long. -97.04263° W.  
   Universal Transverse Mercator: 
   Name of nearest waterbody: unnamed tributary Sand Branch  
   Name of nearest Traditional Navigable Water (TNW) into which the aquatic resource flows: Washita River  
   Name of watershed or Hydrologic Unit Code (HUC): 11130303  
   Check if map/diagram of review area and/or potential jurisdictional areas is/are available upon request.  
   Check if other sites (e.g., offsite mitigation sites, disposal sites, etc.) are associated with this action and are recorded on a different JD form.

D. REVIEW PERFORMED FOR SITE EVALUATION (CHECK ALL THAT APPLY):
   ☒ Office (Desk) Determination. Date: April 6, 2015  
   ☐ Field Determination. Date(s):

SECTION II: SUMMARY OF FINDINGS
A. RHA SECTION 10 DETERMINATION OF JURISDICTION.
   There are no “navigable waters of the U.S.” within Rivers and Harbors Act (RHA) jurisdiction (as defined by 33 CFR part 329) in the review area. [Required]
   ☐ Waters subject to the ebb and flow of the tide.  
   ☐ Waters are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce. Explain: .

B. CWA SECTION 404 DETERMINATION OF JURISDICTION.
   There are “waters of the U.S.” within Clean Water Act (CWA) jurisdiction (as defined by 33 CFR part 328) in the review area. [Required]

   1. Waters of the U.S.
      a. Indicate presence of waters of U.S. in review area (check all that apply): ¹
         ☐ TNWs, including territorial seas  
         ☐ Wetlands adjacent to TNWs  
         ☐ Relatively permanent waters² (RPWs) that flow directly or indirectly into TNWs  
         ☒ Non-RPWs that flow directly or indirectly into TNWs  
         ☐ Wetlands directly abutting RPWs that flow directly or indirectly into TNWs  
         ☐ Wetlands adjacent to but not directly abutting RPWs that flow directly or indirectly into TNWs  
         ☐ Wetlands adjacent to non-RPWs that flow directly or indirectly into TNWs  
         ☐ Impoundments of jurisdictional waters  
         ☐ Isolated (interstate or intrastate) waters, including isolated wetlands
      b. Identify (estimate) size of waters of the U.S. in the review area:
         Non-wetland waters: 200 linear feet: 2 width (ft) and/or .005 acres.  
         Wetlands: 0.0 acres.
      c. Limits (boundaries) of jurisdiction based on: Established by OHWM
         Elevation of established OHWM (if known): .

   2. Non-regulated waters/wetlands (check if applicable):³
      ☒ Potentially jurisdictional waters and/or wetlands were assessed within the review area and determined to be not jurisdictional.  
      Explain: There are two ponds identified within the reviewed area. The ponds (stock tanks) were excavated in the uplands and are identified by Pond 1 and Pond 2.

¹ Boxes checked below shall be supported by completing the appropriate sections in Section III below.
² For purposes of this form, an RPW is defined as a tributary that is not a TNW and that typically flows year-round or has continuous flow at least “seasonally” (e.g., typically 3 months).
³ Supporting documentation is presented in Section III.F.
NOTIFICATION OF ADMINISTRATIVE APPEAL OPTIONS AND PROCESS AND REQUEST FOR APPEAL

<table>
<thead>
<tr>
<th>Attached is:</th>
<th>Date: Apr 15, 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>INITIAL PROFFERED PERMIT (Standard Permit or Letter of Permission)</td>
<td>See Section below</td>
</tr>
<tr>
<td>PROFFERED PERMIT (Standard Permit or Letter of Permission)</td>
<td>A</td>
</tr>
<tr>
<td>PERMIT DENIAL</td>
<td>B</td>
</tr>
<tr>
<td>APPROVED JURISDICTIONAL DETERMINATION</td>
<td>C</td>
</tr>
<tr>
<td>PRELIMINARY JURISDICTIONAL DETERMINATION</td>
<td>D</td>
</tr>
</tbody>
</table>

SECTION I - The following identifies your rights and options regarding an administrative appeal of the above decision at http://www.usace.army.mil/Missions/CivilWorks/RegulatoryProgramandPermits/appeals.aspx or Corps regulations at 33 CFR Part 331.

A: INITIAL PROFFERED PERMIT: You may accept or object to the permit.

- ACCEPT: If you received a Standard Permit, you may sign the permit document and return it to the district engineer for final authorization. If you received a Letter of Permission (LOP), you may accept the LOP and your work is authorized. Your signature on the Standard Permit or acceptance of the LOP means that you accept the permit in its entirety, and waive all rights to appeal the permit, including its terms and conditions, and approved jurisdictional determinations associated with the permit.

- OBJECT: If you object to the permit (Standard or LOP) because of certain terms and conditions therein, you may request that the permit be modified accordingly. You must complete Section II of this form and return the form to the district engineer. Your objections must be received by the district engineer within 60 days of the date of this notice, or you will forfeit your right to appeal the permit in the future. Upon receipt of your letter, the district engineer will evaluate your objections and may: (a) modify the permit to address all of your concerns, (b) modify the permit to address some of your objections, or (c) not modify the permit having determined that the permit should be issued as previously written. After evaluating your objections, the district engineer will send you a proffered permit for your reconsideration, as indicated in Section B below.

B: PROFFERED PERMIT: You may accept or appeal the permit

- ACCEPT: If you received a Standard Permit, you may sign the permit document and return it to the district engineer for final authorization. If you received a Letter of Permission (LOP), you may accept the LOP and your work is authorized. Your signature on the Standard Permit or acceptance of the LOP means that you accept the permit in its entirety, and waive all rights to appeal the permit, including its terms and conditions, and approved jurisdictional determinations associated with the permit.

- APPEAL: If you choose to decline the proffered permit (Standard or LOP) because of certain terms and conditions therein, you may appeal the declined permit under the Corps of Engineers Administrative Appeal Process by completing Section II of this form and sending the form to the division engineer. This form must be received by the division engineer within 60 days of the date of this notice.

C: PERMIT DENIAL: You may appeal the denial of a permit under the Corps of Engineers Administrative Appeal Process by completing Section II of this form and sending the form to the division engineer. This form must be received by the division engineer within 60 days of the date of this notice.

