Weaver Consultants Group

April 22, 2019

Mr. Jeremiah Jackson, R.G.
Unit Chief, Environmental Assistance Unit
Missouri Geological Survey
111 Fairgrounds Road
Rolla, Missouri 65402-0250

Re: Detailed Site Investigation Work Plan
City of Columbia Sanitary Landfill Expansion (101908)
Columbia, Boone County, MO

Dear Mr. Jackson:

On behalf of the City of Columbia, Weaver Consultants Group North Central, LLC (WCG) has prepared the attached Detailed Site Investigation Work Plan for your review. The Work Plan incorporates the comments provided during our meeting with you and your staff as well as the Missouri Department of Natural Resources' Waste Management Program staff on April 10, 2019. A Preliminary Site Investigation for the proposed expansion area was approved on December 31, 2018. The attached work plan was prepared in general accordance with the Missouri Geological Survey's "Guidance for Conducting and Reporting Detailed Geologic and Hydrologic Investigations at a Proposed Solid-Waste Disposal Area."

We trust the enclosed plan meets with your requirements. Please contact me if you have any questions or need additional information.

Sincerely,

Weaver Consultants Group North Central, LLC

Andrew Limmer, P.G.
Senior Project Manager

Attachments: April 2019 Detailed Site Investigation Work Plan

C: Adam White, Landfill Superintendent – Columbia Landfill
Dustin Thoenen, P.E. – Weaver Consultants Group
Frank Barthol – Weaver Consultants Group

April 22, 2019

DETAILED SITE INVESTIGATION WORK PLAN

CITY OF COLUMBIA LANDFILL EXPANSION
(Permit Number 101908)

Prepared for:

city of
Columbia
Public Works

STATE OF MISSOURI
ANDREW J. LIMMER
24 APR 2019
RG0077
REGISTERED GEOLOGIST

PREPARED BY

Weaver
Consultants
Group

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1 INTRODUCTION

The City of Columbia, Missouri owns and operates a sanitary landfill in Boone County, Missouri. The City of Columbia seeks to expand the existing landfill south of the existing landfill disposal area. This work plan describes the hydrogeologic detailed site investigation (DSI) for the expansion area. A Preliminary Site Investigation (PSI) request was submitted on November 7, 2018, which was approved by the Missouri Department of Natural Resources- Geological Survey Program (MDNR- GSP) on December 31, 2018.

1.1 Site Background

The Columbia Sanitary Landfill was initially permitted for municipal solid waste disposal in 1985 by the Missouri Department of Natural Resources, which issued Permit Number 101908. The current waste disposal area is approximately 107 acres of the approximate 560 acre landfill facility. The facility property is located in Section 22 and the north half of Section 27 of T49N and R12W, with a small portion in the southeast corner of Section 15. More specifically, the facility is located approximately 1 mile east of state Highway B on Peabody Road. The facility boundaries are Rodgers Road to the east, North Hinkson Creek Road and North Wyatt Lane to the south, and Hinkson Creek to the west and north. The location of the current facility and the expansion area are shown on **Figure 1**.

The existing waste disposal area includes an approximately 51-acre pre-Subtitle D landfill and 56-acre Subtitle D disposal area. This disposal area is located north of Peabody Road. The proposed expansion area is located south of Peabody Road and includes approximately 144 acres of the 560 acre facility. The proposed expansion area has a planned sub-base grade elevation of 740 feet above mean sea level (AMSL). The base grades will require fills on the southwest to cuts of up to 80 feet on the north and northeast.

The area of the proposed landfill expansion was previously strip mined for coal, generally regarded as coal of the Bevier Formation, in the 1960s through the 1970s by Peabody Coal Company. The reclamation of the strip mines resulted in rock waste and surficial material (mine spoil) placed above the remaining bedrock. Two final cut lakes are present in the former strip mined area as shown on **Figure 2.** The area north and northwest of the final cut lakes has been backfilled with spoil. The spoil piles are currently used for borrow material to construct liner and for other operational needs at the existing landfill. Some spoil may have been placed on the natural ground surface to the southeast of the final cut lakes as well. South and southeast of the final cut lakes is relatively undisturbed ground with a thin mantle of loess or glacial till resting directly on Pennsylvanian Age shale. The results of this proposed DSI will be used to develop a plan to address the final cut lakes present in the proposed waste boundary. The geologic data, hydrogeologic data, and the design landfill base elevations will determine whether the lakes are filled, used as subgrade, or used for surface water control. The design plan will also include a plan for the area of the cut lake not in the waste boundary.

The undisturbed areas south and east of the final cut lakes are tree covered with a small rectangular section that appears to have been borrowed or stripped in the past and is covered in cedar trees. The western portion of the facility bordering Hinkson Creek appears to be alluvial deposits overlying bedrock. The alluvium is used for agricultural crop production.

1.2 Purpose

This DSI work plan defines the scope of work necessary to characterize the geologic and hydrologic conditions at the proposed expansion area. It has been prepared in general accordance with the criteria described in 10 CSR 80-2.015, "*Guidance for Conducting and Reporting Detailed Geologic and Hydrologic Investigations at a Proposed Solids-Waste Disposal Area.*" Included in this DSI work plan are the descriptions of the expected geological setting, proposed methods for drilling and sampling, data collection, record-keeping procedures, laboratory and field testing, piezometer construction and development, and reporting.

2 PHYSICAL SETTING

2.1 Regional Setting

The Columbia Sanitary Landfill is located within the south central Dissected Till Plains. Topographically, the region consists of dissected hills to flat flood plains and flat uplands. The stream valleys range from shallow on the uplands to more deeply incised as they approach the Missouri River. Streams generally flow southwest towards the Missouri River. Streams in this region are generally classified as gaining. Surface water runoff is to the east and south, into Hinkson and Nelson Creeks, respectively. Both creeks are tributaries to the Missouri River. The site is topographically high in the drainage basin due to its location on glacial ridges as well as historic coal mine spoil piles. No known springs or karst features are present within a one mile radius of the site.

Surficial materials onsite consist of Hinkson Creek and Nelson Creek alluvial deposits, loess, glacial deposits, and coal mine spoil of irregular thicknesses. The moderately-low to highly permeable surficial materials range in size from fine to coarse grained. Boulder-sized glacial erratics may also be found randomly deposited within the glacial material. There are no known sinkholes, faults, or other geologic structures mapped within one mile of the proposed expansion area per the approved PSI.

Bedrock in the region consists of middle Pennsylvanian limestone, clay, coal, and shale. The uppermost bedrock at this site is typically Pennsylvanian age shale with thin limestone and sandstone layers. This formation is typically yellow to pale brown, and clayey. The shale is competent with low permeability. Where present, the shale unit is up to eight feet thick. Below the shale is a thin bed of the Bevier coal. The Bevier coal is black, bituminous, and historically surface-mined at the proposed landfill site, and throughout the region. Underlying the Bevier coal is a section of Pennsylvanian age interbedded limestone and shale with an approximate thickness of 5.5 to 12 feet. A distinctive bed of Pennsylvanian shale is at the base of this succession, with an approximate thickness of 13 to 23.5 feet. The shale is black to light gray in color, weathered and weakly lithified. Below the shale is the Mississippian age Keokuk-Burlington Limestone. This bedrock unit is a light gray fossiliferous limestone. According to logs of nearby potable wells, the Burlington-Keokuk Limestone is at least 150 feet thick in this region. The uppermost section is highly fractured interbedded chert and limestone, with shale and clay filling the fractures.[1] A generalized stratigraphic column of the regional geology near the facility is shown on **Figure 3**.

[1] "Prelimnary Site Investigation of Proposed Solid-Waste Disposal Area," MDNR- GSP, December 31, 2018.

2.2 Groundwater

Shallow groundwater is present in two zones at the facility[2]. Shallow groundwater is perched above the shale in the surficial deposits above the shale in either the mine spoil or the areas where the unconsolidated deposits are thicker. This groundwater flows from topographic highs towards Hinkson Creek. The second groundwater zone at the site is present below the shale in the Burlington-Keokuk Limestone and potable water supply wells use this formation as a water supply. The groundwater in the limestone flows towards the east away from Hinkson Creek. Generally, the water elevation in the limestone is nearly the same as the shallow water level in the alluvium, but is separated by approximately 80 feet on the east side of the existing landfill near Rogers Road.

