Appendix E
HDD Design Reports, HDD Cross-Sections, and Geotechnical Reports

for
DRAFT
ENVIRONMENTAL ASSESSMENT

Dakota Access Pipeline Project
Crossings of Federal Projects and Flowage Easements

DRAFT

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August 2016

Horizontal Directional Drill Design Services

Dakota Access Pipeline Project
Illinois River HDD
Pike and Morgan Counties, Illinois

for
Dakota Access, LLC

August 7, 2015

GeoEngineers
Earth Science + Technology

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GEOENGINEERS

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EXECUTIVE SUMMARY

This report provides the Horizontal Directional Drill (HDD) design of GeoEngineers, Inc. (GeoEngineers) for the proposed Dakota Access Pipeline (DAPL) Project Illinois River HDD at approximate DAPL milepost (MP) 901 in Pike and Morgan Counties, Illinois. This report replaces and supersedes previous HDD reports for this proposed crossing. The location of the site is shown on the Vicinity Map, Figure 1.

We understand that Dakota Access, LLC (Dakota Access) is proposing to construct approximately 1,020 miles of 30-inch-diameter steel pipeline extending from Mountrail County, North Dakota through eastern South Dakota, Central Iowa, and terminating in Marion County, Illinois. The proposed Illinois River HDD would cross beneath the Illinois River and adjacent levee under the jurisdiction of the United States Army Corp of Engineers (USACE) in Pike and Morgan Counties, Illinois. The layout of the proposed HDD and approximate boring locations are shown in the attached draft design drawings included in Appendix A.

We explored subsurface conditions near the proposed HDD site between November 11 and 15, 2014, February 10 and 12, 2015, and July 7 and 12, 2015 by drilling seven geotechnical borings (IR-B-1 through IR-B-7) to depths of up to approximately 110 feet below ground surface (bgs) adjacent to the alignment of the proposed HDD. In general, the subsurface conditions encountered in the borings were consistent with published geology for the area, consisting of very soft to medium stiff clay, soft to medium stiff silt, and loose to dense sand with varying amounts of silt and gravel overlying limestone bedrock. Details of our subsurface exploration program are included in our geotechnical data report attached as Appendix B.

Hydraulic fracture and drilling fluid surface release analyses were performed along the HDD profile. In general, the results indicate that the risk of localized hydraulic fracture and drilling fluid surface release are low due to the sand units along the HDD profile, with calculated factors of safety greater than 2 along the majority of the crossing as shown in Figure 3. Also shown in Figure 3, the factors of safety within the USACE Pressure Monitoring Zone (PMZ) are greater than 2.0. The risk of hydraulic fracture and drilling fluid surface release is moderate to high within approximately 600 feet of the HDD exit point. Low factors of safety against drilling fluid surface release are common near the exit point because the thickness of the soil above the HDD profile decreases as it nears the exit point while the estimated annular pressures caused during pilot hole operations increase.

The contractor's means and methods during construction are crucial to the successful completion of the HDD. Specifically, during pilot hole operations, the HDD contractor's ability to maintain proper drilling fluid properties with appropriate penetration and drilling fluid flow rates will be critical factors to consider during drilling because hole conditions and annular drilling fluid pressures will be directly affected by these factors. Maximum allowable annular drilling fluid pressures will be dictated by the USACE permit and annular drilling fluid pressures in excess of the permitted pressures will not be allowed. The HDD contractor should take all precautions to maintain drilling fluid returns during HDD operations to reduce the risk of hydraulically fracturing the formation along the drill profile. The HDD contractor should be prepared to maintain an annular solids content of less than 20 percent during drilling operations to reduce the risk of the annulus becoming blocked from an accumulation of drill cuttings falling out of suspension from the drilling fluid. <u>If the hole becomes blocked and drilling fluid returns to the entry or exit pits are lost, the hydraulic fracture and inadvertent drilling fluid returns evaluation is no longer valid.</u> The HDD contractor should be required to maintain drilling fluid returns at all times during each stage of the HDD process, which may require

additional efforts such as tripping out the drill pipe string and downhole tooling to restore drilling fluid returns or other adjustments to the drilling procedures.

Based on the information available at this time, the results of our exploration and laboratory testing program and our engineering analyses, it is our opinion that the proposed Illinois River HDD is technically feasible and can be completed in compliance with USACE requirements. However, this opinion is based upon the HDD contractor using best drilling practices and implementing plans and procedures that are in accordance with the USACE permit requirements.

A prequalification process of the candidate HDD contractors should be initiated and then an agreement set in place with the selected contractor so that detailed construction procedures can be agreed upon during the preconstruction phase. *We recommend that only HDD contractors with experience successfully completing pipeline installations beneath USACE levees be selected to complete the work.* The HDD contractor will need to fully understand and embrace the USACE's permit conditions and performance requirements to successfully complete this crossing. Provided the recommendations contained in this report are incorporated into the HDD contractor's procedures, and the contractor uses appropriate construction methods during all phases of the project, we anticipate successful installation of this HDD project.

This Executive Summary should be used only in context of the full report for which it is intended.

1.0 INTRODUCTION

At the request of Dakota Access, LLC (Dakota Access) and in general accordance with our subcontract agreement (No. 07-PSA-0017) GeoEngineers, Inc. (GeoEngineers) is pleased to submit this report which replaces and supersedes previous reports provided for the Horizontal Directional Drill (HDD) design of the proposed Dakota Access Pipeline (DAPL) project Illinois River HDD located at approximate DAPL Milepost (MP) 901 in Pike and Morgan Counties, Illinois. The project site is shown on the Vicinity Map, Figure 1.

We understand that Dakota Access is proposing to construct approximately 1,020 miles of 30-inch diameter steel pipeline extending from Mountrail County, North Dakota through eastern South Dakota, Central Iowa, and terminating in Marion County, Illinois. Further, we understand Dakota Access is proposing to construct approximately 151 miles of gathering line, consisting of 12.75, 20, 24, and 30-inch-diameter steel pipeline in McKenzie, Mountrail, and Williams Counties, North Dakota.

The proposed Illinois River HDD will consist of a 30-inch-diameter steel crude oil pipeline crossing beneath the Illinois River and adjacent levee under the jurisdiction of the United States Army Corp of Engineers (USACE) within Pike and Morgan Counties, Illinois as part of the DAPL 30-inch mainline system. The proposed plan and profile of the HDD are shown on the design drawings in Appendix A.

We explored subsurface conditions near the proposed HDD site between November 11 and 15, 2014, February 10 and 12, 2015, and July 7 and 12, 2015 by drilling seven geotechnical borings (IR-B-1 through IR-B-7) to depths of up to approximately 110 feet below ground surface (bgs) adjacent to the alignment of the proposed HDD. In general, the subsurface conditions encountered in the borings were consistent with published geology for the area, consisting of very soft to medium stiff clay, soft to medium stiff silt, and loose to dense sand with varying amounts of silt and gravel overlying limestone bedrock. GeoEngineers previously submitted a Geotechnical Data Report for the referenced location dated July 17, 2015; this report is attached as Appendix B.

1.1 Basis of Design

Our HDD design has been completed in general accordance with the latest versions of the Code of Federal Regulations (CFR), Title 49, Part 195, American Society of Mechanical Engineers (ASME) B31.4 and generally accepted practices within the pipeline industry. Where more conservative, we analyzed the design per the gas pipeline requirements found in Part 192 of the CFR Title 49 and ASME B31.8. The HDD design engineering was completed based on the parameters discussed with the project team, and are presented below in Table 1.

TABLE 1. BASIS OF DESIGN FOR THE 30-INCH ILLINOIS RIVER HDD

Product pipe Data	Design Parameter
Product pipe Specifications	30 inches x 0.625 inches w.t.[a] API 5L – X70
Horizontal Crossing Length	6,500 feet
Maximum Allowable Operating Pressure	1,440 psig[b]
Maximum Operating Temperature	100 degrees F
Tie-In Temperature	70 degrees F
Design Factor[c]	0.50

Notes:

[a] w.t. – wall thickness

[b] psig – pounds per square inch gauge

[c] As defined in CFR 49 Sections 192.5 and 192.111

2.0 HDD CONSTRUCTION REQUIREMENTS AND RECOMMENDATIONS

2.1 General

Based on the information available at this time, the results of our subsurface exploration and laboratory testing program and our engineering analyses, it is our opinion that the proposed Illinois River HDD is technically feasible, provided the construction requirements specified within the Dakota Access Construction Specification, Specification Number: DAPL-WGM-GN000-PRE-SPC-00001 (Construction Specification) dated April 20, 2015, and noted in the design drawing are incorporated into the HDD contractor's drill plan. However, this opinion is based upon the HDD contractor adhering to the requirements contained herein and implementing plans and procedures that are in accordance with the USACE permit requirements as discussed in Section 2.2. In addition, the HDD contractor should make all reasonable attempts to utilize "Best Drilling Practices" during all construction phases of the project. This report also provides our construction recommendations that, in our opinion will help mitigate some of the risks inherent with this project and increase the likelihood that the installation will be completed successfully and on schedule. The construction recommendations for consideration by the project team and prospective HDD contractors are provided in Section 2.3. A detailed discussion of the construction risks and general construction considerations is provided in Section 3.0.

2.2 USACE Permit Requirements

Because this HDD will cross beneath a levee under the jurisdiction of the USACE, special construction requirements will be enforced on this project. The following items are typically required based on our experience with similar projects under the jurisdiction of the USACE:

1. The HDD contractor will be required to prepare and submit a detailed HDD drill plan for review and approval that describes their planned equipment and drilling procedures to successfully complete the installation in compliance with the USACE permit requirements.
2. A third-party geotechnical engineer is required to be on-site during all HDD operations. The third-party engineer and all USACE staff shall be permitted full-time access to the drill cab, all drilling operations and data.

3. The USACE limits the allowable annular drilling fluid pressure when jetting or reaming the hole within the PMZ. This is typically within 300 feet of the levee crest. Downhole annular drilling fluid pressures above the maximum allowable limits specified by the USACE are not permitted within the PMZ.
4. The contractor must use a downhole survey system capable of monitoring and recording downhole annular drilling fluid pressures while jetting and reaming the hole through the PMZ. The downhole annular pressure sensor is required to be within 5 feet of the drill bit or reaming tool. The USACE has allowed exceptions to this requirement in the past depending on conditions encountered during drilling operations. However, the HDD contractor should anticipate mobilizing jetting and reaming assemblies to the site that meet this requirement.
5. Changes to the HDD design or drilling plan that will affect the potential for hydraulic fracture and/or inadvertent drilling fluid returns must be submitted to the USACE for approval prior to implementation, along with an updated hydraulic fracture analysis utilizing the changed parameters.
6. As soon as practical after the product pipe is pulled into the reamed hole, the annulus between the reamed hole and the installed product pipe must be grouted with a cement-bentonite grout on the entry side of the drill profile. The contractor is responsible for submitting a plan for installing the grout plug.

During the bidding process, the prospective HDD contractors should be made aware of the permit stipulations so that they can prepare a submittal that accounts for the additional permit requirements. GeoEngineers can assist in answering questions regarding the permitting process and requirements. Additionally, we recommend that DAPL engage HDD contractors with experience successfully completing USACE Levee crossings to complete this project.

2.3 Construction Recommendations

This section provides GeoEngineers' construction recommendations that we recommend be considered by the prospective HDD contractor to increase the likelihood that the pipeline can be successfully installed without damage or significant construction difficulties and delays. Our recommendations are not meant to be exhaustive and do not relieve the contractor from the responsibility of reviewing all of the information related to the proposed crossing and developing his own plan to accomplish the installation without damage to the product pipe, or unplanned delay.

We recommend that the risks we identify, along with any other risks that the contractor perceives be discussed prior to construction. In this manner the project team will be able to identify and quantify costs associated with project risk. The implementation of our recommendations may, in some instances, increase the initial cost estimates for construction. However, in our experience, the higher initial estimates can be much more reflective of ultimate project costs and reduce the budget uncertainty related to construction risk. We recommend the construction bid packages require that prospective HDD contractors supply unit costs for risk mitigation items so that they can be better evaluated in the bid selection phase. In the event that some of these measures are deemed necessary after award of the contract, their associated costs will have already been negotiated.

TABLE 2. GEOENGINEERS' CONSTRUCTION RECOMMENDATIONS

General Recommendations
We recommend that the prospective contractors visit the site and evaluate the designated access routes to determine what improvements might be necessary and what considerations may be needed to mobilize their equipment to the site.
We recommend that the prospective contractors visit the workspace areas to determine the extent of preconstruction site preparation necessary for HDD activities.
Pilot Hole Recommendations
We recommend that the secondary survey wires be placed at least as wide as the design profile is deep plus an allowance for any deviations from the design that may occur during pilot hole operations. As a result, the depth of the HDD profile will require the coil to increase in width from approximately 20 feet wide near the entry and exit locations to a minimum of approximately 115 feet wide through deeper portions of the drill profile.
We recommend that the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system.
We recommend that the HDD contractor install small diameter conductor casing while conducting pilot hole operations because of the loose soils within the entry tangent. The casing should help to improve hole stability, lower downhole annular drilling fluid pressures and aid in steering the bottom hole assembly.
We recommend that the HDD contractor consider completing the pilot hole via the intersect method.
We recommend that the HDD contractor's as-built drawing be reviewed by GeoEngineers prior to storing the data in the project file.
Reaming and Swabbing Recommendations
We recommend that the HDD contractor consider forward reaming the pilot hole from entry toward exit in an effort maintain lower downhole annular drilling fluid pressures through the PMZ. This could include bi-directional reaming of the hole in preparation for pullback operations.
If pull reaming passes from exit to entry are conducted, we recommend that the HDD contractor utilize a high pressure drilling fluid pump and drilling fluid recycling system within the exit workspace to facilitate recycling drilling fluid returns and to assist with preventing delays which may be incurred from drilling fluid returns flowing to the exit pit.
We recommend that the HDD contractor adjust the penetration and/or pump rates while conducting reaming operations to maintain an annular solids content of 20 percent or less.
Installation Recommendations
We recommend a minimum bending radius of 1,000 feet while stringing and handling the product pipe to protect against pipe damage while moving the product pipe into position for pullback.
We recommend that the HDD contractor utilize a drill rig that provides an adequate factor of safety between the drill rig capacity and the pull loads they anticipate.
We recommend that buoyancy control measures be utilized during pullback operations.
We recommend the HDD contractor be required to provide the maximum anticipated pull force required to install the product pipe and the maximum allowable pull force that can be applied to their downhole tooling.
Annular Grout Plug
We recommend selecting a specialty contractor experienced in this type of work and who is familiar with the USACE requirements.

3.0 HDD CONSTRUCTION RISKS AND CONSIDERATIONS

3.1 Construction Risks

The contractor's means and methods during construction are critical to the successful completion of the HDD. The USACE will require a qualified drilling fluid engineer to evaluate the drilling fluid properties on a continuous basis during the entire drilling and installation process. Close coordination between the contractor and the drilling fluid engineer is vital to maintaining proper drilling fluid properties, penetration rates and drilling fluid flow rates required for our hydraulic fracture and inadvertent returns calculations to remain valid. If proper construction techniques as described herein are used in conjunction with the presence of a GeoEngineers representative and a drilling fluid engineer, we anticipate the likelihood to be high for successfully completing the proposed HDD installation in accordance with the USACE permit requirements.

3.1.1 Hydraulic Fracture

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the soil surrounding a drill path. Soils that are most vulnerable to hydraulic fracture include relatively weak cohesive soils or loose granular soils with low shear strength. Medium dense to very dense sands and very stiff to hard silts and clays generally have a low to moderate hydraulic fracture potential. HDD installations with greater depth or drill profiles in formations with higher shear strength may reduce the potential for hydraulic fracturing.

3.1.2 Inadvertent Drilling Fluid Returns

Inadvertent drilling fluid returns occur when drilling fluid emerges at the ground surface or in any other undesired location such as wetlands, utility trenches, basements, roads, railroads, and waterbodies. In practice, inadvertent drilling fluid returns typically occur in proximity to the entry and exit points where soil cover is thin. Inadvertent drilling fluid returns can also occur at locations along a drill path where there are low shear strength soils, where the thickness of soil cover is thin or along preexisting fractures or voids. Other locations where inadvertent drilling fluid returns can occur include exploratory boring locations, or along the edges of existing subsurface structures such as piles or utility poles.

The HDD contractor's construction procedures constitute another important factor influencing when and where drilling fluid loss occurs. If the contractor operates with insufficient drilling fluid flow rates, inadequate drilling fluid properties or excessive rates of penetration, the annulus may become blocked through an accumulation of drill cuttings falling out of suspension. This can occur within formations that typically have a low potential for hydraulic fracture. <u>If the accumulation of cuttings creates a blockage downhole, the annulus may become over-pressurized, leading to hydraulic fracturing and potentially inadvertent drilling fluid returns.</u> <u>If this occurs, the hydraulic fracture calculations are no longer applicable.</u>

3.1.3 Hydraulic Fracture and Inadvertent Drilling Fluid Returns Analysis

General

The procedures used to evaluate the potential for drilling fluid loss through hydraulic fracturing are based primarily on research completed by Delft Geotechnics, as discussed in Appendix B of the USACE Report CPAR-GL-98 (Staheli, et al., 1998, "Installation of Pipelines Beneath Levees Using Horizontal Directional Drilling," U.S. Army Corps of Engineers, Waterways Experiment Station, CPAR-98-1). The methodologies used to estimate the hydraulic fracture potential outlined in the research are based on cavity expansion

theory. The cavity expansion model is used to estimate the maximum effective pressure in the drill hole before plastic deformation of the drill hole occurs.

Model Input Parameters

In order to evaluate the hydraulic fracture and inadvertent drilling fluid returns potential for a given case, assumptions must be made when selecting the input parameters. The assumptions used in the model include the extent and uniformity of soil layers, hydrostatic water pressures, drilling fluid properties, penetration rates and pump rates. The soil strength properties are estimated based on interpretations of the boring logs and laboratory test results. The drilling fluid properties, penetration rates and pump rates are estimated based on generally accepted best drilling practices of the HDD industry. Consequently, the results of the evaluation are only estimates of the potential for hydraulic fracture and inadvertent drilling fluid returns.

The soil units encountered in the vicinity of the Illinois River HDD are characterized by borings IR-B-1 through IR-B-7. A general description of the subsurface conditions encountered in the explorations is presented in the exploration logs which are included in Appendix B. In general, the subsurface conditions encountered in the borings were consistent with published geology for the area, consisting of very soft to medium stiff clay, soft to medium stiff silt, and loose to dense sand with varying amounts of silt and gravel overlying limestone bedrock. Based on the results of the subsurface exploration program and subsequent laboratory testing program, the soil properties used in the evaluation are presented in Table 3 below.

TABLE 3. ESTIMATED SOIL PROPERTIES

Soil Description	Unit Weight (pcf)[a]	Friction Angle (degrees)	Cohesion (psf)[b]
Very Soft Clay	115	0	50 – 250
Medium Dense to Dense Sand	110 – 125	26 – 36	0
Medium Dense Sand with Silt	115 – 120	30 – 32	0

Notes:

[a] pcf – pounds per cubic feet

[b] psf – pounds per square foot

In addition to the subsurface soil conditions, the drilling fluid and tooling properties influence the risk of hydraulic fracture and inadvertent returns and are dependent on the field conditions and the construction practices of the HDD contractor and drilling fluid engineer. Changes in these factors can significantly affect the potential for hydraulic fracture and inadvertent drilling fluid returns. The parameters used in the evaluation for the Illinois River HDD installation are summarized in Table 4. Because these parameters are dependent upon the HDD contractor's means and methods, the hydraulic fracture and inadvertent drilling fluid returns evaluation should be refined during the construction phases of the project to reflect the tooling and drilling fluid properties being utilized.

TABLE 4. MODEL INPUT PARAMETERS

Parameter	Typical Values
Pilot Hole Bit Diameter	9.875 inches
Drill Pipe Diameter	5.5 inches
Drilling Fluid Unit Weight	9.5 ppg[a]
Plastic Viscosity	14 CP[b]
Yield Point	30 lb/100 sf[c]

Notes:

[a] ppg – Pounds per gallon

[b] CP – Centipoise

[c] lb/100 sf – Pounds per 100 square feet

Results of Inadvertent Drilling Fluid Returns Evaluation

Based on the soil properties, rheological parameters and anticipated tool dimensions, the model considers the total and effective overburden stresses, shear strengths of the soil, and the estimated drilling fluid pressures along the drill path. A comparison is then made of the estimated drilling fluid pressures immediately behind the drill bit and the ability of the formation to resist plastic deformation.

When evaluating the risk of hydraulic fracture and inadvertent drilling fluid returns, the analysis computes two types of factors of safety. These are:

- Factor of Safety against localized hydraulic fracture; and
- Factor of Safety against drilling fluid surface release.

Local Hydraulic Fracture: The factor of safety against hydraulic fracture is the ratio of the formation limit pressure to the estimated drilling fluid pressure along the profile, shown as the green line in Figure 3. This represents the factor of safety against hydraulic fracture of the soil immediately surrounding the HDD profile and is a localized condition.

Drilling Fluid Surface Release: The factors of safety against inadvertent drilling fluid returns considers the strength of the soil column above the HDD profile that resists drilling fluid migrating to the ground surface. It is computed by comparing the formation limit pressure of the soil units above a specific point along the planned HDD alignment to the anticipated drilling fluid pressure at that same point.

Table 5 below shows the relative risk associated with the estimated factors of safety against hydraulic fracture and inadvertent drilling fluid returns.

TABLE 5. RELATIVE HYDRAULIC FRACTURE AND INADVERTENT DRILLING FLUID RETURNS RISK

Factor of Safety	Relative Risk
Less than 1	Very High
Between 1 and 1.5	High
Between 1.5 and 2	Moderate
Greater than 2	Low

The results of the evaluation of hydraulic fracture potential for the Illinois River HDD are presented in Figures 2 and 3. The formation limit pressure, presented as the green line in Figure 2, represents the estimated ability of the soil to resist plastic deformation and is a product of the overburden stress and shear strength of the soil through which the HDD profile passes.

The estimated drilling fluid pressure is shown as the red line in Figure 2 and represents the drilling fluid pressure along the HDD profile based on the anticipated drilling fluid properties shown in Table 4. The ratio of the formation limit pressure to the estimated drilling fluid pressure is the factor of safety against hydraulic fracture, shown as the green line in Figure 3. The factors of safety against inadvertent drilling fluid returns are also shown in Figure 3 at selected discrete points represented by red triangles.

The hydraulic fracture and inadvertent drilling fluid returns model indicates that there is a low risk of hydraulic fracture along most of the proposed HDD alignment. Figure 3 illustrates this where the factors of safety are greater than 2.0 along most of the HDD alignment. Also shown in Figure 3, the factors of safety within the USACE Pressure Monitoring Zone (PMZ) are greater than 2.0. However, there is what we would consider a moderate risk of hydraulic fracture and inadvertent drilling fluid returns between stations 27+50 and 48+00 due to the relatively lower strength of the sand units and the ground surface topography in this area.

The risk of hydraulic fracture and drilling fluid surface release is moderate to high within approximately 600 feet of the HDD exit point. Low factors of safety against drilling fluid surface release are common near the exit point because the thickness of the soil above the HDD profile decreases as it nears the exit point while the estimated annular drilling fluid pressures during pilot hole operations increase.

The HDD contractor should use best management practices to reduce the potential for hydraulic fracture and inadvertent drilling fluid returns. This includes, but is not limited to maintaining drilling fluid circulation during all phases of HDD operations to prevent the annular drilling fluid pressures from exceeding the maximum allowable pressure. If drilling fluid returns begin to slow or are lost, the HDD contractor should trip out the downhole tooling until full drilling fluid returns are re-established before proceeding forward. The HDD contractor may also reduce the risk of inadvertent returns by completing the pilot hole via the intersect method and bi-directional reaming of the hole. As a requirement for this project the HDD contractor will be required to submit a detailed HDD drill plan outlining their planned drilling practices and contingency procedures.

3.1.4 Drill Hole Stability

In general, soil conditions encountered in the exploration borings near the proposed HDD alignment were consistent with published geology for the area, consisting of very soft to medium stiff clay, soft to medium stiff silt, and loose to dense sand with varying amounts of silt and gravel overlying limestone bedrock. The very loose to loose near-surface soils could present hole stability concerns. We recommend that the HDD contractor install small diameter conductor casing while conducting pilot hole operations because of the loose soils within the entry tangent of the drill profile. The casing should help to improve hole stability, lower downhole annular drilling fluid pressures and aid in steering the bottom hole assembly.

3.2 Construction Considerations

3.2.1 Site Access

The proposed HDD entry workspace will most likely be accessed via a temporary access road from 500th Street northwest of the site. Little to no clearing or grading should be required prior to mobilizing equipment to the site.

The HDD exit and product pipe stringing and fabrication workspaces may be accessed directly from Old Dump Road or Old Naples Lane north and west, respectively of the site. Little to no clearing or grading should be required prior to mobilizing equipment to the site.

Depending upon conditions at the time of construction, load-dispersing materials such as timber mats or quarry rock may be required to maintain stabilization of the equipment entering the locations. We recommend that the prospective contractors visit the site and evaluate the designated access routes to determine what improvements might be necessary and what considerations may be needed to mobilize their equipment to the site.

3.2.2 Workspace Considerations

The temporary workspace at entry includes a rectangular-shaped area measuring 200 feet wide by 250 feet with the entry point positioned 75 feet from the front (southeast side) of the workspace. The entry workspace is located in a relatively flat, open agricultural field such that little to no clearing or grading should be needed prior to mobilization of equipment to the site.

The temporary workspace at exit includes a rectangular-shaped area measuring 200 feet wide by 250 feet in length with the exit point positioned 75 feet from the front (northwest side) of the workspace. The exit workspace is located in a relatively flat, open agricultural field such that little to no clearing or grading should be needed prior to mobilization of equipment to the site.

The proposed product pipe stringing and fabrication workspace will extend 6,700 feet southeast of the temporary workspace at exit and has a 3,600-foot-radius horizontal curve that curves southward as depicted in the HDD Stringing Workspace drawing included in Appendix A. The product pipe stringing and fabrication workspace is of sufficient length to string the product pipe pull section in one continuous section. However, the product pipe stringing area crosses Cemetery Road and may have to be fabricated in two sections that are divided by Cemetery Road to maintain a continuous flow of traffic. Significant grading and clearing of the product pipe stringing area should not be needed prior to stringing and fabricating the product pipe pull section.

We recommend that the prospective contractors visit the workspace areas to determine the extent of clearing and grading necessary to prepare the site for HDD activities and to facilitate planning for the stringing of the product pipe pull section and handling of the pipe during pullback operations.

3.2.3 Proposed HDD Plan and Profile

Plan and profile design drawings for the proposed Illinois River HDD are included in Appendix A. The design drawings include the necessary geometric information required to complete the pilot hole and the site-specific construction requirements. Detailed calculations for minimum allowable radius of curvature, operating stresses and installation loads and stresses are also included for reference in Appendix A.

The proposed Illinois River HDD is approximately 6,500 feet long as measured along the HDD centerline, with a length of approximately 6,510 feet as measured along the drill profile. The radius of curvature for the entry and exit vertical curves is 3,200 feet which is larger than industry design standards to provide additional radius tolerance while advancing the pilot hole. The HDD profile was designed to a depth to help provide adequate clearance under the Illinois River and levee, thereby reducing the risk of experiencing inadvertent drilling fluid returns in the vicinity of these features.

3.2.4 Pilot Hole Considerations

Pilot Hole Survey

The HDD contractor should be required to provide and maintain instrumentation to document and accurately locate the pilot hole. This effort should include the use of a downhole steering tool as well as a secondary survey system (TruTrack, ParaTrack, or equivalent) or gyroscopic steering tool. The HDD contractor should not be allowed to drill any portion of the pilot hole without the use of a secondary survey system or gyroscopic steering tool unless agreed to in advance by the Company. If the HDD contractor elects to use the wire coil grids with these secondary survey systems, we recommend that the secondary survey wires be placed at least as wide as the design profile is deep plus an allowance for any deviations from the design that may occur during pilot hole operations. As a result, the depth of the HDD profile will require the coil to increase in width from approximately 20 feet wide near the entry and exit locations to a minimum of approximately 115 feet wide through deeper portions of the drill profile. The placement of the coils is limited to areas where ground surface conditions, permit requirements, and agreements with landowners allow and as such, we recommend that the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system. After surveying the secondary survey wire, the HDD contractor should report any lack of closure that may indicate incorrectly located entry and/or exit points or any other potential discrepancy with the design information provided on the design drawing.

Annular Pressure Monitoring

The contractor must use a downhole survey system capable of monitoring and recording downhole annular drilling fluid pressures while jetting the hole through the PMZ. In addition, the contractor must also use a downhole survey system capable of monitoring and recording downhole annular drilling fluid pressures while reaming the hole through the PMZ. The downhole annular pressure sensor is required to be within 5 feet of the drill bit and/or reaming tool. The USACE has allowed exceptions to this requirement in the past depending on conditions encountered during drilling operations; however, the HDD contractor should anticipate mobilizing a jetting assembly to the site that meet this requirement. Downhole annular drilling fluid pressures above the maximum allowable limits specified by the USACE are not permitted within the PMZ.

Tolerances

Based on the design geometry and proposed product pipe specifications, the minimum allowable three-joint vertical radius over any consecutive three-joint section should not be less than 2,050 feet. The three-joint radius should be calculated for each three-joint (for Range 2 drill pipe) section (approximately 90 feet) drilled during pilot hole operations. The horizontal pilot hole tolerances are no more than 10 feet left and 10 feet right of the designed alignment. The vertical pilot hole tolerances are no more than 2 feet above and 10 feet below the designed profile. We recommend that the pilot hole not be accepted if its location would result in the pipeline being installed in violation of the Right-of-Way and Permit Stipulations section of the Contract, any Federal, State or Local permit requirements, or required clearances between

Dakota Access and foreign owned utilities and structures. For the entry and exit point tolerances please refer to the HDD design drawings in Appendix A.

We recommend that, upon completion of the pilot hole, GeoEngineers have the opportunity to review the pilot hole survey data prior to the start of reaming operations.

Pilot Hole As-Built

We recommend the HDD contractor be responsible for producing and submitting an as-built drawing of the pilot hole survey data within two weeks of the completion of pullback operations. This drawing should include a tabulation of the supporting as-built survey data used to generate the drawing. We recommend that the HDD contractor's as-built drawing be reviewed by GeoEngineers prior to storing the data in the project file.

3.2.5 Reaming and Swabbing Considerations

Reaming

After completion of the pilot hole, we recommend the HDD contractor maintain a continuous string of drill pipe downhole between entry and exit at all times except when re-establishing a continuous string of drill pipe in the event of a twist off downhole. During reaming operations we anticipate that the HDD contractor will likely ream the hole to a minimum final hole diameter of approximately 42 inches.

The contractor must use a downhole survey system capable of monitoring and recording downhole annular drilling fluid pressures while reaming the hole through the PMZ. The downhole annular pressure sensor is required to be within 5 feet of the reaming tool. The HDD contractor should anticipate mobilizing reaming assemblies to the site that meet this requirement. Downhole annular drilling fluid pressures above the maximum allowable limits specified by the USACE are not permitted within the PMZ. We recommend that the HDD contractor consider forward reaming the pilot hole from entry toward exit in an effort maintain lower downhole annular drilling fluid pressures through the PMZ. This could include bi-directional reaming of the hole in preparation for pullback operations.

If pull ream passes from exit to entry are conducted, a drilling fluid recycling system and high pressure drilling fluid pump operating from the exit side of the crossing would be advantageous to facilitate circulating drilling fluid downhole and recycling of the drilling fluid returns on that side of the crossing.

For HDD installations beneath levees, we recommend an annular solids percentage of 20 percent or less during reaming operations, which requires pumping a volume of drilling fluid greater than five (5) times the volume of soil cuttings being generated. This helps to prevent the soil cuttings from falling out of suspension from the drilling fluid and constricting the hole. We recommend that the HDD contractor adjust the penetration and/or pump rates while conducting reaming operations to maintain an annular solids content of 20 percent or less.

Hole Swabbing

Swabbing the hole after the completion of reaming operations is generally one of the best methods to determine if the hole is in a condition to receive the product pipe. Irregularities in the hole, zones of instability and areas where drill cuttings may have accumulated can often be detected during the swab pass. In the event that any of these conditions are detected or suspected, mitigation measures can be employed prior to pullback operations to increase the likelihood of successfully installing the product pipe without damage. Mitigation measures may include additional reaming or swab passes.

We recommend the HDD contractor be required to complete at a minimum one (1) swab pass to evaluate the condition of the hole prior to pullback operations. The HDD contractor should review the data collected during the reaming and swab passes with Dakota Access before pullback operations begin.

3.2.6 Pullback Considerations

Handling of the Product Pipe

We recommend the contractor be required to supply a pullback lifting procedure as part of their final HDD Work Plan. The minimum allowable radius of curvature for handling and positioning the product pipe in preparation for pullback operations is 800 feet (See Appendix A for detailed calculations of overbend radius). This radius of curvature results in a bending stress of approximately 67 percent of the Specified Minimum Yield Stress (SMYS) or 47,200 pounds per square inch (psi). We recommend an overbend radius of no less than 1,000 feet to reduce the risk of damaging the product pipe during pullback operations.

Installation Loads

For the proposed HDD, we analyzed the anticipated pull loads for the as-designed HDD geometry based upon different drilling fluid weights in the hole with and without the use of buoyancy control inside the product pipe. The proposed 30-inch-diameter steel product pipe will be positively buoyant in the anticipated drilling fluid weights; however, we anticipate that the HDD contractor will add water to the product pipe in an effort to reduce positive buoyancy during pullback. Our analyses include cases with differing drilling fluid densities in the hole during pullback with and without the use of buoyancy control and one in which neutral buoyancy is achieved, for comparison. Installation load and stress calculation results are attached in Appendix A.

The five cases analyzed are as follows:

1. The annulus contains 9.5 pounds per gallon (lb/gal) drilling fluid and the product pipe is empty.
2. The annulus contains 9.5 lb/gal drilling fluid and the product pipe is full.
3. The annulus contains 12 lb/gal drilling fluid and the product pipe is empty.
4. The annulus contains 12 lb/gal drilling fluid and the product pipe is full.
5. The annulus contains 10 lb/gal drilling fluid and the product pipe is neutrally buoyant.

The following table presents a summary of the calculated installation loads for the crossing.

TABLE 6. INSTALLATION LOADS FOR THE 30-INCH ILLINOIS RIVER HDD[A]

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Effective Pipe Weight[b] (lb/ft)	Pullback Force[c] (lb)
9.5	Empty	-152	725,000
9.5	Full	129	605,000
12	Empty	-244	921,000
12	Full	37	450,000
10	Neutral	0	397,000

Notes:

[A] Assumes the as-designed HDD profile. See Appendix A for detailed calculations.

[b] Negative values indicate upward force (positive buoyancy).

[c.] Assumes a fully open drilled hole with no obstructions.

We recommend that the HDD contractor utilize a drill rig that provides a factor of safety of at least 2.0 between the drill rig capacity and the pull loads they anticipate. Based on our analysis of the installation loads (see Table 6), the pullback force during installation of the 30-inch diameter product pipe may be as high as approximately 921,000 pounds depending on the weight of the drilling fluid in the hole at the time of pullback and the buoyancy control measures employed by the HDD contractor. Because of the length of this crossing and the reduction in installation forces when using buoyancy control, we recommend that buoyancy control measures be utilized during pullback of the product pipe pull section. The calculated safe pull is in excess of 2 million pounds such that the limiting pull force will depend on the capacity of the tooling the HDD contractor intends to utilize during pullback operations. We recommend the HDD contractor be required to provide the maximum anticipated pull force required to install the product pipe and the maximum allowable pull force that can be applied to their downhole tooling with their HDD Work Plan.

Pneumatic Hammer Usage

In some instances, a pneumatic hammer can be utilized to assist with the installation of the product pipe. The contractor should not employ the use of a pneumatic hammer without prior approval from Dakota Access.

Drilling Fluid Displacement

During pullback operations, the product pipe will displace approximately 239,000 gallons of drilling fluid. We anticipate that the displaced drilling fluid will likely flow to both the entry and exit points during pullback operations.

3.2.7 Post-Installation Grouting

As soon as practical after the product pipe is pulled into the reamed hole, the annulus between the reamed hole and the installed product pipe should be grouted with a cement-bentonite grout mixture on the entry side of the drill profile. The required depth of grouting is determined by a total stress analysis that results in a factor of safety of 1.2. The annulus will need to be grouted to an elevation of approximately 388 feet (approximately 36 feet below grade on the entry side) see Figure 4 for detailed calculations. The contractor should submitt a plan for installing the grout plug.

The grout plug could be installed either by drilling grout injection holes along the HDD alignment down to the drill profile or by inserting a tremie pipe down the annulus to the required depth. We do not recommend pumping the grout into the hole during pullback operations because any delays in pullback operations could result in the product pipe becoming stuck in the hole. From previous experience, we do not recommend attaching a tremie pipe to the leading end of the product pipe prior to pullback operations for post-installation grouting purposes. Oftentimes, when so attached, the pipe becomes damaged or comes free of the product pipe during the installation process and becomes unusable. A tremie pipe may be attached to the trailing end of the product pipe to grout the annular space around the product pipe on the entry side of the crossing.

We recommend selecting a specialty contractor experienced in this type of work and who is familiar with the USACE requirements. Prior to the start of construction, the grouting contractor should be responsible for submitting a grouting plan for review and approval by the USACE.

4.0 OPERATING CONDITIONS

For our analysis of the operating stresses, the installation and operating temperatures utilized for the 30-inch pipeline were 70 and 100 degrees Fahrenheit, respectively. We can further evaluate different installation and operating temperatures, if necessary. Also, the operating stresses are based on a minimum allowable pilot hole radius of curvature of 2,050 feet. If the as-built minimum radius of the pilot hole is less than 2,050 feet, the operating stresses will be increased. The following table presents a summary of the operating stresses for the product pipe specifications proposed for the HDD.

TABLE 7. OPERATING STRESSES FOR THE 30-INCH ILLINOIS RIVER HDD *

Stress Component	Stress (psi)	Percent SMYS[a] (%)	Maximum Allowable Percent SMYS[a] (%)
Longitudinal Bending Stress	17,900	26	-
Hoop Stress	34,600	49	50[b]
Longitudinal Tensile Stress from Hoop Stress	10,400	15	-
Longitudinal Stress from Thermal Expansion	-5,700	8	90[c]
Maximum Net Longitudinal Stress	22,500	32	67[c]
Maximum Shear Stress	23,900	34	45[d]
Maximum Combined Effective Stress	47,800	68	90[c]

Notes:
* Operating Stresses are Based on an Allowable Minimum Radius of 2,050 feet
[a] Specified Minimum Yield Stress
[b.] Limited by design factor from the Design Basis
[c.] Limited by section 402.3.2 of ASME B31.4
[d.] Limited by Section 402.3.1 of ASME B31.4

5.0 LIMITATIONS

We have prepared this report for use by Dakota Access and their authorized agents and other approved members of the design team involved with this project. The report is not intended for use by others, and the information contained herein is not applicable to other sites. Our report, conclusions and interpretations

should not be construed as a warranty of the subsurface conditions. To increase the likelihood of a successful installation, the conclusions and recommendations in this report should be applied in their entirety.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in developing an HDD Work Plan.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No warranty or other conditions, express, written, or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, and will serve as the official document of record.

Please refer to Appendix C, titled “Report Limitations and Guidelines for Use,” for additional information pertaining to use of this report.