D: APPROVED JURISDICTIONAL DETERMINATION: You may accept or appeal the approved jurisdictional determination (JD) or provide new information.

- ACCEPT: You do not need to notify the Corps to accept an approved JD. Failure to notify the Corps within 60 days of the date of this notice, means that you accept the approved JD in its entirety, and waive all rights to appeal the approved JD.

- APPEAL: If you disagree with the approved JD, you may appeal the approved JD under the Corps of Engineers Administrative Appeal Process by completing Section II of this form and sending the form to the division engineer. This form must be received by the division engineer within 60 days of the date of this notice.

E: PRELIMINARY JURISDICTIONAL DETERMINATION: You do not need to respond to the Corps regarding the preliminary JD. The preliminary JD is not appealable. If you wish, you may request an approved JD (which may be appealed), by contacting the Corps district for further instruction. Also you may provide new information for further consideration by the Corps to reevaluate the JD.
you must submit a completed RFA form to the Southwestern Division Office at the following address:

Mr. Elliott Carman  
Appeals Review Officer  
U.S. Army Corps of Engineers  
1100 Commerce Street, Suite 831  
Dallas, TX 75242-1731  
Tel: 469-487-7061  
Fax: 469-487-7199

In order for an RFA to be accepted by the Corps, the Corps must determine that it is complete, that it meets the criteria for appeal under 33 CFR Part 331.5, and that it has been received by the Division Office within 60 days of the date of the NAP. Should you decide to submit an RFA form, it must be received at the above address by June 14, 2016. It is not necessary to submit an RFA form to the Division Office if you do not object to the determination in this letter.

This case has been assigned Identification No. SWT-2015-412. Please refer to this number during future correspondence. If you have any questions, contact Mr. Marcus Ware at 918-669-7403.

Sincerely,

Andrew R. Commer  
Chief, Regulatory Office

Enclosures
Regulatory Office

Mr. Wade Miller
SCS Aquaterra
1817 Commons Circle, Suite 1
Yukon, OK 73099

Dear Mr. Miller:

Please reference your letter dated June 19, 2015, concerning expansion of the Southern Oklahoma Regional Disposal Landfill. The proposed project is located in Sections 13 and 24, Township 4 South, Range 2 East, Carter County, Oklahoma. The area marked in red on the enclosed map denotes the limits of the property examined under this request. Non-jurisdictional waters are shown in yellow. We reviewed the submitted data relative to Section 404 of the Clean Water Act (CWA).

There are no jurisdictional wetlands located within the reviewed area. However, the unnamed tributary of Sand Branch and on-channel pond is located in the reviewed portion of the property, as shown in blue on the enclosed map, are regulated waterways. If your project requires the placement of dredged or fill material, permanently or temporarily, into the unnamed tributary of Sand Branch or the on-channel pond, the proposal is subject to regulation pursuant to Section 404 of the CWA, and a Department of the Army (DA) permit would be required.

The basis for this determination is the unnamed tributary flow into Sand Branch, which discharges into Caddo Creek which ultimately flows into the Washita River, a navigable waterway.

We believe this determination to be an accurate assessment of the presence of jurisdictional wetlands and other waters on the site which are subject to Section 404 of the CWA. This is a final determination of Federal jurisdiction on the property pursuant to Section 404 of the CWA. This determination is valid for 5 years from the date of this letter unless new information warrants revision of the determination before the expiration date.

This final determination constitutes an approved Jurisdictional Determination subject to the optional Corps Administrative Appeal Process. If you object to this determination, you may request an administrative appeal under Corps regulations at 33 CFR Part 331. Enclosed is a copy of the Notification of Administrative Appeal Options and Process (NAP) and Request for Appeal (RFA) form. If you request to appeal this determination
June 19, 2015

Mr. Andrew Commer
U.S. Army Corps of Engineers
Regulatory Branch
1645 South 101st East Avenue
Tulsa, OK 74128-4629

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Commer:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-32(d), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: No new waste management or disposal areas of a solid waste disposal facility shall be located in wetland areas as designated by the Oklahoma Conservation Commission or other appropriate agency.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
United States Army Corps of Engineers
Figure 3. No Wellhead Protection Areas Located Within 2-Mile Radius
Figure 2. Distance to Nearest Water Supply Well
Figure 1. Distance to Nearest Water Supply Intake
MEMORANDUM

TO: File
FROM: Katie Moore
SUBJECT: Review of public water supply well and intake locations with regard to the proposed expansion of the SORD Landfill

On July 14, 2015, Cathy Poage of the Oklahoma Water Resources Board (OWRB) responded to our inquiry, recommending that we contact the local floodplain administrator. However, no information on the location of public water supply wells or intakes relative to the expansion area was given.

Further correspondence with the OWRB led to a review of the online map entitled Public Water Supply Systems in Oklahoma.¹ The nearest public water supply intake was measured at a distance of approximately nine miles from SORD, surpassing the one mile requirement (Figure 1). The nearest public water supply well was also measured at a distance of approximately nine miles from SORD, but OAC 252:515-5-32(b)(2) states that the expansion must be located at least one year’s travel time from the well (Figure 2).

To determine the one year travel time distance, David Cates of the Oklahoma Department of Environmental Quality (ODEQ) was contacted on March 7, 2018. He provided guidance on calculating the linear velocity of flow in the aquifer, which was determined to be 0.019 ft/day as recorded in the Hydrogeologic and Geotechnical Report prepared by SCS Engineers and dated April 2018. With this information, I calculated that the maximum linear distance groundwater will travel in a year is approximately 7 feet. As stated, the distance to the nearest public water supply well is approximately 9 miles. Therefore, the expansion is not within a one year travel time of a public water supply well.

Additionally, a review of the ODEQ online map system² indicated that no public water supply wells are located within two miles of the proposed expansion, so it is not necessary to identify any wellhead protection areas for the expansion (Figure 3).