In the unmined areas of the expansion with thin surficial deposits and ravines, the surficial deposits have limited in thickness and little to no groundwater is anticipated to be present above the bedrock. Weaver Consultants Group (WCG) does not expect a uniform thickness of surficial material site wide.

[2] "Groundwater Monitoring Plan," Aquaterra Environmental Solutions, April 2009.

3 SITE EXPLORATION

WCG will perform the geologic and hydrogeologic work under the direction of a geologist registered in the State of Missouri per RSMO 256.450 through 256.483, and one that is a qualified groundwater scientist. WCG will use field staff that hold the Missouri restricted monitoring well installation permit to oversee and direct the field activities and log the exploration borings and test pits. WCG will subcontract a non-restricted driller to advance exploration borings and install monitoring wells or piezometers. During the main investigation phase (second phase) two drill rigs and potentially three drill rigs may be on site to perform the drilling, testing, and piezometer construction. Each drill rig will be accompanied by a WCG field staff that has the restricted monitoring well installation permit. During drilling efforts with three drill rigs a Missouri registered geologist will be on site to provide oversight and direction.

3.1 Test Pit and Boring Locations

At least one boring and/or test pit is required for every two acres of the proposed expansion. The borings must be extended to 25 feet below the base of the landfill or to competent bedrock, whichever is shallower. The borings and test pits will be used to characterize the hydrostatigraphic units per the guidance in Appendix I of 10 CSR 80-2. The proposed expansion area for solid waste disposal is approximately 144 acres; therefore, at least 72 borings and/or test pits must be advanced in the expansion area. WCG proposes to advance 73 total borings and/or test pits at the expansion facility. The 73 borings and/or test pits are laid out in a grid, covering the proposed solid waste footprint. The proposed locations of the test pits and borings were placed on a grid and then adjusted based on topographic features. The proposed boring and test pit locations are shown on **Figure 2**.

17 of the 73 locations are planned test pit locations that will be advanced to bedrock. The test pit locations are planned for locations where the anticipated bedrock surface is shallow. A summary of the locations and proposed drilling depths are listed in **Table 1**.

3.2 Piezometers

Piezometers are required to adequately characterize the groundwater at the proposed site. There must be at least one piezometer per four acres of the proposed waste footprint installed in each aquifer to be characterized. As described in **Section 2.1**, there are two monitoring zones anticipated in the expansion area. The upper zone is located in the surficial deposits, and a lower zone present in the Burlington-Keokuk Limestone.

Because there are two monitoring zones at the proposed solid waste expansion area, there will be one piezometer installed per four acres in the upper aquifer (surficial material), and one piezometer installed per four acres in the lower aquifer (Burlington-Keokuk Limestone). WCG plans to install 18 piezometers in the surficial deposits where saturated unconsolidated material is encountered above the bedrock and convert the 38 bedrock borings in the Burlington-Keokuk Limestone to piezometers.

The proposed locations of the piezometers are shown on **Figure 2**. The piezometers are distributed in a grid across the proposed facility, with several piezometers located outside the anticipated fill area.

3.2.1 Surficial Deposits

WCG proposes to advance 35 borings/test pits through the surficial deposits, which are considered to be the glacial deposits and mine spoil. Where present, WCG will drill or excavate through the entirety of the upper monitoring zone, until bedrock is encountered. The depth of the upper monitoring zone borings/piezometers will vary due to the topography of the proposed expansion area. WCG will collect samples of the surficial deposits for laboratory testing of moisture content, soil characterization, and permeability. In addition to the planned laboratory testing, in situ permeability tests will be performed using the piezometers installed in the surficial deposits.

Because of the topography at the proposed facility, WCG anticipates that the surficial deposits will be very thin or absent in some areas. The areas of absent or minimal surficial material are expected to be near the southern boundary and along the western portion of the proposed footprint. In these areas, test pits will us used as an alternative to drilling, due to the limited surficial cover at these locations. The depths of the upper monitoring zone/surficial deposit test pits and borings are anticipated to range from approximately 3.5 feet to 82 feet below the ground surface.

3.2.2 Burlington-Keokuk Limestone

WCG proposes to advance 38 borings into the Burlington-Keokuk Limestone. WCG will drill through overlying shales, coal, and/or underclays of the Pennsylvanian age deposits to the top of the Burlington-Keokuk Limestone. After encountering the Burlington-Keokuk Limestone, WCG anticipates drilling approximately 50 feet into the Burlington-Keokuk Limestone or until encountering water. WCG anticipates that the Burlington-Keokuk Limestone will be relatively uniform based on logs of previous borings advanced into the limestone. WCG will collect core samples of the rock in the proposed expansion area. The depths of the Burlington-Keokuk Limestone borings are anticipated to range from approximately 52 feet to 153 feet below the ground surface.

The shale and underclay of the Pennsylvanian age deposits is considered to be the lower confining layer for the proposed landfill and an aquitard separating the landfill from the underlying Burlington-Keokuk Limestone. WCG will perform in situ permeability testing of the shale at select locations as well as in the limestone.

3.3 Drilling Methods

Several methods will be used to advance the upper zone and lower zone boring/piezometers: exploration or test pits, hollow stem auger, rock coring, and air rotary. To drill the deeper surficial borings, WCG will use hollow stem augers with continuous split-spoon samplers until encountering the top of the bedrock or refusal. In the locations where the surficial material may be absent or minimal, the surficial deposits will be investigated using a track hoe to advance test pits. Hollow stem augers, rock coring, and air rotary drilling methods will be used to advance borings into the bedrock. The detailed methods are described in **Section 4**. All borings advanced for the DSI, whether terminated in unconsolidated material or terminated in rock will remain open for a minimum of 24 hours to allow the water levels to stabilize. Piezometers may not be constructed until 24 hours after each boring has reached the termination depth. The locations of the borings and piezometers will be determined by a surveyor registered in the State of Missouri.

4 INVESTIGATION METHODS & TESTING

WCG will incorporate several field investigation and laboratory methods to characterize the two monitoring zones present at the proposed landfill expansion area. **Figure 4** and **Figure 5** show the boring details expected at each location, including the expected geology at each boring, proposed boring depth, and drilling and sampling planned at each location. The field and laboratory analytical procedures are described below.

4.1 Exploration (Test) Pits

In locations where the upper monitoring zone (surficial deposits) is absent or minimal in thickness, exploration or test pits will be used. The approximate locations of test pits include the area along the south boundary of the proposed footprint and along the west proposed footprint.

WCG will oversee the excavation of the test pits, which will be excavated by City of Columbia Landfill personnel and equipment. During excavation, the soil encountered in each test pit will be described and logged by a geologist or geologic engineer in general accordance with the Unified Soil Classification System (USCS) in general accordance with ASTM 2488 and standard geologic practice. Color of the soil will be referenced to the Munsell Soil Color Chart. Soil samples will be collected approximately every two feet or at changes in strata for laboratory analysis. Soil laboratory analysis tests are described in **Section 4.3**.

WCG does not expect the test pits to exceed approximately 10 feet in depth. After the test pit has been excavated, logged, and sampled the test pits will remain open for up to 24 hours to observe the level of groundwater (if any) in the test pit. After 24 hours the test pits will be backfilled using native material, compacted to natural density condition, the locations marked with a stake and flagging and surveyed into the site coordinate system and the locations and elevations certified by a Missouri licensed surveyor.

4.2 Drilling

4.2.1 Hollow Stem Auger (ASTM D5784)

Hollow stem augers will be used to advance the borings through the surficial deposits. Continuous split-spoon samples will be collected from the surficial unconsolidated deposits and the blow counts of the standard penetration tests will be recorded on the boring logs. The recovered soil will be described in general accordance with the USCS and standard geologic practice.