6.0 REFERENCES

From the CFR Title 49, Part 195

- Code of Federal Regulations (2013), “Design Factor for Steel Pipe,” CFR Transportation, Title 49 Part 192.111
- Code of Federal Regulations (2013), “Design Factor for Steel Pipe,” CFR Transportation, Title 49 Part 195.106

From ASME, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids (B31.4)

- The American Society of Mechanical Engineers (2012), “Allowable Stress Values,” ASME Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids, B31.4 Part 402.3.1
- The American Society of Mechanical Engineers (2012), “Limits of Calculated Stresses Due to Suspended Loads and Thermal Expansion,” ASME Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids, B31.4 Part 402.3.2

From ASME, Gas Transmission and Distribution Piping Systems (B31.8)

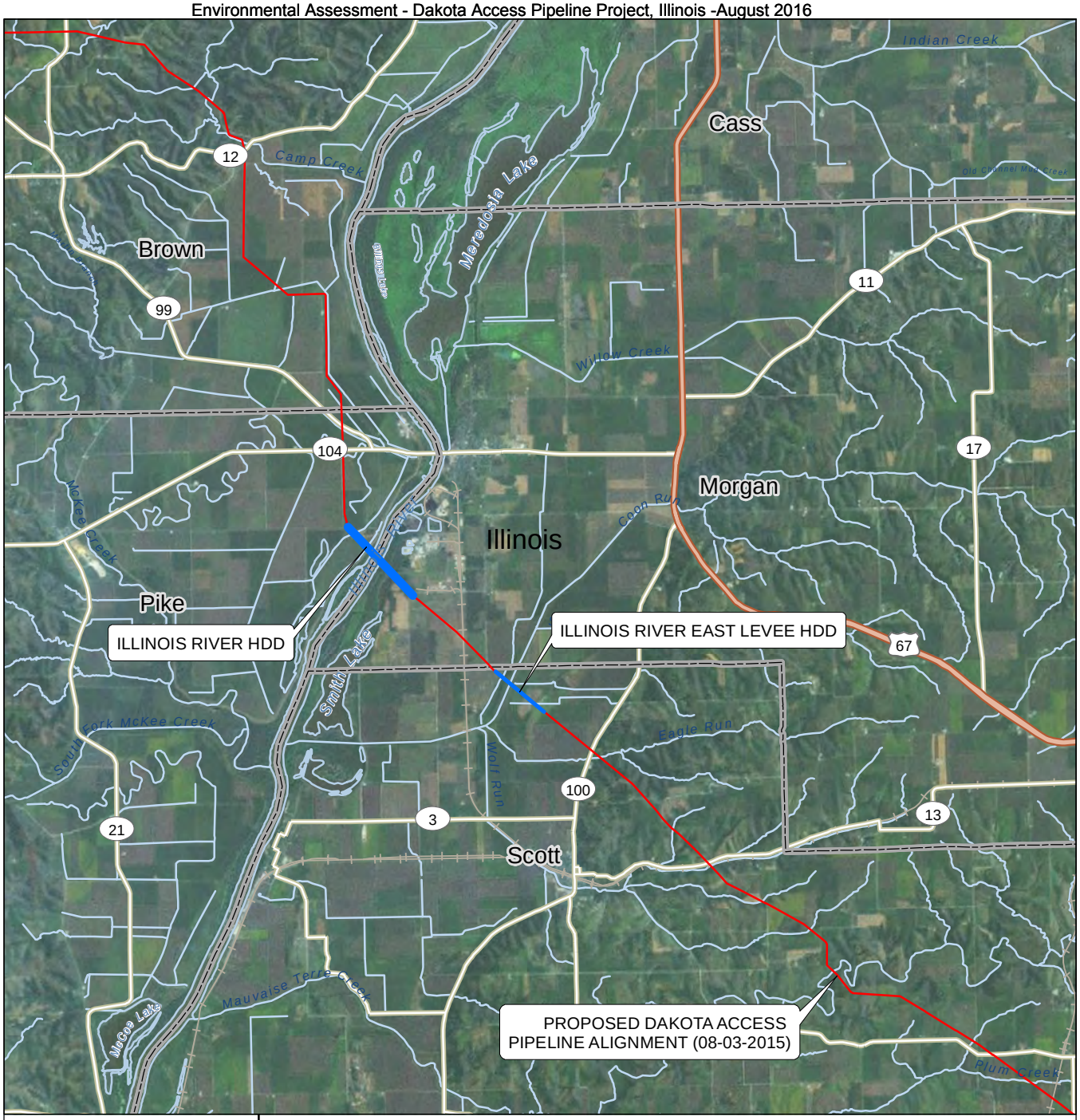
- The American Society of Mechanical Engineers (2010), "Summation of Longitudinal Stress in Restrained Pipe," ASME Gas Transmission and Distribution Piping Systems, B31.8 Part 833.3
- The American Society of Mechanical Engineers (2010), "Combined Stress for Restrained Pipe," ASME Gas Transmission and Distribution Piping Systems, B31.8 Part 833.4

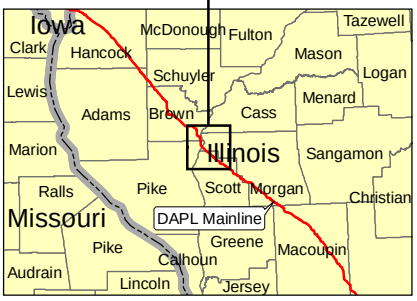
Pipeline Research Committee International (PRCI) of the American Gas Association "Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide," November, 2008.

Dakota Access, LLC, Pipeline Construction Plan Document No. DAPL-WGM-GN000_PRE-SPC-0001, Project No. 10395700, Revision A, Issue Date: April 20, 2015.

FIGURES

GeoEngineers





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Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Imagery from ESRI Data Online.
Projection: NAD 1983, UTM Zone 15 North.

DAKOTA ACCESS PIPELINE PROJECT
VICINITY MAP

PROPOSED 30" PIPELINE
ILLINOIS RIVER HDD
PIKE AND MORGAN COUNTIES, ILLINOIS

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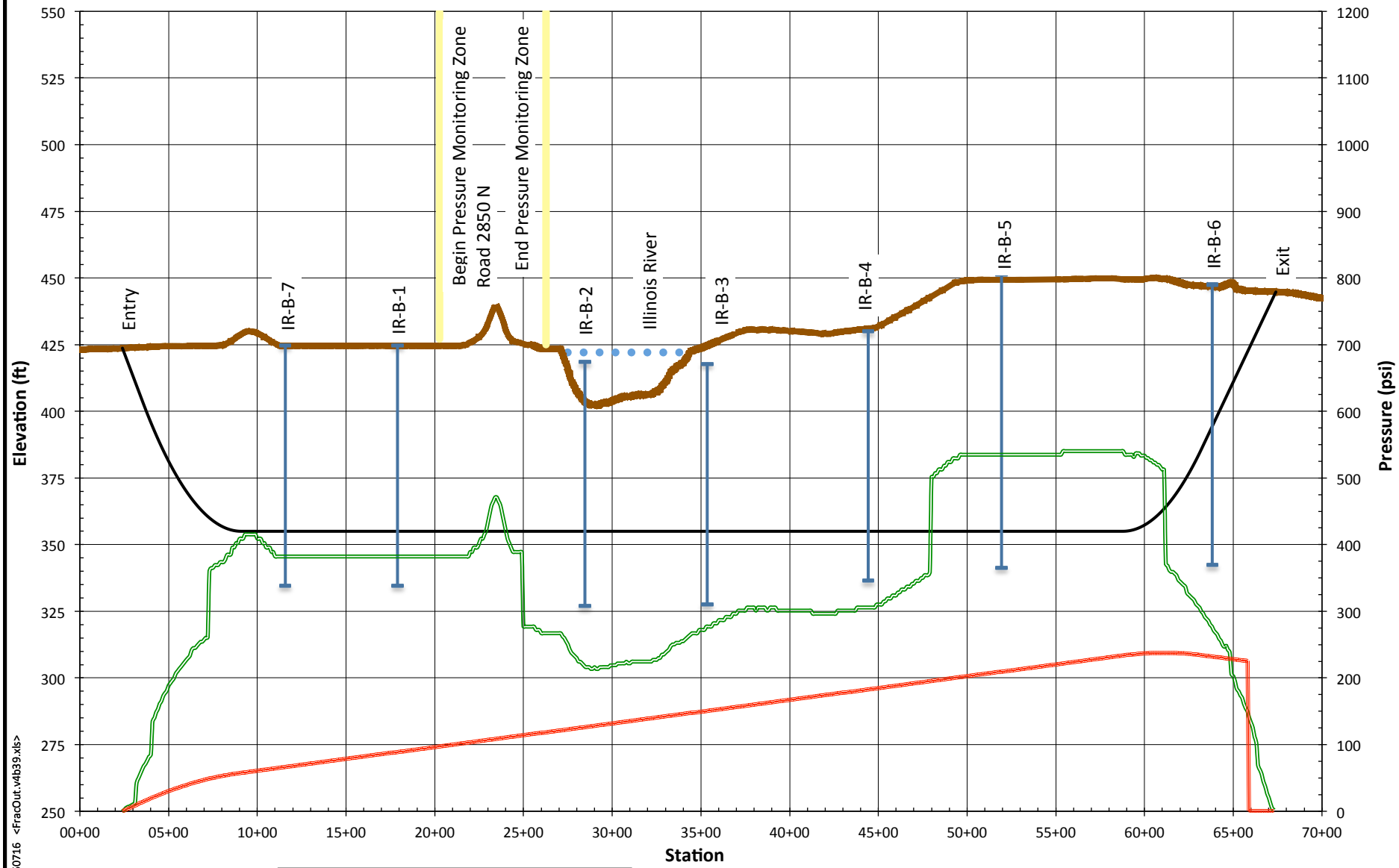
Figure 1

Office: SPR Path: P:\18\1878201101\GIS\Vicinity Maps\Illinois\Illinois River HDD.mxd Map Revised: 04 August 2015 mclevenger

ILLINOIS RIVER HDD - ENTRY TO EXIT



Crossing Length (ft)	6500
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.500
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	14
Yield Point (lb/100 ft)	30

- Ground Surface Elevation (ft)
- HDD Profile (ft)
- Formation Limit Pressure (psi)
- Estimated Annular Drilling Fluid Pressure (psi) for Pilot Hole

ESTIMATED ANNULAR DRILLING FLUID AND FORMATION LIMIT PRESSURES

ILLINOIS RIVER HDD - ENTRY TO EXIT

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FIGURE 2

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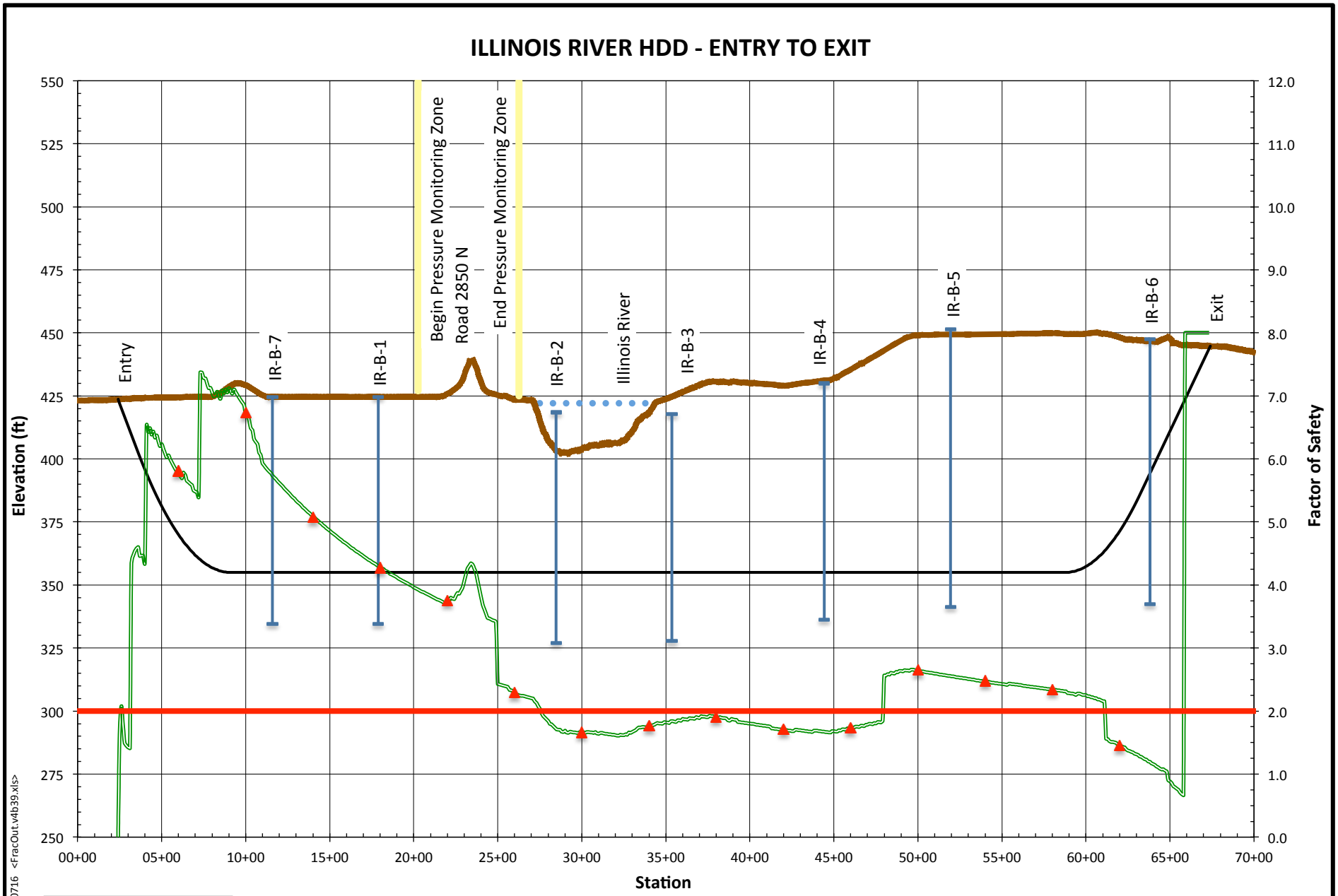

Crossing Length (ft)	6500
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.500
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	14
Yield Point (lb/100 ft)	30

- Ground Surface Elevation (ft)
- HDD Profile (ft)
- Hydraulic Fracture Factor of Safety for Pilot Hole
- Drilling Fluid Surface Release Factor of Safety for Pilot Hole
- Factor of Safety = 2

HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE FACTORS OF SAFETY

ILLINOIS RIVER HDD - ENTRY TO EXIT

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FIGURE 3

18782-011-01 RTB/AES 150716 <FracOut.v4b39.xls>

Required Depth of Annular Grout Plug - Total Stress Analysis Entry Side

Crossing: Dakota Access - Illinois River HDD
Protected Side: Entry Side (Northwest Side)
Subsurface Information From: Boring IR-B-1

Total Unit Weight of Soil Profile Above Groundwater (Υ_{sd}) =	**100**	pcf
Total Unit Weight of Soil Profile Below Groundwater (Υ_{sw}) =	**105**	pcf
Levee Crest Elevation =	**439**	ft
Landside Ground Surface Elevation =	**424.63**	ft
Groundwater Elevation on Landside of Levee =	**424.63**	ft
Depth to Groundwater on Landside of Levee (D_w)=	**0.00**	ft
Head at Flood Stage (H_R)=	**14.37**	ft
Let Υ_w Equal the Unit Weight of Water =	**62.4**	pcf

Let D Equal the Depth of the Grout Plug Below Groundwater
Let D_g Equal the Depth of the Grout Plug = D_w + D

Solve the Following Equation for D

$$\gamma_{sd}D_w + \gamma_{sw}D = 1.2(H_R + D_w + D)\gamma_w$$

Rearrange

$$\gamma_{sd}D_w + \gamma_{sw}D - 1.2\gamma_w D = 1.2(H_R + D_w)\gamma_w$$

Substitute Values

100.0*0.00 + 105*D - 1.2*62.4*D = 1.2*(14.37 + 0.00)*62.4

Reduce

30.12D = 1076.03

Solve for D

D = 35.72 ft

Minimum Required Depth of Grout Plug D_g = D + D_w

Dg = 35.72 + 0.00

Dg = 35.72 ft

Grout Elevation = 388.9 ft

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Dakota Access Illinois River HDD
Total Stress Analysis Entry Side

FIGURE 4

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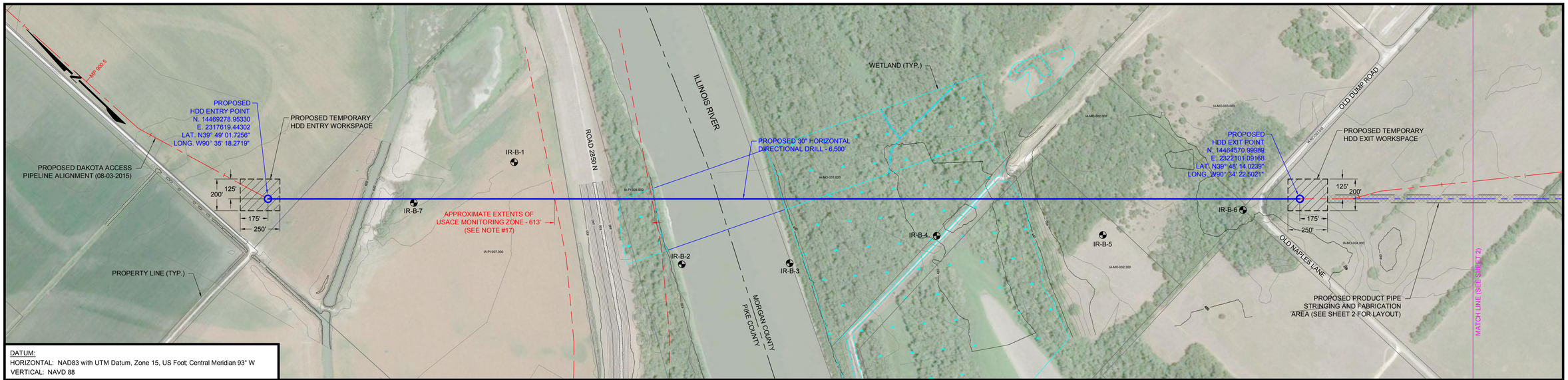
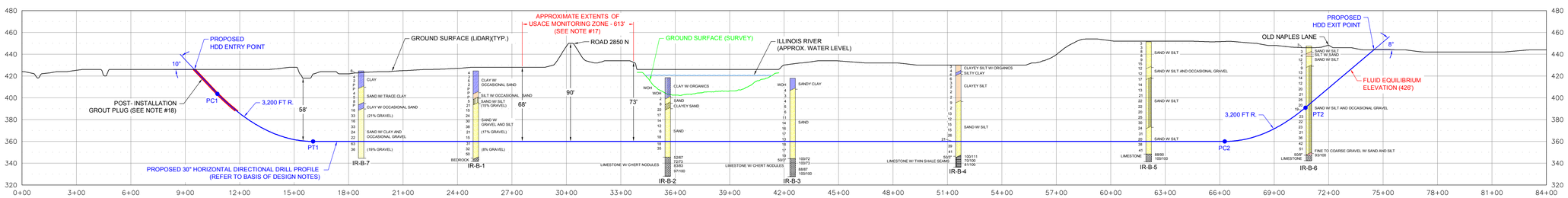
APPENDIX A
HDD Design Drawing and Calculations



NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

300' 0 300'
SCALE IN FEET



PROFILE

300' 0 300'
HORIZONTAL SCALE IN FEET
50' 0 50'
VERTICAL SCALE IN FEET

DIRECTIONAL DRILL DATA ILLINOIS RIVER HDD		
DESCRIPTION	STATION * (FT)	ELEVATION (FT)
ENTRY @ 10°	9+50.00	426.00
P C 1 (10.00° @ 3,200 FT R.)	10+48.59	408.62
P T 1	16+04.27	360.00
P C 2 (8.00° @ 3,200 FT R.)	66+27.68	360.00
P T 2	70+73.03	391.14
EXIT @ 8°	74+50.00	444.12
HORIZONTAL DISTANCE = 6,500.00 FT		
DIRECTIONAL DRILL PIPE LENGTH = 6,509.51 FT		

* STATIONING IS BASED ON AN ARBITRARY REFERENCE POINT.

RECOMMENDED TOLERANCES	
ITEM	TOLERANCE
PILOT HOLE ENTRY ANGLE	INCREASE ANGLE UP TO 1° (STEEPER), BUT NO DECREASE IN ANGLE ALLOWED.
PILOT HOLE ENTRY LOCATION	WITHIN 5 FEET OF ENTRY POINT AS SHOWN ON DRAWING. WITH NO CHANGES WITHOUT COMPANY APPROVAL.
PILOT HOLE EXIT ANGLE	INCREASE ANGLE UP TO 1° (STEEPER) OR DECREASE UP TO 2° (FLATTER).
PILOT HOLE EXIT LOCATION	UP TO 30 FEET BEYOND THE EXIT STAKE. BETWEEN 10 FEET LEFT AND 10 FEET RIGHT OF CENTERLINE.
PILOT HOLE DEPTH	UP TO 2 FEET ABOVE THE DESIGN DRILL PROFILE ALLOWED. UP TO 10 FEET BELOW THE DESIGN DRILL PROFILE ALLOWED.
PILOT HOLE ALIGNMENT	SHALL REMAIN WITHIN 10 FEET LEFT OR RIGHT OF THE HDD ALIGNMENT.

LEGEND

SPT (N) — TYPE OF SOIL (% GRAVEL)
TYPE OF ROCK — RQD/%REC
BORING LOCATION
MAJOR CONTOUR - 10' INTERVAL
MINOR CONTOUR - 2' INTERVAL

BASIS OF DESIGN:

1. PRODUCT PIPE WILL CONSIST OF 30" O.D. X 0.625" W.T., API-5L X-70 PIPE WITH 14-16 MILS OF FUSION BONDED EPOXY (FBE) AND A MINIMUM OF 40 MILS OF ABRASION RESISTANT OVERLAY (ARO).
2. THE MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) = 1,440 psi.
3. THE ASSUMED MAXIMUM OPERATING TEMPERATURE = 100° FAHRENHEIT.
4. THE MINIMUM ALLOWABLE THREE JOINT RADIUS SHALL NOT BE LESS THAN 2,050 FEET.

ISSUED FOR BID

NOTES:

1. CONTRACTOR SHALL ADHERE TO THE SPECIFICATIONS AND REQUIREMENTS PER DAKOTA ACCESS, LLC SPECIFICATIONS, CONTRACT DOCUMENTS AND SPECIAL PERMIT CONDITIONS, EXCEPT AS NOTED ON THIS DRAWING.
2. CONTRACTOR IS RESPONSIBLE FOR CALLING ILLINOIS ONE-CALL AND LOCATING ALL UNDERGROUND UTILITIES PRIOR TO BEGINNING CONSTRUCTION. IF ANY UTILITY IS LOCATED WITHIN 15 FEET OF THE DESIGNED HDD PROFILE AND ALIGNMENT, CONTRACTOR SHALL OBTAIN APPROVAL FROM DAKOTA ACCESS, LLC PRIOR TO INITIATING HDD OPERATIONS.
3. IT IS THE CONTRACTOR'S RESPONSIBILITY TO IDENTIFY AND PROTECT ANY FOREIGN UTILITY THAT MAY BE AFFECTED BY THE HDD OPERATIONS.
4. PLACEMENT OF THE HDD RIG IS NOT FIXED BY THE DESIGNATION OF THE ENTRY AND EXIT POINTS. THE USE OF DUAL HDD RIGS DURING CONSTRUCTION MAY BE AT THE DISCRETION OF THE HDD CONTRACTOR, TO BE APPROVED BY DAKOTA ACCESS, LLC.
5. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
6. WORK SPACE: MAXIMUM WORK SPACE LIMITS ARE DEPICTED. RESTRICT CLEARING TO THE WORK SPACE INDICATED AT THE ENTRY AND EXIT POINTS AND PRODUCT PIPE STRINGING AND FABRICATION AREA ALONG THE CONSTRUCTION RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS REQUIRES PRIOR APPROVAL FROM THE ENVIRONMENTAL INSPECTOR AND IS LIMITED TO THE AMOUNT NECESSARY TO STRING SURVEY WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
7. WATER SOURCE: DRILL WATER AND HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE.
8. HYDROSTATIC TEST: PRE-INSTALLATION AND POST-INSTALLATION HYDROSTATIC TESTS SHALL BE CONDUCTED IN ACCORDANCE WITH THE HYDROSTATIC TEST PLAN. TEST WATER SHALL BE SAMPLED AND TESTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE TEST WATER SHALL BE DISCHARGED IN AN UPLAND AREA INTO AN EROSION CONTROL STRUCTURE OF STRAW BALES AND/OR SILT FENCES, GEOTEXTILE FILTER BAG, OR COLLECTED IN A TRUCK AND HAULED TO AN APPROVED DISPOSAL SITE. UPON COMPLETION OF DEWATERING AND DRYING, A CALIPER PIG SURVEY SHALL BE COMPLETED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
9. SPILL-PREVENTION: REFUELING OF ALL EQUIPMENT SHALL BE COMPLETED IN ACCORDANCE WITH THE SPCC PLAN.
10. EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
11. INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE APPROVED CONSTRUCTION RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. AFTER THE PILOT HOLE IS COMPLETE, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO DAKOTA ACCESS, LLC FOR APPROVAL. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
12. DRILLING FLUID DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING FLUID AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING FLUID WHICH INADVERTENTLY SURFACES AT POINTS OTHER THAN THE ENTRY OR EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
13. CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN THE CLEAN-UP AND RESTORATION REQUIREMENTS. IF THE TERRAIN ALLOWS AND ACCESS IS PERMITTED, CONTRACTOR SHALL UTILIZE LOW GROUND PRESSURE EQUIPMENT OR OTHER EQUIPMENT APPROVED BY OWNER, TO FACILITATE CONTAINMENT AND CLEAN-UP OF ANY INADVERTENT RETURNS THAT OCCUR DURING THE HDD INSTALLATION PROCESS.
14. GEOTECHNICAL DATA: BORE HOLES ARE OFFSET FROM THE PIPELINE CENTERLINE AS SHOWN ON THE PLAN VIEW. THE GEOTECHNICAL INFORMATION PROVIDED ON THIS DRAWING IS A GENERAL SUMMARY. REFER TO THE APPLICABLE GEOTECHNICAL REPORT IN THE CONTRACT DOCUMENTS FOR MORE DETAILED INFORMATION.
15. AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO © 2015, LICENSED TO GEOENGINEERS, INC., IMAGE DATED 07/31/12. GROUND SURFACE SURVEY AND LIDAR PROVIDED BY WOOD GROUP MUSTANG, INC.
16. SHAPE FILES PROVIDED BY CONTRACT LAND STAFF, LLC.
17. REFER TO 'SPECIFICATIONS FOR PERMIT REQUIREMENTS FOR DRILLING THROUGH PRESSURE MONITORING ZONE'.
18. AFTER COMPLETING PULLBACK OF PRODUCT PIPE, GROUT THE ANNULUS BETWEEN PIPE AND REAMED HOLE AT ENTRY WITH CEMENT-BENTONITE MIXTURE TO ELEVATION 388.

REFERENCES	
DRAWING NUMBER	REFERENCE DRAWING TITLE

REVISIONS					
NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
A	ISSUED FOR BID	BTL	06/11/15	MAM	JLR
B	ISSUED FOR BID (ADDED GEOTECHNICAL DATA)	TJB	06/18/15	MAM	JLR
C	ISSUED FOR BID (REVISED ALIGNMENT)	TJB	07/31/15	MAM	JLR
D	ISSUED FOR BID (REVISED WORKING ALIGNMENT)	TJB	08/06/15	MAM	JLR

MAM Design	04/13/15 Date
MWC Drawn	04/13/15 Date
MAM Checked	04/16/15 Date
JLR Approved	04/16/15 Date

GEOENGINEERS
3050 South Delaware
Springfield, MO 65804
Telephone (417) 831-9700
Fax (417) 831-9777

DAKOTA ACCESS PIPELINE PROJECT
SITE PLAN AND PROFILE
PROPOSED 30" PIPELINE
ILLINOIS RIVER HDD
PIKE AND MORGAN COUNTIES, ILLINOIS

Project No. 18782-011-01
Drawing No. W_29004_C100064
Sheet 1 of 2

P:\18187820110\CAD\Crossings\Illinois River\Drawings\Illinois River HDD_FB.dwg\TAB:SHEET 1 modified on Aug 06, 2015 - 12:30pm

DATUM:
HORIZONTAL: NAD83 with UTM Datum, Zone 15, US Foot; Central Meridian 93° W
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

300' 0 300'
SCALE IN FEET

ISSUED FOR BID

LEGEND
- BORING LOCATION
- MAJOR CONTOUR - 10' INTERVAL
- MINOR CONTOUR - 2' INTERVAL

NOTES:

1. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
2. AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO © 2015, LICENSED TO GEOENGINEERS, INC., IMAGE DATED 07/31/12. GROUND SURFACE SURVEY AND LIDAR PROVIDED BY WOOD GROUP MUSTANG, INC.
3. SHAPE FILES PROVIDED BY CONTRACT LAND STAFF, LLC.

P:\18187820110\CADD\Crossings\Illinois\Illinois River\Drawings\Illinois River HDD_JFB.dwg\TAB:SHEET 2 modified on Aug 06, 2015 - 10:01am

REFERENCES

DRAWING NUMBER	REFERENCE DRAWING TITLE

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
A	ISSUED FOR BID	BTL	06/11/15	MAM	JLR
B	ISSUED FOR BID (ADDED GEOTECHNICAL DATA)	TJB	06/18/15	MAM	JLR
C	ISSUED FOR BID (REVISED ALIGNMENT)	TJB	07/31/15	MAM	JLR
D	ISSUED FOR BID (REVISED WORKING ALIGNMENT)	TJB	08/06/15	MAM	JLR

MAM Design	04/13/15 Date
MWC Drawn	04/13/15 Date
MAM Checked	04/16/15 Date
JLR Approved	04/16/15 Date

GEOENGINEERS
3050 South Delaware
Springfield, MO 65804
Telephone (417) 831-9700
Fax (417) 831-9777

DAKOTA ACCESS PIPELINE PROJECT
STRINGING WORKSPACE

PROPOSED 30" PIPELINE
ILLINOIS RIVER HDD
PIKE AND MORGAN COUNTIES, ILLINOIS

Project No. 18782-011-01
Drawing No. W_29004_C100065
Sheet 2 of 2

HDD Design Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Pike & Morgan Counties, Illinois **Date:** Thursday, June 18, 2015

Design Parameters

Pipe Diameter = 30.000 in

Pipe Material = Steel

Yield Stress = 70,000 psi

Wall Thickness = 0.625 in

Assumed Installation Temp = 70 °F

Assumed Operating Temp= 100 °F

Design Factor = 0.5

MAOP = 1,440 psi

Drill Data Box

Point	Station (ft)	Elevation (ft)
ENTRY @ 10°	950.00	426.00
P C 1 (10.00° @ 3,200 ft R.)	1,076.95	403.62
P T 1	1,632.62	355.00
P C 2 (8.00° @ 3,200 ft R.)	6,592.10	355.00
P T 2	7,037.45	386.14
EXIT @ 8°	7,450.00	444.12

Horizontal Alignment Length = 6,500.00 ft

Profile Segment Information

Segment Name	Segment Type	Segment Length (ft)
Entry Tangent	Straight	128.91
Entry Curve	Vertical Curve	558.51
Bottom Tangent	Straight	4,959.48
Exit Curve	Vertical Curve	446.80
Exit Tangent	Straight	416.60

Pipe Length = 6,510.29 ft

Installation Load Summary

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Buoyancy Control (lb/ft)	Effective Pipe Weight (lb/ft)	Total Installation Force (lb)
9.50	Empty	0.00	-152.27	724,000
9.50	Full	281.31	129.04	605,000
12.00	Empty	0.00	-244.07	920,000
12.00	Full	281.31	37.24	450,000
10.00	Neutral	170.63	0.00	397,000

GeoEngineers

Minimum Radius Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Pike & Morgan Counties, Illinois **Date:** Thursday, June 18, 2015

Design Parameters:

Pipe Diameter = 30.000 in **MAOP =** 1,440 psi **Factor of Safety =** 2.00

Wall Thickness = 0.625 in **SMYS =** 70,000 psi

D/t Ratio = 48.00 **Modulus of Elasticity (E) =** 2.93E+007 psi

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 34,560 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 17,280 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 35,000 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 17,720 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 2,046 ft

GeoEngineers

Operating Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Pike & Morgan Counties, Illinois **Date:** Thursday, June 18, 2015

Design Parameters

Pipe diameter =	30.000 in	**Minimum Radius of Curvature =**	2,050 ft
Wall Thickness =	0.625 in	**Coefficient of Thermal Expansion =**	6.5E-06 in/in/°F
SMYS =	70,000 psi	**Assumed Installation Temperature =**	70 °F
MAOP =	1,440 psi	**Assumed Operating Temperature =**	100 °F
Poissons's Ratio =	0.30	**Temperature Derating Factor =**	1.00
Young's Modulus (E) =	2.93E+007 psi	**Groundwater Table Head =**	0.00 ft
Design Factor =	0.5		

Stress Analyses

Longitudinal Stress from Bending =	17,893 psi	
Percent SMYS =	25.56 %	
Hoop Stress =	34,560 psi	
Percent SMYS =	49.37 %	Limited by Design Factor (0.5) according to 49 CFR 195.106
Longitudinal Tensile Stress from Hoop Stress =	10,368 psi	
Percent SMYS =	14.81 %	
Longitudinal Stress from Thermal Expansion =	-5,722 psi	
Percent SMYS =	8.17 %	Limited to 90% SMYS by ASME/ANSI B31.4 section 402.3.2
Net Longitudinal Stress (Comp. side of Curve) =	-13,247 psi	
Percent SMYS =	18.92 %	Limited to 67.5% SMYS by ASME/ANSI B31.4 section 402.3.2
Net Longitudinal Stress (Tension side of Curve) =	22,539 psi	
Percent SMYS =	32.20 %	Limited to 67.5% SMYS by ASME/ANSI B31.4 section 402.3.2
Maximum Shear Stress =	23,903 psi	
Percent SMYS =	34.15 %	Limited to 45% SMYS by ASME/ANSI B31.4 section 402.3.1
Combined BiaxialSress Check =	47,807 psi	
Percent SMYS =	68.30 %	Limited to 90% SMYS by AMSE/ANSI B31.4 section 402.3.2

GeoEngineers

Operating Stress Summary

Project Name:	Dakota Access Pipeline Project	**HDD Name:**	Illinois River HDD	**Owner:**	Dakota Access, LLC
Project No:	18782-011-01 **By:** CGM **Ck'd By:** MAM	**Location:**	Pike & Morgan Counties, Illinois	**Date:**	Thursday, June 18, 2015

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Pike & Morgan Counties, Illinois **Date:** Thursday, June 18, 2015

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	6,510 ft
Moment of Inertia =	6,224 in^4
Pipe Face Area =	57.68 in^2
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	4.91 ft^3/ft
Displaced Fluid Weight =	348.84 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	-152.27 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	416.60 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	23,558 lb
Friction Force =	18,846 lb
Segment Weight =	8,829 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	51,233 lb
Cumulative Force =	**51,233 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	888 psi	
Cumulative Axial Stress =	888 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	687 psi	7,384 psi
Combined Stress =	0.0159	< 1.0
Total Stress =	0.0093	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	446.80 ft	Center Displacement =	7.80 ft

Segment Force Components

Normal Force =	53,671 lb
Drag Force =	25,266 lb
Friction Force =	16,101 lb
Segment Weight =	4,746 lb
Tension =	113,448 lb
Average Tension =	82,341 lb
Segment Force =	62,215 lb
Cumulative Force =	**113,448 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,079 psi	
Cumulative Axial Stress =	1,967 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	1,056 psi	7,384 psi
Combined Stress =	0.4221	< 1.0
Total Stress =	0.1663	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	4,959.48 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	280,452 lb
Friction Force =	226,560 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	507,012 lb
Cumulative Force =	**620,460 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	8,790 psi	
Cumulative Axial Stress =	10,757 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	1,056 psi	7,384 psi
Combined Stress =	0.1921	< 1.0
Total Stress =	0.0695	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	558.51 ft	Center Displacement =	12.18 ft

Segment Force Components

Normal Force =	116,308 lb
Drag Force =	31,583 lb
Friction Force =	34,892 lb
Segment Weight =	-7,412 lb
Tension =	714,415 lb
Average Tension =	667,438 lb
Segment Force =	93,955 lb
Cumulative Force =	**714,415 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,629 psi	
Cumulative Axial Stress =	12,386 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	1,056 psi	7,384 psi
Combined Stress =	0.6082	< 1.0
Total Stress =	0.3440	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	128.91 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,290 lb
Friction Force =	5,799 lb
Segment Weight =	-3,409 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	9,680 lb
Cumulative Force =	**724,096 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	168 psi	
Cumulative Axial Stress =	12,554 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	480 psi	7,384 psi
Combined Stress =	0.2242	< 1.0
Total Stress =	0.0611	< 1.0

Installation Load Calculations

Project Name:	Dakota Access Pipeline Project	**HDD Name:**	Illinois River HDD	**Owner:**	Dakota Access, LLC
Project No:	18782-011-01 **By:** CGM **Ck'd By:** MAM	**Location:**	Pike & Morgan Counties, Illinois	**Date:**	Thursday, June 18, 2015

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	6,510 ft
Moment of Inertia =	6,224 in^4
Pipe Face Area =	57.68 in^2
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	4.91 ft^3/ft
Displaced Fluid Weight =	348.84 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	129.04 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	416.60 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	23,558 lb
Friction Force =	15,970 lb
Segment Weight =	-7,482 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	32,047 lb
Cumulative Force =	**32,047 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	556 psi	
Cumulative Axial Stress =	556 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	84 psi	7,384 psi
Combined Stress =	0.0099	< 1.0
Total Stress =	0.0003	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	446.80 ft	Center Displacement =	7.80 ft

Segment Force Components

Normal Force =	-26,064 lb
Drag Force =	25,266 lb
Friction Force =	7,819 lb
Segment Weight =	-4,022 lb
Tension =	68,929 lb
Average Tension =	50,488 lb
Segment Force =	36,883 lb
Cumulative Force =	**68,929 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	639 psi	
Cumulative Axial Stress =	1,195 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	129 psi	7,384 psi
Combined Stress =	0.4083	< 1.0
Total Stress =	0.1167	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	4,959.48 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	280,452 lb
Friction Force =	191,987 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	472,439 lb
Cumulative Force =	**541,368 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	8,191 psi	
Cumulative Axial Stress =	9,386 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	129 psi	7,384 psi
Combined Stress =	0.1676	< 1.0
Total Stress =	0.0298	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	558.51 ft	Center Displacement =	12.18 ft

Segment Force Components

Normal Force =	18,463 lb
Drag Force =	31,583 lb
Friction Force =	5,539 lb
Segment Weight =	6,281 lb
Tension =	590,310 lb
Average Tension =	565,839 lb
Segment Force =	48,942 lb
Cumulative Force =	**590,310 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	849 psi	
Cumulative Axial Stress =	10,235 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	129 psi	7,384 psi
Combined Stress =	0.5697	< 1.0
Total Stress =	0.2529	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	128.91 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,290 lb
Friction Force =	4,914 lb
Segment Weight =	2,888 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	15,093 lb
Cumulative Force =	**605,402 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	262 psi	
Cumulative Axial Stress =	10,496 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	58 psi	7,384 psi
Combined Stress =	0.1874	< 1.0
Total Stress =	0.0359	< 1.0

Installation Load Calculations

Project Name:	Dakota Access Pipeline Project	**HDD Name:**	Illinois River HDD	**Owner:**	Dakota Access, LLC
Project No:	18782-011-01 **By:** CGM **Ck'd By:** MAM	**Location:**	Pike & Morgan Counties, Illinois	**Date:**	Thursday, June 18, 2015

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	6,510 ft
Moment of Inertia =	6,224 in⁴
Pipe Face Area =	57.68 in²
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	4.91 ft³/ft
Displaced Fluid Weight =	440.64 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	-244.07 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	416.60 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	23,558 lb
Friction Force =	30,208 lb
Segment Weight =	14,151 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	67,917 lb
Cumulative Force =	**67,917 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,178 psi	
Cumulative Axial Stress =	1,178 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	867 psi	7,384 psi
Combined Stress =	0.0210	< 1.0
Total Stress =	0.0149	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	446.80 ft	Center Displacement =	7.80 ft