KBM

¹ http://owrb.maps.arcgis.com/apps/webappviewer/index.html?id=68c5f3fd492a43ee8386f39a80f88af
² http://gis.deq.ok.gov/maps/
OKLAHOMA WATER RESOURCES BOARD
Planning & Management Division
Oklahoma City, OK

PUBLIC NOTICE REVIEW

___ We have no comments to offer.  X We offer the following comments.

WE RECOMMEND THAT YOU CONTACT THE LOCAL FLOODPLAIN ADMINISTRATOR FOR POSSIBLE PERMIT REQUIREMENTS FOR THIS PROJECT. THE OWRB WEB SITE, www.owrb.ok.gov, contains a directory of floodplain administrators and is located under forms/floodplain management/floodplain administrators, listed alphabetically by name of community. If this development would fall on STATE OWNED or operated property, a floodplain development permit is required from OWRB. The Chapter 55 Rules and permit application for this requirement can be found on the OWRB web site listed above. If this project is proposed in a non-participating community, try to ensure that this project is completed so that it is reasonably safe from flooding and so that it does not flood adjacent property if at all possible.

Reviewer:  Cathy Poage, CFM  Date:  07/14/2015

Project Name:  Proposed Landfill Expansion at Southern Oklahoma Regional Disposal Landfill - ODEQ Permit No. 3510007, Located in the E/2 of NE/4 of Section 24 and the S/2 of the S/2 of the SE/4 of Section 13, T4S, R2EIM, on Red Cedar Road, 4 mi, E of Ardmore, in Carter County, OK

FIRM Name:  SCS Aquaterra, Wade Miller, Project Director
CC:  Paul Tucker, FPA, Carter County

* Carter County participates in the NFIP and has a floodplain development permitting system. Please see paragraph above.
June 19, 2015

Ms. Lindy Clay
Oklahoma Water Resources Board
3800 North Classen Blvd.
Oklahoma City, OK 73118

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Ms. Clay:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-32(b), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: Except for solid waste processing facilities where waste is stored or placed on permeable surfaces, no new waste management or disposal areas of a solid waste disposal facility shall be located within one mile upgradient of an existing public water supply surface water intake, or one that is permitted for construction when a complete application has been filed with the DEQ; or a one year time of travel of a public water supply well.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.
Oklahoma Water Resources Board
From: Eve Atkinson [mailto:Eve.Atkinson@travelok.com]  
Sent: Thursday, July 30, 2015 11:37 AM  
To: Miller, Wade  
Cc: Susan Henry  
Subject: Southern Oklahoma Regional Disposal Landfill, Proposed Landfill Expansion Notification ODEQ Permit No. 3510007

Dear Mr. Miller:

According to a check on our database for parks funded with the Land and Water Conservation Fund, originating from the Department of Interior, National Park Service, which we administer for the State of Oklahoma and separately, the Oklahoma State Parks system, there are no parks within a half mile of the project.

There appears to be a lake with a fishing dock within a mile, in Section 19, T 4 S, R 3 E to the southeast, but I found no indication it is under public management.

Eve L. Atkinson, Planner II  
Oklahoma Tourism and Recreation Department  
120 North Robinson, Suite 600  
Oklahoma City, OK 73102

405.230.8483.  
405.230.8683 fax  
Eve.Atkinson@travelok.com
June 19, 2015

Ms. Susan Henry
Oklahoma Tourism and Recreation Department
120 N. Robinson, 6th Floor
Oklahoma City, OK 73105

Subject: Southern Oklahoma Regional Disposal Landfill
        Proposed Landfill Expansion Notification
        ODEQ Permit No. 3510007

Dear Ms. Henry:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-31(b), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: no area within the permit boundary of a new solid waste disposal facility, or expansion of the permit boundary of an existing solid waste disposal facility, shall be located within one-half mile of any area formally dedicated and managed for public recreation or natural preservation by a federal, state, or local government agency, unless the appropriate management agency provides a statement that the proposed facility is not expected to adversely affect the existing recreation or natural preservation area.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Tourism and Recreation Department
June 19, 2015

Mr. Edward H. Fite
Oklahoma Scenic Rivers Commission
P.O. Box 292
Tahlequah, Oklahoma 74465-0292

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Fite:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-31(a), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: no area within the permit boundary of a new solid waste disposal facility, or expansion of the permit boundary of an existing solid waste disposal facility, shall be located within the drainage basin of any river designated under the Oklahoma Scenic Rivers Commission Act, unless the Scenic Rivers Commission that manages the affected river provides a statement that the proposed facility is not expected to adversely affect the river or any of the public purposes for which it was designated.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
June 19, 2015

Mr. Edward H. Fite
Oklahoma Scenic Rivers Commission
P.O. Box 292
Tahlequah, Oklahoma 74465-0292

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Fite:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-31(a), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: no area within the permit boundary of a new solid waste disposal facility, or expansion of the permit boundary of an existing solid waste disposal facility, shall be located within the drainage basin of any river designated under the Oklahoma Scenic Rivers Commission Act, unless the Scenic Rivers Commission that manages the affected river provides a statement that the proposed facility is not expected to adversely affect the river or any of the public purposes for which it was designated.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Scenic Rivers Commission
July 9, 2015

Mr. Wade Miller
SCS Aquaterra
1817 Commons Circle, Suite 1
Yukon, OK 73099

RE:  File #1696-15; SCS Aquaterra Notice of Landfill Expansion

Dear Mr. Miller:

We have received the documentation submitted concerning the referenced project in Carter County.

We are unable to process your request for review at this time and ask that you supply a completed Historic Preservation Resource Identification Form and appropriate photographs for each of the structures to be affected by the project, OR a letter indicating that there are no structures on the site and that none have been removed in the recent past, in anticipation of this project.

**NOTE:** If properties within the area of potential affect are less than 45 years old, Historic Preservation Resource Identification Forms and photos are not required. However, your review request must include the address and date of construction of each property.

If properties within the area of potential affect are 45 years old or older, and you have not received Historic Preservation Resource Identification Forms and the Review & Compliance Manual which is necessary to complete the forms, you may call or write to request hard copies from our office, or go online at www.okhistory.org and select "SHPO," then "Programs," then "Section 106," then click on "Review & Compliance (Section 106 Process) Manual" which includes instructions and the form.

If you have any questions regarding this request, you may reach me at 405/521-6381. Your response must reference the above underlined file number. Thank you.