4.2.1.1 Split Spoon Samplers (ASTM D1586)

Split spoons will be used through the extent of the upper monitoring zone (surficial deposits) except where replaced by a Shelby-tube. Soil samples while drilling through the upper aquifer (surficial materials) will be collected directly from the split spoons. The field moisture, amount of recovered soil, the soil type/texture, the relative strength/consistency or density/compactness of the soil, and the color will be described and recorded on the field boring logs. The samples will be placed in zip lock bags or jars and labeled with the project name, the date of collection, the boring number, the sample number, the depth, and the blow counts if from a boring. An example of the sample labeling is presented below:

Columbia LF Exp
6-11-2019
B12 SS-4
6’
3/4/6

The samples will be submitted to the laboratory under standard chain of custody for geotechnical testing and characterization. The blow counts will be used to assist in determining the stability during excavation of the landfill subgrade.

4.2.1.2 Shelby Tube Samples (ASTM D1587)

WCG will collect relatively undisturbed Shelby tube samples from 18 (1 per 2 borings/test pits) of the surficial borings or test pits. The Shelby tube samples will be collected above the anticipated shallow groundwater level for testing of soil density and permeability to determine if a low permeable zone is present below the proposed landfill subgrade and the shallow monitoring zone. The Shelby tubes will be pushed approximately 24-inches in depth at a slow rate, allowed to swell if clayey and recovered. The amount of recovered material will be determined and field shear strength tests performed on the recovered soil. Compressive and shear strength will be measured in the field by using a hand-held penetrometer and a Torvane (ASTM D4648) on the base of each Shelby tube. The color of the soil, consistency, and the compressive and shear strength information will be recorded on the field boring log. Each tube will be capped and taped, labeled with the project name, the date of collection, the boring number, sample number, and depth and submitted for laboratory testing under standard chain of custody. An example of the Shelby tube labeling is below.

Columbia LF Exp
6-11-2019
B12 ST-8
16’

4.2.2 Rock Coring (ASTM D2113)

WCG anticipates coring thirteen (13) bedrock borings advanced into the Burlington-Keokuk Limestone. Borings B-4, B-6, B-10, B-16, B-30, B-36, B-42, B-48, B-53, B-60, B-64, B-70, and B-72 will be cored from the first bedrock encountered to approximately 50 feet into the lower aquifer. Additional spot coring will occur in borings B-14 B-18, B-22, B-28, B-38, and B-58 for the purposes of in situ permeability (packer) testing. WCG expects to collect approximately 1,424 feet of total core from the above listed borings. The core samples will be logged and properly labeled and placed into boxes for onsite storage. The core samples will be made available for GSP review. The core boxes will be stored in the facility's administration building through closure of the facility.

The amount of water used during each core run, water return, downhole pressure, and time of each core run will be documented on the field boring logs. The recovered rock core will be described in general accordance with ASTM D5434 and standard geologic practice. The percentage of rock recovered, rock quality designation (RQD by ASTM D6032), fractures, orientation, rock matrix, layering, inclusions, porosity, etc. will be recorded on the field boring logs.

4.2.3 Air Rotary Drilling (ASTM D5782)

If the confining rock layers appear to be consistent across the site and the limestone appears to be consistent, WCG intends to advance the bedrock borings not cored to the termination depths using air rotary methods. If the shale confining layer is not consistent, the confining layer will be cored to the top of the Burlington-Keokuk Limestone following the methods described in **Section 4.2.2**. Any boring that is advanced using air rotary methods will be logged from rock chips from the cuttings. The time to drill the boring, any changes in drilling rate, rock cutting production, and depth of saturated layers will be recorded on the field boring logs. Recovered rock chips will be collected approximately every two feet or drilling rate or formation change, placed in a zip lock bag and labeled with the project name, date of collection, boring number, and depth. The collected rock chips will be rinsed with water and a descriptive log prepared following standard geologic practice. The collected and bagged samples will be stored in totes for later review by MDNR-GSP. The samples will be stored in the facility's administration office through closure of the facility.

4.3 Laboratory Soil Testing

WCG will collect soil samples from the surface material encountered in the unconsolidated deposits for further characterization of the aquifer. The soil samples will be collected at least every two feet while drilling through the upper aquifer. The soil samples will be distinctly labeled in the field, noted on the boring log, and directed to an approved laboratory for soil analysis. The soil samples will be analyzed according to American Society for Testing and Materials (ASTM) standards and protocols. The soil samples will be split for laboratory testing or the untested sample portions recovered from the laboratory for storage and review. If samples are to be held at the laboratory for later recovery, a note will be placed on the chain of custody instructing the laboratory to retain the untested portion of each sample. The samples will be stored in the facility's administration office through closure of the facility.

4.3.1 Moisture Content (ASTM 2216)

Moisture content will be analyzed in soil samples collected from the upper monitoring zone (surficial deposits) borings and test pits. One soil sample will be collected every two feet while drilling or during excavation.

The moisture content results of the samples will aid in characterizing the upper aquifer and identifying groundwater intervals more accurately. WCG anticipates collecting approximately 376 soil samples for moisture content analytical testing based on estimated thickness of the surficial deposits. The samples will be labeled as indicated in **Section 4.2.1.1**.

4.3.2 Atterberg Limits (ASTM D4318)

Atterberg limits (liquid and plastic limits) will be analyzed on representative soil samples collected from the surficial deposits. Limits testing will be assigned based on the uniformity of the surficial materials during drilling or excavation. The Atterberg limit soil samples will be labeled as indicated in **Section 4.2.1.1**.

The Atterberg limits results of the samples will aid in characterizing the upper monitoring zone and provide additional geotechnical information for stability purposes. WCG anticipates collecting approximately 70 soil samples for Atterberg limit analysis or approximately 2 samples per boring or test pit of the unconsolidated deposits.

4.3.3 Particle Size Analysis (ASTM D422 & D6913)

In addition to the index testing in **Section 4.3.2**, soil samples representing the different unconsolidated soil types will be submitted for analysis of particle size by the combined sieve and hydrometer methods. WCG anticipates that 2 samples per boring or test pits in the unconsolidated deposits will be submitted for the particle size analysis or a total of 70 tests. The particle size samples will be labeled as indicated in **Section 4.2.1.1**.

4.4 Permeability Testing

4.4.1 Upper Monitoring Zone (ASTM D2434)

Permeability will be determined from Shelby tube soil samples collected from the upper monitoring zone borings and test pits. Permeability samples will be collected from the upper aquifer (surficial materials) encountered prior to hitting the water bearing location. WCG anticipates the water bearing location in the upper aquifer will be just above the bedrock. The Shelby tube samples will be labeled as indicated in **Section 4.2.1.2**.

The permeability testing data will aid in characterization of the upper monitoring zone (surficial materials). WCG anticipates collecting approximately 18 samples (Shelby tubes) for permeability testing of the aquifer, or approximately 1 sample per 2 borings/test pits in the upper monitoring zone.

4.4.2 Confining Layer Packer Testing

In situ packer tests (pressure injection) will be performed to assess the permeability of the confining layer above the lower aquifer (Burlington-Keokuk Limestone). The packer testing will be conducted after coring to the location of the confining layer. WCG anticipates using a single packer apparatus to isolate zones of interest in the shale. The shale will be cored and the rock core reviewed and the core barrel will be pulled back several feet and the packer apparatus will be extended through the core barrel into the cored interval. The core rods will be extracted to allow the packer to be inflated in the core hole and seat against the bedrock borehole so that only the tested interval is open to receive water.

The packer testing will generally follow the guidance in *"Standard Operating Procedures for Borehole Packer Testing,"* Royle (2002) and in Chapter 16 of the U.S. Bureau of Reclamation's *"Engineering Geology Field Manual, Second Edition, Volume II,"* DOI (2001). WCG plans to perform step pressure testing at each interval. Each test interval will begin at 10 psi increasing by 10 psi up to a maximum of 40 psi. Each step will then be decreased by 10 psi back to the starting pressure of 10 psi. Each pressure step will last approximately 15 minutes and the injection pressure will be observed to keep a steady pressure. If a test interval does not take water, then the testing may be stopped after the 40 psi step. The flow rate and the injection pressures will be graphed to assist in determining the permeability of the shale intervals tested. WCG will test the shale at ~~18~~ 19 various locations to identify a consistent less than permeable interval above the Burlington-Keokuk Limestone.