Segment Force Components

Normal Force =	80,536 lb
Drag Force =	25,266 lb
Friction Force =	24,161 lb
Segment Weight =	7,607 lb
Tension =	149,112 lb
Average Tension =	108,514 lb
Segment Force =	81,195 lb
Cumulative Force =	**149,112 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,408 psi	
Cumulative Axial Stress =	2,585 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	1,333 psi	7,384 psi
Combined Stress =	0.4331	< 1.0
Total Stress =	0.1930	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	4,959.48 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	280,452 lb
Friction Force =	363,144 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	643,596 lb
Cumulative Force =	**792,708 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	11,158 psi	
Cumulative Axial Stress =	13,744 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	1,333 psi	7,384 psi
Combined Stress =	0.2454	< 1.0
Total Stress =	0.1124	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	558.51 ft	Center Displacement =	12.18 ft

Segment Force Components

Normal Force =	161,349 lb
Drag Force =	31,583 lb
Friction Force =	48,405 lb
Segment Weight =	-11,881 lb
Tension =	909,219 lb
Average Tension =	850,963 lb
Segment Force =	116,511 lb
Cumulative Force =	**909,219 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	2,020 psi	
Cumulative Axial Stress =	15,764 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	1,333 psi	7,384 psi
Combined Stress =	0.6685	< 1.0
Total Stress =	0.4387	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	128.91 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,290 lb
Friction Force =	9,296 lb
Segment Weight =	-5,464 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	11,122 lb
Cumulative Force =	**920,341 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	193 psi	
Cumulative Axial Stress =	15,957 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	606 psi	7,384 psi
Combined Stress =	0.2849	< 1.0
Total Stress =	0.0986	< 1.0

Installation Load Calculations

Project Name:	Dakota Access Pipeline Project	**HDD Name:**	Illinois River HDD	**Owner:**	Dakota Access, LLC
Project No:	18782-011-01 **By:** CGM **Ck'd By:** MAM	**Location:**	Pike & Morgan Counties, Illinois	**Date:**	Thursday, June 18, 2015

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	6,510 ft
Moment of Inertia =	6,224 in^4
Pipe Face Area =	57.68 in^2
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	4.91 ft^3/ft
Displaced Fluid Weight =	440.64 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	37.24 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	416.60 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	23,558 lb
Friction Force =	4,609 lb
Segment Weight =	-2,159 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	26,008 lb
Cumulative Force =	**26,008 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	451 psi	
Cumulative Axial Stress =	451 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	264 psi	7,384 psi
Combined Stress =	0.0081	< 1.0
Total Stress =	0.0014	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	446.80 ft	Center Displacement =	7.80 ft

Segment Force Components

Normal Force =	-1,831 lb
Drag Force =	25,266 lb
Friction Force =	549 lb
Segment Weight =	-1,161 lb
Tension =	51,212 lb
Average Tension =	38,610 lb
Segment Force =	25,204 lb
Cumulative Force =	**51,212 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	437 psi	
Cumulative Axial Stress =	888 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	406 psi	7,384 psi
Combined Stress =	0.4028	< 1.0
Total Stress =	0.1214	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	4,959.48 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	280,452 lb
Friction Force =	55,403 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	335,855 lb
Cumulative Force =	**387,067 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	5,823 psi	
Cumulative Axial Stress =	6,711 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	406 psi	7,384 psi
Combined Stress =	0.1198	< 1.0
Total Stress =	0.0204	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	558.51 ft	Center Displacement =	12.18 ft

Segment Force Components

Normal Force =	32,897 lb
Drag Force =	31,583 lb
Friction Force =	9,869 lb
Segment Weight =	1,813 lb
Tension =	440,200 lb
Average Tension =	413,634 lb
Segment Force =	53,133 lb
Cumulative Force =	**440,200 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	921 psi	
Cumulative Axial Stress =	7,632 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	406 psi	7,384 psi
Combined Stress =	0.5233	< 1.0
Total Stress =	0.2189	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	128.91 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,290 lb
Friction Force =	1,418 lb
Segment Weight =	834 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	9,541 lb
Cumulative Force =	**449,742 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	165 psi	
Cumulative Axial Stress =	7,797 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	185 psi	7,384 psi
Combined Stress =	0.1392	< 1.0
Total Stress =	0.0216	< 1.0

Installation Load Calculations

Project Name:	Dakota Access Pipeline Project	**HDD Name:**	Illinois River HDD	**Owner:**	Dakota Access, LLC
Project No:	18782-011-01 **By:** CGM **Ck'd By:** MAM	**Location:**	Pike & Morgan Counties, Illinois	**Date:**	Thursday, June 18, 2015

Installation Case:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	6,510 ft
Moment of Inertia =	6,224 in⁴
Pipe Face Area =	57.68 in²
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	4.91 ft³/ft
Displaced Fluid Weight =	367.20 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	0.00 lb/ft

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	416.60 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	23,558 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	23,558 lb
Cumulative Force =	**23,558 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	408 psi	
Cumulative Axial Stress =	408 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	723 psi	7,384 psi
Combined Stress =	0.0073	< 1.0
Total Stress =	0.0096	< 1.0

Installation Load Calculations

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	8.00 deg
Segment Length =	446.80 ft	Center Displacement =	7.80 ft

Segment Force Components

Normal Force =	8,500 lb
Drag Force =	25,266 lb
Friction Force =	2,550 lb
Segment Weight =	0 lb
Tension =	53,924 lb
Average Tension =	38,741 lb
Segment Force =	30,366 lb
Cumulative Force =	**53,924 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	526 psi	
Cumulative Axial Stress =	935 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	1,111 psi	7,384 psi
Combined Stress =	0.4037	< 1.0
Total Stress =	0.1558	< 1.0

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	4,959.48 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	280,452 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	280,452 lb
Cumulative Force =	**334,376 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	4,862 psi	
Cumulative Axial Stress =	5,797 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	1,111 psi	7,384 psi
Combined Stress =	0.1035	< 1.0
Total Stress =	0.0399	< 1.0

Installation Load Calculations

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.00 deg
Segment Length =	558.51 ft	Center Displacement =	12.18 ft

Segment Force Components

Normal Force =	39,875 lb
Drag Force =	31,583 lb
Friction Force =	11,963 lb
Segment Weight =	0 lb
Tension =	389,884 lb
Average Tension =	362,130 lb
Segment Force =	55,508 lb
Cumulative Force =	**389,884 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	962 psi	
Cumulative Axial Stress =	6,760 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	1,111 psi	7,384 psi
Combined Stress =	0.5077	< 1.0
Total Stress =	0.2431	< 1.0

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	128.91 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	7,290 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	7,290 lb
Cumulative Force =	**397,174 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	126 psi	
Cumulative Axial Stress =	6,886 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	505 psi	7,384 psi
Combined Stress =	0.1230	< 1.0
Total Stress =	0.0236	< 1.0

Overbend Radius Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Pike & Morgan Counties, Illinois **Date:** Thursday, June 18, 2015

Design Parameters:

Pipe Diameter = 30.000 in **MAOP =** 0 psi **Factor of Safety =** 1.50

Wall Thickness = 0.625 in **SMYS =** 70,000 psi

D/t Ratio = 48.00 **Modulus of Elasticity (E) =** 2.93E+007 psi

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 0 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 0 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 46,667 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 46,667 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 777 ft

GeoEngineers

Overbend Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Pike & Morgan Counties, Illinois **Date:** Thursday, June 18, 2015

Design Parameters

Pipe diameter = 30.000 in

Wall Thickness = 0.625 in

SMYS = 70,000 psi

Internal Pressure = 0 psi

Poissons's Ratio = 0.30

Young's Modulus (E) = 2.93E+007 psi

Factor of Safety = 1.50

Overbend Radius of Curvature = 777 ft

Assumed Installation Temperature = 70 °F

Stress Analyses

Longitudinal Stress from Bending = 47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Hoop Stress = 0 psi

Percent SMYS = 0 %

Longitudinal Tensile Stress from Hoop Stress = 0 psi

Percent SMYS = 0 %

Longitudinal Stress from Thermal Expansion = 0 psi

Percent SMYS = 0 %

Net Longitudinal Stress (Comp. side of Curve) = -47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Net Longitudinal Stress (Tension side of Curve) = 47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Maximum Shear Stress = 23,610 psi

Percent SMYS = 33.73 % Limited to 40% SMYS

Combined Biaxial Stress Check = 47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

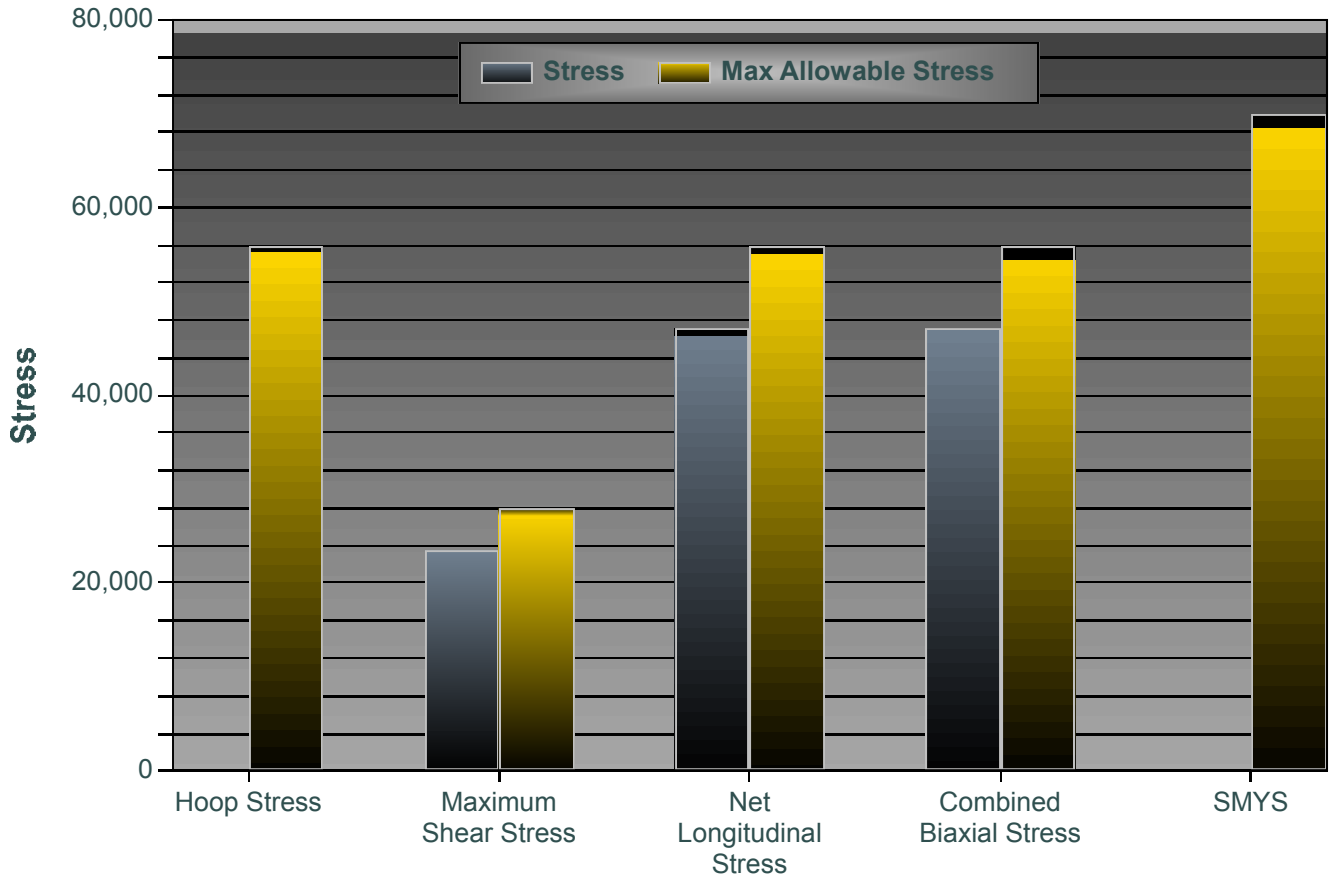
GeoEngineers

Overbend Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Pike & Morgan Counties, Illinois **Date:** Thursday, June 18, 2015

Overbend Stress Check



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APPENDIX B
Geotechnical Data Report

Geotechnical Data Report

Dakota Access Pipeline Project
Illinois River HDD
Pike and Morgan Counties, Illinois

for
Dakota Access, LLC

July 17, 2015

GeoEngineers

3050 South Delaware Avenue
Springfield, Missouri 65804
417.831.9700

Geotechnical Data Report

Dakota Access Pipeline Project
Illinois River HDD
Pike and Morgan Counties, Illinois

File No. 18782-011-01

July 17, 2015

Prepared for:

Dakota Access, LLC
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Attention: Adam Broad

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Jonathan L. Robison, PE
Principal

NWH:JLR:mlh

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Appendix B. Report Limitations and Guidelines for Use

1.0 INTRODUCTION

At the request of Dakota Access, LLC (Dakota Access), and in general accordance with our contract agreement (No. 07-PSA-0017), GeoEngineers, Inc. (GeoEngineers) is pleased to submit this geotechnical data report for the proposed Dakota Access Pipeline (DAPL) Project Illinois River Horizontal Directional Drill (HDD) located near proposed DAPL Milepost (MP) 901 in Pike and Morgan Counties, Illinois. The general location of the proposed HDD along with the proposed DAPL pipeline route in the area is noted on the attached Vicinity Map, Figure 1.

We understand that Dakota Access is proposing to construct approximately 1,020 miles of 30-inch-diameter steel pipeline extending from Mountrail County, North Dakota through eastern South Dakota, Central Iowa, and terminating in Wayne County, Illinois. The proposed Illinois River HDD would cross beneath the Illinois River in Pike and Morgan Counties, Illinois. The conceptual plan and profile of the proposed HDD along with the conceptual HDD stringing area is shown in the attached Conceptual Site Plan and Profile, and Conceptual Stringing Workspace, Figures 2A and 2B, respectively.

Our geotechnical services included completing a subsurface exploration program by drilling seven borings near the proposed HDD alignment and preparing this geotechnical data report. Our assessment of the feasibility of HDD installation and detailed engineering design, and recommendations for HDD construction will be provided under a separate cover.

2.0 SCOPE OF SERVICES

The purpose of our services was to evaluate the existing surface and subsurface soil, rock, and groundwater conditions and to prepare a geotechnical data report. The specific scope of services provided by GeoEngineers included the following:

1. Contacted the Illinois “One-Call” utility locating agency to locate utilities in the project area prior to the start of the exploratory borings.
2. Explored subsurface conditions by drilling seven borings to depths of up to 110 feet below ground surface (bgs) using hollow-stem auger and/or mud rotary and NQ-sized rock coring drilling techniques. GeoEngineers field engineers directed the drilling completed by Geotechnology, Inc., and Strata Earth Services, LLC using All-Terrain-Vehicle (ATV), barge, and truck-mounted drilling equipment.
3. Obtained soil samples at representative intervals from the borings using Standard Penetration Test (SPT), and:
   - Classified the soils encountered in the borings in general accordance with ASTM D2488; and
   - Observed groundwater conditions encountered in the borings, where possible.
4. Completed a laboratory-testing program on selected soil, and rock samples obtained from the borings to evaluate pertinent engineering properties. The tests included the following:
   - Moisture Content (ASTM D2216);
   - Atterberg limits determination (ASTM D4318); and
   - Sieve Analysis (ASTM D422).

- Unconfined compressive strength of rock (ASTM D7012).

5. Prepared logs of the borings which included the following:
   - SPT values as an indication of in-situ soil density;
   - Index and classification properties of soil, as applicable;
   - Rock quality designation (RQD), percent recovery, and Mohs hardness; and
   - Other soil, rock, and groundwater properties as applicable.
6. Prepared and submitted to Dakota Access this data report summarizing the results of the geotechnical investigation.

3.0 SITE DESCRIPTION

3.1 Geological Conditions

3.1.1 Regional Geologic Setting

From approximately MP 882 to MP 999, the proposed DAPL alignment crosses the Springfield Plain sub-section of the Till Plains section. The Springfield Plain includes the level portion of the Illinoian drift-sheet in central and south-central Illinois. It is distinguished mainly by its flatness and by shallow entrenchment of drainage as compared with the more sharply incised valleys of the Galesburg Plain. Although the greater part of the district is a flat till plain, the morainic features in the western part of the region are much more conspicuous than elsewhere on the Illinoian drift-sheet. The moraines are low and broad, but they are readily recognized because of their continuity and the associated kames and kame terraces. Drainage systems are well developed, and the district as a whole is in a late youthful stage of dissection. The uplands are low with respect to the master streams, and the valleys are relatively shallow. Most of the principal streams have low gradients and occupy broad alluviated and terraced valleys; the secondary tributaries have wide V-shaped valleys; and the headwaters, flowing essentially on the till plain, have broad shallow valleys and low gradients. The Illinoian drift is moderately thick and is underlain by older drift except in areas where the bedrock is close to the surface. Only the larger valleys and uplands of the bedrock surface are reflected in the present topography. Along the southeast side of the Illinois Valley there is a belt of thick loess, with dune-contours characterizing the bluff-margin, but this body of loess thins rapidly to the southeast (Leighton, et al, 1948).

3.1.2 Site Geology

Geologic mapping indicates that Quaternary Age (2.6 million years to present) Cahokia Alluvium is present at the Illinois River crossing site, within floodplain of the Illinois River. The Cahokia consists mostly of poorly sorted sand, silt or clay containing local deposits of sandy gravel. In many places the Cahokia overlies well-sorted glacial outwash of the Henry Formation. Mapping indicates that Quaternary (Pleistocene) Age Carmi Member of the Equality Formation will likely be present on the eastern banks of the Illinois River. The Carmi Member consists of well-bedded silt and some clay and includes sediment of proglacial lakes and slack-water lakes in valleys tributary to major river valleys. These surficial deposits are likely to be underlain by Quaternary (Pleistocene) Age Kellerville Till Member of the Glasford Formation on the west side of the Illinois River. The Glasford Formation consists of brown and gray silty till with discontinuous sand and gravel beds and may include some older tills of similar composition. On the east side of the Illinois River, the Vandalia Member of the Glasford Formation may be encountered, consisting of hard, compact sandy till

with sand and gravel. Mapping indicates the total thickness of till above bedrock ranges from 50 to 200 feet at the Illinois River Crossing Site (Lineback, 1979).

Geologic mapping indicates that Mississippian Age (359 to 318 million years ago) Meppen Limestone, Fern Glen Formation, and Burlington-Keokuk Limestone, consisting of limestone, shale and siltstone, may also be encountered at depth (Kolata, 2005).

3.1.3 Subsurface Conditions

Mapping indicates that the soil types likely to be encountered at the Illinois River crossing site are primarily silty clay loam, silt loam and sand residual from alluvium and eolian sands. Surficial materials and bedrock as described above will likely to be encountered below these surficial soils (NRCS Soil Survey).

3.2 Surface Conditions

3.2.1 General

We evaluated the surface conditions in the vicinity of the proposed trenchless crossing during our geotechnical exploration program between November 11 and 15, 2014, February 10 and 12, 2015, and July 7 and 12, 2015.

3.2.2 Surface Description

The proposed HDD alignment trends northwest to southeast (proposed entry to proposed exit), crossing beneath the Illinois River as shown in Conceptual Site Plan and Profile, Figure 2A. The conceptual entry point is located approximately 650 feet northwest of the toe of the USACE Levee and 1,200 feet northwest of the Illinois River's northwest bank, in a relatively flat field at an approximate elevation of 425 feet (North American Vertical Datum [NAVD] 88). Moving southeast from entry, the ground surface along the proposed HDD alignment slopes slightly upward toward the Illinois River then becomes relatively flat upon approaching the Illinois River to approximately 430 feet NAVD 88. The conceptual HDD lies beneath the Illinois River for roughly 280 feet as measured along the path of the proposed HDD skew. Continuing from the Illinois River southeast, the ground surface ascends gradually upward toward exit point located within a relatively flat field roughly 3,200 feet southeast of the Illinois River (as measured along the conceptual HDD) at approximately 450 feet NAVD 88.

3.3 Subsurface Conditions

3.3.1 General

Subsurface conditions were explored at the site between November 11 and 15, 2014, February 10 and 12, 2015, and July 7 and 12, 2015 by drilling seven geotechnical borings (IR-B-1 through IR-B-7). The borings were drilled to depths of up to 110 feet bgs using ATV-mounted, barge-mounted, and truck-mounted drilling equipment. In order to characterize the subsurface conditions for trenchless crossing design, the borings were drilled near the alignment of the proposed crossing.

Soil samples were generally obtained from the borings at 5-foot depth intervals using 1.5-inch inside-diameter (I.D.) split spoon samplers. GeoEngineers staff managed the geotechnical explorations and logged the borings on a full-time basis. Soil samples were visually classified and collected. Other pertinent drilling information was also documented. Laboratory tests, including moisture content determinations, sieve analyses, Atterberg limits, and Unconfined Compressive Strength (UC) tests were completed on

selected samples from the borings. A description of the field exploration and laboratory testing procedures, logs of the borings, and graphs and tables of our laboratory testing results are presented in Appendix A.

3.3.2 Subsurface Description

Boring IR-B-1 was drilled with ATV-mounted drilling equipment to a depth of approximately 83 feet bgs. From the ground surface, the boring encountered approximately 20 feet of very soft to medium stiff clay, 5 feet of very soft silt, and roughly 55 feet of loose to dense sand with vary amounts of silt and gravel. Limestone bedrock was encountered at an approximate depth of 80 feet bgs and mud rotary drilling methods were used to advance the boring to its termination depth. During our subsurface exploration the Illinois River was at flood stage and a water bearing sand layer was encountered which caused groundwater to flow up through the boring. The water was stopped by utilizing a barite grouting mixture.

Boring IR-B-2 was drilled with barge-mounted drilling equipment to a depth of approximately 90½ feet bgs. From the river bottom or mudline, the boring encountered approximately 18½ feet of very soft high plasticity clay, 54½ feet of very loose medium dense sand with varying amounts of silt, clay, and gravel, overly limestone bedrock to the termination depth of the boring. The bedrock RQD ranged from fair to excellent quality.

Boring IR-B-3 was drilled with barge-mounted drilling equipment to a depth of approximately 90 feet bgs. From the river bottom or mudline, the boring encountered approximately 10 feet of very soft clay, 63½ feet of loose to medium dense sand with occasional gravel, overlying limestone bedrock to the termination depth of the boring. The bedrock RQD ranged from good to excellent.

Boring IR-B-4 was drilled with ATV-mounted drilling equipment to a depth of approximately 93½ feet bgs. From the ground surface, the boring encountered approximately 6 feet of soft to medium stiff silt, 2½ feet of medium stiff clay, 24 feet of soft to medium stiff silt with varying amounts of clay and sand, 50 feet of very loose to medium dense sand with varying amounts of silt and occasional gravel overlying a combination of limestone and shale bedrock to the termination depth of the boring. The bedrock RQD ranged from fair to good quality.

Boring IR-B-5 was drilled with ATV-mounted drilling equipment to a depth of approximately 110 feet bgs. From the ground surface, the boring encountered approximately 103 feet very loose to medium dense sand with vary amounts of silt and occasional gravel, overlying limestone bedrock to the termination depth of the boring. The bedrock RQD ranged from good to excellent.

Boring IR-B-6 was drilled with ATV-mounted drilling equipment to a depth of approximately 105 feet bgs. From the ground surface, the boring encountered approximately 6 feet of very loose sand with trace silt, 3½ feet of medium stiff silt, 89 feet of loose to very dense sand varying amounts of silt and occasional, roughly 1½ feet of very dense gravel with sand and trace silt, overlying limestone bedrock to the termination depth of the boring. The RQD of the bedrock was excellent.

Boring IR-B-7 was drilled with ATV-mounted drilling equipment to a depth of approximately 80 feet bgs. From the ground surface, the boring encountered approximately 15 feet of very soft to medium stiff clay with occasional gravel, 15 feet of loose sand with trace clay and occasional gravel, 5 feet of very soft clay with occasional sand, overlying 44 feet of medium dense to very dense sand with varying amounts of silt and

gravel. Limestone bedrock was encountered at an approximate depth of 79 feet bgs and mud rotary drilling methods were used to advance the boring to its termination depth.

3.3.3 Groundwater Conditions

At the time of drilling, groundwater was observed at approximately 15 feet bgs in Boring IR-B-4 and 5 feet in Boring IR-B-7. Due to the drilling techniques used, the groundwater level can be difficult to measure and will fluctuate over time due to seasonal variations in precipitation and the level of the nearby Illinois River.

4.0 LIMITATIONS

We have prepared this data report for use by Dakota Access, their authorized agents and other approved members of the design team involved with this project. The data report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. A trenchless feasibility assessment and design report for this location will be delivered separately with our conclusions and recommendations based on our subsurface exploration program, design recommendations are not covered in this data report.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to evaluate that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, express, written or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, and will serve as the official document of record.

Please refer to Appendix B, titled “Report Limitations and Guidelines for Use,” for additional information pertaining to use of this report.

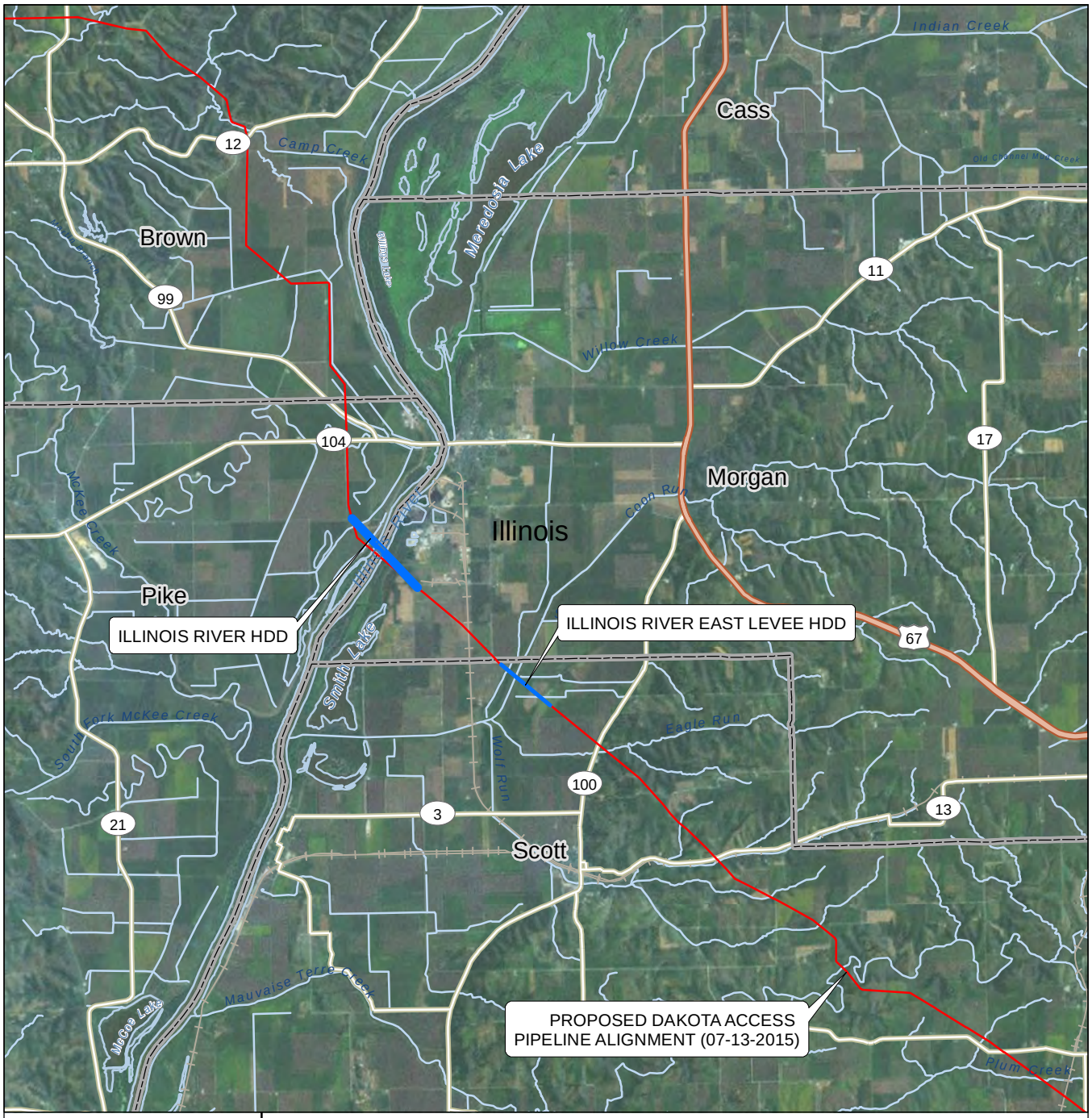
5.0 REFERENCES

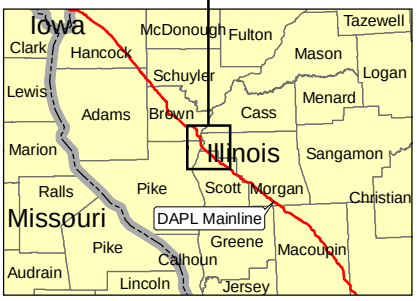
Kolata, D.R., 2005, Bedrock Geology of Illinois, Illinois State Geological Survey, Scale 1:500,000

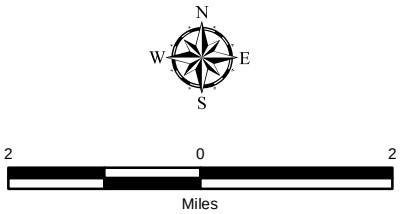
Leighton, M.M., Ekblaw, G.E. and Horberg, L., 1948, Physiographic Divisions of Illinois, Illinois State Geological Survey, Publication RI 129.

Lineback, J.A., 1979, Quaternary Deposits of Illinois, Illinois State Geological Survey, Scale 1:500,000.

NRCS Soil Survey, National Cooperative Soil Survey, Natural Resources Conservation Service, USDA, (http://websoilsurvey.nrcs.usda.gov).







Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Imagery from ESRI Data Online.
Projection: NAD 1983, UTM Zone 15 North.

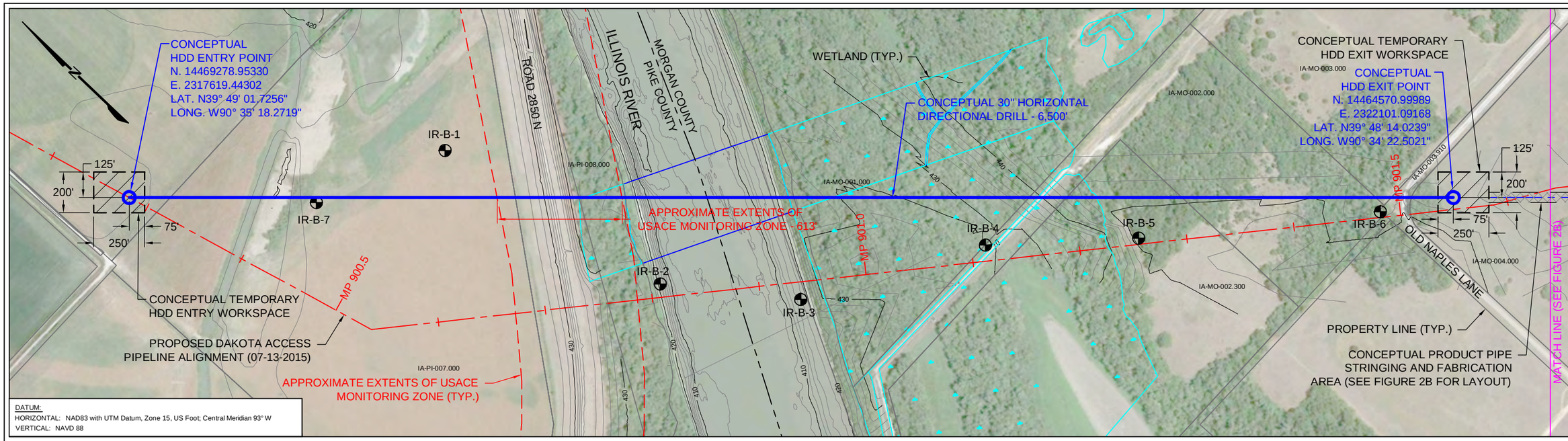
DAKOTA ACCESS PIPELINE PROJECT
VICINITY MAP

PROPOSED 30" PIPELINE
ILLINOIS RIVER HDD
PIKE AND MORGAN COUNTIES, ILLINOIS

GEOENGINEERS

Figure 1

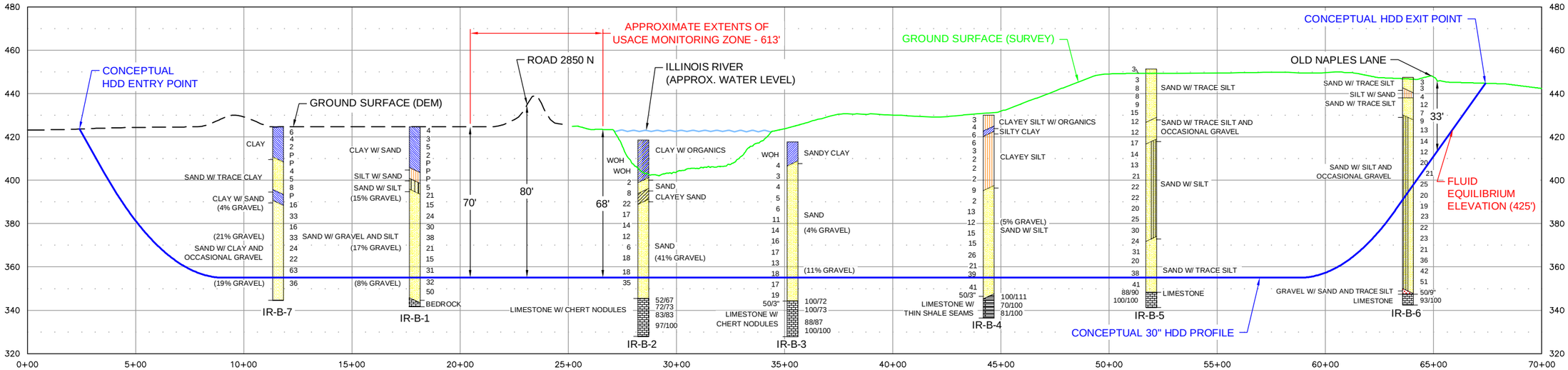
Office: SPR Path: P:\18\1878201101\GIS\Vicinity Maps\Illinois\Illinois River HDD.mxd Map Revised: 16 July 2015 mclevenger



PLAN

500' 0 500'

SCALE IN FEET



PROFILE

500' 0 500'

HORIZONTAL SCALE IN FEET

50' 0 50'

VERTICAL SCALE IN FEET

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Refer to the boring logs in the accompanying report for more detailed soil descriptions.
4. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Ground surface DEM (1/3 Arc Second) downloaded from http://NationalMap.Gov.
Ground surface survey provided by Wood Group Mustang, Inc.
Aerial image taken from Google Earth Pro © 2015, licensed to GeoEngineers, Inc., image dated 07/31/12.
Shape files provided by Contract Land Staff, LLC.

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

LEGEND:

SPT (N) | TYPE OF SOIL (% GRAVEL)
TYPE OF ROCK | RQD/ % REC

Boring Location
Major Contour - 10' Interval
Minor Contour - 2' Interval

DAKOTA ACCESS PIPELINE PROJECT
CONCEPTUAL SITE PLAN AND PROFILE

PROPOSED 30" PIPELINE
ILLINOIS RIVER HDD
PIKE AND MORGAN COUNTIES, ILLINOIS

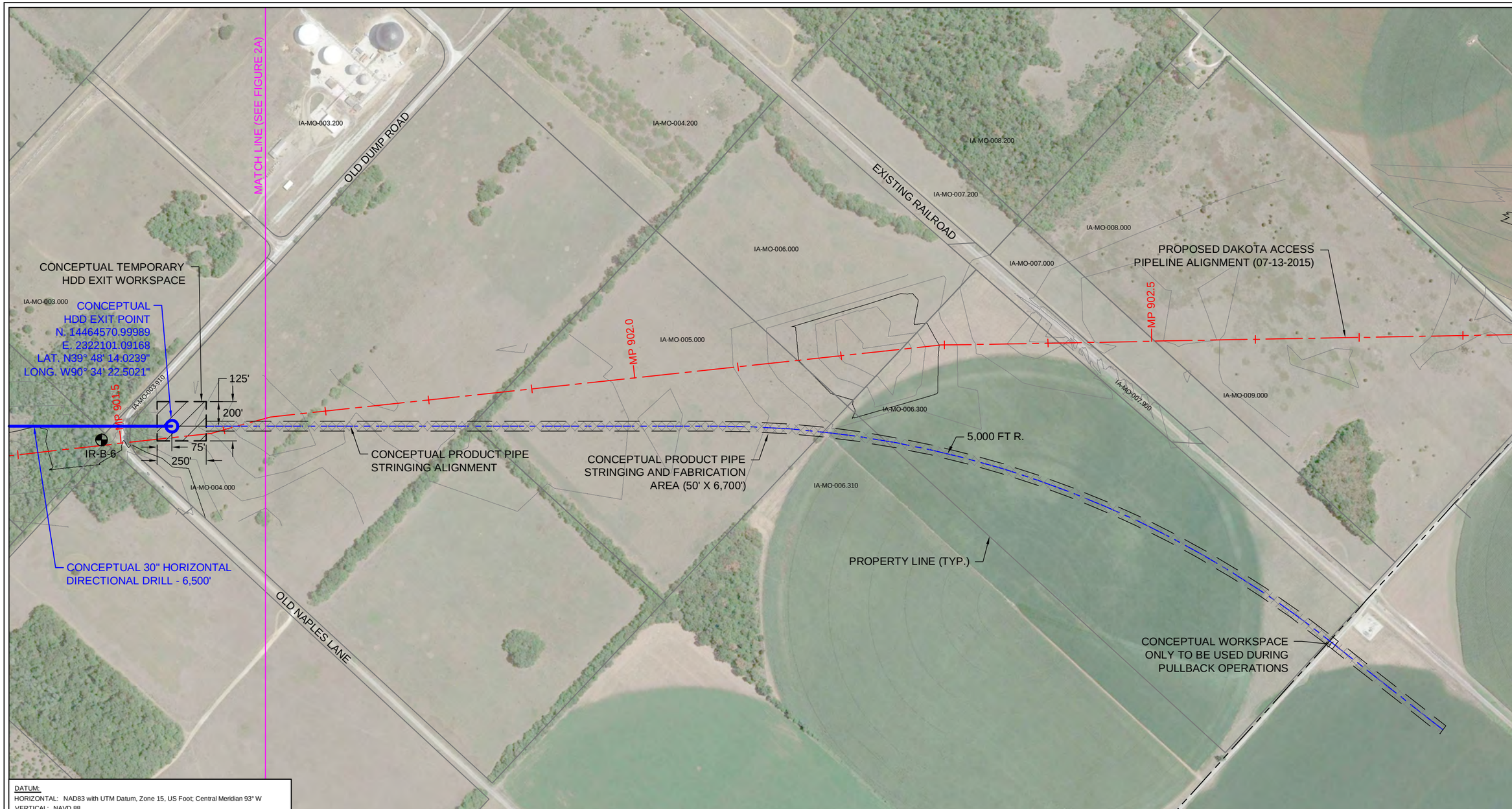
GEOENGINEERS

FIGURE 2A

DATE ISSUED: JULY 17, 2015

MAM : MWC

P:\18\1878201\01\CAD\Crossings\Illinois\Illinois River\Drawings\Illinois River HDD Figure 2.dwg\TAB:Figure 2A modified on Jul 17, 2015 - 1:17pm



Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Ground surface DEM (1/3 Arc Second) downloaded from http://NationalMap.Gov.
Ground surface survey provided by Wood Group Mustang, Inc.
Aerial image taken from Google Earth Pro © 2015, licensed to GeoEngineers, Inc., image dated 07/31/12.
Shape files provided by Contract Land Staff, LLC.