Sincerely,

Catharine M. Wood
Historical Archaeologist

CMW:jr
June 22, 2015

Ms. Catharine Wood
State Historic Preservation Office
800 Nazih Zuhdi Drive
Oklahoma City, OK 73105

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Ms. Wood:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-31(b), SCS Aquterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: no area within the permit boundary of a new solid waste disposal facility, or expansion of the permit boundary of an existing solid waste disposal facility, shall be located within one-half mile of any area formally dedicated and managed for public recreation or natural preservation by a federal, state, or local government agency, unless the appropriate management agency provides a statement that the proposed facility is not expected to adversely affect the existing recreation or natural preservation area.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Historical Society
Figure 24. Map shows general distribution of karst terrains in Oklahoma (modified from Johnson and Quinlan, 1995).
Figure 1. ODEQ Online Map Geology

<table>
<thead>
<tr>
<th>Geology</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age and Formation</td>
<td>IPO</td>
</tr>
<tr>
<td>Symbol</td>
<td></td>
</tr>
<tr>
<td>Formation</td>
<td>Oscar Group</td>
</tr>
<tr>
<td>Name</td>
<td>PENNSYLVANIAN</td>
</tr>
<tr>
<td>Age</td>
<td>PENNSYLVANIAN</td>
</tr>
<tr>
<td>Description</td>
<td>Shale red-brown to gray with arkosic sandstones and limestone conglomerates near Arbuckle Mountains; Hart Limestone at base;</td>
</tr>
<tr>
<td>Description</td>
<td>thickness 300 to 500 ft decreasing southeastward.</td>
</tr>
<tr>
<td>Cont. 2</td>
<td>Buffer</td>
</tr>
</tbody>
</table>

31 Sord Dr, Ardmore, Oklahoma, 73401
March 12, 2018
File No. 27215136.00

MEMORANDUM

TO: File

FROM: Katie Moore

SUBJECT: Review of karst terrain in Oklahoma with regard to the proposed expansion of the SORD Landfill

On July 6, 2015, Rick Andrews of the Oklahoma Geological Survey (OGS) responded to our inquiry, stating that seismicity in the area was not a concern. However, no information on karst terrain relative to the expansion area was given.

On March 12, 2018, Dr. Netra Regmi of the OGS confirmed that *Geologic Hazards in Oklahoma* is the most up-to-date map of karst terrain in Oklahoma. A review of Figure 24 of *Geologic Hazards in Oklahoma*¹ and the ODEQ online map system² confirmed that no karst terrain exists in the vicinity of the proposed expansion area. See attached figures.

KBM

Enclosures

¹ *Geologic Hazards in Oklahoma*, Kenneth V. Luza and Kenneth S. Johnson, Oklahoma Geological Survey
² http://gis.deq.ok.gov/maps/
August 13, 2015

MEMORANDUM

TO: File
FROM: Kris Mutz

SUBJECT: Review of alluvium and terrace deposits and their recharge areas with regard to the proposed expansion of the SORD Landfill

Rick Andrews, Associate Director of the Oklahoma Geological Society, responded to our inquiry on July 6, 2015. Mr. Andrews stated that according to the Ardmore East 7.5 Minute Geologic Quadrangle, part of the proposed expansion area has alluvium deposits.

Further correspondence with Mr. Andrews indicated the map he consulted was actually publication OGQ-86, Preliminary Geologic Map of the Ardmore 30' X 60' Quadrangle and the Oklahoma Part of the Gainesville 30' X 60' Quadrangle, Carter, Jefferson, Love, Murray, and Stephens Counties, Oklahoma. However, OAC 252:515-5-51(a)(1) states, “no area within the permit boundary of a new land disposal facility, or expansion of the permit boundary of an existing land disposal facility, shall be located within an area designated as alluvium or terrace deposits and their recharge areas, as shown on "Map of Aquifers and Recharge Areas in Oklahoma" compiled by Kenneth S. Johnson, Oklahoma Geological Survey (1991).”

Review of the Map of Aquifers and Recharge Areas in Oklahoma indicates that there are no areas designated as alluvium or terrace deposits and their recharge areas in the proposed landfill expansion area (see figure).

KWM

In response to the ODEQ regulations and the Proposed Southern Oklahoma Regional Disposal Landfill:

**Earthquake Epicenter Area** – There are no magnitude 4.0 on the Richter Scale or V on the Modified Mercalli Scale earthquakes located by the OGS within five miles of the permit boundary of the proposed Southern Oklahoma Regional Disposal Landfill.

Attached is a csv file for all earthquakes located by the OGS, dating back to 1977, within 10 miles of the proposed site. The largest event recorded was a magnitude 2.9 on Sept. 8th 2013 located in Marshall County at 34.10932 -96.88317. Also you can download the entire OGS earthquake catalog and information to navigate the header information at: [http://www.okgeosurvey1.gov/pages/earthquakes/catalogs.php](http://www.okgeosurvey1.gov/pages/earthquakes/catalogs.php)

**Fault Areas** – There are no mapped faults within 200ft of the permit boundary of the proposed Southern Oklahoma Regional Disposal Landfill.

Attached is a pdf image of the proposed site including mapped faults and earthquakes. You can download our file database at: [http://www.okgeosurvey1.gov/pages/research.php](http://www.okgeosurvey1.gov/pages/research.php)

Under:

**Seismic Impact Zone** – The proposed site is not in a seismic impact zone for naturally occurring seismicity, an area with a ten percent or greater probability that the maximum horizontal acceleration will exceed 0.10g in 250 years.

However, hazards from induced seismicity should also be considered for this area.

Links to the 2014 USGS Seismic Hazard map and USGS webpage used to create site-specific hazard curves (Attached):

Amberlee Darold
*Research Seismologist* | Oklahoma Geological Survey
The University of Oklahoma Mewbourne College of Earth and Energy
Sarkeys Energy Center, 100 E. Boyd St., Room E-132, Norman, OK 73019-0628
adarold@ou.edu | PH: (405) 325-8611 | CELL: (541) 915-7572
FYI, not sure how this came to me – here it is!