The collected data will be analyzed following the Sevee (1991) *"Methods and Procedures for Defining Aquifer Parameters"*.

4.4.3 Slug Testing (ASTM D4044)

The MDNR Guidance for a DSI requires that the hydraulic conductivity must be determined in one out of every four piezometers installed for each aquifer tested. There are 18 proposed surficial deposit/upper monitoring zone piezometers and 38 proposed limestone rock piezometers. WCG proposes to slug test 9 of the surficial deposit piezometers if sufficient unconsolidated material is present, and 10 of the bedrock piezometers. A "slug" is a volume of displacement and can be a physical slug, a volume of water, or air that is added or removed instantaneously from the aquifer.

Based on WCG review of the existing hydraulic conductivity data for the upper monitoring zone and the lower aquifer, slug tests will be appropriate to collect the required information and pumping tests will not be needed. If the formations are highly permeable so that the slug testing cannot displace an appropriate amount of water to yield quality data for analysis, then a pumping test may be required and a plan submitted to the GSP at that time.

WCG will use a pressure transducer and data logger to automatically record the displacement and recovery of the tested groundwater zones. The data collection interval will be sufficiently short to record fast changes in the recovery data. The data will be downloaded in the field to check that the equipment was recording and the data are useable for analysis. The slug tests will be allowed to run until the static water level is recovered or within a few tenths of feet. The slug tests will be terminated after 45 minutes if the water levels have not recovered to static levels at that time because the formation permeability is less than the lower bound of hydraulic conductivity that can be calculated by the slug test analysis methods.

Typically, each test will be performed by a "slug-in" (falling head test) and a "slug-out" (rising head test). If the water level is below the top of the screen interval, the slug-in test will not be performed and the slug will be placed in the saturated interval and the slug-out test will be performed once the water level has stabilized. The slug-in test assumes that the filter pack is fully saturated and the pressure exerted on the aquifer is transferred directly to the borehole wall. The collected data will be evaluated using the method appropriate to the well construction and data following the analysis in Hvorslev (1951)[3], Cooper and others (1967)[4] and further refined by the Kansas Geological Survey[5], or Bouwer and Rice (1976)[6] and updated by Bouwer (1989)[7].

4.5 Piezometer Construction

The piezometer construction will follow the Missouri Monitoring Well Construction Code in 10 CSR 23-4. The piezometers are planned to be 2-inch diameter PVC construction. The piezometers will typically have 10 foot long screen intervals, except for those areas where saturated surficial deposits are too thin to allow use of a 10 foot long screen. A typical piezometer construction diagram is provided in **Figure 6**. Prior to construction of each piezometer, the boring will be allowed to equilibrate for a minimum of 24 hours. The location and elevation of each piezometer will be determined by a land surveyor registered in the State of Missouri.

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[3] "Time Lag and Soil Permeability in Ground-Water Observations" Bul. 36, USACE, J. Hvorslev (1951).
[4] "Response of a Finite-Diameter Well to an Instantaneous Charge of Water" Vol. 3, No. 1, WRR, H.H. Cooper, Jr., J.D. Bredehoeft, & I.S. Papadopulos (1967).
[5] "A User Interface for the Kansas Geological Survey Slug Test Model" Vol. 47, No. 4, Ground Water, S. Esling & J.E. Keller (2009).
[6] "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells" Vol. 12, No. 3, WRR, H. Bouwer & R.C. Rice (1976).
[7] "The Bouwer and Rice Slug Test – An Update" Vol. 27, No. 3, Ground Water, H. Bouwer (1989).

4.6 Piezometric Data

Measurements of water level, to the nearest hundredth (0.01) of a foot, will be made every month for one year for all wells and piezometers. The water level measurements in all wells and piezometers will be performed within a 48-hour period. WCG acknowledges that additional measurements may be necessary as determined by the MDNR-GSP.

4.7 On Site Precipitation Measurements

A continuously recording precipitation gauge, capable of measuring precipitation events greater than one-tenth (0.1) inch, will be installed at the site concurrent with, or prior to, installation of piezometers. Data from the gauge will be used to interpret any fluctuations in potentiometric level(s) throughout the site characterization period and may be used for other purposes later.

WCG intends to rely on the facility's precipitation gauge and will request copies of the precipitation data collected by facility personnel.

5 PHASED INVESTIGATION PLAN

5.1 Phase 1A Investigation

Because the site topography varies from previous surface mining to thin cover over bedrock with narrowly incised ravines, WCG proposes to complete an initial investigation of the subsurface by completing test pits and bedrock borings in areas that present concerns to meeting the MDNR's requirements for the geologic conditions. WCG will first excavate 10 test pits located in areas of minimal surficial cover. The initial phase of test pits is listed in **Table 2**. If a test pit does not reach the bedrock surface a boring will be drilled adjacent to the test pit and advanced to the bedrock surface. The boring will be sampled from the base of the test pit to the bedrock surface following the sampling plan described above in **Section 4.3.1**.

The results of the preliminary test pit investigation will be relayed to the MDNR-GSP prior to start of drilling of the preliminary borings described below. If any changes to the DSI work plan are required, WCG will prepare a draft revision and schedule a meeting with the MDNR-GSP. If no changes are anticipated, the second phase of the initial investigation will be completed by advancing the 6 borings as described in **Section 5.2**.

5.2 Phase 1B Investigation

Once the depth to bedrock and type of bedrock is discerned in the initial 10 test pits, 6 borings will be advanced. Five of the borings will be cored, and the shale confining layer packer tested. One of the borings is an unconsolidated boring used to evaluate the mine spoil and permeability of the mine spoil above the water table. The borings to be advanced and completed as piezometers during the initial investigation phase are listed in **Table 2**. The borings will be drilled and sampled as described in **Section 4** for the hollow stem auger and coring methods.

5.3 Phase 2 Investigation

If the test pits and borings reveal that the shale confining layer is absent in the test pits or borings, WCG will discuss revising the proposed waste foot print with the City of Columbia and alert the MDNR-GSP to any modifications. If the waste footprint is modified, WCG will revise the DSI work plan and communicate the changes with the MDNR-GSP. Any changes to the DSI will be submitted to the MDNR-GSP for approval and a meeting will be scheduled with the MDNR-GSP to discuss the changes in the DSI work plan. The findings and results of the initial phase will be included in the revised DSI work plan. If no changes are anticipated to the work plan after the initial investigation phase, WCG will also communicate the findings to the MDNR-GSP and the intent to follow the approved work plan.

TABLES

Weaver Consultants Group

Table 1
Boring/Test Summary
City of Columbia LF 2019 DSI Work Plan
Columbia, Missouri
April 2019

Upper Aquifer (Surficial Deposits)							
				Field Analysis			
Boring/ Test Pit	Surface Elevation	Total Depth	Bottom Elevation	Piezometer	Slug Test	Permeability (Shelby Tube)	MC/AL/GS
TP-1	764.90	6.01	758.89			X	X
TP-3	760.28	6.45	753.83				X
TP-5	732.82	4.00	728.82			X	X
TP-7	734.82	3.50	731.32				X
TP-11	761.78	7.16	754.62			X	X
TP-13	745.15	3.80	741.35				X
TP-15	784.35	6.40	777.95				X
TP-17	810.87	6.65	804.22			X	X
TP-19	811.92	11.41	800.51			X	X
B-21	802.89	21.29	781.60	X	X		X
B-23	778.93	29.06	749.87	X		X	X
TP-25	725.36	6.00	719.36				X
B-27	778.82	41.67	737.15	X		X	X
B-29	803.59	48.62	754.97	X	X		X
TP-31	794.91	3.92	790.99				X
B-33	834.01	20.88	813.13	X		X	X
TP-35	813.03	3.79	809.24				X
TP-37	811.28	5.36	805.92				X
B-39	824.06	44.35	779.71	X	X	X	X
B-41	818.36	72.65	745.71	X	X		X
TP-43	733.84	6.00	727.84				X
TP-45	751.05	8.77	742.28			X	X
B-47	832.00	82.12	749.88	X	X		X
B-49	836.04	47.89	788.15	X		X	X
B-51	838.00	23.42	814.58	X		X	X
B-54	834.45	24.99	809.46	X		X	X
B-56	807.69	17.91	789.78	X	X	X	X
B-57	826.14	63.33	762.81	X			X
TP-59	759.94	12.34	747.60			X	X
B-61	739.31	14.06	725.25	X	X		X
TP-63	751.23	9.66	741.57			X	X
B-65	796.67	39.01	757.66	X	X		X
B-67	810.90	39.86	771.04	X		X	X
B-69	819.56	44.56	775.00	X		X	X
B-71	833.56	30.11	803.45	X	X		X
Upper Aquifer (Surficial Deposits) Totals:				18	9	18	35