PLAN
500' 0 500'
SCALE IN FEET

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

LEGEND:
- Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

DAKOTA ACCESS PIPELINE PROJECT
CONCEPTUAL STRINGING WORKSPACE

PROPOSED 30" PIPELINE
ILLINOIS RIVER HDD
PIKE AND MORGAN COUNTIES, ILLINOIS

GEOENGINEERS

FIGURE 2B

DATE ISSUED: JULY 17, 2015

MAM : MWC

P:\18\1878201\1\01\CAD\Crossings\Illinois\Illinois River\Drawings\Illinois River HDD Figure 2.dwg\TAB:Figure 2B modified on Jul 17, 2015 - 1:19pm

Looking South from Boring IR-B-6 Toward the Exit Workspace and Product Pipe Stringing Area

Looking Northwest from Boring IR-B-7 towards the Entry Workspace

GEOENGINEERS

Dakota Access Pipeline Project – Illinois River HDD
Site Photographs

FIGURE 3

APPENDIX A
Field Explorations and Laboratory Testing

APPENDIX A
FIELD EXPLORATIONS AND LABORATORY TESTING

Field Explorations

Subsurface conditions were explored at the site between November 11 and 15, 2014, February 10 and 12, 2015, and July 7 and 12, 2015 by drilling seven geotechnical borings using All-Terrain-Vehicle (ATV) and Truck-mounted drill rigs. The Illinois State "One-Call" utility locating agency was contacted to locate utilities in the project area prior to the start of the exploratory borings. The borings were drilled near the alignment of the proposed trenchless crossing in order to characterize the subsurface conditions.

The drilling operations were monitored by GeoEngineers staff who examined and classified the soils encountered, obtained representative samples, observed groundwater conditions where possible and prepared a detailed log of each exploration. The soils encountered were classified visually in general accordance with ASTM International (ASTM) D2488, which is described in Figure A-1. The rock encountered was classified in accordance with the rock classification system described in Figure A-2. The approximate locations of the explorations are shown in the Conceptual Site Plan and Profile, Figure 2A.

In general, soil samples were obtained from the borings at 5-foot-depth intervals using a 1.5-inch inside-diameter (I.D.) split spoon standard penetration test (SPT) sampler. The SPT sampler was driven 18 inches, using a 140-pound hammer with a 30-inch drop. The number of hammer blows required to drive the sampler the final 12-inches was recorded on field logs. Rock core samples were obtained using a 2-inch I.D. NQ core barrel. Each boring was backfilled full depth with cement-grout.

The relative density of the SPT samples recovered at each interval was evaluated based on correlations with lab and field observations in general accordance with the values outlined in Table A-1 below.

TABLE A-1 CORRELATION BETWEEN BLOW COUNTS AND RELATIVE DENSITY [1]

Cohesive Soils (Clay/Silt)						
Parameter	Very Soft	Soft	Medium Stiff	Stiff	Very Stiff	Hard
Blows, N	< 2	2 – 4	4 – 8	8 – 16	16 – 32	>32
Cohesionless Soils (Gravel/Sand/Silty Sand) [2]						
	Very Loose	Loose	Medium Dense	Dense	Very Dense	
Blows, N	0 – 4	4 – 10	10 – 30	30 – 50	> 50	

Notes:

[1] After Terzaghi, K and Peck, R.B., "Soil Mechanics in Engineering Practice," John Wiley & Sons, Inc., 1962.

[2] Classification applies to soils containing additional constituents; that is, organic clay, silty or clayey sand, etc.

The Rock quality designation (RQD) of the rock core samples recovered from each core run was evaluated and are presented on the exploration logs in Figures A-3 through A-9. The rock quality descriptions are correlated to RQD (%) as outlined in Table A-2, below.

TABLE A-2 ROCK QUALITY DESIGNATION

RQD (%)	Rock Quality Description
0-25	Very Poor
26-50	Poor
51-75	Fair
76-90	Good
91-100	Excellent

The exploration logs are presented in Figures A-3 through A-9. The logs are based on our interpretation of the field data and indicate the various types of soils encountered. They also indicate the approximate depths at which the subsurface conditions change.

Laboratory Testing

General

Soil samples obtained from the explorations were transported to SCI ENGINEERING, Inc. in Rolla, Missouri and GeoEngineers' office in Springfield, Missouri examined to confirm or modify field classifications. Representative samples were selected for laboratory testing consisting of moisture content determinations, sieve analyses, and Atterberg limits testing. The laboratory testing procedures are discussed in more detail below.

Moisture Content Testing

Moisture content tests were completed for representative soil samples obtained from the explorations in general accordance with ASTM D2216. The results of these tests are presented on the exploration logs in Figures A-3 through A-9 at the depths at which the samples were obtained.

Sieve Analyses

Sieve analyses were performed on selected samples in general accordance with ASTM D422. The results of the sieve analyses were plotted and classified in general accordance with the Unified Soil Classification System (USCS) and are presented in Figures A-10 through A-14. The sample gravel content (% Gravel) and percentage passing the U.S. No. 200 sieve (% Fine) are shown on the boring logs at the respective sample depths.

Atterberg Limits Testing

Atterberg Limits were performed on selected fine grained soil samples in general accordance with ASTM D4318. The tests were used to classify the soil as well as to evaluate its index properties. The results of the Atterberg Limits testing are shown in Figures A-15 and A-16.

Unconfined Compression Testing

Unconfined compression (UC) tests were performed on selected rock samples obtained from the borings. The tests were used to evaluate shear strength characteristics and were completed in general accordance with ASTM D 7012. The results of testing are presented on the boring logs at their respective sample depths and are summarized in table form in Figure A-17. Rock core sample photographs are presented in Figures A-18 through A-21.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% RETAINED ON NO. 200 SIEVE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Continuous Coring

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PI	Plasticity index
PP	Pocket penetrometer
PPM	Parts per million
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

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FIGURE A-1

UNIFIED ROCK CLASSIFICATION SYSTEM (URCS)*

BASIC ELEMENTS

DEGREE OF WEATHERING

WEATHERED		ALTERED	REPRESENTATIVE	
SAND SIZE COMPLETELY DECOMPOSED STATE (CDS) E	GRAVEL SIZE PARTLY DECOMPOSED STATE (PDS) D	STAINED STATE (STS) C	VISUALLY FRESH STATE (VFS) B	MICRO FRESH STATE (HAND LENSE) (MFS) A
PLASTIC NON-PLASTIC	PLASTIC NON-PLASTIC	COMPARE TO FRESH STATE	UNIT WEIGHT, RELATIVE ABSORPTION	

ESTIMATED STRENGTH

REMOLDING		REACTION TO IMPACT OF 1 LB. BALLPEEN HAMMER		
"MOLDABLE" (FRIABLE) (MBL) E	"CRATERS" (SHEARS) (CQ) D	"DENTS" (COMPRESSIVE) (DQ) C	"PITS" (TENSIONAL) (PQ) B	"REBOUNDS" (ELASTIC) (RQ) A
<1,000 PSI (<7 MPa)	1,000 to 3,000 PSI (7 to 21 Ma)	3,000 to 8,000 PSI (21 to 55 MPa)	3,000 to 15,000 PSI (55 to 103 MPA)	>15,000 PSI (>103 MPa)

DISCONTINUITIES

TRANSMITS WATER						
YES	NO	YES	NO	LATENT PLANES OF SEPARATION (LPS) C	SOLID-PREFERRED BREAKAGE (SPB) B	SOLID-RANDOM BREAKAGE (SRB) A
3-DIMENSIONAL PLANES OF SEPARATION (3D) E		2-DIMENSIONAL PLANES OF SEPARATION (2D) D				
INTERLOCK		ATTITUDE				

UNIT WEIGHT

LESS THAN 130 LBS/CU FT (2.10 Mg/CU M) (<130) E	130 TO 140 LBS/CU FT (2.10 TO 2.25 Mg/CU M) (130) D	140 TO 150 LBS/CU FT (2.25 TO 2.40 Mg/CU M) (140) C	150 TO 160 LBS/CU FT (2.40 TO 2.55 Mg/CU M) (150) B	GREATER THAN 160 LBS/CU FT (2.55 Mg/CU M) (>160) A

DESIGN NOTATION

WEATHERING	STRENGTH	DISCONTINUITY	WEIGHT
A-E	A-E	A-E	A-E

* Williamson, Douglas A., 1984, Unified Rock Classification System: Association of Engineering Geologists Bulletin, Vol. XXI, No. 3, pp. 345-354

GEOENGINEERS

ROCK CLASSIFICATION SYSTEM

FIGURE A-2

Drilled Start 7/9/2015 End 7/9/2015	Total Depth (ft) 83	Logged By SMS Checked By NWH	Driller Strata Earth Services, LLC	Drilling Method Mud Rotary	
Surface Elevation (ft) Vertical Datum 425	Hammer Data Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment Diedrich D-120-ATV Mounted Drill Rig			
Latitude 39° 48' 43.657" N Longitude 90° 35' 06.329" W	System Datum Geographic	Groundwater Date Measured / Depth to Water (ft) / Elevation (ft): N/A			
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		13	4		S1			CL	Brown clay with occasional sand (medium stiff, moist)	31		
			17	3		S2				Becomes soft	27		Water observed
420	5		18	5		S3				Becomes medium stiff, wet	28		
			18	2		S4				Becomes soft	35		
415	10		18	P		S5				Becomes very soft	30		
410	15		18	P		S6					33		LL = 31 PI = 13
405	20		14	P		S7			ML	Brown silt with occasional sand (very soft, wet)	33		
400	25		18	5		S8			SM	Brown fine to coarse sand with silt (loose, wet)			
395	30		11	21		S9			SP	Brown fine to coarse sand with gravel and silt (medium dense, wet)			% Fine = 7 % Gravel = 15
390	35												

Springfield: Date:7/17/15 Path:P:\18\18782011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-1

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-3
Sheet 1 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35		12	15		S10							
385	40		12	24		S11							
380	45		12	30		S12				Becomes dense			
375	50		12	38		S13							
370	55		13	21		S14				Becomes medium dense			% Fine = 5 % Gravel = 17
365	60		12	15		S15							
360	65		15	31		S16				Becomes dense			Rough drilling
355	70		18	32		S17				Becomes with occasional gravel			% Fine = 5 % Gravel = 8
350	75		10	50		S18				Becomes very dense			

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-1 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-3
Sheet 2 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
345	80								Limestone	Bedrock encountered			Hard drilling Drilling method Mud Rotary No sample obtained

Log of Boring IR-B-1 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-3

Sheet 3 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 11/14/2014 End 11/15/2014	Total Depth (ft) 90.5	Logged By NAA Checked By JLR	Driller Geotechnology, Inc.	Drilling Method Mud Rotary	
Surface Elevation (ft) Vertical Datum 418	Hammer Data Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment CME-750 Barge Mounted			
Latitude 39° 48' 39.875" N Longitude 90° 34' 59.831" W	System Datum Geographic	Groundwater Date Measured / Depth to Water (ft) / Elevation (ft) N/A			
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
415	0												
	5												
410			8	WOH		S1			CH	Gray clay with organics (very soft, wet)	30		
	10												
405			13	WOH		S2					34		
	15												
400			3	2		S3			SP	Gray fine to medium sand (very loose, wet)			
	20												
395			14	8		S4			SC	Gray clayey fine to medium sand (loose, moist)			
	25												
390			9	22		S5			SP	Gray fine to medium sand (medium dense, wet)			
	30												
385			9	17		S6				With occasional coarse sand			
	35												

FIELD DATA

Springfield: Date:7/17/15 Path:P:\18\18782011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-2

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-4

Sheet 1 of 3

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
380													
			8	14		S7				Grades to brown			
	40												
375													
			7	12		S8							
	45												
370													
			7	6		S9				Becomes loose			
	50												
365													
			5	18		S10				Becomes with coarse sand and fine gravel and medium dense			% Fine = 2 % Gravel = 41
	55												
360													
			10	18		S11				Becomes fine sand			
	60												
355													
			12	35		S12				Becomes dense			
	65												
350													
	70												
345			16	52		R1			Limestone	Gray limestone with chert nodules, stained state, rebound quality, 2D discontinuities			
	75												
			43	72		R2							Fair quality

Log of Boring IR-B-2 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-4
Sheet 2 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
340													
	80		50	83		R3							Good quality
335										Becomes visually fresh state			
	85		58	97		R4							Excellent quality
330													
	90												

Log of Boring IR-B-2 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-4

Sheet 3 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 11/13/2014 End 11/13/2014	Total Depth (ft) 90	Logged By NAA Checked By JLR	Driller Geotechnology, Inc.	Drilling Method Mud Rotary	
Surface Elevation (ft) Vertical Datum 418	Hammer Data Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment CME-750 Barge Mounted			
Latitude 39° 48' 34.926" N Longitude 90° 34' 53.557" W	System Datum Geographic	Groundwater Date Measured / Depth to Water (ft) / Elevation (ft): N/A			

Notes: Upon completion, borehole backfilled with cement-bentonite grout.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0												
415													
	5		13	WOH		S1			CL	Gray fine sandy clay (very soft, wet)	36		
410													
	10		6	4		S2			SP	Brown fine sand (loose, wet)			
405													
	15		11	3		S3							
400													
	20		9	4		S4							
395													
	25		7	5		S5							
390													
	30		8	6		S6				Becomes with occasional coarse sand			
385													
	35												

Log of Boring IR-B-3

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-5

Sheet 1 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35		11	11		S7				Becomes medium dense, with occasional gravel			
380													
	40		10	14		S8							% Fine = 4 % Gravel = 4
375													
	45		10	16		S9							
370													
	50		12	17		S10							
365													
	55		12	13		S11				Becomes with fine to medium sand			
360													
	60		9	18		S12				Grades to gray, becomes with occasional gravel			% Fine = 9 % Gravel = 11
355													
	65		10	17		S13							
350													
	70		9	19		S14				Becomes with trace fine gravel			
345			0	50/3"		S15							
			26	100		R1			Limestone	Gray limestone with chert nodules, stained state, rebound quality, 2D discontinuities			Auger refusal at 73.5 feet bgs Excellent quality
	75												

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-3 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-5
Sheet 2 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
340			58	100		R2							Excellent quality
	80												
335			41	88		R3							Good quality
	85												
330			34	100		R4							Excellent quality
	90												

Log of Boring IR-B-3 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-5

Sheet 3 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 11/11/2014 End 11/12/2014	Total Depth (ft) 93.5	Logged By MJP Checked By JLR	Driller Geotechnology, Inc.	Drilling Method HSA/Mud Rotary/RockCore	
Surface Elevation (ft) Vertical Datum 430		Hammer Data Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment CME-750 ATV Mounted	
Latitude 39° 48' 29.343" N Longitude 90° 34' 44.425" W		System Datum Geographic		Groundwater Date Measured	Depth to Water (ft) N/A / Elevation (ft)
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		14	3		S1			ML	Dark brown clayey silt with organics (small roots and wood debris) (soft, moist)	34		
425	5		12	4		S2				Becomes medium stiff			
			14	6		S3			CL	Dark brown to gray silty clay (medium stiff, moist)			
420	10		14	6		S4			ML	Dark gray clayey silt (medium stiff, moist)	23		
415	15		15	3		S5				Becomes gray, sandy, and soft	23		Water observed at 15 feet bgs
410	20		18	2		S6					28		Switched to mud rotary
405	25		18	2		S7					32		LL = 26 PI = 3
400	30		18	2		S8					35		
395	35		12	9		S9			SP	Brown fine to medium sand with silt (loose, wet)			

Log of Boring IR-B-4

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-6

Sheet 1 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
390	40		5	2		S10				Becomes very loose			
385	45		15	13		S11				Becomes medium dense			
380	50		14	12		S12				Becomes fine to coarse sand with silt and occasional gravel			% Fine = 6 % Gravel = 5
375	55		16	15		S13				Becomes darker brown			
370	60		14	15		S14							
365	65		14	26		S15							
360	70		12	21		S16							
355	75		14	39		S17				Becomes dense			

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-4 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-6
Sheet 2 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
350	80		13	41		S18					15		
345	85		9 20	50/3" 100		S19 R1			Limestone Shale	Gray limestone with very thin shale seams, stained state, rebound quality, solid preferred breakage Gray limestone with large chert pockets, stained state, rebound quality, solid preferred breakage, very hard	18		Hit rougher drilling High blow counts due to bedrock Switched to rock core Fair quality
			60	70		R2							
340	90		42	81		R3							UC = 3,950 psi Mohs = 5 Good quality

Log of Boring IR-B-4 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-6

Sheet 3 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 2/11/2015 End 2/12/2015	Total Depth (ft) 110	Logged By EKV Checked By JLR	Driller Geotechnology, Inc.	Drilling Method Mud Rotary	
Surface Elevation (ft) Vertical Datum 451		Hammer Data Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment CME 550X ATV	
Latitude 39° 48' 24.047" N Longitude 90° 34' 37.644" W		System Datum Geographic		Groundwater Date Measured	Depth to Water (ft) N/A / Elevation (ft)
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
450	0		14	3		S1			SP	Brown fine sand with trace silt (very loose, moist)			
			14	3		S2							
445	5		15	8		S3				Becomes loose			
			14	8		S4							
440	10												
			13	9		S5							
435	15												
			14	15		S6				Becomes medium dense			
430	20												
			15	12		S7			SP	Brown fine to coarse sand with trace silt and occasional gravel (medium dense, wet)			
425	25												
			12	12		S8							
420	30												
			14	17		S9			SP-SM	Brown fine sand with silt (medium dense, wet)			
	35												

Log of Boring IR-B-5

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-7

Sheet 1 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
415	35											
		10	14		S10							
410	40											
		10	13		S11							
405	45											
		12	21		S12							
400	50											
		12	22		S13							
395	55											
		13	22		S14							% Fine = 5 % Gravel = 2
390	60											
		13	20		S15							
385	65											
		12	25		S16							
380	70											
		12	30		S17				Becomes dense			
375	75											

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-5 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-7
Sheet 2 of 3

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
			12	24		S18			SP	Brown fine to coarse sand with trace silt (medium dense, wet)			
370	80												
			12	31		S19				Becomes dense			% Fine = 5 % Gravel = 1
365	85												
			11	20		S20				Becomes medium dense			
360	90												
			12	38		S21				Becomes dense			
355	95												
			10	41		S22							
350	100												
			27	88		R1			Limestone	Gray limestone, closed fractures, visually fresh state			Good quality
345	105		54	100		R2							Excellent quality UC = 5,700 psi Mohs = 4
	110												

Log of Boring IR-B-5 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-7
Sheet 3 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 2/10/2015 End 2/11/2015	Total Depth (ft) 105	Logged By EKV Checked By JLR	Driller Geotechnology, Inc.	Drilling Method Mud Rotary	
Surface Elevation (ft) Vertical Datum 447		Hammer Data Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment CME 550X ATV	
Latitude 39° 48' 16.1911" N Longitude 90° 34' 26.2395" W		System Datum Geographic		Groundwater Date Measured	Depth to Water (ft) N/A / Elevation (ft)
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		10	3		S1			SP	Tan fine sand with trace silt (very loose, moist)			
445			10	3		S2							
	5		10	4		S3			ML	Brown silt with fine sand (medium stiff, moist)	16		
440			12	12		S4				Becomes stiff			
	10								SP	Tan fine sand with trace silt (loose, moist)			
435			10	7		S5							
	15												
430			9	9		S6			SP-SM	Brown fine to medium sand with silt and occasional gravel (loose, wet)			
	20												
425			10	13		S7				Becomes medium dense			
	25												
420			12	14		S8							
	30												
415			10	12		S9							
	35												

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-6

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-8

Sheet 1 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
410	35											
		10	20		S10							
405	40											
		10	21		S11							
400	45											
		14	25		S12							
395	50											
		8	20		S13							% Fine = 5
390	55											
		10	19		S14							
385	60											
		14	23		S15							
380	65											
		15	22		S16							
375	70											
		14	23		S17							
	75											

Springfield: Date:7/17/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-6 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-8

Sheet 2 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
370													
			14	21		S18							
	80												
365													
			10	36		S19				Becomes dense			
	85												
360													
			8	42		S20							
	90												
355													
			8	51		S21				Becomes very dense			
	95												
350													
			8	50/9"		S22			GP	Brown and gray fine to coarse gravel with sand and trace silt (very dense, wet)			
	100		60	93		R1			Limestone	Gray limestone, visually fresh state			Excellent quality UC = 4,720 Mohs = 4
345													
	105												

Log of Boring IR-B-6 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-8

Sheet 3 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 7/7/2015 End 7/8/2015	Total Depth (ft) 80	Logged By SMS Checked By NWH	Driller Strata Earth Services, LLC	Drilling Method Mud Rotary	
Surface Elevation (ft) Vertical Datum 425	Hammer Data Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment Diedrich D-120-ATV			
Latitude 39° 48' 51.87" N Longitude 90° 35' 2.72" W	System Datum Geographic	Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)	
Notes: Upon completion, borehole backfilled with cement-bentonite grout.		N/A			

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		14	6		S1			CL	Brown clay (medium stiff, moist)	29		
			17	4		S2				Becomes with occasional sand	37		
420	5		18	2		S3				Becomes soft, wet	50		Water observed
			14	P		S4				Becomes very soft	73		
415	10		18	P		S5				Becomes with occassional gravel	40		
410	15		18	4		S6			SP	Dark brown sand with trace clay (loose, wet)			
405	20		14	5		S7				Becomes light brown with occasional gravel			
400	25		12	8		S8							
395	30		18	P		S9			CL	Brown clay with occasional sand (very soft, wet)	50		
390	35												

Springfield: Date:7/17/15 Path:P:\18\18782011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-7

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-9
Sheet 1 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35		13	16		S10			S	Brown sand with clay and occasional gravel (medium dense, wet)			% Fine = 15 % Gravel = 4
385	40		14	33		S11				Becomes without gravel and clay and with trace silt (dense)			
380	45		11	16		S12				Becomes medium dense			
375	50		16	33		S13				Becomes with silt and gravel (dense)			% Fine = 5 % Gravel = 21
370	55		10	24		S14				Becomes medium dense			
365	60		14	22		S1							
360	65		18	63		S16				Becomes with occasional gravel and trace silt and very dense			
355	70		17	36		S17				Becomes dense			Hard drilling % Fine = 4 % Gravel = 19
350	75												

Springfield: Date:7/17/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring IR-B-7 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-9
Sheet 2 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
345	80								Limestone				

Log of Boring IR-B-7 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River HDD

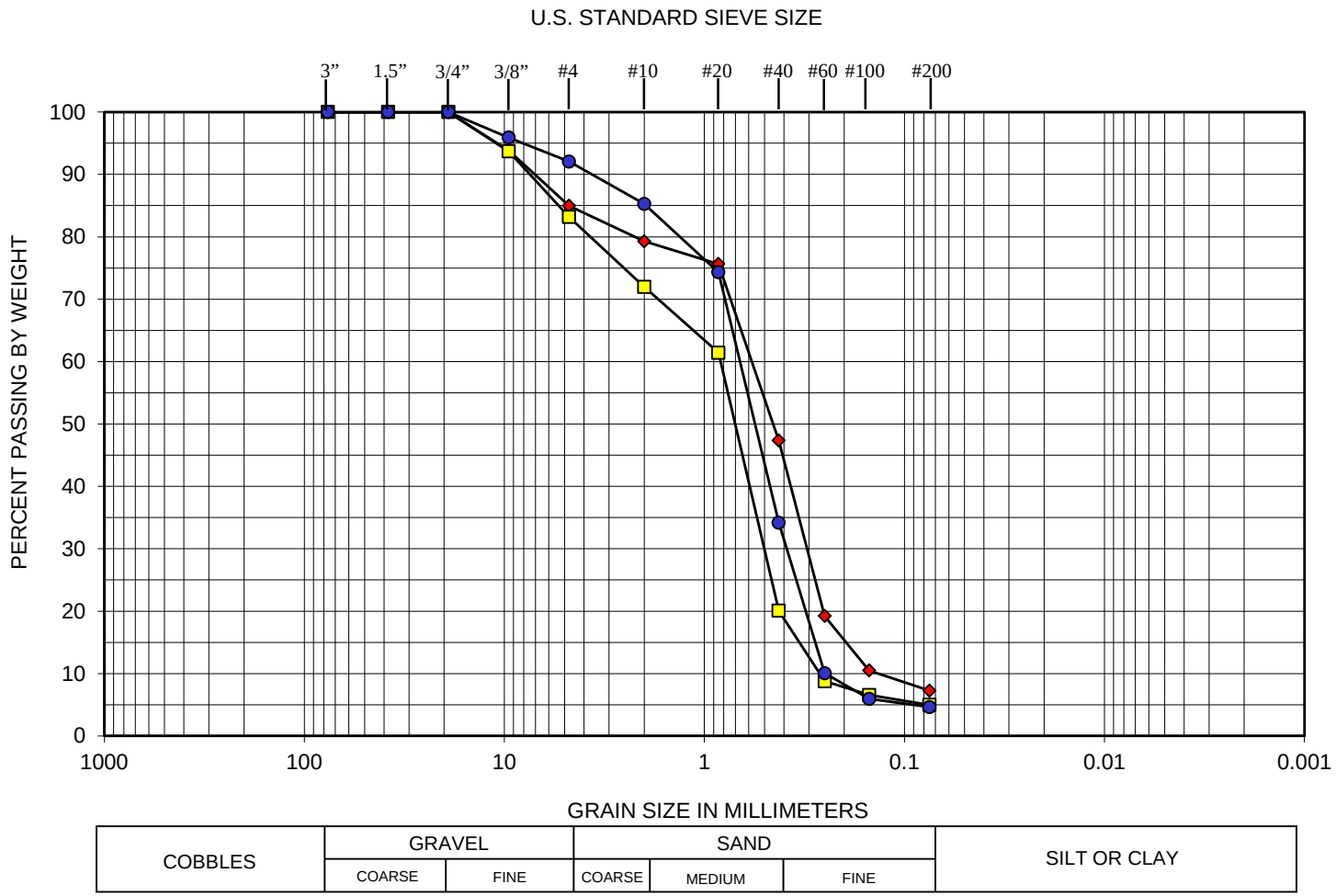
Project Location: Pike and Morgan Counties, Illinois

Project Number: 18782-011-01

Figure A-9

Sheet 3 of 3

Springfield: Date:7/17/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	IR-B-1	30.0 – 31.5	Brown fine to coarse SAND with gravel and silt (SP)
■	IR-B-1	53.5 – 55.0	Brown fine to coarse SAND with gravel and silt (SP)
●	IR-B-1	68.5 – 70.0	Brown fine to coarse SAND occasional gravel and silt (SP)

Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River HDD
Pike & Morgan Counties, Illinois

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Figure A-10

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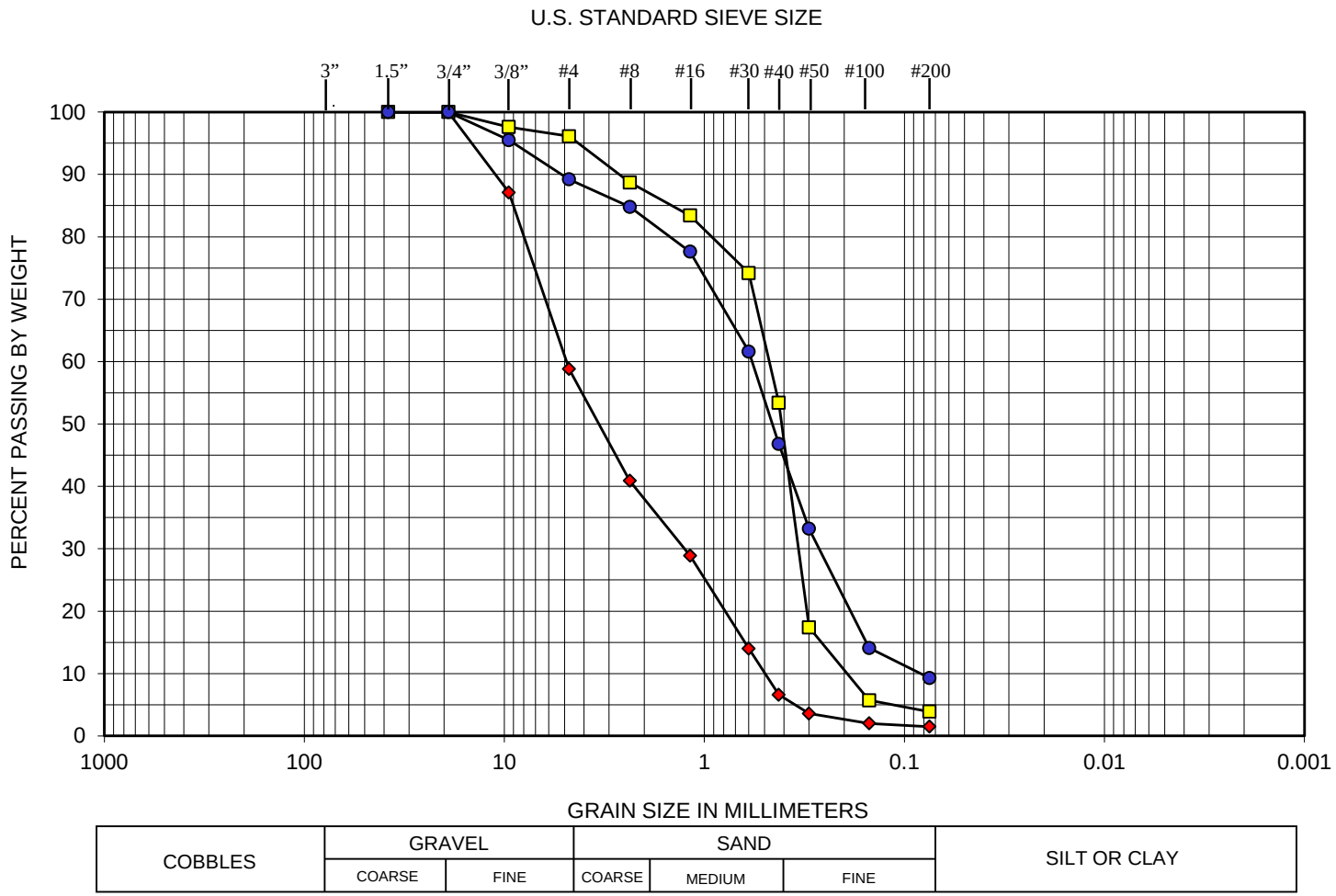

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	IR-B-2	53.5 – 55.0	Brown fine to Coarse SAND with gravel and trace silt (SP)
■	IR-B-3	40.0 - 41.5	Brown fine to Coarse SAND with occasional gravel and trace silt (SP)
●	IR-B-3	60.0 - 61.5	Gray fine to Coarse SAND with occasional gravel and silt (SP)

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Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River HDD
Pike & Morgan Counties, Illinois

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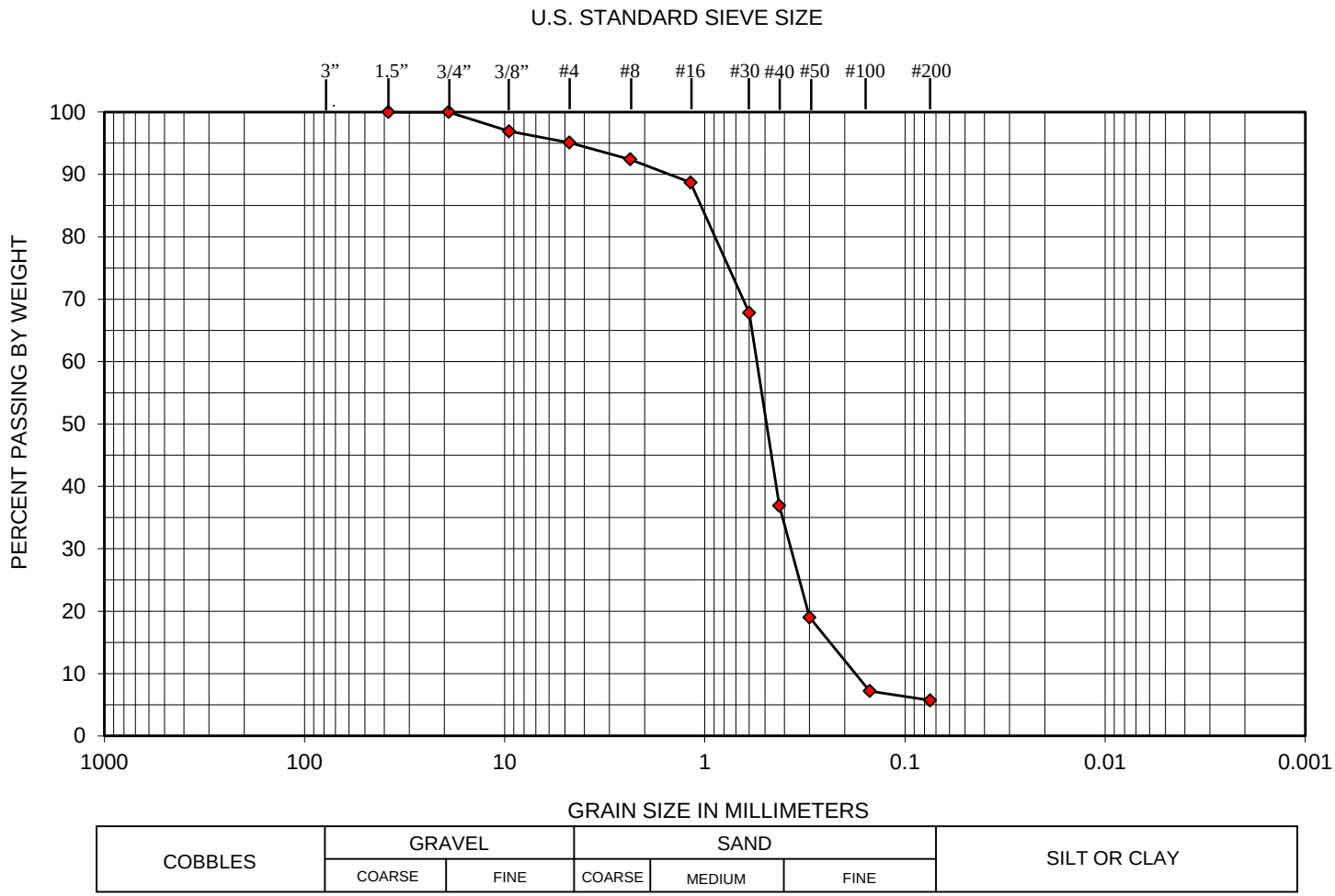
Figure A-11



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
♦	IR-B-4	48.5 – 50.0	Brown fine to coarse SAND with silt and occasional gravel (SP)

Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River HDD
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Figure A-12

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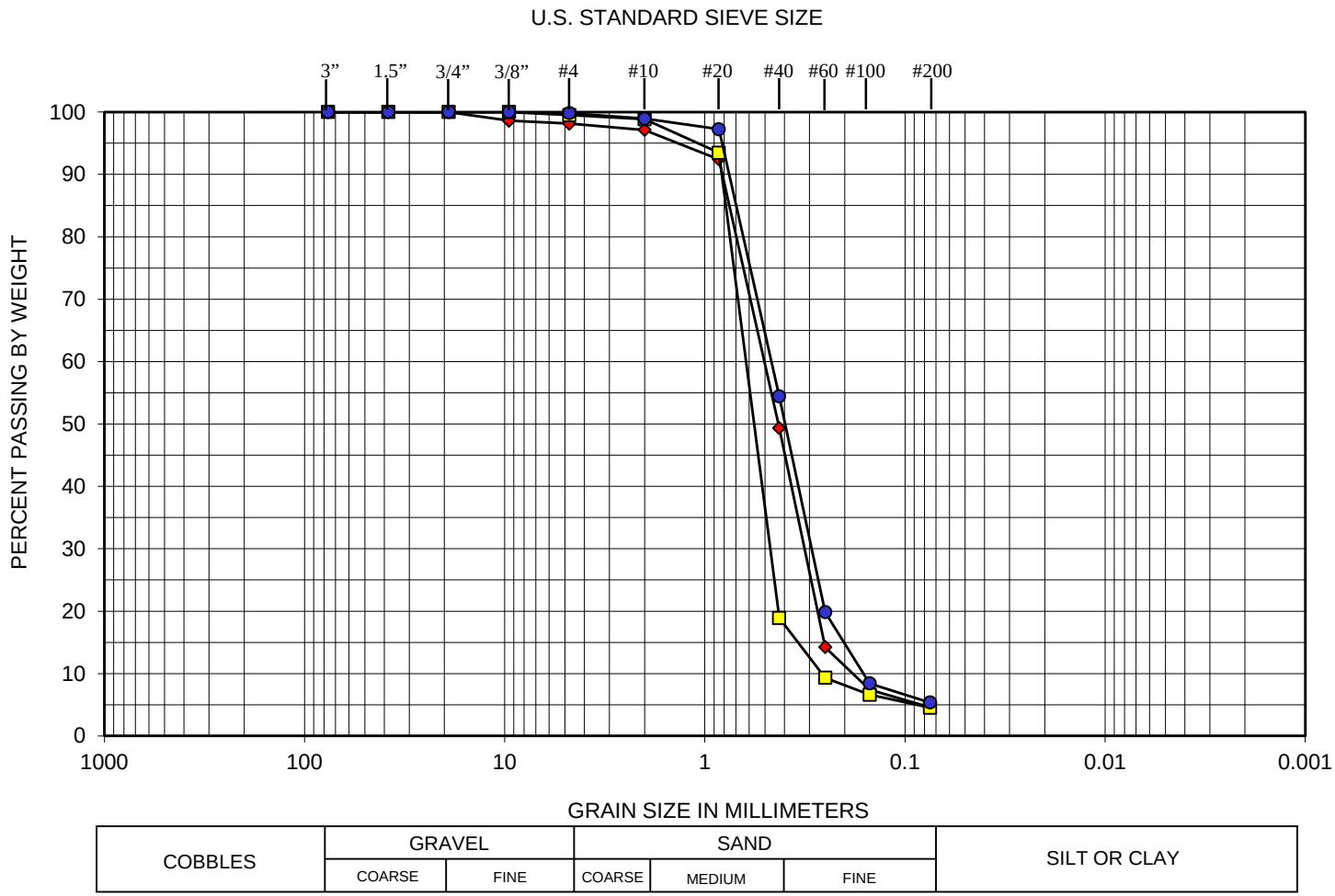

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	IR-B-5	58.5 – 60.0	Brown fine to medium SAND with occasional fine gravel (SP)
□	IR-B-5	83.5 – 85.0	Brown medium SAND with occasional fine sand (SP)
●	IR-B-6	48.5 – 50.0	Brown fine to medium SAND (SP)

Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River HDD
Pike & Morgan Counties, Illinois