Doug Doerr, P.E.
SCS Aquaterra

913.681.0030 office
913.302.1557 cell

From: Andrews, Richard D. [mailto:rdandrews@ou.edu]
Sent: Monday, July 06, 2015 1:07 PM
To: Doerr, Douglas
Subject: Southern OK regional disposal landfill: attn Kris Mutz and Wade Miller

Wade and Kris:

The OGS evaluated the proposed landfill area in southern Oklahoma (ODEQ No. 3510007) and noted that part of the proposed area has alluvium deposits (see Ardmore East Quadrangle, 7.5 Minute Series).

Additionally, seismicity does not seem to be a problem.

Sincerely,

Rick Andrews
Associate Director, OGS
405 325-3991
rdandrews@ou.edu
On behalf of our client, we request you review the attached maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
June 19, 2015

Mr. Richard Andrews, Interim Director  
Oklahoma Geological Survey  
100 East Boyd Street, Suite N131  
Norman, OK 73109

Subject: Southern Oklahoma Regional Disposal Landfill  
Proposed Landfill Expansion Notification  
ODEQ Permit No. 3510007

Dear Mr. Andrews:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-51 & 52, SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following:

Terrace Deposits — no area within the permit boundary of a new land disposal facility, or expansion of the permit boundary of an existing land disposal facility, shall be located within an area designated as alluvium or terrace deposits and their recharge areas.

Karst Terrain — no area within the permit boundary of a new MSWLF shall be located that is both (1) within a locally fractured or cavernous limestone or cherty limestone bedrock and (2) within five miles of any water well owned by a rural water district that is used or has the potential to be used to provide water to customers of the district.

Earthquake Epicenter Area - no area within the permit boundary of a new land disposal facility accepting NHIW shall be located within five miles of a known epicenter of an earthquake of more than 4.0 on the Richter Scale, or a number V on the modified Mercalli Scale, as recorded by the Oklahoma Geological Survey.

Fault Areas — no new waste management or disposal areas of a land disposal facility shall be located within 200 feet of a fault that has had displacement in Holocene time.

Seismic Impact Zones — no new waste management or disposal areas of a land disposal facility shall be located in a seismic impact zone.
Oklahoma Geologic Survey
I apologize for the delay in this response. If you have any questions about the contents of this letter or any future correspondence regarding this project, please contact me at (405) 990-7259 or at mark.howery@odwc.ok.gov. I have not been the point of contact for this type of project in more than eight years; therefore, if you have any correspondence regarding future projects, please direct them to Clayton Porter, Fisheries Biologist, Oklahoma Fisheries Research Lab, 500 East Constellation, Norman, OK 73072.

Sincerely,

Mark Howery
Wildlife Diversity Biologist
August 5, 2015

Kris Wright-Mutz  
SCS AQUATERRA  
1817 Commons Circle, Suite 1  
Yukon, OK 73099

Subject: Threatened and Endangered Species Review for Landfill Expansion, Carter County

Dear Ms. Wright-Mutz,

This responds to your letter of June 19, 2015 requesting information regarding threatened and endangered species with respect to an application to the Oklahoma Department of Environmental Quality to expand the existing Southern Regional Disposal Inc. landfill. The project site is located within Sections 13 and 24, T04S, R02E, Carter County, approximately four miles east of the city of Ardmore.

Please understand that due to the limitations of our legal authority, financial constraints and personnel limitations, the Oklahoma Department of Wildlife Conservation (ODWC) has not conducted an actual field survey of this property. However, we have compared your project description and map against our records for state-listed threatened and endangered species. Based upon that review, we have no records to indicate that any of these are likely to occur on or in the vicinity of the subject property. We do not have the resources or authority to expand our analysis beyond a review of threatened and endangered species. It appears that this project may eliminate as much as 80 additional acres of native oak woodland and forest. This will affect a number of native, but not endangered, species that occur on the site.

Please note that we do not maintain records for threatened, endangered and rare plant species. For that reason we recommend that you contact the Oklahoma Natural Heritage Inventory at 111 East Chesapeake Street, University of Oklahoma, Norman, OK 73019, for any information that they may have. Similarly, our records for federally-listed threatened and endangered species are not as complete as those of the U.S. Fish and Wildlife Service, which holds the management authority for these species under the Endangered Species Act. If you have not done so previously, we recommend that you contact the U.S. Fish and Wildlife Service’s Tulsa Field Office for any information that they may have.
June 19, 2015

Mr. Mark Howery, Wildlife Biologist
Oklahoma Department of Wildlife Conservation
P.O. Box 53465
Oklahoma City, OK 73152

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Howery:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-31(c), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: For a new solid waste disposal facility, or expansion of the permit boundary of an existing solid waste disposal facility, a statement from the Oklahoma Department of Wildlife Conservation shall be submitted regarding current information about endangered or threatened wildlife or plant species listed in state and federal laws, that exist within one mile of the permit boundary or expansion area.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Department of Wildlife Conservation
June 19, 2015

Mr. Darrell Shults, Geologist
Oklahoma Department of Mines
2915 N. Classen Blvd., Suite 213
Oklahoma City, OK 73106-5406

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Shults:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-52(d), SCS Aquterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: No new waste management or disposal areas of a land disposal facility shall be located over a subsurface mining area or any other unstable area.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Department of Mines
June 19, 2015

Ms. Lynne Moss
Oklahoma Department of Environmental Quality
Wellhead Protection
707 North Robinson
Oklahoma City, OK 73101

Subject: Southern Oklahoma Regional Disposal Landfill
         Proposed Landfill Expansion Notification
         ODEQ Permit No. 3510007

Dear Ms. Moss:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-32(c), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: If any new waste management or disposal areas will be located within two miles of a public water supply well, a wellhead protection area shall be identified, as specified by the State Wellhead Protection Plan, and information submitted to ODEQ.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
June 19, 2015

Ms. Kay Coffey
Oklahoma Department of Environmental Quality
Public Water Supply
707 North Robinson
Oklahoma City, OK 73101

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Ms. Coffey:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-32, SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: Except for solid waste processing facilities where waste is stored or placed on permeable surfaces, no new waste management or disposal areas of a solid waste disposal facility shall be located within one mile upgradient of an existing public water supply surface water intake, or one that is permitted for construction when a complete application has been filed with the DEQ; or a one year time of travel of a public water supply well.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