Notes:
Surface Elevations are approximate based on facility aerial from January 12, 2018.
Total Depths are approximated based on regional historical boring data.
MC- moisture content analysis
AL- Atterburg Limit analysis
GS - Combined Grain Size analysis

Table 1
Boring/Test Summary
City of Columbia LF 2019 DSI Work Plan
Columbia, Missouri
April 2019

Lower Aquifer (Burlington- Keokuk Limestone)							
				Field Analysis			
Boring/ Test Pit	Surface Elevation	Total Depth	Bottom Elevation	Piezometer	Slug Test	Permeability (Packer Test)	Core
B-2	776.42	**92.42**	684.00	X			
B-4	742.76	**61.76**	681.00	X	X	X	X
B-6	743.79	**64.79**	679.00	X		X	X
B-8	726.37	**52.00**	674.37	X			
B-9	726.50	**52.00**	674.50	X			
B-10	752.90	**74.65**	678.25	X	X	X	X
B-12	781.98	**102.23**	679.75	X			
B-14	788.98	**105.73**	683.25	X		X	X
B-16	793.72	**108.47**	685.25	X	X	X	X
B-18	818.78	**134.28**	684.50	X		X	X
B-20	780.27	**99.02**	681.25	X			
B-22	771.38	**93.13**	678.25	X		X	X
B-24	760.10	**82.60**	677.50	X			
B-26	729.27	**52.17**	677.10	X	X		
B-28	802.93	**125.43**	677.50	X		X	X
B-30	816.81	**136.31**	680.50	X	X	X	X
B-32	820.43	**136.68**	683.75	X			
B-34	811.49	**125.24**	686.25	X			
B-36	832.85	**147.85**	685.00	X		X	X
B-38	824.52	**142.77**	681.75	X		X	X
B-40	821.06	**142.81**	678.25	X			
B-42	761.2	**84.10**	677.10	X		X	X
B-44	737.77	**62.02**	675.75	X			
B-46	819.30	**142.00**	677.30	X			
B-48	830.23	**150.48**	679.75	X	X	X	X
B-50	832.85	**149.05**	683.80	X			
B-52	833.17	**145.92**	687.25	X	X		
B-53	840.81	**153.31**	687.50	X		X	X
B-55	818.24	**135.44**	682.80	X			
B-58	826.19	**148.79**	677.40	X	X	X	X
B-60	752.57	**77.07**	675.50	X		X	X
B-62	738.36	**64.06**	674.30	X	X		
B-64	770.44	**95.64**	674.80	X		X	X
B-66	805.54	**128.79**	676.75	X			
B-68	826.00	**142.20**	683.80	X			
B-70	837.26	**150.14**	687.12	X	X	X	X
B-72	830.16	**148.16**	682.00	X		X	X
B-73	836.48	**150.73**	685.75	X			
Lower Aquifer (Burlington- Keokuk Limestone) Totals:				**38**	**10**	**19**	**19**

Notes:

Surface Elevations are approximate based on facility aerial from January 12, 2018.

Total Depths are approximated based on regional historical boring data.

Table 2
Phase 1 Boring/Test Summary
City of Columbia LF 2019 DSI Work Plan
Columbia, Missouri
April 2019

Boring/ Test Pit	Northing	Easting	Surface Elevation	Total Depth	Bottom Elevation
TP-1	1,154,258	1,712,385	764.9	**6**	758.9
TP-3	1,154,209	1,711,774	760.3	**6**	753.8
TP-5	1,154,131	1,711,120	732.8	**4**	728.8
TP-7	1,154,095	1,710,450	734.8	**4**	731.3
TP-13	1,154,437	1,711,338	745.2	**4**	741.4
TP-17	1,154,912	1,712,619	810.9	**7**	804.2
TP-31	1,155,177	1,711,440	794.9	**4**	791.0
TP-37	1,155,497	1,711,768	811.3	**5**	805.9
TP-35	1,155,532	1,712,634	813.0	**4**	809.2
TP-45	1,155,909	1,710,021	751.1	**9**	742.3
B-16	1,154,560	1,712,560	793.7	**108**	685.3
B-10	1,154,347	1,710,620	752.9	**75**	678.3
B-48	1,155,827	1,711,150	830.2	**150**	679.8
B-53	1,156,201	1,712,651	840.8	**153**	687.5
B-57	1,156,275	1,711,052	826.1	**63**	762.8
B-72	1,156,524	1,711,455	830.2	**148**	682.0

FIGURES

Weaver Consultants Group

US TOPOGRAPHIC MAP, 1:24,000 QUAD, COLUMBIA, MO (2017) USGS
US TOPOGRAPHIC MAP, 1:24,000 QUAD, MILLERSBURG, MO (2017) USGS
US TOPOGRAPHIC MAP, 1:24,000 QUAD, BROWNS, MO (2017) USGS
US TOPOGRAPHIC MAP, 1:24,000 QUAD, HAILSVILLE, MO (2017)USGS

LOCATION: I:\PROJECTS\Columbia Landfill\2101-300-10-04 DSI Plan\DSI Workplan.dwg
LAYOUT: Topographic Map
DATE/TIME: March 14, 2019 - 3:26pm
PLOTTED BY: fbarthol

SCALE: 1" = 2,000'
0 1,000' 2,000' 4,000'

PREPARED FOR:

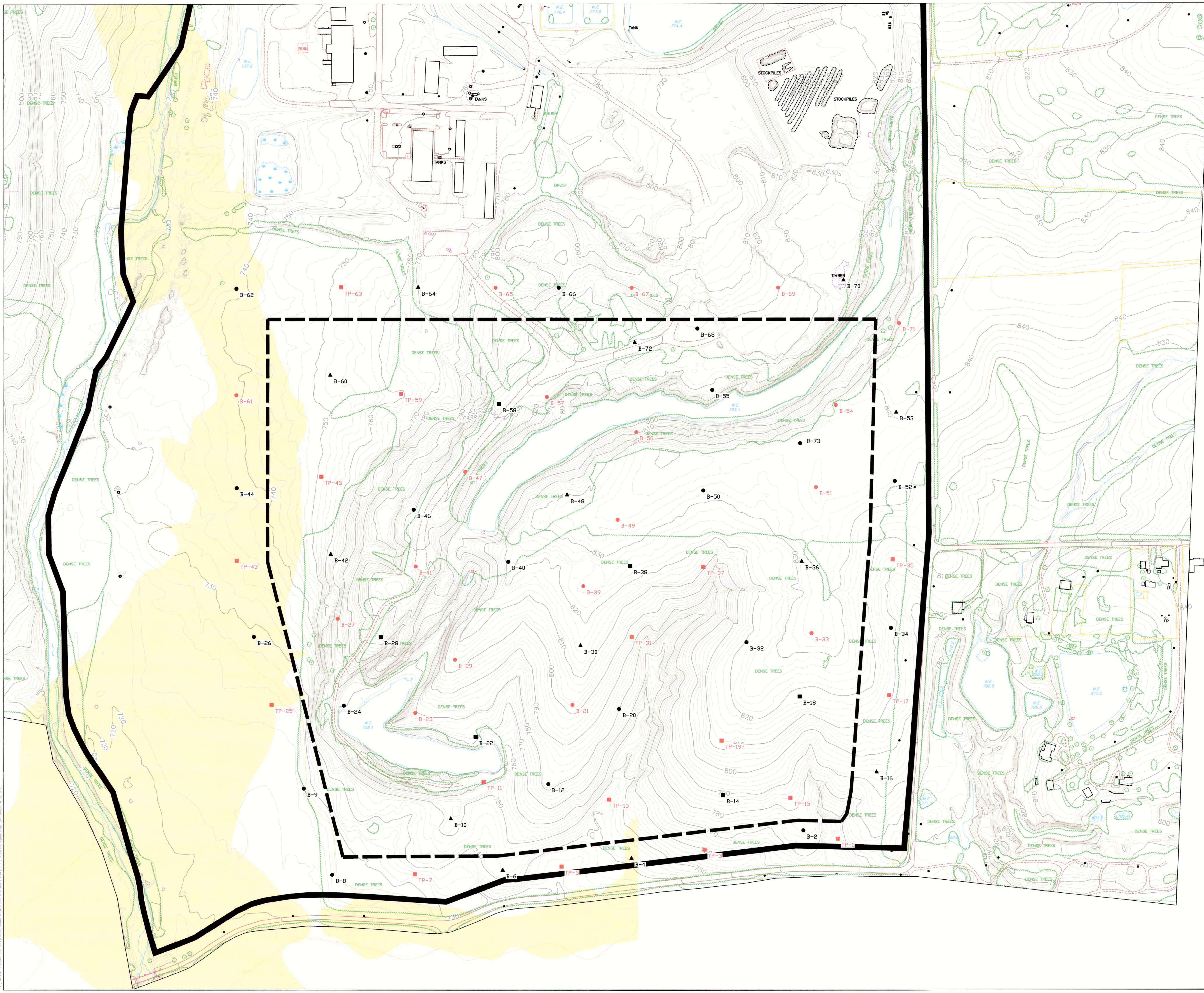
CITY OF COLUMBIA

TOPOGRAPHIC MAP
CITY OF COLUMBIA LANDFILL
2019 DETAILED SITE INVESTIGATION
COLUMBIA, MISSOURI

Weaver Consultants Group
COLLINSVILLE, ILLINOIS
(855) 457-1710 www.wcgrp.com

DRAWN BY: FRB
REVIEWED BY: AJL
DATE: 02/19/2019
FILE: 2101-300-10-04
CAD: DSI Workplan.dwg

FIGURE 1 OF 6



LEGEND:

- APPROXIMATE PROPERTY BOUNDARY
- PROPOSED SOLID WASTE BOUNDARY
- AERIAL CONTOUR
- ROAD
- TREES/BRUSHLINE
- FENCE
- WATER
- FLOODPLAIN
- B-47 ● UPPER AQUIFER (SURFICIAL DEPOSITS) BORING
- TP-1 ■ UPPER AQUIFER (SURFICIAL DEPOSITS) TEST PIT
- B-2 ● LOWER AQUIFER (ROCK) BORING- AIR ROTARY ONLY
- B-2 ■ LOWER AQUIFER (ROCK) BORING- SPOT CORE & AIR ROTARY
- B-2 ▲ LOWER AQUIFER (ROCK) BORING- FULL CORE

NOTES:

1. AERIAL DATED JANUARY 12, 2018.
2. TOTAL UPPER AQUIFER BORINGS: 18
3. TOTAL UPPER AQUIFER TEST PITS: 17
4. TOTAL LOWER AQUIFER BORINGS: 38
5. ALL BORINGS COMPLETED IN THE UPPER AQUIFER (SURFICIAL DEPOSITS) AND LOWER AQUIFER (BURLINGTON-KEOKUK LIMESTONE) WILL BE COMPLETED AS PIEZOMETERS.

N

SCALE: 1" = 200'

0 100' 200' 400'

☐ DRAFT
☐ RELEASED FOR BID
☐ APPROVED FOR CONSTRUCTION
☐ CLIENT APPROVAL BY: ____

PREPARED FOR:
CITY OF COLUMBIA, MO

BORING/ PIEZOMETER LOCATIONS
DIS WORKPLAN
CITY OF COLUMBIA LANDFILL
COLUMBIA, MISSOURI

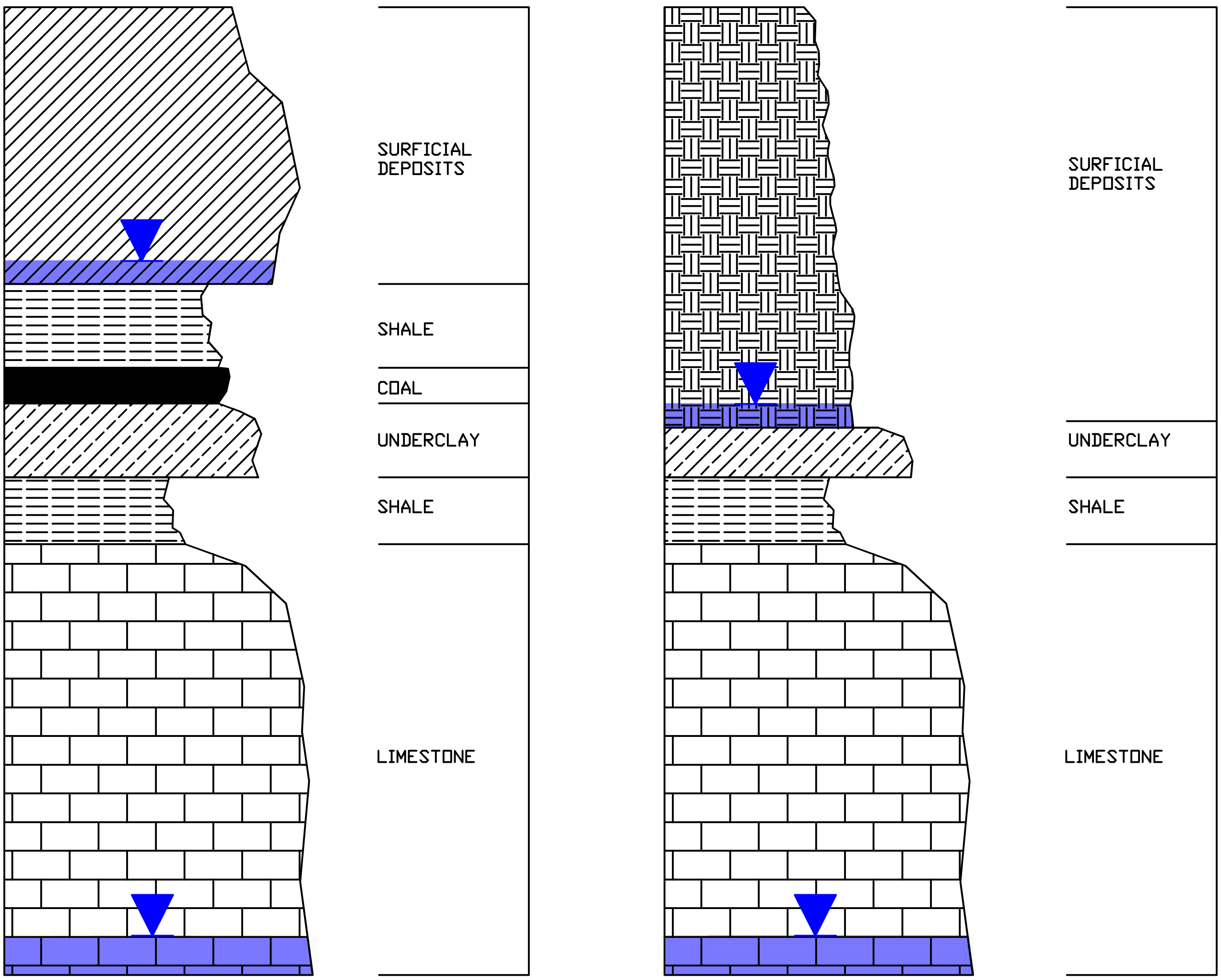
No.	DATE	REVISION DESCRIPTION

Weaver Consultants Group

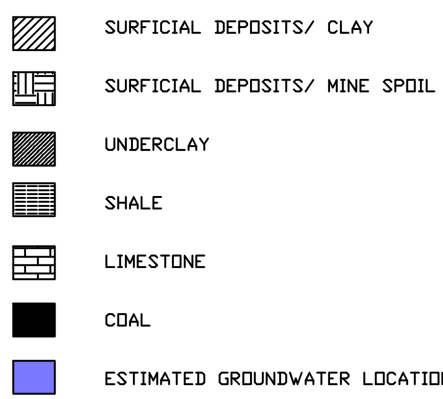
WEAVER CONSULTANTS GROUP
1604 EASTPORT PLAZA DRIVE
SUITE 104
COLLINSVILLE, ILLINOIS 62234
(855) 457-1710
www.wcgrp.com