GEOENGINEERS

Figure A-13

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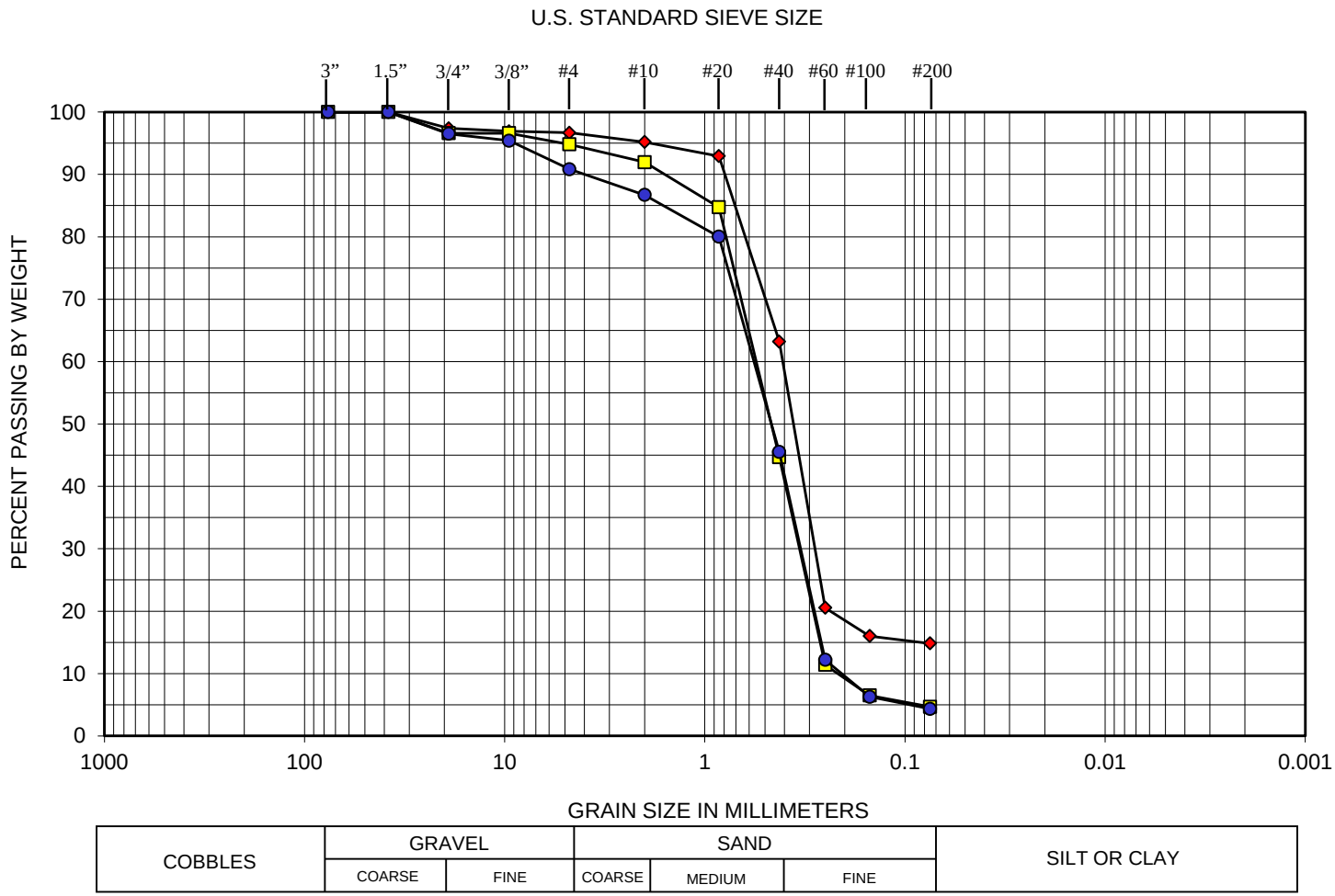

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	IR-B-7	35.0 – 36.5	Brown fine to coarse SAND with silt and occasional gravel (SP)
■	IR-B-7	50.0 – 51.5	Brown fine to coarse SAND occasional gravel and trace silt (SP)
●	IR-B-7	70.0 – 71.5	Brown fine to coarse SAND occasional gravel and trace silt (SP)

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Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River HDD
Pike & Morgan Counties, Illinois

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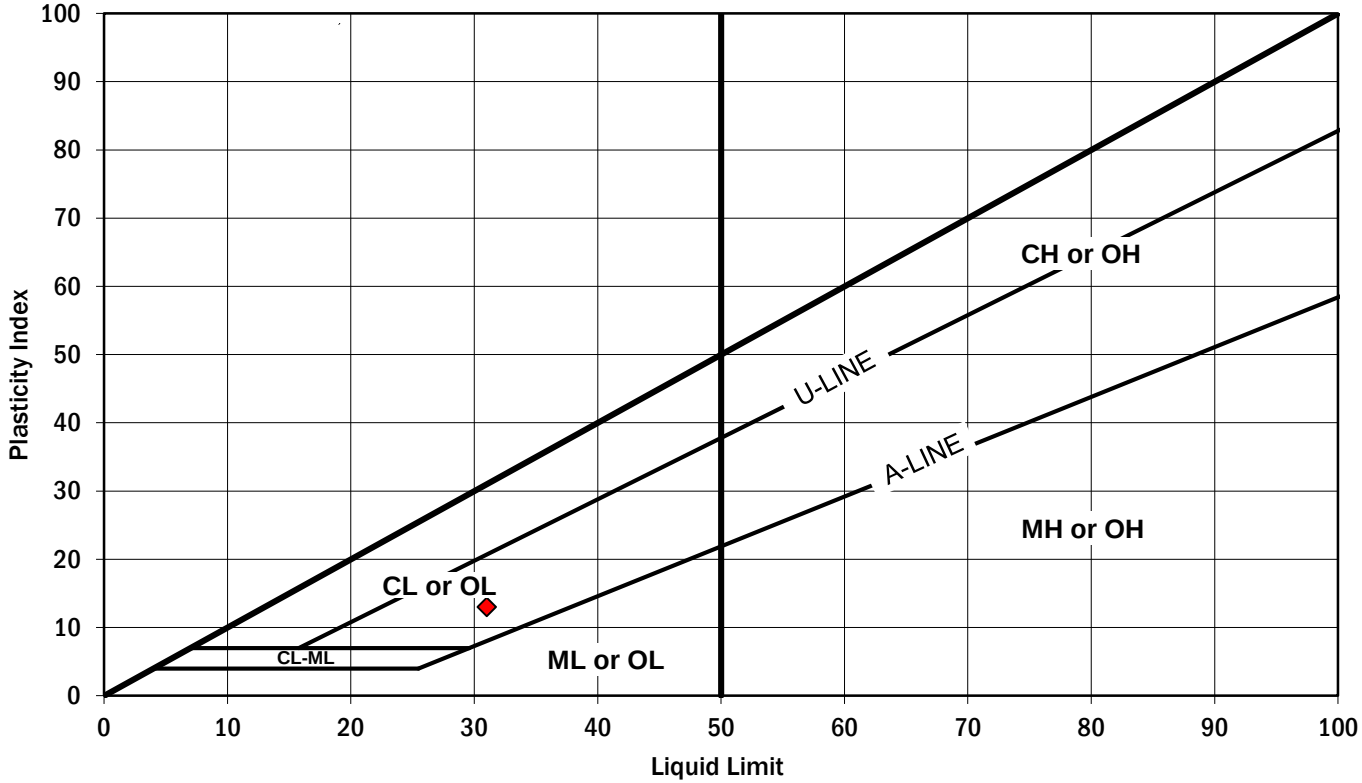
Figure A-14

PLASTICITY CHART



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆	IR-B-1	15.0 – 16.5	33	31	13	Brown low plasticity CLAY (CL)

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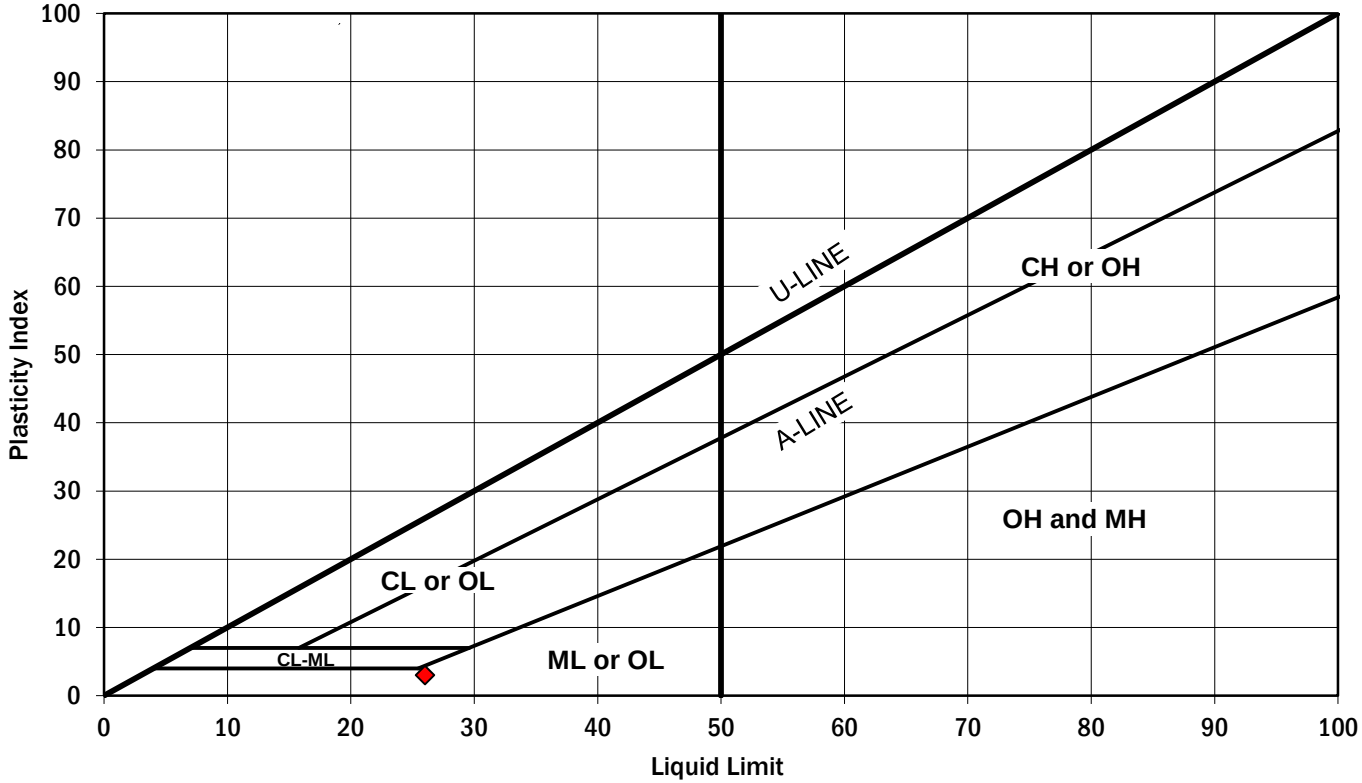
Atterberg Limits Test Results

Dakota Access Pipeline Project – Illinois River HDD
Pike & Morgan Counties, Illinois

GeoEngineers

Figure A-15

PLASTICITY CHART



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆	IR-B-4	23.5 – 25.0	32	26	3	Gray Sandy Silt (ML)

Notes: The geotechnical laboratory testing results were provided by SCI Engineering, Inc.
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Atterberg Limits Test Results

Dakota Access Pipeline Project – Illinois River HDD
Pike & Morgan Counties, Illinois

GeoEngineers

Figure A-16

BORING	DEPTH (FEET)	RQD (%)	ROCK QUALITY	MOHS' HARDNESS	UNCONFINED COMPRESSIVE STRENGTH (TSF)	UNCONFINED COMPRESSIVE STRENGTH (PSI)
IR-B-4	90.0 – 90.5	81	Good	5	284	3950
IR-B-5	106.0 – 106.5	100	Excellent	4	419	5820
IR-B-6	101.5 – 102.0	93	Excellent	4	340	4720

Rock Core Test Results

Dakota Access Pipeline Project
Illinois River HDD
Pike & Morgan Counties, Illinois

GEOENGINEERS

Figure A-17

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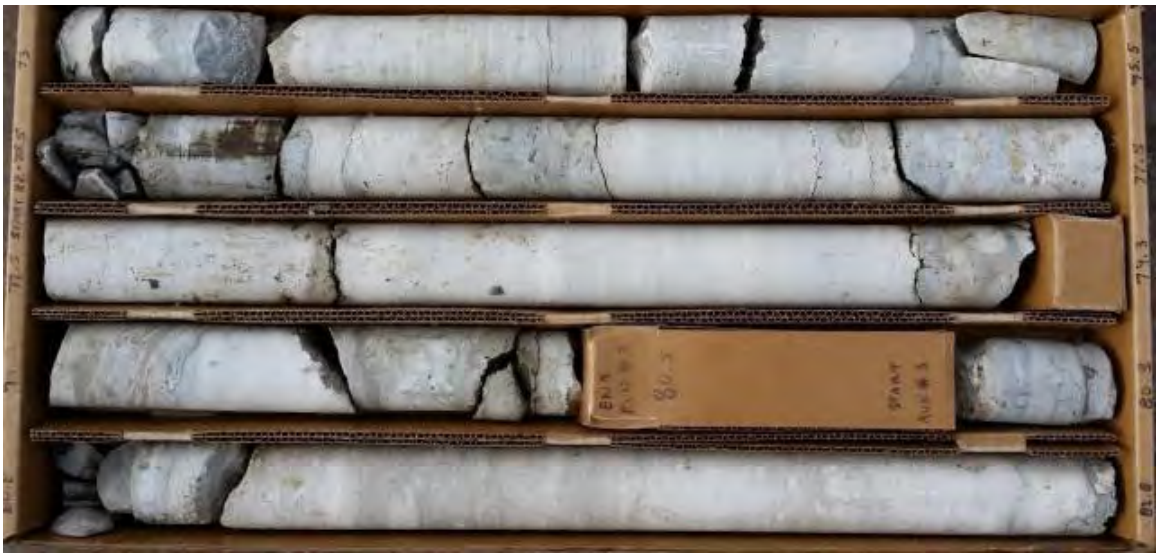
IR-B-2: 73' to 82.8'



0 0.5 1.0 Scale In Feet 1.5 2.0

IR-B-2: 82.8' to 90.5'

0 0.5 1.0 Scale In Feet 1.5 2.0

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Dakota Access Pipeline Project
Illinois River HDD
Rock Core Sample Photographs

FIGURE A-18

IR-B-3: 73.5' to 82.5'

0 0.5 1.0 Scale In Feet 1.5 2.0

IR-B-3: 82.5' to 89.8'

0 0.5 1.0 Scale In Feet 1.5 2.0

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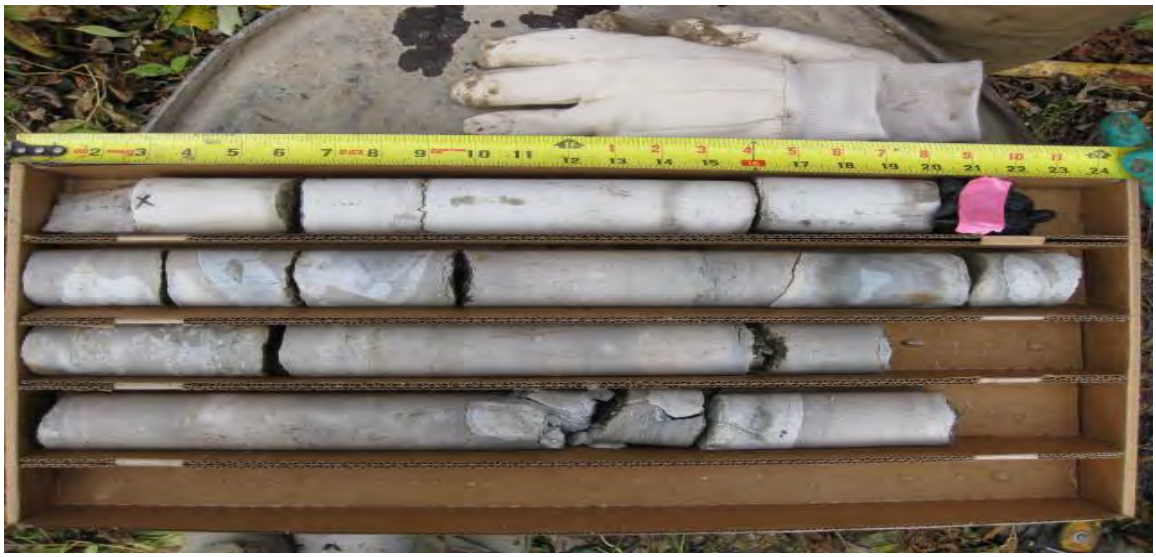
Dakota Access Pipeline Project
Illinois River HDD
Rock Core Sample Photographs

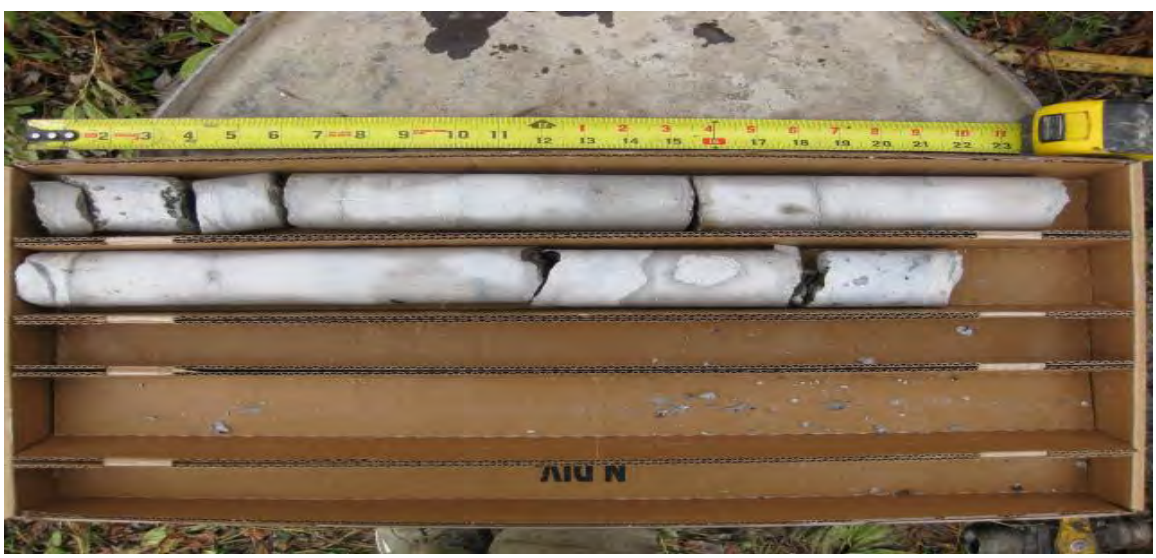
FIGURE A-19

IR-B-4: 83.5' to 90.0'



0 0.5 1.0 Scale In Feet 1.5 2.0

IR-B-4: 90.0' to 93.5'



0 0.5 1.0 Scale In Feet 1.5 2.0

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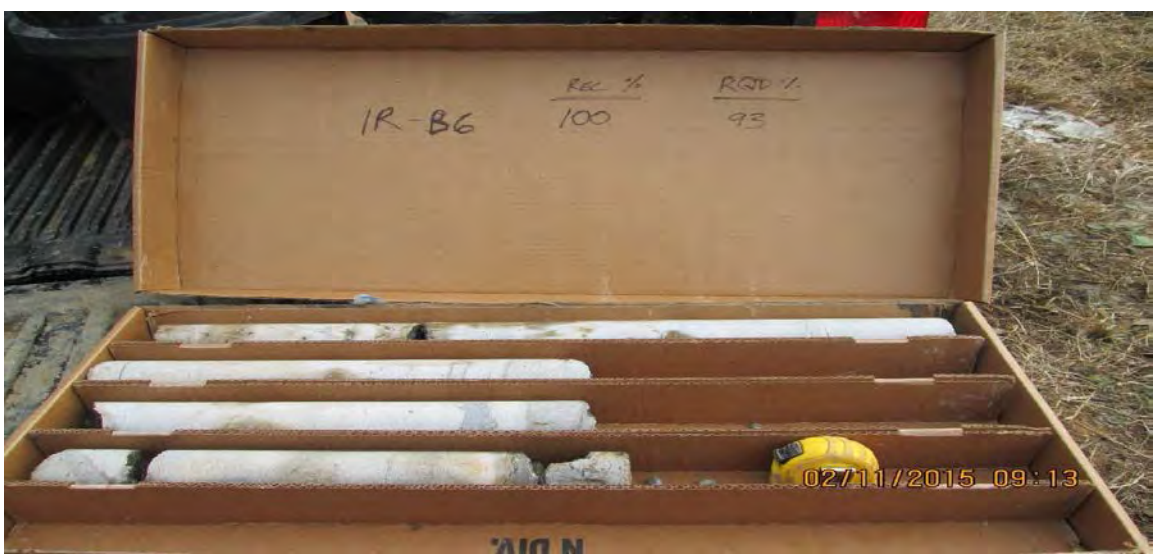
Dakota Access Pipeline Project
Illinois River HDD
Rock Core Sample Photographs

FIGURE A-20

IR-B-5: 103' to 110'

0 0.5 1.0 Scale In Feet 1.5 2.0

IR-B-6: 100' to 105'



0 0.5 1.0 Scale In Feet 1.5 2.0

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Dakota Access Pipeline Project
Illinois River HDD
Rock Core Sample Photographs

FIGURE A-21

APPENDIX B
Report Limitations and Guidelines for Use

APPENDIX B
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geotechnical and Environmental Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of Dakota Access and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Similarly, an environmental assessment study conducted for a property owner may not fulfill the needs of a prospective purchaser of the same property. Because each study is unique, each report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering or Environmental Report Is Based on a Unique Set of Project-Specific Factors

This report has been prepared for the proposed Illinois River HDD located in Pike and Morgan Counties, Illinois. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure;

[1] Developed based on material provided by ASFE/The Best People on Earth, Professional Firms Practicing in the Geosciences; www.asfe.org.

- elevation, configuration, location, orientation or weight of the proposed structure;
- composition of the design team; or
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Subsurface Conditions Can Change

This report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, by new releases of hazardous substances, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Top Soil

For the purposes of this report, we consider topsoil to consist of generally fine-grained soil with an appreciable amount of organic matter, based on visual examination, and to be unsuitable for direct support of the proposed improvements. However, the organic content and other mineralogical and gradational characteristics used to evaluate the suitability of soil for use in landscaping and agricultural purposes were not determined, nor were they considered in our analyses. Therefore, the information and recommendations in this report, and our logs and descriptions, should not be used as a basis for estimating the volume of topsoil available for such purposes.

Most Geotechnical and Environmental Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on field observations and laboratory test results from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Geotechnical Engineering Report Recommendations Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient monitoring and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not construction activities are completed in accordance with our

recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A Geotechnical Engineering or Geologic Report Could Be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also, retain GeoEngineers to review pertinent elements of the design team's plans and specifications. If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

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APPENDIX C
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A Geotechnical Engineering or Environmental Report Is Based on a Unique Set of Project-Specific Factors

This report has been prepared for the proposed Illinois River Horizontal Directional Drill (HDD) located in Pike and Morgan Counties, Illinois. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

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Horizontal Directional Drill Design Services

Dakota Access Pipeline Project
Illinois River East Levee HDD
Scott County, Illinois

for
Dakota Access, LLC

August 6, 2015

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Horizontal Directional Drill Design Services

Dakota Access Pipeline Project
Illinois River East Levee HDD
Scott County, Illinois

for
Dakota Access, LLC

August 6, 2015

GeoEngineers

3050 South Delaware Avenue
Springfield, Missouri 65804
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Horizontal Directional Drill Design Services

Dakota Access Pipeline Project
Illinois River East Levee HDD
Scott County, Illinois

File No. 18782-011-01

August 6, 2015

Prepared for:

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Attention: Adam Broad

Prepared by:

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ENGINEER
OF
ILLINOIS

6 August - 2015

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GEOENGINEERS

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EXECUTIVE SUMMARY

This report provides the Horizontal Directional Drill (HDD) design of GeoEngineers, Inc. (GeoEngineers) for the proposed Dakota Access Pipeline (DAPL) Project Illinois River East Levee HDD at approximate milepost (MP) 903 in Scott County, Illinois. This report replaces and supersedes previous HDD reports for this proposed crossing. The location of the site is shown on the Vicinity Map, Figure 1.

We understand that Dakota Access, LLC (Dakota Access) is proposing to construct approximately 1,020 miles of 30-inch-diameter steel pipeline extending from Mountrail County, North Dakota through eastern South Dakota, Central Iowa, and terminating in Marion County, Illinois. The proposed Illinois River East Levee HDD would cross beneath a canal and adjacent levees under the jurisdiction of the United States Army Corp of Engineers (USACE) in Scott County, Illinois. The layout of the proposed HDD and approximate boring locations are shown in the attached draft design drawings included in Appendix A.

We explored subsurface conditions near the proposed HDD site from November 13 through November 18, 2014, and from April 15 through April 21, 2015 by drilling six geotechnical borings (EL-B-1 through EL-B-6) to depths of up to approximately 95 feet below ground surface (bgs) adjacent to the alignment of the proposed HDD. In general, the subsurface conditions encountered in the borings were consistent with published geology for the area, consisting of very loose to dense sand with varying amounts of silt and gravel and very soft to medium stiff silt and clay overlying limestone bedrock. Details of our subsurface exploration program are included in our geotechnical data report attached as Appendix B.

Hydraulic fracture and drilling fluid surface release analyses were performed along the HDD profile. In general, the results indicate that the risk of localized hydraulic fracture and drilling fluid surface release are low due to the sand units along the HDD profile, with calculated factors of safety greater than 2 along the majority of the crossing as shown in Figure 3. Also shown in Figure 3, the factors of safety within the USACE Pressure Monitoring Zone (PMZ) are greater than 3.0. The risk of hydraulic fracture and drilling fluid surface release is high to very high within approximately 300 feet of the HDD exit point. Low factors of safety against drilling fluid surface release are common near the exit point because the thickness of the soil above the HDD profile decreases as it nears the exit point while the estimated annular pressures caused during pilot hole operations increase.

The contractor's means and methods during construction are crucial to the successful completion of the HDD. Specifically, during pilot hole operations, the HDD contractor's ability to maintain proper drilling fluid properties with appropriate penetration and drilling fluid flow rates will be critical factors to consider during drilling because hole conditions and annular drilling fluid pressures will be directly affected by these factors. Maximum allowable annular drilling fluid pressures will be dictated by the USACE permit and annular drilling fluid pressures in excess of the permitted pressures will not be allowed. The HDD contractor should take all precautions to maintain drilling fluid returns during HDD operations to reduce the risk of hydraulically fracturing the formation along the drill profile. The HDD contractor should be prepared to maintain an annular solids content of less than 20 percent during drilling operations to reduce the risk of the annulus becoming blocked from an accumulation of drill cuttings falling out of suspension from the drilling fluid. <u>If the hole becomes blocked and drilling fluid returns to the entry or exit pits are lost, the hydraulic fracture and inadvertent drilling fluid returns evaluation is no longer valid.</u> The HDD contractor should be required to maintain drilling fluid returns at all times during each stage of the HDD process, which may require

additional efforts such as tripping out the drill pipe string and downhole tooling to restore drilling fluid returns or other adjustments to the drilling procedures.

Based on the information available at this time, the results of our exploration and laboratory testing program and our engineering analyses, it is our opinion that the proposed Illinois River East Levee HDD is technically feasible and can be completed in compliance with USACE requirements. However, this opinion is based upon the HDD contractor implementing plans and procedures that are in accordance with the USACE permit requirements.

A prequalification process of the candidate HDD contractors should be initiated and then an agreement set in place with the selected contractor so that detailed construction procedures can be agreed upon during the preconstruction phase. *We recommend that only HDD contractors with experience successfully completing pipeline installations beneath USACE levees be selected to complete the work.* The HDD contractor will need to fully understand and embrace the USACE's permit conditions and performance requirements to successfully complete this crossing. Provided the recommendations contained in this report are incorporated into the HDD contractor's procedures, and the contractor uses appropriate construction methods during all phases of the project, we anticipate successful completion of this HDD project.

This Executive Summary should be used only in context of the full report for which it is intended.

1.0 INTRODUCTION

At the request of Dakota Access, LLC (Dakota Access) and in general accordance with our subcontract agreement (No. 07-PSA-0017) GeoEngineers, Inc. (GeoEngineers) is pleased to submit this report which replaces and supersedes previous reports provided for the Horizontal Directional Drill (HDD) design of the proposed Dakota Access Pipeline (DAPL) project Illinois River East Levee HDD located at approximate DAPL Milepost (MP) 903.0 in Scott County, Illinois. The project site is shown on the Vicinity Map, Figure 1.

We understand that Dakota Access is proposing to construct approximately 1,020 miles of 30-inch-diameter steel pipeline extending from Mountrail County, North Dakota through eastern South Dakota, Central Iowa, and terminating in Marion County, Illinois. Further, we understand Dakota Access is proposing to construct approximately 151 miles of gathering line, consisting of 12.75, 20, 24, and 30-inch-diameter steel pipeline in McKenzie, Mountrail, and Williams Counties, North Dakota.

The proposed Illinois River East Levee HDD will consist of a 30-inch-diameter steel crude oil pipeline crossing beneath a canal and adjacent levees under the jurisdiction of the United States Army Corp of Engineers (USACE) within Scott County, Illinois as part of the DAPL 30-inch mainline system. The proposed plan and profile of the HDD are shown on the design drawings in Appendix A.

We explored subsurface conditions near the proposed HDD site from November 13 through November 18, 2014, and from April 15 through April 21, 2015 by drilling six geotechnical borings (EL-B-1 through EL-B-6) to depths of up to approximately 95 feet below ground surface (bgs) adjacent to the alignment of the proposed HDD. In general, the subsurface conditions encountered in the borings were consistent with published geology for the area, consisting of very loose to dense sand with varying amounts of silt and gravel and very soft to medium stiff silt and clay overlying limestone bedrock. GeoEngineers previously submitted a Geotechnical Data Report for the referenced location dated June 9, 2015; this report is attached as Appendix B.

1.1 Basis of Design

Our HDD design has been completed in general accordance with the latest versions of the Code of Federal Regulations (CFR), Title 49, Part 195, American Society of Mechanical Engineers (ASME) B31.4 and generally accepted practices within the pipeline industry. Where more conservative, we analyzed the design per the gas pipeline requirements found in Part 192 of the CFR Title 49 and ASME B31.8. The HDD design engineering was completed based on the parameters discussed with the project team, and are presented below in Table 1.

TABLE 1. BASIS OF DESIGN FOR THE 30-INCH ILLINOIS RIVER EAST LEVEE HDD

Product pipe Data	Design Parameter
Product pipe Specifications	30 inches x 0.625 inches w.t.[a] API 5L – X70
Horizontal Crossing Length	4,341 feet
Maximum Allowable Operating Pressure	1,440 psig[b]
Maximum Operating Temperature	100 degrees F
Tie-In Temperature	70 degrees F
Design Factor[c]	0.50

Notes:

[a] w.t. – wall thickness

[b] psig – pounds per square inch gauge

[c] As defined in CFR 49 Sections 192.5 and 192.111

2.0 HDD CONSTRUCTION REQUIREMENTS AND RECOMMENDATIONS

2.1 General

Based on the information available at this time, the results of our subsurface exploration and laboratory testing program and our engineering analyses, it is our opinion that the proposed Illinois River East Levee HDD is technically feasible, provided the construction requirements specified within the Dakota Access Construction Specification, Specification Number: DAPL-WGM-GN000-PRE-SPC-00001 (Construction Specification) dated April 20, 2015, and noted in the design drawing are incorporated into the HDD contractor's drill plan. However, this opinion is based upon the HDD contractor adhering to the requirements contained herein and implementing plans and procedures that are in accordance with the USACE permit requirements as discussed in Section 2.2. In addition, the HDD contractor should make all reasonable attempts to utilize "Best Drilling Practices" during all construction phases of the project. This report also provides our construction recommendations that, in our opinion will help mitigate some of the risks inherent with this project and increase the likelihood that the installation will be completed successfully and on schedule. The construction recommendations for consideration by the project team and prospective HDD contractors are provided in Section 2.3. A detailed discussion of the construction risks and general construction considerations is provided in Section 3.0.

2.2 USACE Permit Requirements

Because this HDD will cross beneath a levee under the jurisdiction of the USACE, special construction requirements will be enforced on this project. The following items are typically required based on our experience with similar projects under the jurisdiction of the USACE:

1. The HDD contractor will be required to prepare and submit a detailed HDD drill plan for review and approval that describes their planned equipment and drilling procedures to successfully complete the installation in compliance with the USACE permit requirements.
2. A third-party geotechnical engineer is required to be on-site during all HDD operations. The third-party engineer and all USACE staff shall be permitted full-time access to the drill cab, all drilling operations and data.

3. The USACE limits the allowable annular drilling fluid pressure when jetting or reaming the hole within the PMZ. This is typically within 300 feet of the levee crest. Downhole annular drilling fluid pressures above the maximum allowable limits specified by the USACE are not permitted within the PMZ.
4. The contractor must use a downhole survey system capable of monitoring and recording downhole annular drilling fluid pressures while jetting and reaming the hole through the PMZ. The downhole annular pressure sensor is required to be within 5 feet of the drill bit or reaming tool. The USACE has allowed exceptions to this requirement in the past depending on conditions encountered during drilling operations; however, the HDD contractor should anticipate mobilizing jetting and reaming assemblies to the site that meet this requirement.
5. Changes to the HDD design or drilling plan that will affect the potential for hydraulic fracture and/or inadvertent drilling fluid returns must be submitted to the USACE for approval prior to implementation, along with an updated hydraulic fracture analysis utilizing the changed parameters.
6. As soon as practical after the product pipe is pulled into the reamed hole, the annulus between the reamed hole and the installed product pipe must be grouted with a cement-bentonite grout at both ends of the drill profile. The contractor is responsible for submitting a plan for installing the grout plugs.

During the bidding process, the prospective HDD contractors should be made aware of the permit stipulations so that they can prepare a submittal that accounts for the additional permit requirements. GeoEngineers can assist in answering questions regarding the permitting process and requirements. Additionally, we recommend that DAPL engage HDD contractors with experience successfully completing USACE Levee crossings to complete this project.

2.3 Construction Recommendations

This section provides GeoEngineers' construction recommendations that we recommend be considered by the prospective HDD contractor to increase the likelihood that the pipeline can be successfully installed without damage or significant construction difficulties and delays. Our recommendations are not meant to be exhaustive and do not relieve the contractor from the responsibility of reviewing all of the information related to the proposed crossing and developing his own plan to accomplish the installation without damage to the product pipe, or unplanned delay.

We recommend that the risks we identify, along with any other risks that the contractor perceives be discussed prior to construction. In this manner the project team will be able to identify and quantify costs associated with project risk. The implementation of our recommendations may, in some instances, increase the initial cost estimates for construction. However, in our experience, the higher initial estimates can be much more reflective of ultimate project costs and reduce the budget uncertainty related to construction risk. We recommend the construction bid packages require that prospective HDD contractors supply unit costs for risk mitigation items so that they can be better evaluated in the bid selection phase. In the event that some of these measures are deemed necessary after award of the contract, their associated costs will have already been negotiated.

TABLE 2. GEOENGINEERS' CONSTRUCTION RECOMMENDATIONS

General Recommendations
We recommend that the prospective contractors visit the site and evaluate the designated access routes to determine what improvements might be necessary and what considerations may be needed to mobilize their equipment to the site.
We recommend that the prospective contractors visit the workspace areas to determine the extent of preconstruction site preparation necessary for HDD activities.
Pilot Hole Recommendations
We recommend that the secondary survey wires be placed at least as wide as the survey probe is deep. As a result, the depth of the HDD profile will require the coil to increase in width from approximately 20 feet wide near the entry and exit locations to a minimum of approximately 100 feet wide through portions of the drill profile.
We recommend that the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system.
We recommend that the HDD contractor install small diameter conductor casing while conducting pilot hole operations because of the loose soils within the entry tangent. The casing should help to improve hole stability, lower downhole annular drilling fluid pressures and aid in steering the bottom hole assembly.
We recommend that the HDD contractor's as-built drawing be reviewed by GeoEngineers prior to storing the data in the project file.
Reaming and Swabbing Recommendation
We recommend that the HDD contractor consider forward reaming the pilot hole from entry toward exit in an effort maintain lower downhole annular drilling fluid pressures through the PMZ. This could include di-directional reaming of the hole in preparation for pullback operations.
If pull reaming passes from exit to entry are conducted, we recommend that the HDD contractor utilize a high pressure drilling fluid pump and drilling fluid recycling system within the exit workspace to facilitate recycling drilling fluid returns, and to assist with preventing delays which may be incurred from the majority of drilling fluid returns flowing to the exit pit.
We recommend that the HDD contractor be required to adjust the penetration and/or pump rates while conducting reaming operations to maintain an annular solids content of 20 percent or less.
Installation Recommendations
We recommend a minimum bending radius of 1,000 feet while stringing and handling the product pipe to protect against pipe damage while moving the product pipe into position for pullback.
We recommend that the HDD contractor utilize a drill rig that provides a factor of safety of at least 2.0 between the drill rig capacity and the pull loads they anticipate.
We recommend that buoyancy control measures be utilized during pullback operations.
We recommend the HDD contractor be required to provide the maximum anticipated pull force required to install the product pipe and the maximum allowable pull force that can be applied to their downhole tooling.
Annular Grout Plugs
We recommend selecting a specialty contractor experienced in this type of work and who is familiar with the USACE requirements.

3.0 HDD CONSTRUCTION RISKS AND CONSIDERATIONS

3.1 Construction Risks

The contractor's means and methods during construction are critical to the successful completion of the HDD. The USACE will require a qualified drilling fluid engineer to evaluate the drilling fluid properties on a continuous basis during the entire drilling and installation process. Close coordination between the contractor and the drilling fluid engineer is vital to maintaining proper drilling fluid properties, penetration rates and drilling fluid flow rates required for our hydraulic fracture and inadvertent returns calculations to remain valid. If proper construction techniques as described herein are used in conjunction with the presence of a GeoEngineers representative and a drilling fluid engineer, we anticipate the likelihood to be high for successfully completing the proposed HDD installation in accordance with the USACE permit requirements.

3.1.1 Hydraulic Fracture

Hydraulic fracture is a term typically used to describe the condition in which the downhole drilling fluid pressure exceeds the overburden pressure and shear strength of the soil surrounding a drill path. Soils that are most vulnerable to hydraulic fracture include relatively weak cohesive soils or loose granular soils with low shear strength. Medium dense to very dense sands and very stiff to hard silts and clays generally have a low to moderate hydraulic fracture potential. HDD installations with greater depth or drill profiles in formations with higher shear strength may reduce the potential for hydraulic fracturing.

3.1.2 Inadvertent Drilling Fluid Returns

Inadvertent drilling fluid returns occur when drilling fluid emerges at the ground surface or in any other undesired location such as wetlands, utility trenches, basements, roads, railroads, and waterbodies. In practice, inadvertent drilling fluid returns typically occur in proximity to the entry and exit points where soil cover is thin. Inadvertent drilling fluid returns can also occur at locations along a drill path where there are low shear strength soils, where the thickness of soil cover is thin or along preexisting fractures or voids. Other locations where inadvertent drilling fluid returns can occur include exploratory boring locations, or along the edges of existing subsurface structures such as piles or utility poles.

The HDD contractor's construction procedures constitute another important factor influencing when and where drilling fluid loss occurs. If the contractor operates with insufficient drilling fluid flow rates, inadequate drilling fluid properties or excessive rates of penetration, the annulus may become blocked through an accumulation of drill cuttings falling out of suspension. This can occur within formations that typically have a low potential for hydraulic fracture. If the accumulation of cuttings creates a blockage downhole, the annulus may become over-pressurized, leading to hydraulic fracturing and potentially inadvertent drilling fluid returns. If this occurs, the hydraulic fracture calculations are no longer applicable.

3.1.3 Hydraulic Fracture and Inadvertent Drilling Fluid Returns Analysis

General

The procedures used to evaluate the potential for drilling fluid loss through hydraulic fracturing are based primarily on research completed by Delft Geotechnics, as discussed in Appendix B of the USACE Report CPAR-GL-98 (Staheli, et al., 1998, "Installation of Pipelines Beneath Levees Using Horizontal Directional Drilling," U.S. Army Corps of Engineers, Waterways Experiment Station, CPAR-98-1). The methodologies used to estimate the hydraulic fracture potential outlined in the research are based on cavity expansion

theory. The cavity expansion model is used to estimate the maximum effective pressure in the drill hole before plastic deformation of the drill hole occurs.

Model Input Parameters

In order to evaluate the hydraulic fracture and inadvertent drilling fluid returns potential for a given case, assumptions must be made when selecting the input parameters. The assumptions used in the model include the extent and uniformity of soil layers, hydrostatic water pressures, drilling fluid properties, penetration rates and pump rates. The soil strength properties are estimated based on interpretations of the boring logs and laboratory test results. The drilling fluid properties, penetration rates and pump rates are estimated based on generally accepted BMPs of the HDD industry. Consequently, the results of the evaluation are only estimates of the potential for hydraulic fracture and inadvertent drilling fluid returns.

The soil units encountered in the vicinity of the Illinois River East Levee HDD are characterized by borings EL-B-1 through EL-B-6. A general description of the subsurface conditions encountered in the explorations is presented in the exploration logs which are included in Appendix B. In general, the subsurface conditions encountered in the borings were consistent with published geology for the area, consisting of very loose to dense sand with varying amounts of silt and gravel and very soft to medium stiff silt and clay overlying limestone bedrock. Based on the results of the subsurface exploration program and subsequent laboratory testing program, the soil properties used in the evaluation are presented in Table 3 below.