[Signature]
Wade Miller
Project Director
SCS AQUATERRA

[Signature]
Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Department of Environmental Quality
June 19, 2015

Ms. Brandy Wreath, Director
Public Utilities Division
Oklahoma Corporation Commission
P.O. Box 52000
Oklahoma City, OK 73152-2000

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Ms. Wreath:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-52(a), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: A minimum horizontal separation of twenty-five feet (25') shall be maintained between all waste management and disposal areas of a land disposal facility and any above-ground or underground pipeline or transmission line. Information on the location and owners of all such lines and easements shall be provided to the DEQ.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

[Signature]
Wade Miller
Project Director
SCS AQUATERRA

[Signature]
Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Corporation Commission
June 25, 2015

Wade Miller
Project Director
SCS Aquaterra
1817 Commons Circle
Suite 1
Yukon, OK 73099

RE: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Miller:

Your request for a wetland determination for the referenced project, as described in your letter of June 19, 2015 has been reviewed using the Soil Survey of Carter County and the U.S. Fish and Wildlife National Wetlands Inventory (NWI) maps. Neither hydric soils nor wetlands are indicated, indicating that these areas most likely do not contain wetland ecosystems and that your project should not significantly impact wetland resources in the area. If your policy guidelines, which prohibit development or rehabilitation on floodplains or wetland areas, are followed, you will be in compliance and no problems relative to wetland regulatory issues shall exist. If you believe this determination to be inaccurate, an on-site investigation may be needed. This investigation needs to be coordinated with the U.S. Army Corps of Engineers, Regulatory Branch, in Tulsa. Their address and phone number is:

U.S. Army Corps of Engineers
Mr. Andy Commer
Chief of Regulatory Branch
1645 South 101st East Avenue
Tulsa, OK 74128-4629
918/669-7400

Based on our wetlands determination criteria there should be no significant impact on wetland resources in the area described. If you have any further questions or concerns, please contact me at 405/522-6908.

Sincerely,

Brooks Tramell
Wetlands Program Coordinator
Water Quality Division

cc: Wetlands file
June 19, 2015

Mr. Brooks Tramell
Oklahoma Conservation Commission
2800 N. Lincoln Blvd., Suite 160
Oklahoma City, Oklahoma 73105

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Tramell:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-32(d), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: no new waste management or disposal areas of a solid waste disposal facility shall be located in wetland areas as designated by the Oklahoma Conservation Commission or other appropriate agency.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Conservation Commission
OBS Ref. 2015-289-BUS-SCS

Dear Mr. Miller,  

June 25, 2015

We have reviewed occurrence information on federal and state threatened, endangered or candidate species, as well as non-regulatory rare species and ecological systems of importance currently in the Oklahoma Natural Heritage Inventory database for the following location you provided:

Sec. 13-T4S-R2E, Carter County

We found no occurrences of relevant species within the vicinity of the project location as described. However, absence from our database does not preclude such species from occurring in the area.

If you have any questions about this response, please send me an email, or call us at the number given below.

Although not specific to your project, you may find the following links helpful.

ONHI guide to ranking codes for endangered and threatened species:  
http://vmpincel.ou.edu/heritage/ranking_guide.html

Information regarding the Oklahoma Natural Areas Registry:  
http://www.oknaturalheritage.ou.edu/registry_faq.htm

Todd Fagin

Oklahoma Natural Heritage Inventory/  
Department of Geography and Environmental Sustainability
June 19, 2015

Mr. Bruce Hoagland
Oklahoma Biological Survey
111 East Chesapeake Street
Norman, OK 73019

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Hoagland:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-31(c), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: For a new solid waste disposal facility, or expansion of the permit boundary of an existing solid waste disposal facility, a statement from the Oklahoma Biological Survey (OBS) shall be submitted regarding current information about endangered or threatened wildlife or plant species listed in state and federal laws, that exist within one mile of the permit boundary or expansion area.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Biological Survey
July 9, 2015

Wade Miller
SCS Aquaterra
1817 Commons Circle, Ste. 1
Yukon, Ok 73099

RE: Proposed Landfill Expansion Notification, ODEQ Permit # 3510007. Legal Description: E ¼ NE ¼ Section 24 and S ½ S ½ SE ¼ Section 13 T4S R2E, Carter County, Oklahoma.

Dear Mr. Miller:

The Community Assistance Program staff of the Oklahoma Archeological Survey has reviewed the above referenced project in order to identify potential areas that may contain prehistoric or historic archaeological materials (historic properties). The location of your project has been crosschecked with the state site files containing approximately 23,000 archaeological sites that are currently recorded for the State of Oklahoma. No sites are listed as occurring within your project area, and based on the topographic and hydrologic setting, no archaeological materials are likely to be encountered. Thus an archaeological field inspection is not considered necessary. However, should construction activities expose buried archaeological materials such as chipped stone tools, pottery, bone, historic crockery, glass, metal items or building materials, this agency should be contacted immediately at (405) 325-7211. A member of our staff will be sent to evaluate the significance of these remains.

This environmental review and evaluation is performed in order to locate, record, and preserve Oklahoma’s prehistoric and historic cultural heritage in cooperation with the State Historic Preservation Office, Oklahoma Historical Society, and you must also have a letter from that office to document your consultant pursuant to Section 106 of the National Historic Preservation Act. In addition to our review comments, under 36CFR Part 800.3 you are reminded of your responsibility to consult with the appropriate Native American tribe/groups to identify any concerns they may have pertaining to this undertaking and potential impacts to properties of traditional and/or ceremonial value.