DRAWN BY:	FRB
REVIEWED BY:	AJL
DATE:	04/16/2019
FILE:	2101-300-10-04
CAD:	DIS Workplan.dwg

FIGURE 2 OF 6



LEGEND:

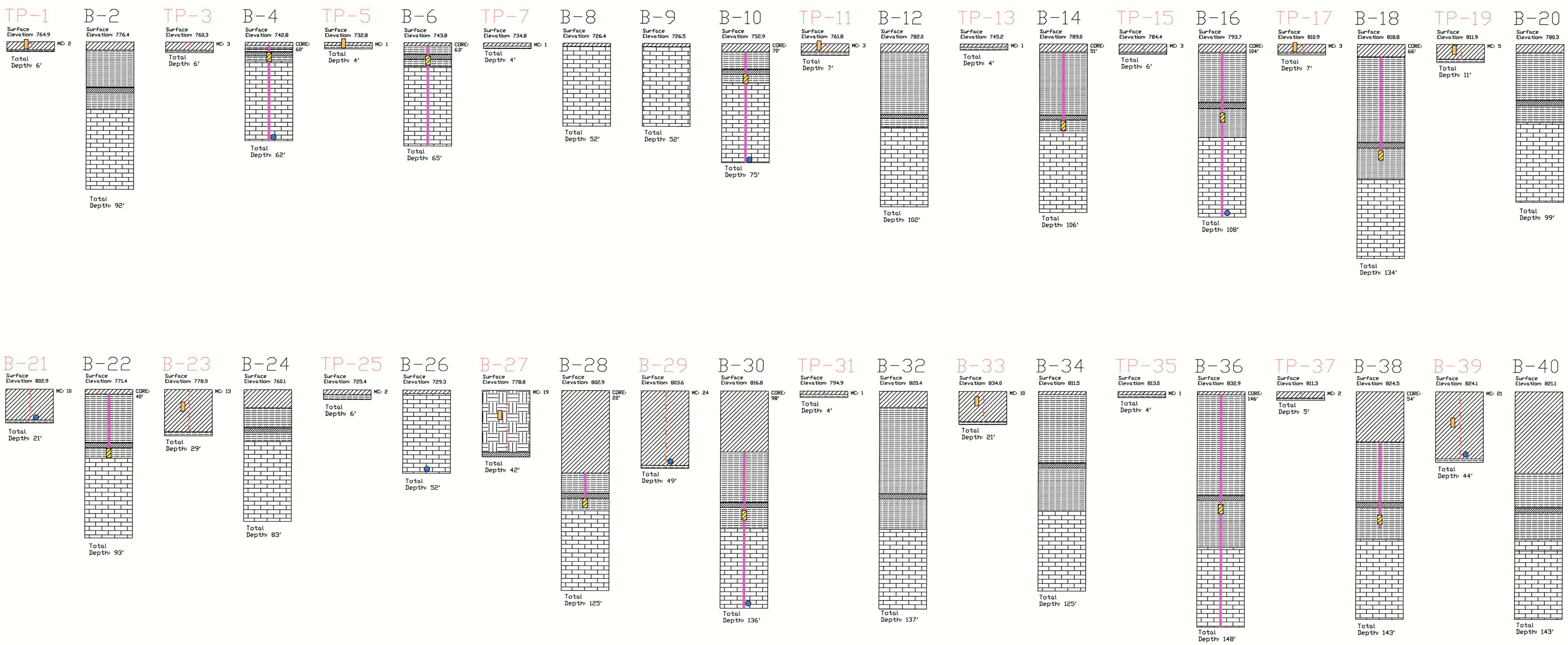


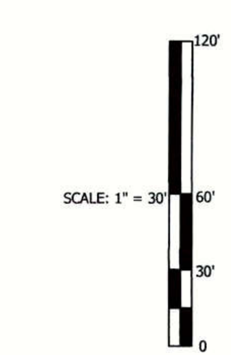
NOTES:

1. DRAWING NOT TO SCALE
2. STRATIGRAPHIC COLUMN APPROXIMATE BASED ON LOCAL BORING LOGS AND REGIONAL GEOLOGIC MAPPING.

LOCATION: I:\PROJECTS\Columbia Landfill\2101-300-10-04 DSI Plan\DSI Workplan.dwg
LAYOUT: Strat Column
DATE/TIME: March 14, 2019 - 11:25am
PLOTTED BY: fbarthol

PREPARED FOR:	STRATIGRAPHIC COLUMN	Weaver Consultants Group	DRAWN BY: FRB
CITY OF COLUMBIA	CITY OF COLUMBIA LANDFILL 2019 DETAILED SITE INVESTIGATION COLUMBIA, MISSOURI	COLLINSVILLE, ILLINOIS (855) 457-1710 www.wcgrp.com	REVIEWED BY: AJL DATE: 02/19/2019 FILE: 2101-300-10-04 CAD: DSI Workplan.dwg FIGURE 3 OF 6





STATE OF MISSOURI
ANDREW J. LIMMER
RG0077
REGISTERED GEOLOGIST
2019

NOTES:

1. DEPTHS OF FORMATIONS ARE APPROXIMATE BASED ON REGIONAL HISTORICAL BORING DATA.
2. SURFACE ELEVATIONS BASED ON SITE AERIAL DATED JANUARY 12, 2018.
3. ANALYSIS LOCATIONS AND INTERVALS ARE APPROXIMATE AND NOT TO SCALE.
4. LOWER AQUIFER (ROCK) BORINGS NOT CORED WILL DRILLED TO THE TERMINATION DEPTHS USING AIR ROTARY.

LEGEND:

- SURFICIAL DEPOSITS/ CLAY
- SURFICIAL DEPOSITS/ MINE SPOIL
- UNDERCLAY
- SHALE
- LIMESTONE
- COAL
- B-49 UPPER AQUIFER (SURFICIAL) BORING/ PIEZOMETER
- TP-1 UPPER AQUIFER (SURFICIAL) TEST PIT
- B-2 LOWER AQUIFER (ROCK) BORING/ PIEZOMETER

ANALYSIS METHOD:	ANALYSIS TOTALS:
MOISTURE CONTENT (MC)	376 SAMPLES (1 EVERY 2 FT)
PERMEABILITY TEST (SHELBY TUBE)	18 (1 PER 2 SURFICIAL BORINGS)
PERMEABILITY TEST (PACKER TEST)	19 (1 PER 2 ROCK BORINGS)
SLUG/ PUMP TEST	19 (9 IN UPPER AQUIFER 10 IN LOWER AQUIFER)
CORE INTERVAL	1,424 TOTAL FT. OF CORE

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☐ APPROVED FOR CONSTRUCTION
☐ CLIENT APPROVAL BY: ______

PREPARED FOR:
CITY OF COLUMBIA

BORING DETAIL

CITY OF COLUMBIA LANDFILL
2019 DETAILED SITE INVESTIGATION
COLUMBIA, MISSOURI

No.	DATE	REVISION DESCRIPTION

Weaver Consultants Group

WEAVER CONSULTANTS GROUP
1604 EASTPORT PLAZA DRIVE
SUITE 104
COLLINSVILLE, ILLINOIS 62234
(855) 457-1710
www.wcgrp.com

DRAWN BY:	FRB
REVIEWED BY:	AJL
DATE:	04/16/2019
FILE:	2101-300-10-04
CAD:	Drilling Outline.dwg

FIGURE 4 OF 6

NOTES:

1. DEPTHS OF FORMATIONS ARE APPROXIMATE BASED ON REGIONAL HISTORICAL BORING DATA.
2. SURFACE ELEVATIONS BASED ON SITE AERIAL DATED JANUARY 12, 2018.
3. ANALYSIS LOCATIONS AND INTERVALS ARE APPROXIMATE AND NOT TO SCALE.
4. LOWER AQUIFER (ROCK) BORINGS NOT CORED WILL DRILLED TO THE TERMINATION DEPTHS USING AIR ROTARY.