TABLE 3. ESTIMATED SOIL PROPERTIES

Soil Description	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)
Medium Dense Sand with Clay	115	24	0
Medium Dense Silty Sand	115	22	0
Medium Dense to Dense Sand with Silt	120 – 125	28 – 34	0
Medium Dense to Dense Sand	115 – 120	28 – 32	0

Notes:

[a] pcf – pounds per cubic feet

[b] psf – pounds per square foot

In addition to the subsurface soil conditions, the drilling fluid and tooling properties influence the risk of hydraulic fracture and inadvertent returns and are dependent on the field conditions and the construction practices of the HDD contractor and drilling fluid engineer. Changes in these factors can significantly affect the potential for hydraulic fracture and inadvertent drilling fluid returns. The parameters used in the evaluation for the Illinois River East Levee HDD installation are summarized in Table 4. Because these parameters are dependent upon the HDD contractor's means and methods, the hydraulic fracture and inadvertent drilling fluid returns evaluation should be refined during the construction phases of the project to reflect the tooling and drilling fluid properties being utilized.

TABLE 4. MODEL INPUT PARAMETERS

Parameter	Typical Values
Pilot Hole Bit Diameter	9.875 inches
Drill Pipe Diameter	5.5 inches
Drilling Fluid Unit Weight	9.5 ppg[a]
Plastic Viscosity	14 CP[b]
Yield Point	28 lb/100 sf[c]

Notes:

[a] ppg – Pounds per gallon

[b] CP – Centipoise

[c] lb/100 sf – Pounds per 100 square feet

Results of Inadvertent Drilling Fluid Returns Evaluation

Based on the soil properties, rheological parameters and anticipated tool dimensions, the model considers the total and effective overburden stresses, shear strengths of the soil, and the estimated drilling fluid pressures along the drill path. A comparison is then made of the estimated drilling fluid pressures immediately behind the drill bit and the ability of the formation to resist plastic deformation.

When evaluating the risk of hydraulic fracture and inadvertent drilling fluid returns, the analysis computes two types of factors of safety. These are:

- Factor of Safety against localized hydraulic fracture; and
- Factor of Safety against drilling fluid surface release.

Local Hydraulic Fracture: The factor of safety against hydraulic fracture is the ratio of the formation limit pressure to the estimated drilling fluid pressure along the profile, shown as the green line in Figure 3. This represents the factor of safety against hydraulic fracture of the soil immediately surrounding the HDD profile and is a localized condition.

Drilling Fluid Surface Release: The factors of safety against inadvertent drilling fluid returns considers the strength of the soil column above the HDD profile that resists drilling fluid migrating to the ground surface. It is computed by comparing the formation limit pressure of the soil units above a specific point along the planned HDD alignment to the anticipated drilling fluid pressure at that same point.

Table 5 below shows the relative risk associated with the estimated factors of safety against hydraulic fracture and inadvertent drilling fluid returns.

TABLE 5. RELATIVE HYDRAULIC FRACTURE AND INADVERTENT DRILLING FLUID RETURNS RISK

Factor of Safety	Relative Risk
Less than 1	Very High
Between 1 and 1.5	High
Between 1.5 and 2	Moderate
Greater than 2	Low

The results of the evaluation of hydraulic fracture potential for the Illinois River East Levee HDD are presented in Figures 2 and 3. The formation limit pressure, presented as the green line in Figure 2, is the ability of the soil to resist plastic deformation and is a product of the overburden stress and shear strength of the soil through which the HDD profile passes.

The estimated drilling fluid pressure is also shown as the red line in Figure 2 and represents the drilling fluid pressure along the HDD profile based on the anticipated drilling fluid properties shown in Table 4. The ratio of the formation limit pressure to the estimated drilling fluid pressure is the factor of safety against hydraulic fracture, shown as the green line in Figure 3. The factors of safety against inadvertent drilling fluid returns are also shown in Figure 3 at selected discrete points represented by red triangles.

The hydraulic fracture and inadvertent drilling fluid returns model indicates that there is a low risk of hydraulic fracture along most of the proposed HDD alignment. Figure 3 illustrates this where the factors of safety are greater than 2.0 along most of the HDD alignment. Also shown in Figure 3, the factors of safety within the USACE Pressure Monitoring Zone (PMZ) are greater than or equal to 3.0.

The risks of hydraulic fracture are relatively low along most of the alignment because the drill profile is located within the medium dense to dense sand units observed in the borings. The risk of hydraulic fracture and drilling fluid surface release is high to very high within approximately 300 feet of the HDD exit point. Low factors of safety against drilling fluid surface release are common near the exit point because the thickness of the soil above the HDD profile decreases as it nears the exit point while the estimated annular pressures caused during pilot hole operations increase.

The HDD contractor should use best management practices to reduce the potential for hydraulic fracture and inadvertent drilling fluid returns. This includes, but is not limited to maintaining drilling fluid circulation during all phases of HDD operations to prevent the annular drilling fluid pressures from exceeding the maximum allowable pressure. If drilling fluid returns begin to slow or are lost, the HDD contractor should trip out the downhole tooling until full drilling fluid returns are re-established before proceeding forward. The HDD contractor may also reduce the risk of inadvertent returns by completing the pilot hole via the intersect method and bi-directional reaming of the hole. As a requirement for this project the HDD contractor will be required to submit a detailed HDD drill plan outlining their planned drilling practices and contingency procedures.

3.1.4 Drill Hole Stability

In general, soil conditions encountered in the exploration borings near the proposed HDD alignment were consistent with published geology for the area, consisting of very loose to dense sand with varying amounts of silt and gravel and very soft to medium stiff silt and clay overlying limestone bedrock. Zones of gravelly soils were observed within the soil borings completed at the site. The HDD profile was designed to avoid

these zones, however; gravelly zones of soil could be encountered at locations and depths not observed in the borings. In addition, the very loose to loose near-surface soils could present hole stability concerns. We recommend that the HDD contractor install small diameter conductor casing while conducting pilot hole operations because of the loose soils within the entry tangent of the drill profile. The casing should help to improve hole stability, lower downhole annular drilling fluid pressures and aid in steering the bottom hole assembly.

3.2 Construction Considerations

3.2.1 Site Access

The proposed HDD entry workspace will most likely be accessed via the pipeline right-of-way (ROW) from Cemetery Road northwest of the site. Little to no clearing or grading should be required prior to mobilizing equipment to the site.

The HDD exit and product pipe stringing and fabrication workspaces may be accessed via the pipeline ROW from County Road 100 southeast of the site. Little to no clearing or grading should be required prior to mobilizing equipment to the site.

Depending upon conditions at the time of construction, load-dispersing materials such as timber mats or quarry rock may be required to maintain stabilization of the equipment entering the locations. We recommend that the prospective contractors visit the site and evaluate the designated access routes to determine what improvements might be necessary and what considerations may be needed to mobilize their equipment to the site.

3.2.2 Workspace Considerations

The temporary workspace at entry includes an odd-shaped area measuring 1.09 acres with the entry point positioned 75 feet from the front (southeast side) of the workspace. The entry workspace is located in a relatively flat, open agricultural field such that little to no clearing or grading should be needed prior to mobilization of equipment to the site.

The temporary workspace at exit includes a rectangular-shaped area measuring 200 feet wide by 250 feet in length with the exit point positioned 75 feet from the front (northwest side) of the workspace. The exit workspace is located in a relatively flat, open agricultural field such that little to no clearing or grading should be needed prior to mobilization of equipment to the site.

The proposed product pipe stringing and fabrication workspace will extend 4,015 feet southeast of the temporary workspace at exit as depicted in the HDD Stringing Workspace drawing included in Appendix A. The product pipe stringing and fabrication workspace is not of sufficient length to string the product pipe pull section in one continuous section which will require the pull section to be laid out in two sections with one tie-in weld that will need to be completed during pullback operations. Significant grading and clearing of the product pipe stringing area should not be needed prior to stringing and fabricating the product pipe pull section.

We recommend that the prospective contractors visit the workspace areas to determine the extent of clearing and grading necessary to prepare the site for HDD activities and to facilitate planning for the stringing of the product pipe pull section and handling of the pipe during pullback operations.

3.2.3 Proposed HDD Plan and Profile

Plan and profile design drawings for the proposed Illinois River East Levee HDD are included in Appendix A. The design drawings include the necessary geometric information required to complete the pilot hole and the site-specific construction requirements. Detailed calculations for minimum allowable radius of curvature, operating stresses and installation loads and stresses are also included for reference in Appendix A.

The proposed Illinois River East Levee HDD is approximately 4,341 feet long as measured along the HDD centerline, with a length of 4,350 feet as measured along the drill profile. The radius of curvature for the entry and exit vertical curves is 3,200 feet which is larger than industry design standards to provide additional radius tolerance while advancing the pilot hole. The HDD profile was designed to a depth to help provide adequate clearance under the Illinois River East Levee, thereby reducing the risk of experiencing inadvertent drilling fluid returns in the vicinity of these features. In addition, the bottom tangent of the HDD profile was sloped slightly to attempt to increase the depth of the profile yet still avoid intersecting the soil/bedrock interface below.

3.2.4 Pilot Hole Considerations

Pilot Hole Survey

The HDD contractor should be required to provide and maintain instrumentation to document and accurately locate the pilot hole. This effort should include the use of a downhole steering tool as well as a secondary survey system (TruTrack, ParaTrack, or equivalent) or gyroscopic steering tool. The HDD contractor should not be allowed to drill any portion of the pilot hole without the use of a secondary survey system or gyroscopic steering tool unless agreed to in advance by the Company. If the HDD contractor elects to use the wire coil grids with these secondary survey systems, we recommend that the secondary survey wires be placed at least as wide as the design profile is deep plus an allowance for any deviations from the design that may occur during pilot hole operations. As a result, the depth of the HDD profile will require the coil to increase in width from approximately 20 feet wide near the entry and exit locations to a minimum of approximately 100 feet wide through portions of the drill profile. The placement of the coils is limited to areas where ground surface conditions, permit requirements, and agreements with landowners allow and as such, we recommend that the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system. After surveying the secondary survey wire, the HDD contractor should report any lack of closure that may indicate incorrectly located entry and/or exit points or any other potential discrepancy with the design information provided on the design drawing.

Annular Pressure Monitoring

The contractor must use a downhole survey system capable of monitoring and recording downhole annular drilling fluid pressures while jetting the hole through the PMZ. The downhole annular pressure sensor is required to be within 5 feet of the drill bit. The USACE has allowed exceptions to this requirement in the past depending on conditions encountered during drilling operations; however, the HDD contractor should anticipate mobilizing a jetting assembly to the site that meet this requirement. Downhole annular drilling fluid pressures above the maximum allowable limits specified by the USACE are not permitted within the PMZ.

Tolerances

Based on the design geometry and proposed product pipe specifications, the minimum allowable three-joint vertical radius over any consecutive three-joint section should not be less than 2,050 feet. The three-joint radius should be calculated for each three-joint (for Range 2 drill pipe) section (approximately 90 feet) drilled during pilot hole operations. The horizontal pilot hole tolerances are no more than 10 feet left and 10 feet right of the designed alignment. The vertical pilot hole tolerances are no more than 2 feet above and 10 feet below the designed profile. We recommend that the pilot hole not be accepted if its location would result in the pipeline being installed in violation of the Right-of-Way and Permit Stipulations section of the Contract, any Federal, State or Local permit requirements, or required clearances between Dakota Access and foreign owned utilities and structures. For the entry and exit point tolerances please refer to the HDD design drawings in Appendix A.

We recommend that, upon completion of the pilot hole, GeoEngineers have the opportunity to review the pilot hole survey data prior to the start of reaming operations.

Pilot Hole As-Built

We recommend the HDD contractor be responsible for producing and submitting an as-built drawing of the pilot hole survey data within two weeks of the completion of pullback operations. This drawing should include a tabulation of the supporting as-built survey data used to generate the drawing. We recommend that the HDD contractor's as-built drawing be reviewed by GeoEngineers prior to storing the data in the project file.

3.2.5 Reaming and Swabbing Considerations

Reaming

After completion of the pilot hole, we recommend the HDD contractor maintain a continuous string of drill pipe downhole between entry and exit at all times except when re-establishing a continuous string of drill pipe in the event of a twist off downhole. During reaming operations we anticipate that the HDD contractor will likely ream the hole to a minimum final hole diameter of approximately 42 inches.

The contractor must use a downhole survey system capable of monitoring and recording downhole annular drilling fluid pressures while reaming the hole through the PMZ. The downhole annular pressure sensor is required to be within 5 feet of the reaming tool. The HDD contractor should anticipate mobilizing reaming assemblies to the site that meet this requirement. Downhole annular drilling fluid pressures above the maximum allowable limits specified by the USACE are not permitted within the PMZ. We recommend that the HDD contractor consider forward reaming the pilot hole from entry toward exit in an effort maintain lower downhole annular drilling fluid pressures through the PMZ. This could include di-directional reaming of the hole in preparation for pullback operations.

If pull ream passes from exit to entry are conducted, a drilling fluid recycling system and high pressure drilling fluid pump operating from the exit side of the crossing would be advantageous to facilitate circulating drilling fluid downhole and recycling of the drilling fluid returns on that side of the crossing.

For HDD installations beneath levees, we recommend an annular solids percentage of 20 percent or less during reaming operations, which requires pumping a volume of drilling fluid greater than five (5) times the volume of soil cuttings being generated. This helps to prevent the soil cuttings from falling out of suspension from the drilling fluid and constricting the hole. We recommend that the HDD contractor adjust the

penetration and/or pump rates while conducting reaming operations to maintain an annular solids content of 20 percent or less.

Hole Swabbing

Swabbing the hole after the completion of reaming operations is generally one of the best methods to determine if the hole is in a condition to receive the product pipe. Irregularities in the hole, zones of instability and areas where drill cuttings may have accumulated can often be detected during the swab pass. In the event that any of these conditions are detected or suspected, mitigation measures can be employed prior to pullback operations to increase the likelihood of successfully installing the product pipe without damage. Mitigation measures may include additional reaming or swab passes.

We recommend the HDD contractor be required to complete at a minimum one (1) swab pass to evaluate the condition of the hole prior to pullback operations. The HDD contractor should review the data collected during the reaming and swab passes with Dakota Access before pullback operations begin.

3.2.6 Pullback Considerations

Handling of the Product Pipe

We recommend the contractor be required to supply a pullback lifting procedure as part of their final HDD Work Plan. The minimum allowable radius of curvature for handling and positioning the product pipe in preparation for pullback operations is 800 feet (See Appendix A for detailed calculations of overbend radius). This radius of curvature results in a bending stress of approximately 67 percent of the Specified Minimum Yield Stress (SMYS) or 47,200 pounds per square inch (psi). We recommend an overbend radius of no less than 1,000 feet to reduce the risk of damaging the product pipe during pullback operations.

Installation Loads

For the proposed HDD, we analyzed the anticipated pull loads for the as-designed HDD geometry based upon different drilling fluid weights in the hole and without the use of buoyancy control inside the product pipe. The proposed 30-inch-diameter steel product pipe will be positively buoyant in the anticipated drilling fluid weights; however, we anticipate that the HDD contractor will add water to the product pipe in an effort to reduce positive buoyancy during pullback. Our analyses include cases with differing drilling fluid densities in the hole during pullback with and without the use of buoyancy control and one in which neutral buoyancy is achieved, for comparison. Installation load and stress calculation results are attached in Appendix A.

The five cases analyzed are as follows:

1. The annulus contains 9.5 pounds per gallon (lb/gal) drilling fluid and the product pipe is empty.
2. The annulus contains 9.5 lb/gal drilling fluid and the product pipe is full.
3. The annulus contains 12 lb/gal drilling fluid and the product pipe is empty.
4. The annulus contains 12 lb/gal drilling fluid and the product pipe is full.
5. The annulus contains 10 lb/gal drilling fluid and the product pipe is neutrally buoyant.

The following table presents a summary of the calculated installation loads for the crossing.

TABLE 6. INSTALLATION LOADS FOR THE 30-INCH ILLINOIS RIVER EAST LEVEE HDD[A]

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Effective Pipe Weight[b] (lb/ft)	Pullback Force[c] (lb)
9.5	Empty	-152	487,000
9.5	Full	129	393,000
12	Empty	-244	618,000
12	Full	37	296,000
10	Neutral	0	267,000

Notes:

[A] Assumes the as-designed HDD profile. See Appendix A for detailed calculations.

[b] Negative values indicate upward force (positive buoyancy).

[c.] Assumes a fully open drilled hole with no obstructions.

We recommend that the HDD contractor utilize a drill rig that provides a factor of safety of at least 2.0 between the drill rig capacity and the pull loads they anticipate. Based on our analysis of the installation loads (see Table 6), the pullback force during installation of the 30-inch diameter product pipe may be as high as approximately 618,000 pounds depending on the weight of the drilling fluid in the hole at the time of pullback and the buoyancy control measures employed by the HDD contractor. Because of the length of this crossing and the reduction in installation forces when using buoyancy control, we recommend that buoyancy control measures be utilized during pullback of the product pipe pull section. The calculated safe pull is in excess of 2 million pounds such that the limiting pull force will depend on the capacity of the tooling the HDD contractor intends to utilize during pullback operations. We recommend the HDD contractor be required to provide the maximum anticipated pull force required to install the product pipe and the maximum allowable pull force that can be applied to their downhole tooling with their HDD Work Plan.

Pneumatic Hammer Usage

In some instances, a pneumatic hammer can be utilized to assist with the installation of the product pipe. The contractor should not employ the use of a pneumatic hammer without prior approval from Dakota Access.

Drilling Fluid Displacement

During pullback operations, the product pipe will displace approximately 160,000 gallons of drilling fluid. We anticipate that the displaced drilling fluid will likely flow to both the entry and exit points during pullback operations.

3.2.7 Post-Installation Grouting

To reduce the risk of the HDD bore becoming a pathway for water flow, the annulus between the reamed hole and the installed product pipe should be grouted with a cement-bentonite grout mixture on the entry side and exit side of the drill profile as soon as practical after the product pipe is pulled into the reamed hole. The required depth of grouting is determined by a total stress analysis that results in a factor of safety of 1.2. The annulus will need to be grouted to an elevation of approximately 431 feet (approximately 13 feet below grade on the entry side) and 426 feet (approximately 18 feet below grade on the exit side) see

Figures 4 and 5 for detailed calculations. The contractor is responsible for submitting a plan for installing the grout plug.

The grout plug could be installed either by drilling grout injection holes along the HDD alignment down to the drill profile or by inserting a tremie pipe down the annulus to the required depth. We do not recommend pumping the grout into the hole during pullback operations because any delays in pullback operations could result in the product pipe becoming stuck in the hole. From previous experience, we also do not recommend attaching a tremie pipe to the leading end of the product pipe prior to pullback operations for post-installation grouting purposes. Oftentimes, when this is attempted, the pipe becomes damaged or comes free of the product pipe during the installation process and becomes unusable. A tremie pipe may be attached to the trailing end of the product pipe to grout the annular space around the product pipe on the entry side of the crossing.

We recommend selecting a specialty contractor experienced in this type of work and who is familiar with the USACE requirements. Prior to the start of construction, the grouting contractor should submit a grouting plan for review and approval by the USACE.

4.0 OPERATING CONDITIONS

For our analysis of the operating stresses, the installation and operating temperatures utilized for the 30-inch pipeline were 70 and 100 degrees Fahrenheit, respectively. We can further evaluate different installation and operating temperatures, if necessary. Also, the operating stresses are based on a minimum allowable pilot hole radius of curvature of 2,050 feet. If the as-built minimum radius of the pilot hole is less than 2,050 feet, the operating stresses will be increased. The following table presents a summary of the operating stresses for the product pipe specifications proposed for the HDD.

TABLE 7. OPERATING STRESSES FOR THE 30-INCH ILLINOIS RIVER EAST LEVEE HDD *

Stress Component	Stress (psi)	Percent SMYS[a] (%)	Maximum Allowable Percent SMYS[a] (%)
Longitudinal Bending Stress	17,900	26	-
Hoop Stress	34,600	49	50[b]
Longitudinal Tensile Stress from Hoop Stress	10,400	15	-
Longitudinal Stress from Thermal Expansion	-5,700	8	90[c]
Maximum Net Longitudinal Stress	22,500	32	67[c]
Maximum Shear Stress	23,900	34	45[d]
Maximum Combined Effective Stress	47,800	68	90[c]

Notes:
* Operating Stresses are Based on an Allowable Minimum Radius of 2,050 feet
[a] Specified Minimum Yield Stress
[b.] Limited by design factor from the Design Basis
[c.] Limited by section 402.3.2 of ASME B31.4
[d.] Limited by Section 402.3.1 of ASME B31.4

5.0 LIMITATIONS

We have prepared this report for use by Dakota Access and their authorized agents and other approved members of the design team involved with this project. The report is not intended for use by others, and the information contained herein is not applicable to other sites. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. To increase the likelihood of a successful installation, the conclusions and recommendations in this report should be applied in their entirety.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in developing an HDD Work Plan.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No warranty or other conditions, express, written, or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, and will serve as the official document of record.

Please refer to Appendix C, titled “Report Limitations and Guidelines for Use,” for additional information pertaining to use of this report.

6.0 REFERENCES

From the CFR Title 49, Part 195

- Code of Federal Regulations (2013), “Design Factor for Steel Pipe,” CFR Transportation, Title 49 Part 192.111
- Code of Federal Regulations (2013), “Design Factor for Steel Pipe,” CFR Transportation, Title 49 Part 195.106

From ASME, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids (B31.4)

- The American Society of Mechanical Engineers (2012), “Allowable Stress Values,” ASME Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids, B31.4 Part 402.3.1

- The American Society of Mechanical Engineers (2012), "Limits of Calculated Stresses Due to Suspended Loads and Thermal Expansion," ASME Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids, B31.4 Part 402.3.2

From ASME, Gas Transmission and Distribution Piping Systems (B31.8)

- The American Society of Mechanical Engineers (2010), "Summation of Longitudinal Stress in Restrained Pipe," ASME Gas Transmission and Distribution Piping Systems, B31.8 Part 833.3
- The American Society of Mechanical Engineers (2010), "Combined Stress for Restrained Pipe," ASME Gas Transmission and Distribution Piping Systems, B31.8 Part 833.4

Pipeline Research Committee International (PRCI) of the American Gas Association "Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide," November, 2008.

Dakota Access, LLC, Pipeline Construction Plan Document No. DAPL-WGM-GN000_PRE-SPC-0001, Project No. 10395700, Revision A, Issue Date: April 20, 2015.

FIGURES

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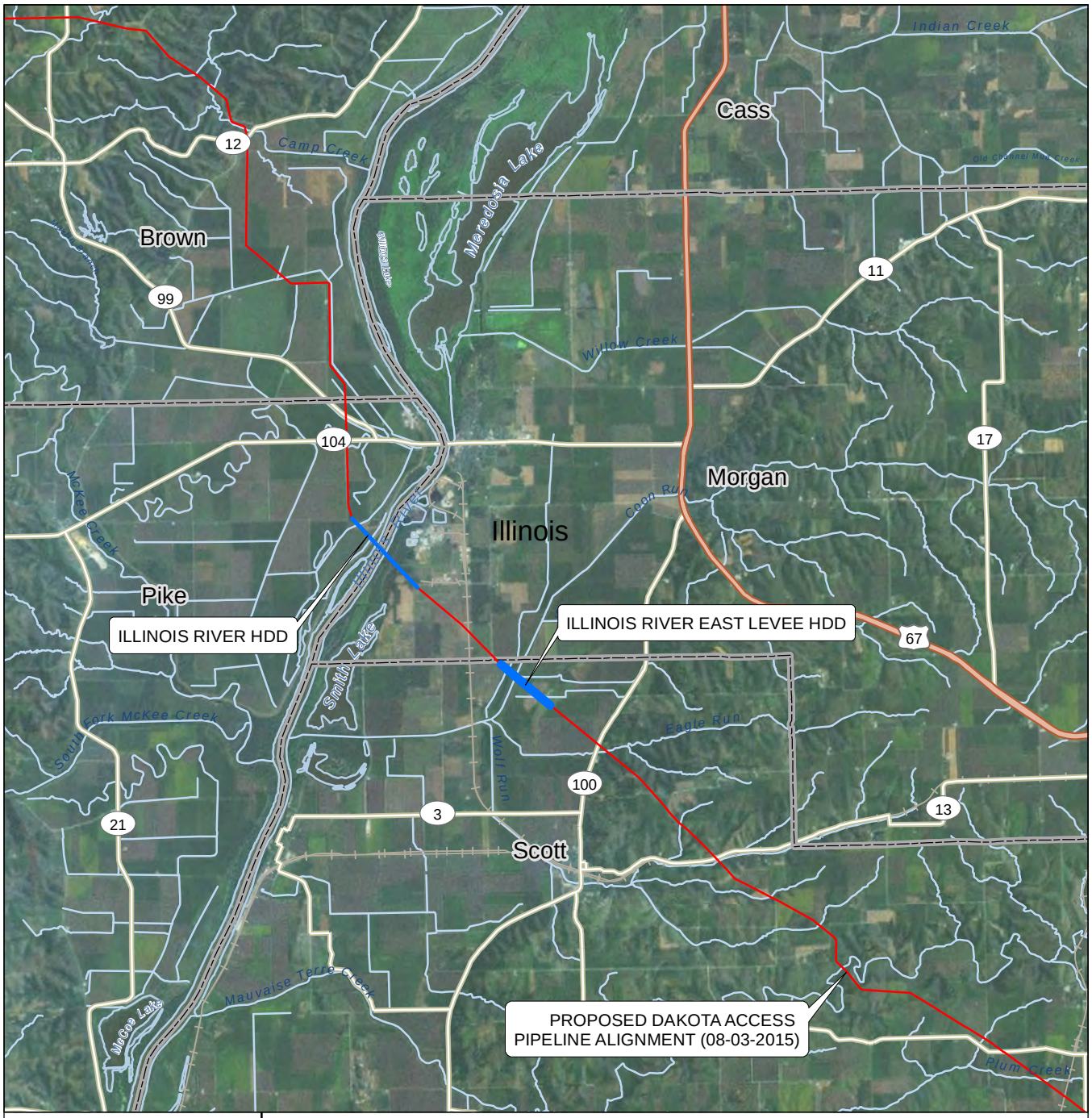

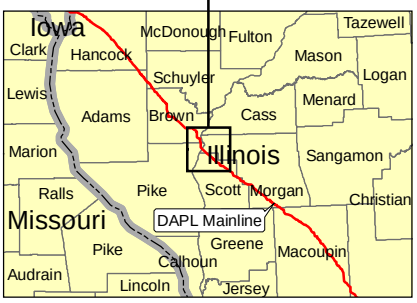

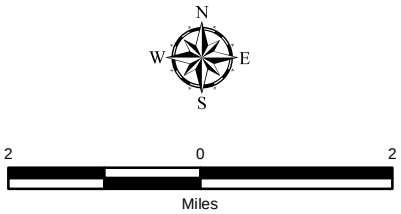

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Imagery from ESRI Data Online.
Projection: NAD 1983, UTM Zone 15 North.

DAKOTA ACCESS PIPELINE PROJECT
VICINITY MAP

PROPOSED 30" PIPELINE
ILLINOIS RIVER EAST LEVEE HDD
SCOTT COUNTY, ILLINOIS

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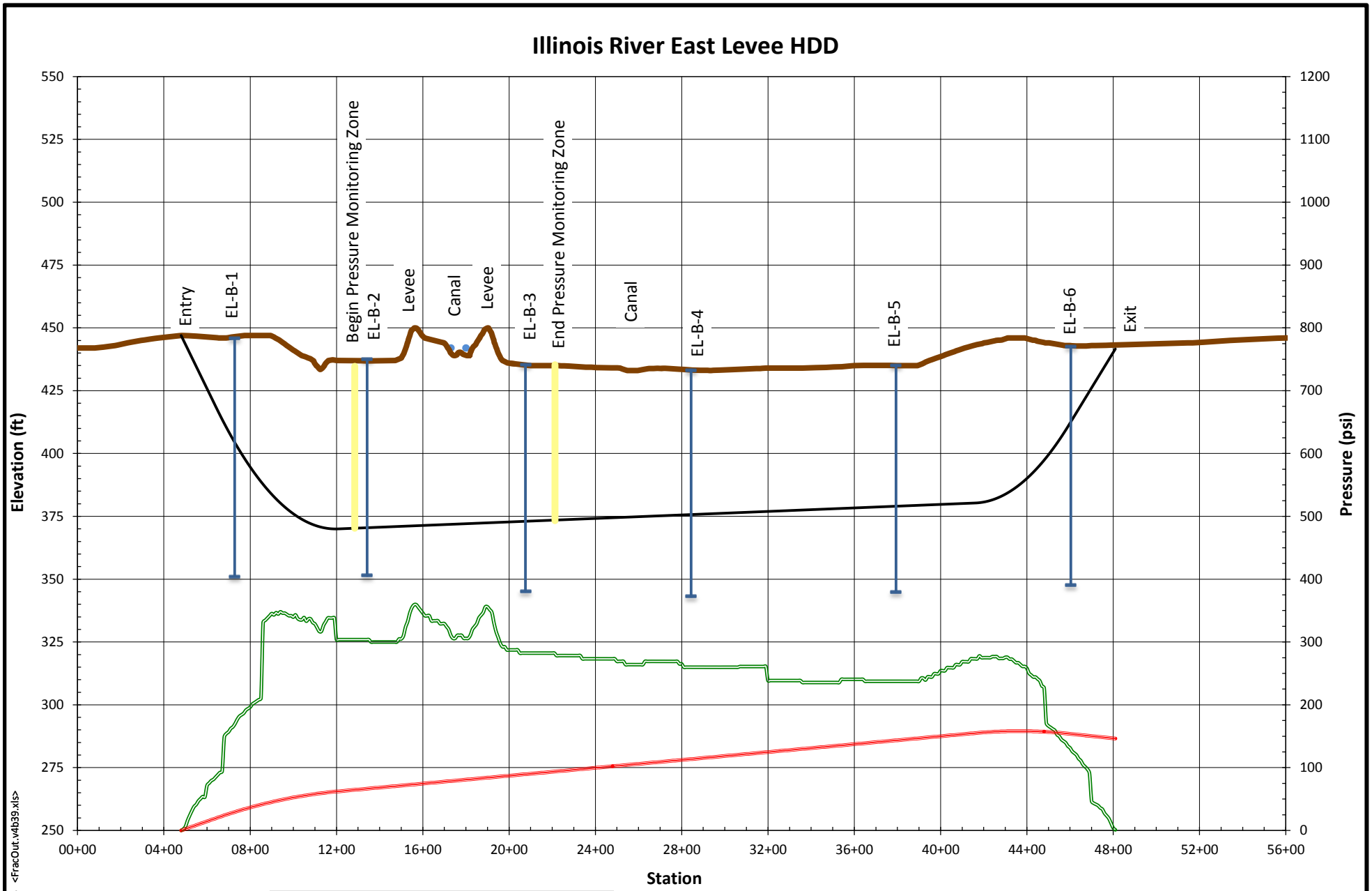
Figure 1

Office: SPR Path: P:\18\1878201\01\GIS\Vicinity Maps\Illinois\Illinois River East Levee HDD.mxd Map Revised: 04 August 2015 mclevenger



Crossing Length (ft)	4341
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.500
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	14
Yield Point (lb/100 ft)	28

- Ground Surface Elevation (ft)
- HDD Profile (ft)
- Formation Limit Pressure (psi)
- Estimated Annular Drilliing Fluid Pressure (psi) for Pilot Hole

ESTIMATED ANNULAR DRILLING FLUID AND FORMATION LIMIT PRESSURES

Illinois River East Levee HDD

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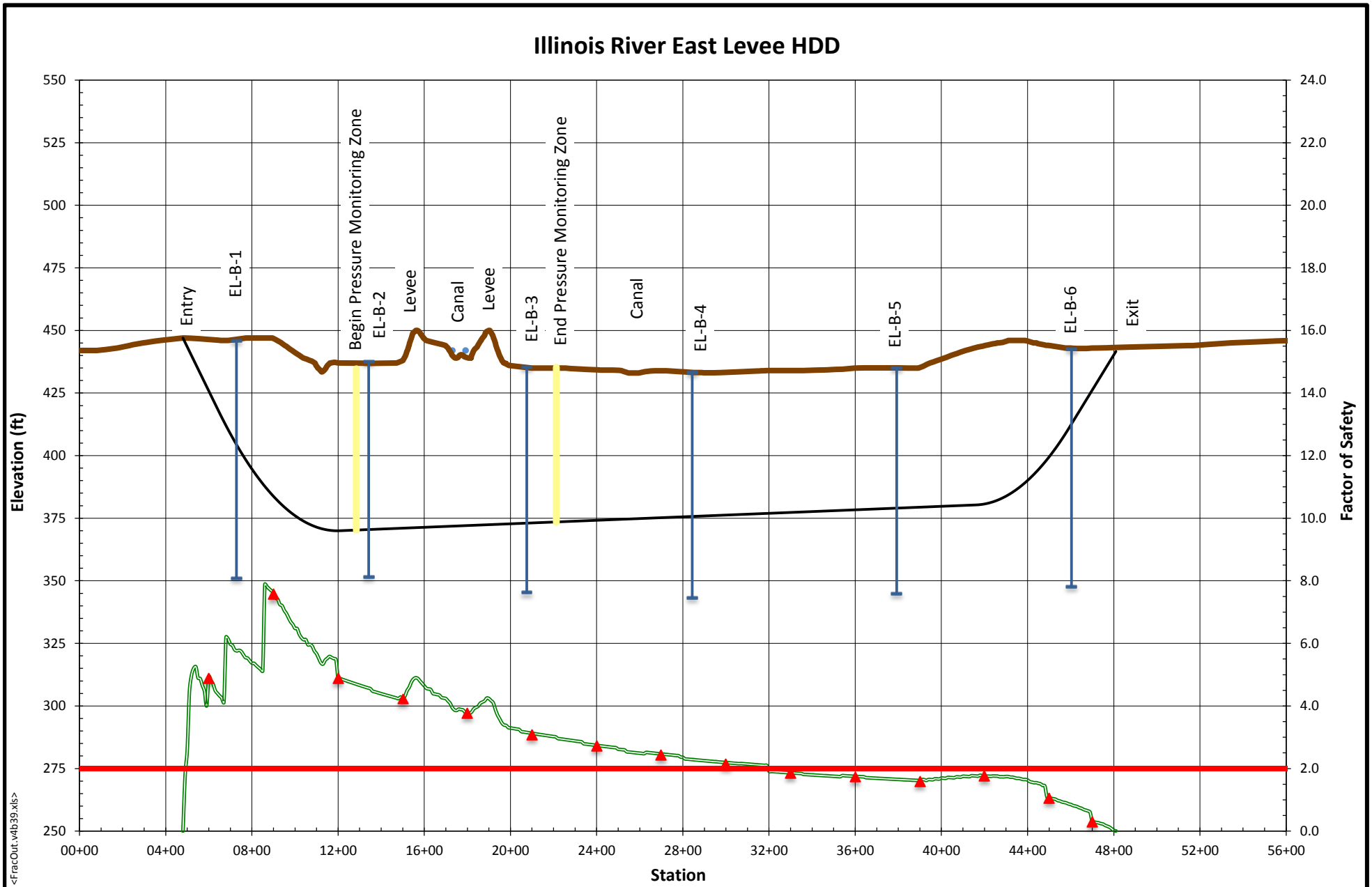
FIGURE 2

18782-011-01 RTB 061115 <FracOut.v4b39.xls>



Crossing Length (ft)	4341
Hole Diameter (in)	9.875
Drill Pipe O.D. (in)	5.500
Drilling Fluid Weight (ppg)	9.5
Plastic Viscosity (CP)	14
Yield Point (lb/100 ft)	28

- Ground Surface Elevation (ft)
- HDD Profile (ft)
- Hydraulic Fracture Factor of Safety for Pilot Hole
- Drilling Fluid Surface Release Factor of Safety for Pilot Hole
- Factor of Safety = 2

HYDRAULIC FRACTURE AND DRILLING FLUID SURFACE RELEASE FACTORS OF SAFETY

Illinois River East Levee HDD

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FIGURE 3

18782-011-01 RTB 061115 <FracOut.v4b39.xls>

Required Depth of Annular Grout Plug - Total Stress Analysis Entry Side

Crossing: **Dakota Access - Illinois River East Levee HDD**
Protected Side: **Entry Side (Northwest Side)**
Subsurface Information From: **Boring EL-B-1**

Total Unit Weight of Soil Profile Above Groundwater (Υ_{sd}) =	**105**	pcf
Total Unit Weight of Soil Profile Below Groundwater (Υ_{sw}) =	**110**	pcf
Levee Crest Elevation =	**451**	ft
Landside Ground Surface Elevation =	**444.69**	ft
Groundwater Elevation on Landside of Levee =	**444.69**	ft
Depth to Groundwater on Landside of Levee (D_w)=	**0.00**	ft
Head at Flood Stage (H_R)=	**6.31**	ft
Let Υ_w Equal the Unit Weight of Water =	**62.4**	pcf

Let D Equal the Depth of the Grout Plug Below Groundwater
Let D_g Equal the Depth of the Grout Plug = D_w + D

Solve the Following Equation for D

$$\gamma_{sd}D_w + \gamma_{sw}D = 1.2(H_R + D_w + D)\gamma_w$$

Rearrange

$$\gamma_{sd}D_w + \gamma_{sw}D - 1.2\gamma_w D = 1.2(H_R + D_w)\gamma_w$$

Substitute Values

105.0*0.00 + 110*D - 1.2*62.4*D = 1.2*(6.31 + 0.00)*62.4

Reduce

35.12D = 472.49

Solve for D

D = 13.45 ft

Minimum Required Depth of Grout Plug D_g = D + D_w

Dg = 13.45 + 0.00

Dg = 13.45 ft

Grout Elevation = 431.2 ft

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Dakota Access Illinois River East Levee HDD
Total Stress Analysis Entry Side

FIGURE 4

Required Depth of Annular Grout Plug - Total Stress Analysis Exit Side

Crossing: **Dakota Access - Illinois River East Levee HDD**
Protected Side: **Exit Side (Southeast Side)**
Subsurface Information From: **Boring EL-B-6**

Total Unit Weight of Soil Profile Above Groundwater (Υ_{sd}) =	**105**	pcf
Total Unit Weight of Soil Profile Below Groundwater (Υ_{sw}) =	**110**	pcf
Levee Crest Elevation =	**451**	ft
Landside Ground Surface Elevation =	**442.55**	ft
Groundwater Elevation on Landside of Levee =	**442.55**	ft
Depth to Groundwater on Landside of Levee (D_w)=	**0.00**	ft
Head at Flood Stage (H_R)=	**8.45**	ft
Let Υ_w Equal the Unit Weight of Water =	**62.4**	pcf

Let D Equal the Depth of the Grout Plug Below Groundwater
Let D_g Equal the Depth of the Grout Plug = D_w + D

Solve the Following Equation for D

$$\gamma_{sd}D_w + \gamma_{sw}D = 1.2(H_R + D_w + D)\gamma_w$$

Rearrange

$$\gamma_{sd}D_w + \gamma_{sw}D - 1.2\gamma_w D = 1.2(H_R + D_w)\gamma_w$$

Substitute Values

105.0*0.00 + 110*D - 1.2*62.4*D = 1.2*(8.45 + 0.00)*62.4

Reduce

35.12D = 632.74

Solve for D

D = 18.02 ft

Minimum Required Depth of Grout Plug D_g = D + D_w

Dg = 18.02 + 0.00

Dg = 18.02 ft

Grout Elevation = 424.5 ft

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Dakota Access Illinois River East Levee HDD
Total Stress Analysis Exit Side

FIGURE 5

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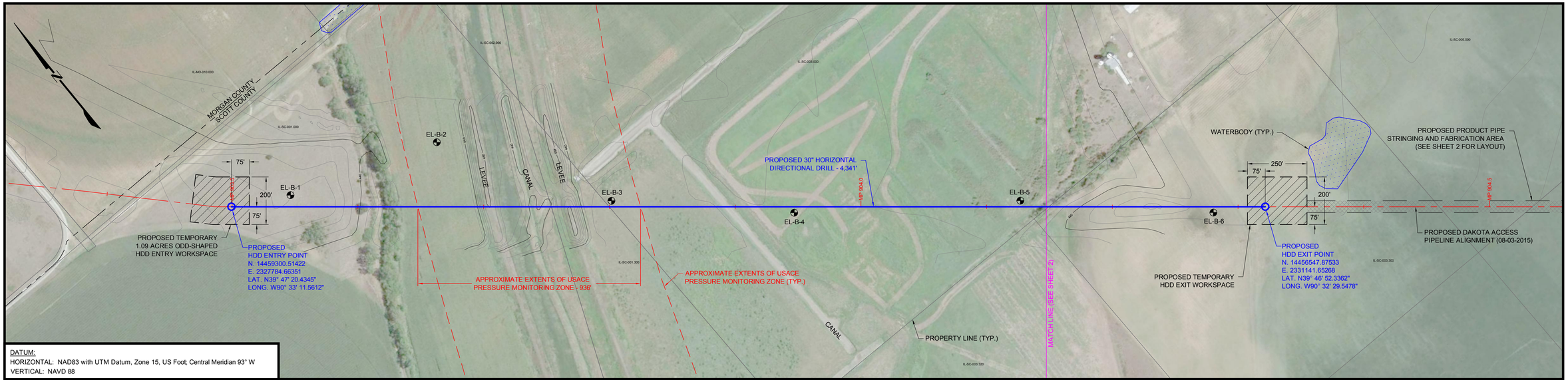
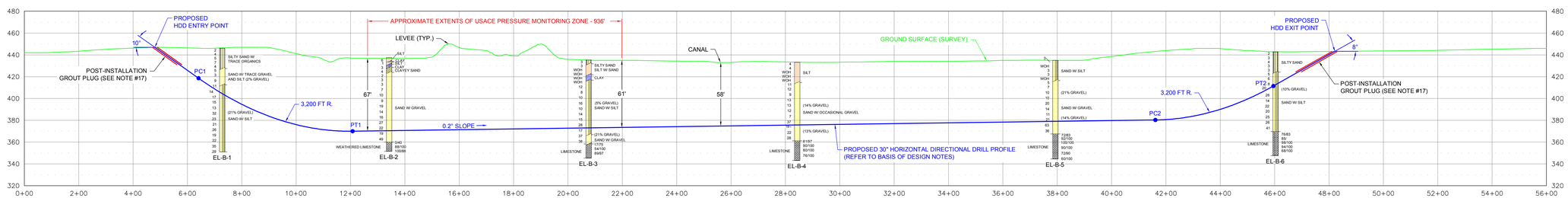
APPENDIX A
HDD Design Drawing and Calculations



DATUM:
HORIZONTAL: NAD83 with UTM Datum, Zone 15, US Foot; Central Meridian 93° W
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN
200' 0 200'
SCALE IN FEET



PROFILE
200' 0 200'
HORIZONTAL SCALE IN FEET
50' 0 50'
VERTICAL SCALE IN FEET

DIRECTIONAL DRILL DATA ILLINOIS RIVER EAST LEVEE HDD		
DESCRIPTION	STATION * (FT)	ELEVATION (FT)
ENTRY @ 10°	4+80.00	446.96
P C 1 (10.20° @ 3,200 FT R.)	6+40.89	418.60
P T 1	12+07.73	370.00
P C 2 (7.80° @ 3,200 FT R.)	41+61.01	380.31
P T 2	45+95.19	411.43
EXIT @ 8°	48+21.24	443.20
HORIZONTAL DISTANCE = 4,341.24 FT		
DIRECTIONAL DRILL PIPE LENGTH = 4,350.25 FT		

RECOMMENDED TOLERANCES	
ITEM	TOLERANCE
PILOT HOLE ENTRY ANGLE	INCREASE ANGLE UP TO 1° (STEEPER), BUT NO DECREASE IN ANGLE ALLOWED.
PILOT HOLE ENTRY LOCATION	WITHIN 5 FEET OF ENTRY POINT AS SHOWN ON DRAWING. WITH NO CHANGES WITHOUT COMPANY APPROVAL.
PILOT HOLE EXIT ANGLE	INCREASE ANGLE UP TO 1° (STEEPER) OR DECREASE UP TO 2° (FLATTER).
PILOT HOLE EXIT LOCATION	UP TO 30 FEET BEYOND THE EXIT STAKE. BETWEEN 10 FEET LEFT AND 10 FEET RIGHT OF CENTERLINE.
PILOT HOLE DEPTH	UP TO 2 FEET ABOVE THE DESIGN DRILL PROFILE ALLOWED. UP TO 10 FEET BELOW THE DESIGN DRILL PROFILE ALLOWED.
PILOT HOLE ALIGNMENT	SHALL REMAIN WITHIN 10 FEET LEFT OR RIGHT OF THE HDD ALIGNMENT.