Sincerely,

Lauren Cleeland
Staff Archaeologist

Robert L. Brooks
State Archaeologist

Cc: SHPO
June 19, 2015

Ms. Lisa Stambeck
Oklahoma Archeological Survey
111 East Chesapeake Street
Norman, OK 73019

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Ms. Stambeck:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-31(b), SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: no area within the permit boundary of a new solid waste disposal facility, or an expansion of the permit boundary of an existing solid waste disposal facility, shall be located within one-half mile of any area formally dedicated and managed for public recreation or natural preservation by a federal, state, or local government agency unless the appropriate management agency provides a statement that the proposed facility is not expected to adversely affect the existing recreation or natural preservation area.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

[Signature]
Wade Miller
Project Director
SCS AQUATERRA

[Signature]
Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Oklahoma Archaeological Survey
June 19, 2015

Federal Emergency Management Agency
Region VI Environmental & Historic Preservation Office
FRC 800 North Loop 288
Denton, TX 76209

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Sir or Madam:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-32, SCS Aquaterra is requesting a determination for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: No Waste management or disposal areas of a solid waste disposal facility shall be located within the 100-year floodplain.

On behalf of our client, we request you review the enclosed maps and provide this determination as required by the ODEQ within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
Federal Emergency Management Agency
Mr. Michael Lamprecht
6/19/2015
Page 2

On behalf of our client, we request your review of the enclosed maps. Please advise us of any concerns the Federal Aviation Administration may have with the proposed landfill expansion location within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

[Signature]

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
June 19, 2015

Mr. Michael Lamprecht
Federal Aviation Administration
Southwest Region
2601 Meacham Boulevard
Fort Worth, TX 76137-4298

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Lamprecht:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-52(e)(1), SCS Aquaterra is submitting this notification for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: if any waste management or disposal area of a new land disposal facility, or expansion of waste management or disposal areas of an existing land disposal facility, is to be located within 10,000 feet of any airport runway end used by turbojet aircraft or within 5,000 feet of any airport runway end used by only piston-type aircraft, a demonstration that the facility will not pose a bird hazard to aircraft shall be provided to the DEQ.

If any waste management or disposal areas of a new land disposal facility, or expansion of waste management or disposal areas of an active land disposal facility, will be located within a 5-mile radius of any airport runway end used by turbojet or piston-type aircraft, the affected airport and the FAA must be notified and proof of such notification provided to the DEQ.
Federal Aviation Administration
On behalf of our client, we request your review of the enclosed maps. Please advise us of any concerns that Bass Aero may have with the proposed landfill expansion location within 45 days of receipt of this letter. If you have any questions or comments or need additional information, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade Miller
Project Director
SCS AQUATERRA

Kris Wright Mutz
Project Professional
SCS AQUATERRA

cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.

Enclosures
June 19, 2015

Mr. Eddy Ralph Bass
Bass Aero
PO Box 988
Lone Grove, OK 73443

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

Dear Mr. Bass:

As required by Oklahoma Department of Environmental Quality (ODEQ) Oklahoma Administrative Code 252:515-5-52(e)(1), SCS Aquaterra is submitting this notification for the proposed expansion of the Southern Oklahoma Regional Disposal Landfill which is owned and operated by Southern Oklahoma Regional Disposal, Inc. (SORD). The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of the city of Ardmore, Oklahoma. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East of the Indian Meridian, Carter County, Oklahoma. Two general site location maps are enclosed.

The ODEQ regulation states the following: if any waste management or disposal area of a new land disposal facility, or expansion of waste management or disposal areas of an existing land disposal facility, is to be located within 10,000 feet of any airport runway end used by turbojet aircraft or within 5,000 feet of any airport runway end used by only piston-type aircraft, a demonstration that the facility will not pose a bird hazard to aircraft shall be provided to the DEQ.

If any waste management or disposal areas of a new land disposal facility, or expansion of waste management or disposal areas of an active land disposal facility, will be located within a 5-mile radius of any airport runway end used by turbojet or piston-type aircraft, the affected airport and the FAA must be notified and proof of such notification provided to the DEQ.
Bass Aero Airport
Location Restriction Letters
Wade Miller
SCS Engineers
1817 Commons Circle
Suite 1
Yukon OK 73099

CERTIFIED MAIL

9415 5118 9956 0429 0687 25

RETURN RECEIPT REQUESTED

Article Addressed To:

Maher Farms
8001 US HWY 177
Ardmore OK 73401-0864
Service type: FedEx Express Saver®
Packaging type: FedEx® Envelope
Number of pieces: 1
Weight: 0.50 lb.
Special handling/Services: Deliver Weekday Residential Delivery
Standard transit: 12/7/2018 by 8:00 pm

☐ Please do not respond to this message. This email was sent from an unattended mailbox. This report was generated at approximately 2:50 PM CST on 12/05/2018.

All weights are estimated.

To track the latest status of your shipment, click on the tracking number above.
Standard transit is the date and time the package is scheduled to be delivered by, based on the selected service, destination and ship date. Limitations and exceptions may apply. Please see the FedEx Service Guide for terms and conditions of service, including the FedEx Money-Back Guarantee, or contact your FedEx Customer Support representative.

© 2018 Federal Express Corporation. The content of this message is protected by copyright and trademark laws under U.S. and international law. Review our privacy policy. All rights reserved.

Thank you for your business.
Your package has been delivered

Tracking # 773878322625

Ship date: Tue, 12/4/2018

Wade Miller
SCS Engineers
Wichita, KS 67226
US

Delivery date: Wed, 12/5/2018 2:48 pm

Kelly Kendrick
8607 Davis Drive
FRISCO, TX 75036
US

Shipment Facts

Our records indicate that the following package has been delivered.

Tracking number: 773878322625

Status: Delivered: 12/05/2018 2:48
PM Signed for By: Signature not required

Reference: 27215136.00

Signed for by: Signature not required

Delivery location: FRISCO, TX

Delivered to: Residence
Wade Miller
SCS Engineers
1817 Commons Circle
Suite 1
Yukon OK 73099

CERTIFIED MAIL

RETURN RECEIPT REQUESTED

Article Addressed To:
Jerry Holley, Jr
c/o Kristi Holley
3474 Dogwood Rd
Ardmore OK 73401-7946
<table>
<thead>
<tr>
<th>COMPLETE THIS SECTION ON DELIVERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Signature: (☐ Addressess or ☐ Agent) X Rhonda Dade</td>
</tr>
<tr>
<td>B. Received By: (Please Print Clearly)</td>
</tr>
<tr>
<td>C. Date of Delivery</td>
</tr>
<tr>
<td>D. Addressed's Address (If Different From Address Used by Sender)</td>
</tr>
<tr>
<td>Secondary Address / Suite / Apt. / Floor (Please Print Clearly)</td>
</tr>
<tr>
<td>Delivery Address</td>
</tr>
<tr>
<td>City State ZIP + 4 Code</td>
</tr>
</tbody>
</table>