LEGEND:

- SURFICIAL DEPOSITS/ CLAY
- SURFICIAL DEPOSITS/ MINE SPOIL
- UNDERCLAY
- SHALE
- LIMESTONE
- COAL
- B-49 UPPER AQUIFER (SURFICIAL) BORING/ PIEZOMETER
- TP-1 UPPER AQUIFER (SURFICIAL) TEST PIT
- B-2 LOWER AQUIFER (ROCK) BORING/ PIEZOMETER

ANALYSIS METHOD:	ANALYSIS TOTALS:
MOISTURE CONTENT (MC)	376 SAMPLES (1 EVERY 2 FT)
PERMEABILITY TEST (SHELBY TUBE)	18 (1 PER 2 SURFICIAL BORINGS)
PERMEABILITY TEST (PACKER TEST)	19 (1 PER 2 ROCK BORINGS)
SLUG/ PUMP TEST	19 (9 IN UPPER AQUIFER 10 IN LOWER AQUIFER)
CORE INTERVAL	1,424 TOTAL FT. OF CORE

STATE OF MISSOURI
ANDREW J. LIMMER
RG0077
REGISTERED GEOLOGIST

☐ DRAFT
☐ RELEASED FOR BID
☐ APPROVED FOR CONSTRUCTION
☐ CLIENT APPROVAL BY: ______

PREPARED FOR:
CITY OF COLUMBIA

BORING DETAIL

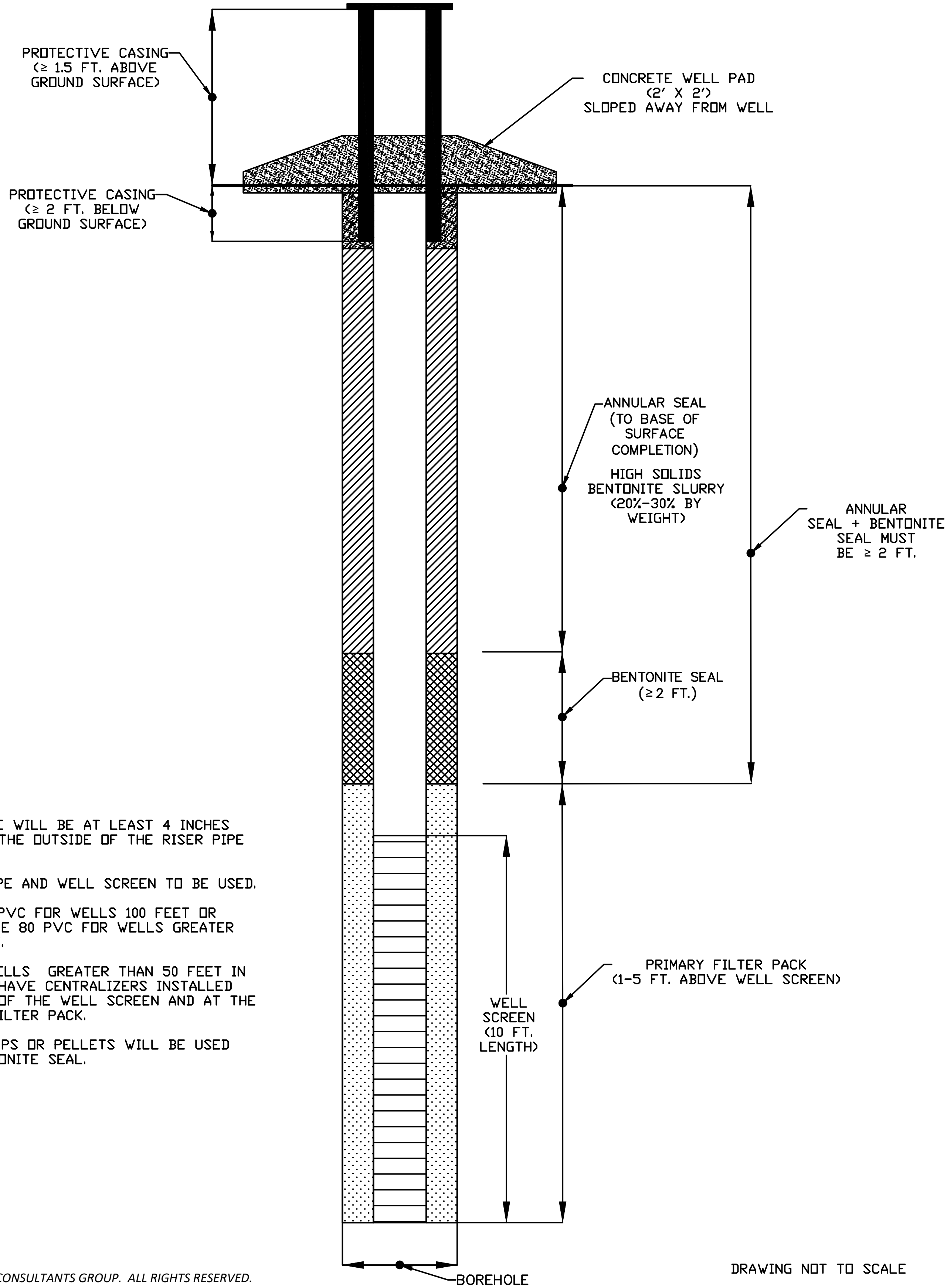
CITY OF COLUMBIA LANDFILL
2019 DETAILED SITE INVESTIGATION
COLUMBIA, MISSOURI

No.	DATE	REVISION DESCRIPTION

Weaver Consultants Group
WEAVER CONSULTANTS GROUP
1604 EASTPORT PLAZA DRIVE
SUITE 104
COLLINSVILLE, ILLINOIS 62234
(855) 457-1710
www.wcgrp.com

DRAWN BY:	FRB
REVIEWED BY:	AJL
DATE:	04/16/2019
FILE:	2101-300-10-04
CAD:	Drilling Outline.dwg

FIGURE 5 OF 6



NOTES:

1. BOREHOLE SIZE WILL BE AT LEAST 4 INCHES LARGER THAN THE OUTSIDE OF THE RISER PIPE AND SCREEN.
2. PVC RISER PIPE AND WELL SCREEN TO BE USED.
3. SCHEDULE 40 PVC FOR WELLS 100 FEET OR LESS. SCHEDULE 80 PVC FOR WELLS GREATER THAN 100 FEET.
4. MONITORING WELLS GREATER THAN 50 FEET IN DEPTH SHALL HAVE CENTRALIZERS INSTALLED AT THE BASE OF THE WELL SCREEN AND AT THE TOP OF THE FILTER PACK.
5. BENTONITE CHIPS OR PELLETS WILL BE USED FOR THE BENTONITE SEAL.

LOCATION: I:\PROJECTS\Columbia Landfill\2101-300-10-04 DSI Plan\DSI Workplan.dwg
LAYOUT: Well Diagram
DATE/TIME: March 14, 2019 - 11:34am
PLOTTED BY: fbarthol

PREPARED FOR:	PIEZOMETER WELL CONSTRUCTION DIAGRAM	Weaver Consultants Group	DRAWN BY: FRB
CITY OF COLUMBIA	CITY OF COLUMBIA LANDFILL 2019 DETAILED SITE INVESTIGATION COLUMBIA, MISSOURI	COLLINSVILLE, ILLINOIS (855) 457-1710 www.wcgrp.com	REVIEWED BY: AJL DATE: 02/19/2019 FILE: 2101-300-10-04 CAD: DSI Workplan.dwg FIGURE 6 OF 6