* STATIONING IS BASED ON AN ARBITRARY REFERENCE POINT.

LEGEND
SPT (N) — TYPE OF SOIL (% GRAVEL)
TYPE OF ROCK — RQD/%REC
BORING LOCATION
MAJOR CONTOUR - 10' INTERVAL
MINOR CONTOUR - 2' INTERVAL

BASIS OF DESIGN:

1. PRODUCT PIPE WILL CONSIST OF 30" O.D. X 0.625" W.T., API-5L X-70 PIPE WITH 14-16 MILS OF FUSION BONDED EPOXY (FBE) AND A MINIMUM OF 40 MILS OF ABRASION RESISTANT OVERLAY (ARO).
2. THE MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) = 1,440 psi.
3. THE ASSUMED MAXIMUM OPERATING TEMPERATURE = 100° FAHRENHEIT.
4. THE MINIMUM ALLOWABLE THREE JOINT RADIUS SHALL NOT BE LESS THAN 2,050 FEET.

ISSUED FOR BID

NOTES:

1. CONTRACTOR SHALL ADHERE TO THE SPECIFICATIONS AND REQUIREMENTS PER DAKOTA ACCESS, LLC SPECIFICATIONS, CONTRACT DOCUMENTS AND SPECIAL PERMIT CONDITIONS, EXCEPT AS NOTED ON THIS DRAWING.
2. CONTRACTOR IS RESPONSIBLE FOR CALLING ILLINOIS ONE-CALL AND LOCATING ALL UNDERGROUND UTILITIES PRIOR TO BEGINNING CONSTRUCTION. IF ANY UTILITY IS LOCATED WITHIN 15 FEET OF THE DESIGNED HDD PROFILE AND ALIGNMENT, CONTRACTOR SHALL OBTAIN APPROVAL FROM DAKOTA ACCESS, LLC PRIOR TO INITIATING HDD OPERATIONS.
3. IT IS THE CONTRACTOR'S RESPONSIBILITY TO IDENTIFY AND PROTECT ANY FOREIGN UTILITY THAT MAY BE AFFECTED BY THE HDD OPERATIONS.
4. PLACEMENT OF THE HDD RIG IS NOT FIXED BY THE DESIGNATION OF THE ENTRY AND EXIT POINTS. THE USE OF DUAL HDD RIGS DURING CONSTRUCTION MAY BE AT THE DISCRETION OF THE HDD CONTRACTOR, TO BE APPROVED BY DAKOTA ACCESS, LLC.
5. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
6. WORK SPACE: MAXIMUM WORK SPACE LIMITS ARE DEPICTED. RESTRICT CLEARING TO THE WORK SPACE INDICATED AT THE ENTRY AND EXIT POINTS AND PRODUCT PIPE STRINGING AND FABRICATION AREA ALONG THE CONSTRUCTION RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS REQUIRES PRIOR APPROVAL FROM THE ENVIRONMENTAL INSPECTOR AND IS LIMITED TO THE AMOUNT NECESSARY TO STRING SURVEY WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
7. WATER SOURCE: DRILL WATER AND HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE.
8. HYDROSTATIC TEST: PRE-INSTALLATION AND POST-INSTALLATION HYDROSTATIC TESTS SHALL BE CONDUCTED IN ACCORDANCE WITH THE HYDROSTATIC TEST PLAN. TEST WATER SHALL BE SAMPLED AND TESTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE TEST WATER SHALL BE DISCHARGED IN AN UPLAND AREA INTO AN EROSION CONTROL STRUCTURE OF STRAW BALES AND/OR SILT FENCES, GEOTEXTILE FILTER BAG, OR COLLECTED IN A TRUCK AND HAULED TO AN APPROVED DISPOSAL SITE. UPON COMPLETION OF DEWATERING AND DRYING, A CALIPER PIG SURVEY SHALL BE COMPLETED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
9. SPILL-PREVENTION: REFUELING OF ALL EQUIPMENT SHALL BE COMPLETED IN ACCORDANCE WITH THE SPCC PLAN.
10. EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
11. INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE APPROVED CONSTRUCTION RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. AFTER THE PILOT HOLE IS COMPLETE, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO DAKOTA ACCESS, LLC FOR APPROVAL. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
12. DRILLING FLUID DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING FLUID AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING FLUID WHICH INADVERTENTLY SURFACES AT POINTS OTHER THAN THE ENTRY OR EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
13. CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN THE CLEAN-UP AND RESTORATION REQUIREMENTS. IF THE TERRAIN ALLOWS AND ACCESS IS PERMITTED, CONTRACTOR SHALL UTILIZE LOW GROUND PRESSURE EQUIPMENT OR OTHER EQUIPMENT APPROVED BY OWNER, TO FACILITATE CONTAINMENT AND CLEAN-UP OF ANY INADVERTENT RETURNS THAT OCCUR DURING THE HDD INSTALLATION PROCESS.
14. GEOTECHNICAL DATA: BORE HOLES ARE OFFSET FROM THE PIPELINE CENTERLINE AS SHOWN ON THE PLAN VIEW. THE GEOTECHNICAL INFORMATION PROVIDED ON THIS DRAWING IS A GENERAL SUMMARY. REFER TO THE APPLICABLE GEOTECHNICAL REPORT IN THE CONTRACT DOCUMENTS FOR MORE DETAILED INFORMATION.
15. AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO © 2015, LICENSED TO GEOENGINEERS, INC., IMAGE DATED 07/31/12. GROUND SURFACE DEM (1/3 ARC SECOND) DOWNLOADED FROM HTTP://VIEWER.NATIONALMAP.GOV/VIEWER/. GROUND SURFACE SURVEY PROVIDED BY WOOD GROUP MUSTANG, INC.
16. SHAPE FILES PROVIDED BY CONTRACT LAND STAFF, LLC.
17. AFTER COMPLETING PULLBACK OF PRODUCT PIPE, GROUT THE ANNULUS BETWEEN PIPE AND REAMED HOLE WITH CEMENT-BENTONITE MIXTURE TO ELEVATION 431 AT ENTRY AND 424 AT EXIT.

REFERENCES	
DRAWING NUMBER	REFERENCE DRAWING TITLE

REVISIONS					
NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
A	ISSUED FOR BID	MWC	06/11/15	MAM	JLR
B	ISSUED FOR BID	BTL	08/05/15	MAM	JLR

JLR Design	04/13/15 Date
MWC Drawn	04/13/15 Date
MAM Checked	04/13/15 Date
JLR Approved	04/14/15 Date

GEOENGINEERS
3050 South Delaware
Springfield, MO 65804
Telephone (417) 831-9700
Fax (417) 831-9777

DAKOTA ACCESS PIPELINE PROJECT
SITE PLAN AND PROFILE
PROPOSED 30" PIPELINE
ILLINOIS RIVER EAST LEVEE HDD
SCOTT COUNTY, ILLINOIS

Project No. 18782-011-01
Drawing No. W_29004_C100066
Sheet 1 of 2

P:\18\18782\011\CAD\Crossing\Illinois\Illinois River East Levee\Drawing\Illinois River East Levee HDD_PB.dwg\TAB:SHEET 1 modified on Aug 05, 2015 - 4:29pm

DATUM:
HORIZONTAL: NAD83 with UTM Datum, Zone 15, US Foot; Central Meridian 93° W
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

200' 0 200'
SCALE IN FEET

ISSUED FOR BID

LEGEND
- BORING LOCATION
- MAJOR CONTOUR - 10' INTERVAL
- MINOR CONTOUR - 2' INTERVAL

NOTES:

1. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
2. AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO © 2015, LICENSED TO GEOENGINEERS, INC., IMAGE DATED 07/31/12. GROUND SURFACE DEM (1/3 ARC SECOND) DOWNLOADED FROM HTTP://VIEWER.NATIONALMAP.GOV/VIEWER/. GROUND SURFACE SURVEY PROVIDED BY WOOD GROUP MUSTANG, INC.
3. SHAPE FILES PROVIDED BY CONTRACT LAND STAFF, LLC.

REFERENCES

DRAWING NUMBER	REFERENCE DRAWING TITLE

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
A	ISSUED FOR BID	MWC	06/11/15	MAM	JLR
B	ISSUED FOR BID	BTL	08/05/15	MAM	JLR

JLR Design	04/13/15 Date
MWC Drawn	04/13/15 Date
MAM Checked	04/13/15 Date
JLR Approved	04/14/15 Date

GEOENGINEERS
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Springfield, MO 65804
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DAKOTA ACCESS PIPELINE PROJECT
STRINGING WORKSPACE

PROPOSED 30" PIPELINE
ILLINOIS RIVER EAST LEVEE HDD
SCOTT COUNTY, ILLINOIS

Project No. 18782-011-01
Drawing No. W_29004_C100067
Sheet 2 of 2

P:\18\18782\011\01\CAD\Crossings\Illinois River East Levee\Drawings\Illinois River East Levee HDD_IFB.dwg\7&8\SHEET 2 modified on Aug 05, 2015, 4:26pm

HDD Design Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Design Parameters

Pipe Diameter = 30.000 in
Pipe Material = Steel
Yield Stress = 70,000 psi
Wall Thickness = 0.625 in
Assumed Installation Temp = 70 °F
Assumed Operating Temp= 100 °F
Design Factor = 0.5
MAOP = 1,440 psi

Drill Data Box

Point	Station (ft)	Elevation (ft)
ENTRY @ 10°	480.00	444.69
P C 1 (10.20° @ 3,200 ft R.)	627.97	418.60
P T 1	1,194.81	370.00
P C 2 (7.80° @ 3,200 ft R.)	4,166.09	380.37
P T 2	4,600.27	411.49
EXIT @ 8°	4,821.24	442.55

Horizontal Alignment Length = 4,341.24 ft

Profile Segment Information

Segment Name	Segment Type	Segment Length (ft)
Entry Tangent	Straight	150.25
Entry Curve	Vertical Curve	569.68
Bottom Tangent	Straight	2,971.29
Exit Curve	Vertical Curve	435.63
Exit Tangent	Straight	223.15

Pipe Length = 4,350.00 ft

Installation Load Summary

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Buoyancy Control (lb/ft)	Effective Pipe Weight (lb/ft)	Total Installation Force (lb)
9.50	Empty	0.00	-152.27	487,000
9.50	Full	281.31	129.04	393,000
12.00	Empty	0.00	-244.07	618,000
12.00	Full	281.31	37.24	296,000
10.00	Neutral	170.63	0.00	267,000

GeoEngineers

Minimum Radius Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Design Parameters:

Pipe Diameter = 30.000 in **MAOP =** 1,440 psi **Factor of Safety =** 2.00

Wall Thickness = 0.625 in **SMYS =** 70,000 psi

D/t Ratio = 48.00 **Modulus of Elasticity (E) =** 2.93E+007 psi

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 34,560 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 17,280 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 35,000 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 17,720 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 2,046 ft

GeoEngineers

Operating Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Design Parameters

Pipe diameter =	30.000 in	**Minimum Radius of Curvature =**	2,050 ft
Wall Thickness =	0.625 in	**Coefficient of Thermal Expansion =**	6.5E-06 in/in/°F
SMYS =	70,000 psi	**Assumed Installation Temperature =**	70 °F
MAOP =	1,440 psi	**Assumed Operating Temperature =**	100 °F
Poissons's Ratio =	0.30	**Temperature Derating Factor =**	1.00
Young's Modulus (E) =	2.93E+007 psi	**Groundwater Table Head =**	0.00 ft
Design Factor =	0.5		

Stress Analyses

Longitudinal Stress from Bending =	17,893 psi	
Percent SMYS =	25.56 %	
Hoop Stress =	34,560 psi	
Percent SMYS =	49.37 %	Limited by Design Factor (0.5) according to 49 CFR 195.106
Longitudinal Tensile Stress from Hoop Stress =	10,368 psi	
Percent SMYS =	14.81 %	
Longitudinal Stress from Thermal Expansion =	-5,722 psi	
Percent SMYS =	8.17 %	Limited to 90% SMYS by ASME/ANSI B31.4 section 402.3.2
Net Longitudinal Stress (Comp. side of Curve) =	-13,247 psi	
Percent SMYS =	18.92 %	Limited to 67.5% SMYS by ASME/ANSI B31.4 section 402.3.2
Net Longitudinal Stress (Tension side of Curve) =	22,539 psi	
Percent SMYS =	32.20 %	Limited to 67.5% SMYS by ASME/ANSI B31.4 section 402.3.2
Maximum Shear Stress =	23,903 psi	
Percent SMYS =	34.15 %	Limited to 45% SMYS by ASME/ANSI B31.4 section 402.3.1
Combined BiaxialSress Check =	47,807 psi	
Percent SMYS =	68.30 %	Limited to 90% SMYS by AMSE/ANSI B31.4 section 402.3.2

GeoEngineers

Operating Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,350 ft
Moment of Inertia =	6,224 in^4
Pipe Face Area =	57.68 in^2
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	4.91 ft^3/ft
Displaced Fluid Weight =	348.84 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	-152.27 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	223.15 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	12,619 lb
Friction Force =	10,095 lb
Segment Weight =	4,729 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	27,442 lb
Cumulative Force =	**27,442 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	476 psi	
Cumulative Axial Stress =	476 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	393 psi	7,384 psi
Combined Stress =	0.0085	< 1.0
Total Stress =	0.0030	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	7.80 deg
Segment Length =	435.63 ft	Center Displacement =	7.41 ft

Segment Force Components

Normal Force =	50,803 lb
Drag Force =	24,635 lb
Friction Force =	15,241 lb
Segment Weight =	4,743 lb
Tension =	87,302 lb
Average Tension =	57,372 lb
Segment Force =	59,859 lb
Cumulative Force =	**87,302 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,038 psi	
Cumulative Axial Stress =	1,514 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	762 psi	7,384 psi
Combined Stress =	0.4140	< 1.0
Total Stress =	0.1443	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	2,971.29 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	168,023 lb
Friction Force =	135,735 lb
Segment Weight =	1,579 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	305,337 lb
Cumulative Force =	**392,638 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	5,294 psi	
Cumulative Axial Stress =	6,807 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	885 psi	7,384 psi
Combined Stress =	0.1216	< 1.0
Total Stress =	0.0354	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.20 deg
Segment Length =	569.68 ft	Center Displacement =	12.67 ft

Segment Force Components

Normal Force =	96,814 lb
Drag Force =	32,214 lb
Friction Force =	29,044 lb
Segment Weight =	-7,711 lb
Tension =	475,230 lb
Average Tension =	433,934 lb
Segment Force =	82,592 lb
Cumulative Force =	**475,230 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,432 psi	
Cumulative Axial Stress =	8,239 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	885 psi	7,384 psi
Combined Stress =	0.5341	< 1.0
Total Stress =	0.2541	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	150.25 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	8,497 lb
Friction Force =	6,760 lb
Segment Weight =	-3,973 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	11,283 lb
Cumulative Force =	**486,513 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	196 psi	
Cumulative Axial Stress =	8,435 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	309 psi	7,384 psi
Combined Stress =	0.1506	< 1.0
Total Stress =	0.0273	< 1.0

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,350 ft
Moment of Inertia =	6,224 in⁴
Pipe Face Area =	57.68 in²
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	4.91 ft³/ft
Displaced Fluid Weight =	348.84 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	129.04 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full

Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	223.15 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	12,619 lb
Friction Force =	8,554 lb
Segment Weight =	-4,007 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	17,165 lb
Cumulative Force =	**17,165 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	298 psi	
Cumulative Axial Stress =	298 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	70 psi	7,384 psi
Combined Stress =	0.0053	< 1.0
Total Stress =	0.0001	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	7.80 deg
Segment Length =	435.63 ft	Center Displacement =	7.41 ft

Segment Force Components

Normal Force =	-26,487 lb
Drag Force =	24,635 lb
Friction Force =	7,946 lb
Segment Weight =	-4,019 lb
Tension =	53,673 lb
Average Tension =	35,419 lb
Segment Force =	36,507 lb
Cumulative Force =	**53,673 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	633 psi	
Cumulative Axial Stress =	931 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	115 psi	7,384 psi
Combined Stress =	0.4036	< 1.0
Total Stress =	0.1131	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	2,971.29 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	168,023 lb
Friction Force =	115,021 lb
Segment Weight =	-1,338 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	281,706 lb
Cumulative Force =	**335,378 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	4,884 psi	
Cumulative Axial Stress =	5,815 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	130 psi	7,384 psi
Combined Stress =	0.1038	< 1.0
Total Stress =	0.0119	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.20 deg
Segment Length =	569.68 ft	Center Displacement =	12.67 ft

Segment Force Components

Normal Force =	-2,239 lb
Drag Force =	32,214 lb
Friction Force =	672 lb
Segment Weight =	6,535 lb
Tension =	375,471 lb
Average Tension =	355,425 lb
Segment Force =	40,093 lb
Cumulative Force =	**375,471 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	695 psi	
Cumulative Axial Stress =	6,510 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	130 psi	7,384 psi
Combined Stress =	0.5032	< 1.0
Total Stress =	0.1905	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	150.25 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	8,497 lb
Friction Force =	5,728 lb
Segment Weight =	3,367 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	17,591 lb
Cumulative Force =	**393,062 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	305 psi	
Cumulative Axial Stress =	6,815 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	60 psi	7,384 psi
Combined Stress =	0.1217	< 1.0
Total Stress =	0.0153	< 1.0

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,350 ft
Moment of Inertia =	6,224 in⁴
Pipe Face Area =	57.68 in²
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	4.91 ft³/ft
Displaced Fluid Weight =	440.64 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	-244.07 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty

Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	223.15 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	12,619 lb
Friction Force =	16,180 lb
Segment Weight =	7,580 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	36,379 lb
Cumulative Force =	**36,379 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	631 psi	
Cumulative Axial Stress =	631 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	497 psi	7,384 psi
Combined Stress =	0.0113	< 1.0
Total Stress =	0.0048	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	7.80 deg
Segment Length =	435.63 ft	Center Displacement =	7.41 ft

Segment Force Components

Normal Force =	76,642 lb
Drag Force =	24,635 lb
Friction Force =	22,993 lb
Segment Weight =	7,602 lb
Tension =	114,601 lb
Average Tension =	75,490 lb
Segment Force =	78,222 lb
Cumulative Force =	**114,601 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,356 psi	
Cumulative Axial Stress =	1,987 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	962 psi	7,384 psi
Combined Stress =	0.4224	< 1.0
Total Stress =	0.1612	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	2,971.29 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	168,023 lb
Friction Force =	217,563 lb
Segment Weight =	2,531 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	388,117 lb
Cumulative Force =	**502,718 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	6,729 psi	
Cumulative Axial Stress =	8,716 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	1,117 psi	7,384 psi
Combined Stress =	0.1556	< 1.0
Total Stress =	0.0573	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.20 deg
Segment Length =	569.68 ft	Center Displacement =	12.67 ft

Segment Force Components

Normal Force =	137,316 lb
Drag Force =	32,214 lb
Friction Force =	41,195 lb
Segment Weight =	-12,360 lb
Tension =	604,962 lb
Average Tension =	553,840 lb
Segment Force =	102,244 lb
Cumulative Force =	**604,962 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,773 psi	
Cumulative Axial Stress =	10,489 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	1,118 psi	7,384 psi
Combined Stress =	0.5743	< 1.0
Total Stress =	0.3108	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	150.25 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	8,497 lb
Friction Force =	10,835 lb
Segment Weight =	-6,368 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	12,963 lb
Cumulative Force =	**617,925 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	225 psi	
Cumulative Axial Stress =	10,713 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	390 psi	7,384 psi
Combined Stress =	0.1913	< 1.0
Total Stress =	0.0440	< 1.0

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,350 ft
Moment of Inertia =	6,224 in⁴
Pipe Face Area =	57.68 in²
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	4.91 ft³/ft
Displaced Fluid Weight =	440.64 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	37.24 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	223.15 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	12,619 lb
Friction Force =	2,469 lb
Segment Weight =	-1,156 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	13,931 lb
Cumulative Force =	**13,931 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	242 psi	
Cumulative Axial Stress =	242 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	174 psi	7,384 psi
Combined Stress =	0.0043	< 1.0
Total Stress =	0.0006	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	7.80 deg
Segment Length =	435.63 ft	Center Displacement =	7.41 ft

Segment Force Components

Normal Force =	-2,507 lb
Drag Force =	24,635 lb
Friction Force =	752 lb
Segment Weight =	-1,160 lb
Tension =	38,910 lb
Average Tension =	26,420 lb
Segment Force =	24,979 lb
Cumulative Force =	**38,910 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	433 psi	
Cumulative Axial Stress =	675 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	316 psi	7,384 psi
Combined Stress =	0.3990	< 1.0
Total Stress =	0.1158	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	2,971.29 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	168,023 lb
Friction Force =	33,193 lb
Segment Weight =	-386 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	200,829 lb
Cumulative Force =	**239,739 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	3,482 psi	
Cumulative Axial Stress =	4,157 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	363 psi	7,384 psi
Combined Stress =	0.0742	< 1.0
Total Stress =	0.0095	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.20 deg
Segment Length =	569.68 ft	Center Displacement =	12.67 ft

Segment Force Components

Normal Force =	18,365 lb
Drag Force =	32,214 lb
Friction Force =	5,510 lb
Segment Weight =	1,886 lb
Tension =	284,858 lb
Average Tension =	262,299 lb
Segment Force =	45,119 lb
Cumulative Force =	**284,858 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	782 psi	
Cumulative Axial Stress =	4,939 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	363 psi	7,384 psi
Combined Stress =	0.4752	< 1.0
Total Stress =	0.1748	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	150.25 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	8,497 lb
Friction Force =	1,653 lb
Segment Weight =	972 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	11,121 lb
Cumulative Force =	**295,979 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	193 psi	
Cumulative Axial Stress =	5,132 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	141 psi	7,384 psi
Combined Stress =	0.0916	< 1.0
Total Stress =	0.0096	< 1.0

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Installation Case:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy

Product Pipe Parameters	
Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,350 ft
Moment of Inertia =	6,224 in⁴
Pipe Face Area =	57.68 in²
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	4.91 ft³/ft
Displaced Fluid Weight =	367.20 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	0.00 lb/ft

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	223.15 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	12,619 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	12,619 lb
Cumulative Force =	**12,619 lb**

Segment Installation Stress Checks		
Stress Component	Calculated	Allowable
Segment Axial Stress =	219 psi	
Cumulative Axial Stress =	219 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	414 psi	7,384 psi
Combined Stress =	0.0039	< 1.0
Total Stress =	0.0031	< 1.0

Installation Load Calculations

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	7.80 deg
Segment Length =	435.63 ft	Center Displacement =	7.41 ft

Segment Force Components

Normal Force =	7,624 lb
Drag Force =	24,635 lb
Friction Force =	2,287 lb
Segment Weight =	0 lb
Tension =	41,828 lb
Average Tension =	27,223 lb
Segment Force =	29,209 lb
Cumulative Force =	**41,828 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	506 psi	
Cumulative Axial Stress =	725 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	802 psi	7,384 psi
Combined Stress =	0.3999	< 1.0
Total Stress =	0.1361	< 1.0

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	2,971.29 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	168,023 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	168,023 lb
Cumulative Force =	**209,850 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	2,913 psi	
Cumulative Axial Stress =	3,638 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	931 psi	7,384 psi
Combined Stress =	0.0650	< 1.0
Total Stress =	0.0234	< 1.0

Installation Load Calculations

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,200 ft
Segment Type =	Vertical Curve	Angle Turned =	10.20 deg
Segment Length =	569.68 ft	Center Displacement =	12.67 ft

Segment Force Components

Normal Force =	27,941 lb
Drag Force =	32,214 lb
Friction Force =	8,382 lb
Segment Weight =	0 lb
Tension =	258,829 lb
Average Tension =	234,340 lb
Segment Force =	48,979 lb
Cumulative Force =	**258,829 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	849 psi	
Cumulative Axial Stress =	4,488 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	931 psi	7,384 psi
Combined Stress =	0.4671	< 1.0
Total Stress =	0.1955	< 1.0

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	150.25 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	8,497 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	8,497 lb
Cumulative Force =	**267,326 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	147 psi	
Cumulative Axial Stress =	4,635 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	325 psi	7,384 psi
Combined Stress =	0.0828	< 1.0
Total Stress =	0.0104	< 1.0

Overbend Radius Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Design Parameters:

Pipe Diameter = 30.000 in **MAOP =** 0 psi **Factor of Safety =** 1.50

Wall Thickness = 0.625 in **SMYS =** 70,000 psi

D/t Ratio = 48.00 **Modulus of Elasticity (E) =** 2.93E+007 psi

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 0 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 0 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 46,667 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 46,667 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 777 ft

GeoEngineers

Overbend Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Design Parameters

Pipe diameter = 30.000 in

Wall Thickness = 0.625 in

SMYS = 70,000 psi

Internal Pressure = 0 psi

Poissons's Ratio = 0.30

Young's Modulus (E) = 2.93E+007 psi

Factor of Safety = 1.50

Overbend Radius of Curvature = 777 ft

Assumed Installation Temperature = 70 °F

Stress Analyses

Longitudinal Stress from Bending = 47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Hoop Stress = 0 psi

Percent SMYS = 0 %

Longitudinal Tensile Stress from Hoop Stress = 0 psi

Percent SMYS = 0 %

Longitudinal Stress from Thermal Expansion = 0 psi

Percent SMYS = 0 %

Net Longitudinal Stress (Comp. side of Curve) = -47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Net Longitudinal Stress (Tension side of Curve) = 47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Maximum Shear Stress = 23,610 psi

Percent SMYS = 33.73 % Limited to 40% SMYS

Combined Biaxial Stress Check = 47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

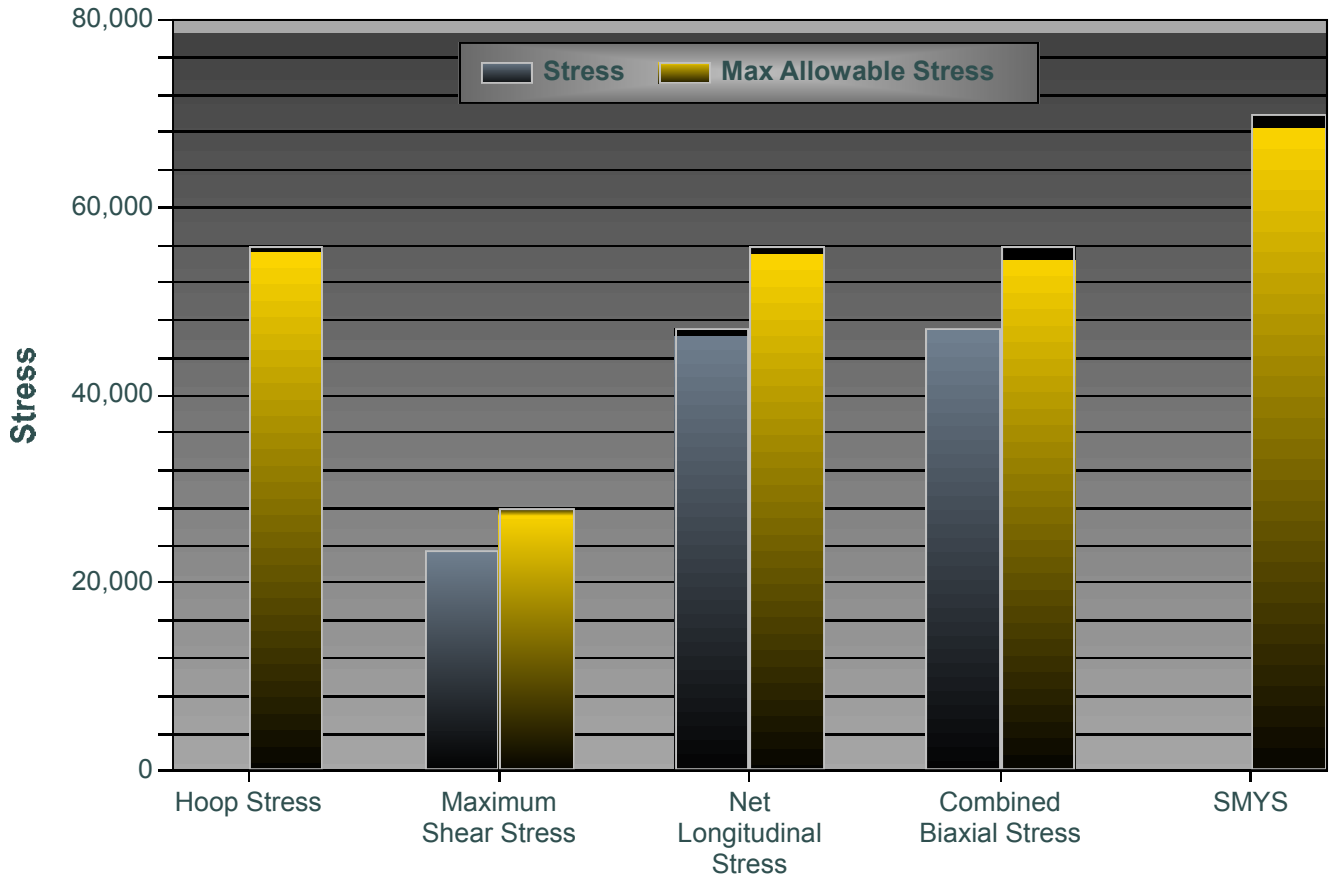
GeoEngineers

Overbend Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Illinois River East Levee HDD **Owner:** Dakota Access, LLC

Project No: 18782-011-01 **By:** MWC **Ck'd By:** MAM **Location:** Scott County, Illinois **Date:** Tuesday, September 02, 2014

Overbend Stress Check



APPENDIX B
Geotechnical Data Report

Geotechnical Data Report

Dakota Access Pipeline Project
Illinois River East Levee HDD
Scott County, Illinois

for
Dakota Access, LLC

June 9, 2015

GeoEngineers

3050 South Delaware Avenue
Springfield, Missouri 65804
417.831.9700

Geotechnical Data Report

Dakota Access Pipeline Project
Illinois River East Levee HDD
Scott County, Illinois

File No. 18782-011-01

June 9, 2015

Prepared for:

Dakota Access, LLC
711 Louisiana Street, Suite 900
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Attention: Adam Broad

Prepared by:

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Appendix B. Report Limitations and Guidelines for Use

1.0 INTRODUCTION

At the request of Dakota Access, LLC (Dakota Access), and in general accordance with our contract agreement (No. 07-PSA-0017), GeoEngineers, Inc. (GeoEngineers) is pleased to submit this geotechnical data report for the proposed Dakota Access Pipeline (DAPL) Project Illinois River East Levee Horizontal Directional Drill (HDD) near proposed DAPL Milepost (MP) 903.5 in Scott County, Illinois. The general location of the proposed HDD is noted on the attached Vicinity Map, Figure 1.

We understand that Dakota Access is proposing to construct approximately 1,020 miles of 30-inch-diameter steel pipeline extending from Mountrail County, North Dakota through eastern South Dakota, Central Iowa, and terminating in Wayne County, Illinois. The proposed Illinois River East Levee HDD would cross beneath a United States Army Corps of Engineers (USACE) regulated levee, and canal in Scott County, Illinois. The layout of the proposed HDD is shown in the attached Conceptual Site Plan and Profile, and Conceptual Stringing Workspace, Figures 2A and 2B, respectively.

Our geotechnical services included completing a subsurface soil exploration program by drilling six borings near the proposed HDD crossing alignment and preparing this geotechnical data report. Our assessment of the feasibility of HDD installation, detailed HDD engineering design, and recommendations for HDD construction will be provided under a separate cover.

2.0 SCOPE OF SERVICES

The purpose of our services was to evaluate the existing surface and subsurface soil, bedrock, and groundwater conditions and to prepare a geotechnical data report. The specific scope of services provided by GeoEngineers included the following:

1. Contacted the Illinois “One-Call” utility locating agency to locate utilities in the project area prior to the start of the exploratory borings.
2. Explored subsurface conditions by drilling six borings to depths of up to 95 feet below ground surface (bgs) using hollow-stem auger, and/or mud rotary, and NQ-sized rock coring drilling equipment. GeoEngineers field staff directed the drilling completed by Geotechnology, Inc., using All-Terrain-Vehicle (ATV) mounted drilling equipment.
3. Obtained soil and rock samples at representative intervals from the borings, and:
   - Classified the soil and rock encountered in the borings in general accordance with ASTM International (ASTM) D2488 and ASTM D5878, respectively; and
   - Observed groundwater conditions encountered in the borings, where possible.
4. Completed a laboratory-testing program on selected soil and rock samples obtained from the borings to evaluate pertinent engineering properties. The tests included the following:
   - Moisture Content (ASTM D2216);
   - Atterberg limits determination (ASTM D4318);
   - Sieve Analysis (ASTM D422); and

- Unconfined compressive strength of rock (ASTM D7012).

5. Prepared logs of the borings which included the following:
   - SPT values as an indication of in-situ soil density;
   - Rock quality designation (RQD), percent recovery, and Mohs hardness;
   - Index and classification properties of soil and rock, as applicable; and
   - Other soil, rock, and groundwater properties as applicable.
6. Prepared and submitted to Dakota Access this data report summarizing the results of the geotechnical investigation.

3.0 SITE DESCRIPTION

3.1 Geology

3.1.1 Regional Geologic Setting

From approximately MP 887 to MP 999, the proposed DAPL alignment crosses the Springfield Plain sub-section of the Till Plains section. The Springfield Plain includes the level portion of the Illinoian drift-sheet in central and south-central Illinois. It is distinguished mainly by its flatness and by shallow entrenchment of drainage as compared with the more sharply incised valleys of the Galesburg Plain. Although the greater part of the district is a flat till plain, the morainic features in the western part of the region are much more conspicuous than elsewhere on the Illinoian drift-sheet. The moraines are low and broad, but they are readily recognized because of their continuity and the associated kames and kame terraces. Drainage systems are well developed, and the district as a whole is in a late youthful stage of dissection. The uplands are low with respect to the master streams, and the valleys are relatively shallow. Most of the principal streams have low gradients and occupy broad alluviated and terraced valleys; the secondary tributaries have wide V-shaped valleys; and the headwaters, flowing essentially on the till plain, have broad shallow valleys and low gradients. The Illinoian drift is moderately thick and is underlain by older drift except in areas where the bedrock is close to the surface. Only the larger valleys and uplands of the bedrock surface are reflected in the present topography. Along the southeast side of the Illinois Valley there is a belt of thick loess, with dune-contours characterizing the bluff-margin, but this body of loess thins rapidly to the southeast (Leighton, et al, 1948).

3.1.2 Site Geology

Geologic mapping indicates that Quarternary Age (2.6 million years to present) Cahokia Alluvium is present at the Illinois River East Levee crossing site, within the floodplain of the Illinois River. The Cahokia consists mostly of poorly sorted sand, silt or clay containing local deposits of sandy gravel. In many places the Cahokia overlies well-sorted glacial outwash of the Henry Formation. Mapping indicates that Quarternary (Pleistocene) Age Carmi Member of the Equality Formation may also be present at the Illinois River East Levee site. The Carmi Member consists of well-bedded silt and some clay and includes sediment of proglacial lakes and slack-water lakes in valleys tributary to major river valleys. These surficial deposits are likely to be underlain by the Quarternary (Pleistocene) Age Vandalia Member of the Glasford Formation, consisting of hard, compact sandy till with sand and gravel. Mapping indicates the total thickness of till above bedrock ranges from 50 to 200 feet at the Illinois River East Levee Site (Lineback, 1979).