RETURN RECEIPT REQUESTED

Article Addressed To:

James and Amerylys Maher
921 East Wynnewood Avenue
Sulphur OK 73086-4074
Bobby Pruitt
PO Box 757
Ardmore OK 73402-0757
Certified Mail Receipts
December 13, 2017
File No. 27215136.00

James and Amerylys Maher
921 East Wynnewood Avenue
Sulphur, Oklahoma 73086

Subject: Southern Oklahoma Regional Disposal Landfill
         Proposed Landfill Expansion Notification
         ODEQ Permit No. 3510007

As required by the Oklahoma Department of Environmental Quality, SCS Engineers is submitting this notification associated with the proposed expansion of the Southern Oklahoma Regional Disposal Landfill, which is owned and operated by Southern Oklahoma Regional Disposal, Inc. As an adjacent property owner, Oklahoma law requires you be notified of the application filing. The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

If you have any questions or comments, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

[Signature]
Wade J. Miller
Project Director
SCS ENGINEERS

[Signature]
Katie Moore, E.I.T.
Staff Professional
SCS ENGINEERS

Cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.
December 13, 2017
File No. 27215136.00

Mary L Pruitt Family Trust
PO Box 757
Ardmore, Oklahoma 73402

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

As required by the Oklahoma Department of Environmental Quality, SCS Engineers is submitting this notification associated with the proposed expansion of the Southern Oklahoma Regional Disposal Landfill, which is owned and operated by Southern Oklahoma Regional Disposal, Inc. As an adjacent property owner, Oklahoma law requires you be notified of the application filing. The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

If you have any questions or comments, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade J. Miller
Project Director
SCS ENGINEERS

Katie Moore, E.I.T.
Staff Professional
SCS ENGINEERS

Cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.
December 13, 2017
File No. 27215136.00

Maher Farms
8001 US HWY 177
Ardmore, Oklahoma 73401

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

As required by the Oklahoma Department of Environmental Quality, SCS Engineers is submitting this notification associated with the proposed expansion of the Southern Oklahoma Regional Disposal Landfill, which is owned and operated by Southern Oklahoma Regional Disposal, Inc. As an adjacent property owner, Oklahoma law requires you be notified of the application filing. The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

If you have any questions or comments, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade J. Miller
Project Director

Katie Moore, E.I.T.
Staff Professional

Cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.
December 13, 2017
File No. 27215136.00

Kim Ritchey
9825 SE 59th
Oklahoma City, Oklahoma 73150

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

As required by the Oklahoma Department of Environmental Quality, SCS Engineers is submitting this notification associated with the proposed expansion of the Southern Oklahoma Regional Disposal Landfill, which is owned and operated by Southern Oklahoma Regional Disposal, Inc. As an adjacent property owner, Oklahoma law requires you be notified of the application filing. The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

If you have any questions or comments, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade J. Miller
Project Director
SCS ENGINEERS

Katie Moore, E.I.T.
Staff Professional
SCS ENGINEERS

Cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.
December 13, 2017
File No. 27215136.00

Kelly Kendrick
8607 Davis Drive
Frisco, Texas 75034

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

As required by the Oklahoma Department of Environmental Quality, SCS Engineers is submitting this notification associated with the proposed expansion of the Southern Oklahoma Regional Disposal Landfill, which is owned and operated by Southern Oklahoma Regional Disposal, Inc. As an adjacent property owner, Oklahoma law requires you be notified of the application filing. The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

If you have any questions or comments, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

[Signature]
Wade J. Miller
Project Director
SCS ENGINEERS

[Signature]
Katie B Moore
Katie Moore, E.I.T.
Staff Professional
SCS ENGINEERS

Cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.
December 13, 2017
File No. 27215136.00

Jerry Holley, Jr.
c/o Kristi Holley
6080 Red Cedar Road
Ardmore, OK 73401

Subject: Southern Oklahoma Regional Disposal Landfill
Proposed Landfill Expansion Notification
ODEQ Permit No. 3510007

As required by the Oklahoma Department of Environmental Quality, SCS Engineers is submitting this notification associated with the proposed expansion of the Southern Oklahoma Regional Disposal Landfill, which is owned and operated by Southern Oklahoma Regional Disposal, Inc. As an adjacent property owner, Oklahoma law requires you be notified of the application filing. The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

If you have any questions or comments, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

Wade J. Miller
Project Director
SCS ENGINEERS

Katie Moore, E.I.T.
Staff Professional
SCS ENGINEERS

Cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.
December 13, 2017
File No. 27215136.00

Bobby Pruitt
PO Box 757
Ardmore, Oklahoma 73402

Subject: Southern Oklahoma Regional Disposal Landfill
         Proposed Landfill Expansion Notification
         ODEQ Permit No. 3510007

As required by the Oklahoma Department of Environmental Quality, SCS Engineers is submitting this notification associated with the proposed expansion of the Southern Oklahoma Regional Disposal Landfill, which is owned and operated by Southern Oklahoma Regional Disposal, Inc. As an adjacent property owner, Oklahoma law requires you be notified of the application filing. The proposed landfill expansion consists of approximately 80 acres and is located on Red Cedar Road, four miles east of Ardmore. The expansion is more specifically described as the east half of the northeast quarter of Section 24 and the south half of the south half of the southeast quarter of Section 13, Township 4 South, Range 2 East, Carter County, Oklahoma.

If you have any questions or comments, please do not hesitate to contact the undersigned at (405) 265-3960. Thank you very much for your time and effort in this matter.

Sincerely,

\[Signature\]
Wade J. Miller
Project Director
SCS ENGINEERS

\[Signature\]
Katie B. Moore
Katie Moore, E.I.T.
Staff Professional
SCS ENGINEERS

Cc: Mr. Troy Duke, Southern Oklahoma Regional Disposal, Inc.
Adjacent Property Owner Notification Letters
Appendix A

Location Restriction Correspondence Letters