Geologic mapping indicates that Mississippian Age (359 to 318 million years ago) Meppen Limestone, Fern Glen Formation, and Burlington-Keokuk Limestone, consisting of limestone, shale and siltstone, may also be encountered at depth (Kolata, 2005).

3.1.3 Mapped Surficial Soils

Mapping indicates that the soil types likely to be encountered at the Illinois River East Levee site are primarily silt loam and silty clay loam derived from alluvium. Surficial materials and bedrock as described above will likely to be encountered below these surficial soils (NRCS Soil Survey).

3.2 Surface Conditions

3.2.1 General

We evaluated the surface conditions in the vicinity of the proposed trenchless crossing during our geotechnical exploration program on November 13 through November 18, 2014, and April 15 through April 21, 2015.

3.2.2 Surface Description

The proposed HDD alignment trends northwest to southeast (proposed entry to proposed exit), crossing beneath a USACE regulated levee, and canals as shown in the Conceptual Site Plan and Profile, Figure 2A. The conceptual entry point is located approximately 1,100 feet from the west levee bank, in an open, relatively level, agricultural field at an approximate elevation of 445 feet (North American Vertical Datum [NAVD] 88). From the entry point, the ground surface descends gently toward the edge of the west levee bank and ascends to the top of the levee at an approximate elevation of 450 feet NAVD 88. From the east levee bank the ground surface remains relatively flat for approximately 1600 horizontal feet before gradually ascending a rolling hillside near the proposed exit point. The proposed exit point is in an open, nearly level, agricultural field at an approximate elevation of 443 feet NAVD 88. Photographs of the site surface conditions at the time of our geotechnical exploration are attached as Figures 3 and 4.

3.3 Subsurface Conditions

3.3.1 General

Subsurface conditions were explored at the site on November 13 through November 18, 2014, and April 15 through April 21, 2015 by drilling six geotechnical borings (EL-B-1 through EL-B-6). The borings were drilled to depths of up to 95 feet bgs using ATV-mounted drilling equipment. In order to characterize the subsurface conditions for HDD crossing design, the borings were drilled near the alignment of the proposed crossing.

Soil samples were generally obtained from the borings at 5-foot depth intervals using 1.5-inch inside-diameter (I.D.) split spoon samplers. Below the bedrock contact, rock core samples were obtained continuously using a 2-inch I.D. NQ core barrel. GeoEngineers staff managed the geotechnical explorations and logged the borings on a full-time basis. Soil and rock samples were visually classified and collected. Other pertinent drilling information was also documented. Laboratory tests, including moisture content determinations, sieve analyses, Atterberg limits, and unconfined compression testing were completed on selected samples from the borings. A description of the field exploration and laboratory testing procedures, logs of the borings, and graphs and tables of our laboratory testing results are presented in Appendix A.

3.3.2 Subsurface Description

Boring EL-B-1 was drilled on November 13 and 14, 2014, with ATV-mounted drilling equipment to a depth of approximately 95 feet bgs. From the ground surface, the boring encountered approximately 18 ½ feet of very loose to loose silty sand overlying roughly 15 feet of very loose to loose sand with varying amounts of gravel and silt, and roughly 61 ½ feet of medium dense to dense sand with varying amounts of silt and gravel.

Boring EL-B-2 was drilled on November 14 through November 18, 2014, with ATV-mounted drilling equipment to a depth of approximately 86 feet bgs. From the ground surface, the boring encountered approximately 8 ½ feet of very soft to medium stiff silt and low plasticity clay with varying amounts of sand and organics overlying roughly 5 feet of loose clayey sand, and approximately 64 feet of very loose to dense sand with varying amounts of silt and gravel. Bedrock was encountered at approximately 77 ½ feet bgs and continuous NQ-sized rock coring techniques were used to advance the boring to the termination depth at approximately 86 feet bgs. Rock encountered consisted primarily of very poor to excellent quality limestone to the termination depth at approximately 86 feet bgs. Rock unconfined compressive strength measured 4,700 pounds per square inch (psi) in this boring.

Boring EL-B-3 was drilled on April 15 and 16, 2015, with ATV-mounted drilling equipment to a depth of approximately 90 feet bgs. From the ground surface, the boring encountered approximately 3 ½ feet of very loose silty sand overlying roughly 10 feet of very soft to soft silt with varying amounts of sand, 5 feet of very soft low plasticity clay, 50 feet of very loose to medium dense sand with varying amounts of silt and gravel, and roughly 8 ½ feet of dense sand with gravel. Bedrock was encountered at approximately 77 feet bgs and continuous NQ-sized rock coring techniques were used to advance the boring to the termination depth at approximately 90 feet bgs. Rock encountered consisted primarily of very poor to good quality limestone to the termination depth at approximately 90 feet bgs. Rock unconfined compressive strength measured 12,700 pounds psi in this boring.

Boring EL-B-4 was drilled on April 16 and 17, 2015, with ATV-mounted drilling equipment to a depth of approximately 90 feet bgs. From the ground surface, the boring encountered approximately 18 ½ feet of very soft to medium stiff silt with varying amounts of sand overlying roughly 53 ½ feet of loose to dense sand with varying amounts of silt and gravel. Bedrock was encountered at approximately 72 feet bgs and continuous NQ-sized rock coring techniques were used to advance the boring to the termination depth at approximately 90 feet bgs. Rock encountered consisted primarily of good quality limestone to the termination depth at approximately 90 feet bgs. Rock unconfined compressive strength results ranged from 2,400 to 5,300 psi in this boring.

Boring EL-B-5 was drilled on April 17 and 18, 2015, with ATV-mounted drilling equipment to a depth of approximately 90 ½ feet bgs. From the ground surface, the boring encountered approximately 18 ½ feet of very loose sand with silt overlying roughly 49 feet of loose to very dense sand with varying amounts of silt and gravel. Bedrock was encountered at approximately 67 ½ feet bgs and continuous NQ-sized rock coring techniques were used to advance the boring to the termination depth at approximately 90 ½ feet bgs. Rock encountered consisted primarily of fair to excellent quality limestone to the termination depth at approximately 90 ½ feet bgs. Rock unconfined compressive strength results ranged from 12,100 to 14,700 psi in this boring.

Boring EL-B-6 was drilled on April 20 and 21, 2015, with ATV-mounted drilling equipment to a depth of approximately 95 feet bgs. From the ground surface, the boring encountered approximately 18 ½ feet of very loose to loose silty sand overlying roughly 54 ½ feet of loose to dense sand with silt and varying amounts gravel. Bedrock was encountered at approximately 73 feet bgs and continuous NQ-sized rock coring techniques were used to advance the boring to the termination depth at approximately 95 feet bgs. Rock encountered consisted primarily of fair to excellent quality limestone to the termination depth at approximately 95 feet bgs. Rock unconfined compressive strength measured 7,300 pounds psi in this boring.

3.3.3 Groundwater Conditions

At the time of drilling, groundwater was observed at approximately 12 feet bgs in boring EL-B-1, approximately 5 ½ feet bgs in boring EL-B-4, and roughly 2-½ feet bgs in boring EL-B-5. Due to the drilling techniques used, the groundwater level can be difficult to measure. The groundwater level will likely fluctuate over time due to seasonal variations in precipitation and the water level of the nearby canals.

4.0 LIMITATIONS

We have prepared this data report for use by Dakota Access, their authorized agents and other approved members of the design team involved with this project. The data report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. A trenchless feasibility assessment for this location will be delivered separately with our conclusions and recommendations based on our subsurface exploration program, design recommendations are not covered in this data report.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to evaluate that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, express, written or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, and will serve as the official document of record.

Please refer to Appendix B, titled "Report Limitations and Guidelines for Use," for additional information pertaining to use of this report.

5.0 REFERENCES

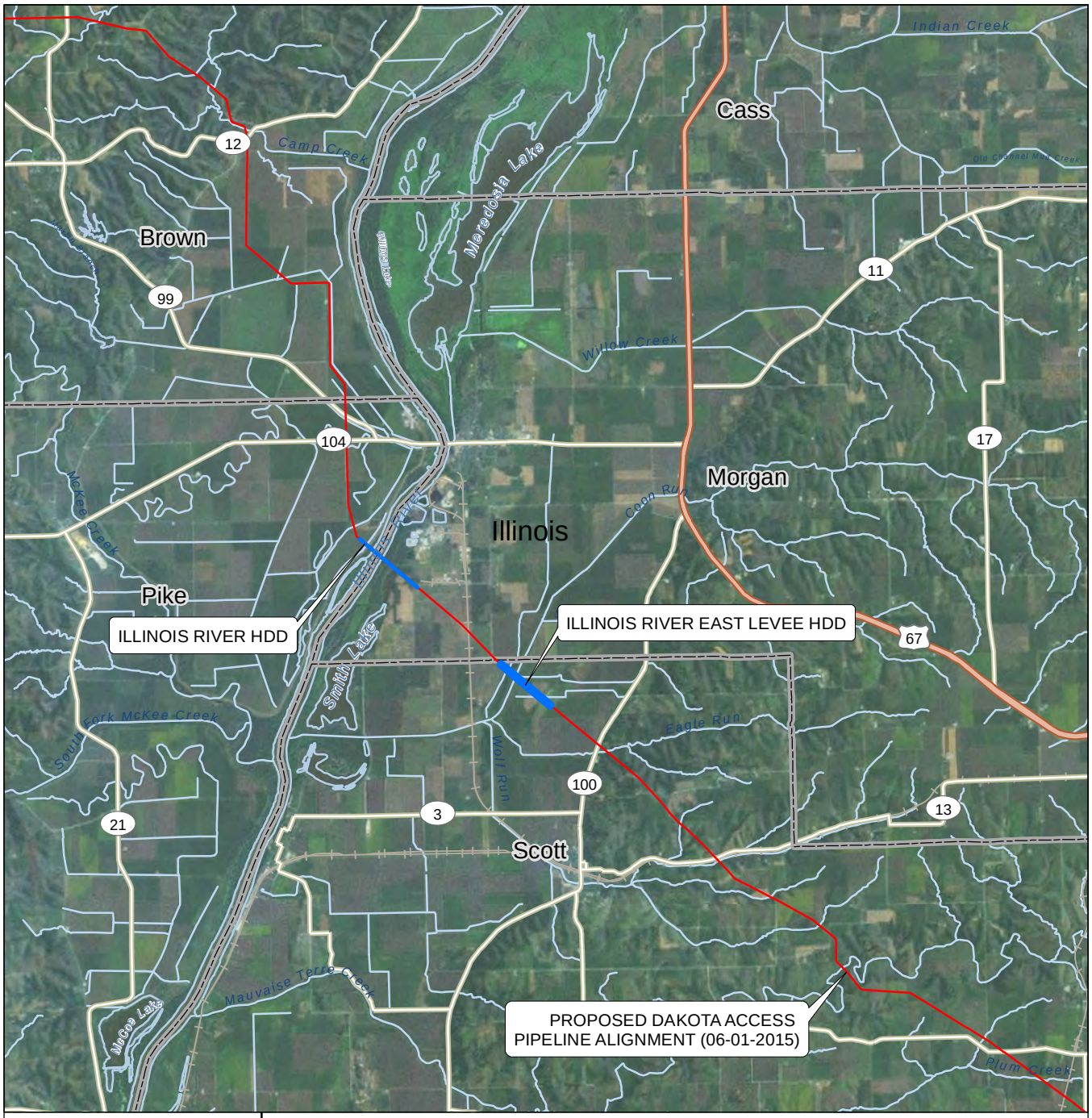
ASTM International. 2010. Annual Book of ASTM Standards, Volume 04.08, "Soil and Rock,"

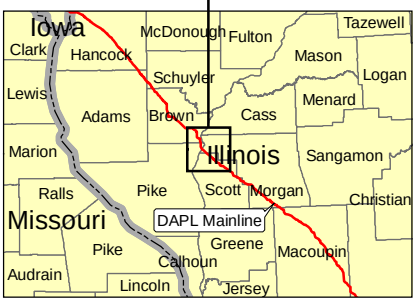
Kolata, D.R., 2005, Bedrock Geology of Illinois, Illinois State Geological Survey, Scale 1:500,000

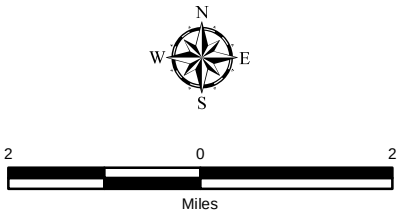
Leighton, M.M., Ekblaw, G.E. and Horberg, L., 1948, Physiographic Divisions of Illinois, Illinois State Geological Survey, Publication RI 129.

Lineback, J.A., 1979, Quaternary Deposits of Illinois, Illinois State Geological Survey, Scale 1:500,000.

NRCS Soil Survey, National Cooperative Soil Survey, Natural Resources Conservation Service, USDA, (http://websoilsurvey.nrcs.usda.gov).







Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Imagery from ESRI Data Online.
Projection: NAD 1983, UTM Zone 15 North.

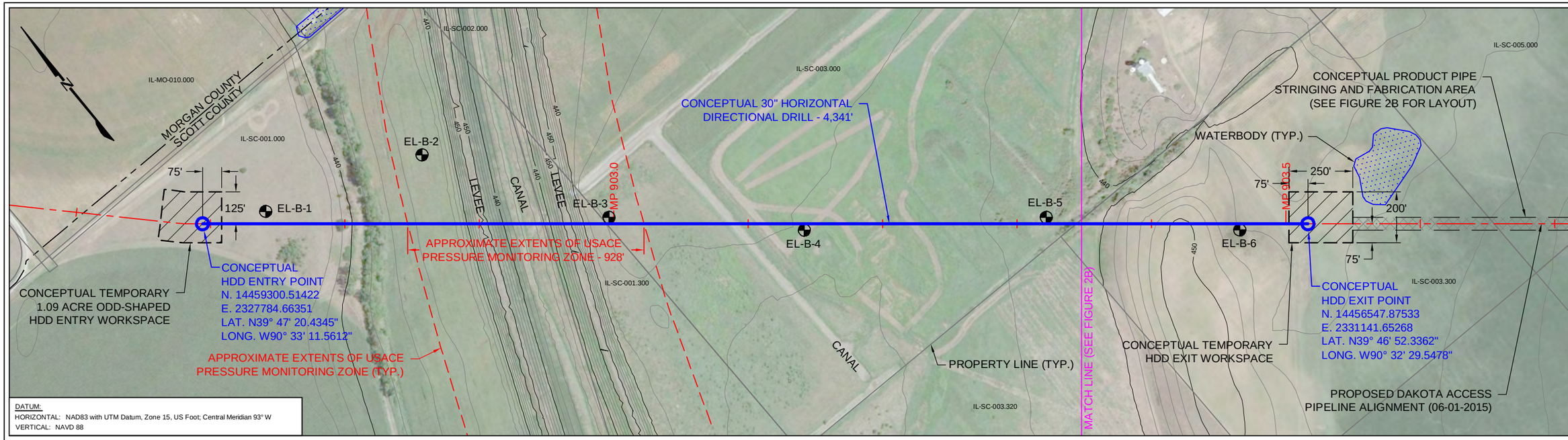
DAKOTA ACCESS PIPELINE PROJECT
VICINITY MAP

PROPOSED 30" PIPELINE
ILLINOIS RIVER EAST LEVEE HDD
SCOTT COUNTY, ILLINOIS

GEOENGINEERS

Figure 1

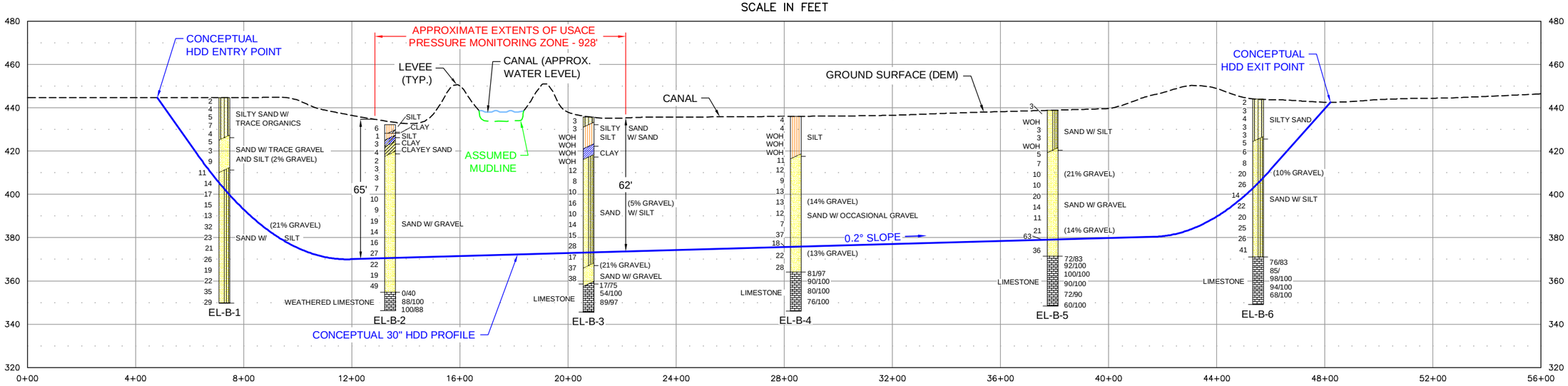
Office: SPR Path: P:\18\1878201101\GIS\Vicinity Maps\Illinois\Illinois River East Levee HDD.mxd Map Revised: 04 June 2015 mclevenger



PLAN

400' 0 400'

SCALE IN FEET



PROFILE

400' 0 400'

HORIZONTAL SCALE IN FEET

50' 0 50'

VERTICAL SCALE IN FEET

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Refer to the boring logs in the accompanying report for more detailed soil descriptions.
4. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Ground surface DEM (1/3 Arc Second) downloaded from http://NationalMap.Gov.
Aerial image taken from Google Earth Pro © 2015, licensed to GeoEngineers, Inc., image dated 07/31/12.
Shape files provided by Contract Land Staff, LLC.

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

LEGEND:

SPT (N) | TYPE OF SOIL (% GRAVEL)
TYPE OF ROCK | RQD/%REC

Boring Location
Major Contour - 10' Interval
Minor Contour - 2' Interval

DAKOTA ACCESS PIPELINE PROJECT
CONCEPTUAL SITE PLAN AND PROFILE

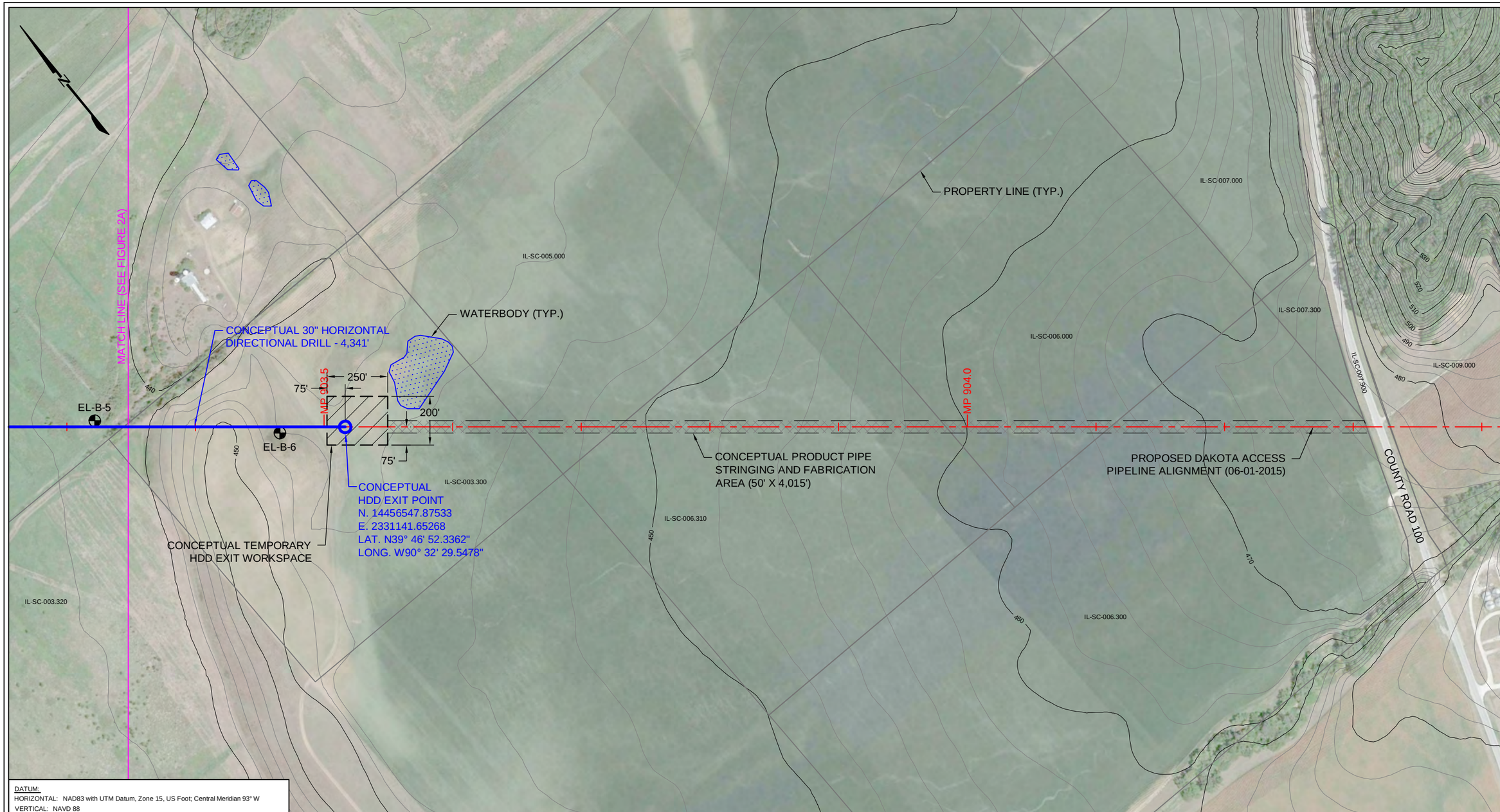
PROPOSED 30" PIPELINE
ILLINOIS RIVER EAST LEVEE HDD
SCOTT COUNTY, ILLINOIS

GEOENGINEERS

FIGURE 2A

ISSUED DATE: JUNE XX, 2015

P:\18\1878201\01\CAD\Crossings\Illinois\Illinois River East Levee\Drawings\Illinois River East Levee HDD Figure 2.dwg\TAB-Figure 2A modified on Jun 08, 2015 - 4:29pm MAM : MWC



Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Ground surface DEM (1/3 Arc Second) downloaded from http://NationalMap.Gov.
Aerial image taken from Google Earth Pro © 2015, licensed to GeoEngineers, Inc., image dated 07/31/12.
Shape files provided by Contract Land Staff, LLC.

PLAN
400' 0 400'
SCALE IN FEET

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

LEGEND:
- Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

DAKOTA ACCESS PIPELINE PROJECT
CONCEPTUAL STRINGING WORKSPACE

PROPOSED 30" PIPELINE
ILLINOIS RIVER EAST LEVEE HDD
SCOTT COUNTY, ILLINOIS

GEOENGINEERS

FIGURE 2B

ISSUED DATE: JUNE XX, 2015

P:\18\1878201\101\CAD\Crossings\Illinois\Illinois River East Levee\Drawings\Illinois River East Levee HDD Figure 2.dwg\TAB:Figure 2B modified on Jun 08, 2015 - 4:30pm MAM : MWC

Looking Southeast Along The Proposed HDD Alignment Near Boring EL-B-1

Looking Northwest Along The Proposed HDD Alignment Near Boring EL-B-3

GEOENGINEERS

Dakota Access Pipeline Project – Illinois River East Levee HDD Site Photographs

FIGURE 3

Looking Northwest Along The Proposed HDD Alignment Near Boring EL-B-4

Looking Southeast Toward The Proposed HDD Exit Point Near Boring EL-B-6

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Dakota Access Pipeline Project – Illinois River East Levee HDD Site Photographs

FIGURE 4

APPENDIX A
Field Explorations and Laboratory Testing

APPENDIX A
FIELD EXPLORATIONS AND LABORATORY TESTING

Field Explorations

Subsurface conditions were explored at the site on November 13 through November 18, 2014, and April 15 through April 21, 2015 by drilling six geotechnical borings using an All-Terrain-Vehicle (ATV) mounted drill rig. The Illinois State "One-Call" utility locating agency was contacted to locate utilities in the project area prior to the start of the exploratory borings. The borings were drilled near the alignment of the proposed trenchless crossing in order to characterize the subsurface conditions.

The drilling operations were monitored by GeoEngineers staff who examined and classified the soils encountered, obtained representative samples, observed groundwater conditions where possible and prepared a detailed log of each exploration. The soils encountered were classified visually in general accordance with ASTM International (ASTM) D2488, which is described in Figure A-1. The rock encountered was classified in accordance with the rock classification system described on Figure A-2. The approximate locations of the explorations are shown in the Conceptual Site Plan and Profile, Figure 2A.

In general, soil samples were obtained from the borings at 5-foot-depth intervals using a 1.5-inch inside-diameter (I.D.) split spoon standard penetration test (SPT) sampler. The SPT sampler was driven 18 inches, using a 140-pound hammer with a 30-inch drop. The number of hammer blows required to drive the sampler the final 12-inches was recorded on field logs. Rock core samples were obtained using a 2-inch I.D. NQ core barrel. Each boring was backfilled upon completion with cement-bentonite grout.

The relative density of the SPT samples recovered at each interval was evaluated based on correlations with lab and field observations in general accordance with the values outlined in Table A-1 below.

TABLE A-1 CORRELATION BETWEEN BLOW COUNTS AND RELATIVE DENSITY [1]

Cohesive Soils (Clay/Silt)						
Parameter	Very Soft	Soft	Medium Stiff	Stiff	Very Stiff	Hard
Blows, N	< 2	2 – 4	4 – 8	8 – 16	16 – 32	> 32
Cohesionless Soils (Gravel/Sand/Silty Sand) [2]						
	Very Loose	Loose	Medium Dense	Dense	Very Dense	
Blows, N	0 – 4	4 – 10	10 – 30	30 – 50	> 50	

Notes:

[1] After Terzaghi, K and Peck, R.B., "Soil Mechanics in Engineering Practice," John Wiley & Sons, Inc., 1962.

[2] Classification applies to soils containing additional constituents; that is, organic clay, silty or clayey sand, etc.

The RQD of the rock core samples recovered from each core run was evaluated and are presented on the exploration logs in Figures A-3 through A-8. The rock quality descriptions are correlated to RQD (%) as outlined in Table A-2, below.

TABLE A-2 ROCK QUALITY DESIGNATION

RQD (%)	Rock Quality Description
0-25	Very Poor
26-50	Poor
51-75	Fair
76-90	Good
91-100	Excellent

The exploration logs are presented in Figures A-3 through A-8. The logs are based on our interpretation of the field data and indicate the various types of soils encountered. They also indicate the approximate depths at which the subsurface conditions change.

Laboratory Testing

General

Soil samples obtained from the explorations were transported to our Springfield, Missouri, office and examined to confirm or modify field classifications. Representative samples were selected for laboratory testing consisting of moisture content determinations, sieve analysis, Atterberg limits, and unconfined compression testing. The laboratory testing procedures are discussed in more detail below.

Moisture Content Testing

Moisture content tests were completed for representative soil samples obtained from the explorations in general accordance with ASTM D2216. The results of these tests are presented on the exploration logs in Figures A-3 through A-8 at the depths at which the samples were obtained.

Sieve Analyses

Sieve analyses were requested on selected coarse grained samples in general accordance with ASTM D422. The results of the sieve analyses were plotted and classified in general accordance with the Unified Soil Classification System (USCS) and are presented in Figures A-9 through A-13. The sample gravel content (% Gravel) and percentage passing the U.S. No. 200 sieve (% Fine) is shown on the boring logs at the respective sample depths.

Atterberg Limits Testing

Atterberg Limits tests were performed on a selected fine grained soil sample in general accordance with ASTM D4318. The test was used to classify the soil as well as to evaluate its index properties. The results of the Atterberg Limits testing are shown in Figure A-14.

Unconfined Compression Testing

Unconfined compression (UC) tests were performed on selected rock samples obtained from the borings. The tests were used to evaluate shear strength characteristics and were completed in general accordance with ASTM D7012. The results of testing are presented on the boring logs at their respective sample depths and are summarized in table form in Figure A-15. Rock core photographs are presented in Figures A-16 through A-21.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% RETAINED ON NO. 200 SIEVE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Continuous Coring

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

"WOH" indicates sampler pushed using the weight of the 140-pound SPT hammer.

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PI	Plasticity index
PP	Pocket penetrometer
PPM	Parts per million
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

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FIGURE A-1

UNIFIED ROCK CLASSIFICATION SYSTEM (URCS)*

BASIC ELEMENTS

DEGREE OF WEATHERING				
WEATHERED		ALTERED	REPRESENTATIVE	
SAND SIZE COMPLETELY DECOMPOSED STATE (CDS) E	GRAVEL SIZE PARTLY DECOMPOSED STATE (PDS) D	STAINED STATE (STS) C	VISUALLY FRESH STATE (VFS) B	MICRO FRESH STATE (HAND LENSE) (MFS) A
PLASTIC NON-PLASTIC	PLASTIC NON-PLASTIC	COMPARE TO FRESH STATE	UNIT WEIGHT, RELATIVE ABSORPTION	

ESTIMATED STRENGTH				
REMOLDING		REACTION TO IMPACT OF 1 LB. BALLPEEN HAMMER		
"MOLDABLE" (FRIABLE) (MBL) E	"CRATERS" (SHEARS) (CQ) D	"DENTS" (COMPRESSIVE) (DQ) C	"PITS" (TENSIONAL) (PQ) B	"REBOUNDS" (ELASTIC) (RQ) A
<1,000 PSI (<7 MPa)	1,000 to 3,000 PSI (7 to 21 Ma)	3,000 to 8,000 PSI (21 to 55 MPa)	3,000 to 15,000 PSI (55 to 103 MPA)	>15,000 PSI (>103 MPa)

DISCONTINUITIES						
TRANSMITS WATER						
YES	NO	YES	NO			
3-DIMENSIONAL PLANES OF SEPARATION (3D) E		2-DIMENSIONAL PLANES OF SEPARATION (2D) D		LATENT PLANES OF SEPARATION (LPS) C	SOLID-PREFERRED BREAKAGE (SPB) B	SOLID-RANDOM BREAKAGE (SRB) A
INTERLOCK		ATTITUDE				

UNIT WEIGHT				
LESS THAN 130 LBS/CU FT (2.10 Mg/CU M) (<130) E	130 TO 140 LBS/CU FT (2.10 TO 2.25 Mg/CU M) (130) D	140 TO 150 LBS/CU FT (2.25 TO 2.40 Mg/CU M) (140) C	150 TO 160 LBS/CU FT (2.40 TO 2.55 Mg/CU M) (150) B	GREATER THAN 160 LBS/CU FT (2.55 Mg/CU M) (>160) A

DESIGN NOTATION			
WEATHERING	STRENGTH	DISCONTINUITY	WEIGHT
A-E	A-E	A-E	A-E

* Williamson, Douglas A., 1984, Unified Rock Classification System: Association of Engineering Geologists Bulletin, Vol. XXI, No. 3, pp. 345-354

ROCK CLASSIFICATION SYSTEM

GEOENGINEERS

FIGURE A-2

Drilled Start 11/13/2014 End 11/14/2014	Total Depth (ft) 95	Logged By MJP Checked By JLR	Driller Geotechnology, Inc.	Drilling Method HSA/Mud Rotary	
Surface Elevation (ft) Vertical Datum 445	Hammer Data Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment CME-750 ATV Mounted			
Latitude 39° 47' 19.193" N Longitude 90° 33' 08.752" W	System Datum Geographic	Groundwater Date Measured	Depth to Water (ft) N/A	Elevation (ft)	
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		12	2		S1			SM	Brown silty fine sand with trace organics (very loose, moist)			
			16	4		S2				Without organics, becomes loose			
440	5		12	5		S3				Becomes light brown and with silt			
			17	7		S4							
435	10												Water observed at 12 feet bgs
			14	4		S5				With fine to medium sand and becomes wet			
430	15												
			11	5		S6			SP	Brown fine to medium sand with trace gravel and silt (loose, moist)			
425	20												
			12	3		S7				Becomes very loose			% Fine = 3 % Gravel = 2
420	25												
			12	9		S8				Becomes loose			
415	30												
			11	11		S9			SP-SM	Gray fine to medium sand with silt (medium dense, moist)			
410	35												

Springfield: Date:6/9/15 Path:P:\18\1878201\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring EL-B-1

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-3
Sheet 1 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
405	40		11	14		S10							
400	45		10	17		S11							
395	50		9	15		S12				With coarse sand			
390	55		6	13		S13							
385	60		13	32		S14				With fine to coarse gravel and becomes dense			% Fine = 8 % Gravel = 21
380	65		12	23		S15				Becomes medium dense			
375	70		13	21		S16				With occasional gravel and trace silt			
370	75		15	26		S17				Becomes brown fine to medium sand with trace silt			

Springfield: Date:6/9/15 Path:P:\18\18782011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring EL-B-1 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-3
Sheet 2 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
			12	19		S18							
365	80												
			13	22		S19				Becomes gray fine to coarse sand with gravel and trace silt			
360	85												
			16	35		S20				Becomes dense			
355	90												
			15	29		S21				Becomes brown fine to medium sand with gravel and silt			
350	95												

Log of Boring EL-B-1 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-3

Sheet 3 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 11/14/2014 End 11/18/2014	Total Depth (ft) 86	Logged By MJP Checked By JLR	Driller Geotechnology, Inc.	Drilling Method HSA/Mud Rotary	
Surface Elevation (ft) Vertical Datum 432	Hammer Data Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment CME-750 ATV Mounted			
Latitude 39° 47' 16.875" N Longitude 90° 33' 00.946" W	System Datum Geographic	Groundwater Date Measured / Depth to Water (ft) / Elevation (ft) N/A			

Notes: Upon completion, borehole backfilled with cement-bentonite grout.

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		12	6		S1			ML	Brown silt with trace organics (medium stiff, moist)			
430													
			18	1		S2			CH	Brown clay (very soft, moist)			
	5								ML	Dark brown and black silt with organics (very soft, moist)			
425			18	3		S3			CH	Dark gray and black clay with organics (soft, moist)			
			14	4		S4				Gray sandy clay (medium stiff, moist)	20		
	10								SC	Gray clayey fine to medium sand (loose, moist)			
420													
			14	2		S5			SP	Gray fine to medium sand with gravel (very loose, moist)			
	15												
415													
			12	3		S6				With trace silt			
	20												
410													
			14	3		S7							
	25												
405													
			13	7		S8				Becomes loose			
	30												
400													
			12	10		S9				Becomes medium dense	21		% Fine = 3
	35												

Log of Boring EL-B-2

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-4
Sheet 1 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
395	35											
		14	9		S10				With occasional gravel and becomes loose			
390	40											
		2	19		S11				With gravel and becomes medium dense			
385	45											
		13	14		S12				With fine to coarse sand and trace silt			
380	50											
		15	16		S13				Becomes fine to medium sand			
375	55											
		13	27		S14				Becomes fine to coarse sand with gravel and trace silt			
370	60											
		15	22		S15				Becomes brown			
365	65											
		14	19		S16							
360	70											
		12	49		S17				Becomes dense			
	75											

Springfield: Date:6/9/15 Path:P:\18\18782011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring EL-B-2 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-4

Sheet 2 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
355													
			17	0		R1			Limestone	Gray highly weathered limestone, partially decomposed state, rebound quality to pit quality, 3D discontinuities			Very poor quality
	80												
350			36	88		R2				Becomes gray and brown weathered limestone with shale lenses, stained state, latent planes of separation			Good quality UC = 4,700 psi Mohs = 4
			21	100		R3				Becomes gray limestone with chert, stained state, rebound quality, solid random breakage			Excellent quality
	85												

Log of Boring EL-B-2 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-4

Sheet 3 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 4/15/2015 End 4/16/2015	Total Depth (ft) 90	Logged By RMB Checked By NAA	Driller Geotechnology, Inc.	Drilling Method HSA/Mud Rotary	
Surface Elevation (ft) Vertical Datum 436		Hammer Data Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment CME-750 ATV Mounted	
Latitude 39° 47' 12" N Longitude 90° 32' 55" W		System Datum Geographic		Groundwater Date Measured	Depth to Water (ft) N/A / Elevation (ft)
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
435	0		4	3		S1			SM	Brown fine silty sand (very loose, moist)			
			7	3		S2			ML	Brown silt with sand (soft, moist)			
430	5		0	WOH		S3				Becomes very soft			
			14	WOH		S4				Becomes gray silt	45		LL = 43 PI = 10
425	10		18	WOH		S5			CL	Gray clay (very soft, moist)	45		
420	15		6	WOH		S6			SP-SM	Gray fine to medium sand with silt (very loose, wet)			
415	20		14	12		S7				Becomes medium dense			
410	25		12	8		S8				Becomes loose			
405	30		13	10		S9				Becomes medium dense			
	35												

Springfield: Date:6/9/15 Path:P:\18\18782011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring EL-B-3

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-5

Sheet 1 of 3

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
400	35												
			12	16		S10				With trace gravel			% Fine = 12 % Gravel = 5
395	40												
			10	10		S11							
390	45												
			9	14		S12							
385	50												
			9	15		S13							
380	55												
			11	28		S14							
375	60												
			10	17		S15							
370	65												
			10	37		S16			SP	Gray fine to medium sand with gravel (dense, moist)			% Fine = 4 % Gravel = 21
365	70												
			12	38		S17							
360	75												

Log of Boring EL-B-3 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-5
Sheet 2 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
			27	17		R1			Limestone	Gray limestone, fine grained, horizontal bedding, open and closed 0º fractures, visually fresh state to stained state			Very poor quality
355	80		60	54		R2				Becomes gray and tan limestone, horizontal and subhorizontal bedding, open and closed 0º and 40º fractures, visually fresh state			UC = 12,700 psi Fair quality
350	85		58	89		R3				Becomes gray and brown limestone, fine and coarse grained, horizontal bedding, open 0º fractures, visually fresh state, vuggy			Good quality
	90												

Log of Boring EL-B-3 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-5

Sheet 3 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 4/16/2015 End 4/17/2015	Total Depth (ft) 90	Logged By RMB Checked By NAA	Driller Geotechnology, Inc.	Drilling Method Hollow Stem Auger	
Surface Elevation (ft) Vertical Datum 436	Hammer Data Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment CME-750 ATV Mounted			
Latitude 39° 47' 5" N Longitude 90° 32' 51" W	System Datum Geographic	Groundwater Date Measured / Depth to Water (ft) / Elevation (ft): N/A			
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
435	0		2	4		S1			MH	Dark brown silt (medium stiff, moist)			
	5		2	4		S2							
430			1	WOH		S3				Becomes gray silt with sand and very soft			Water observed at 5.5 feet bgs
	10		8	WOH		S4					61		
425			18	WOH		S5				Without sand	62		LL = 51 PI = 19
420	15												
	20		13	11		S6			SP	Gray fine to medium sand with occasional gravel (medium dense, wet)			
415													
	25		12	12		S7							
410													
	30		12	9		S8				Becomes loose			
405													
	35		12	13		S9				Becomes medium to coarse sand with gravel and medium dense			Lost drilling fluid returns

Log of Boring EL-B-4

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-6

Sheet 1 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
400	35												
			17	13		S10							% Fine = 2 % Gravel = 14
395	40												
			12	12		S11							
390	45												
			10	7		S12				Becomes loose			
385	50												
			17	37		S13				Becomes dense			
380	55												
			11	18		S14				Becomes brown and medium dense			
375	60												
			11	22		S15				Becomes medium to coarse sand with occasional gravel			Chatter drilling action % Fine = 3 % Gravel = 13
370	65												
			9	28		S16							
365	70												
			35	81		R1			Limestone	Gray fine grained limestone, horizontal bedding, open sediment filled 0° fractures, visually fresh state, 2D discontinuities			Good quality
360	75		60	90		R2							Excellent quality

Log of Boring EL-B-4 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-6

Sheet 2 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	80		60	80		R3							Good quality
355													
	85		60	76		R4				Becomes partially decomposed state Gray fine to coarse grained limestone, horizontal bedding, open and closed 0º fractures, visually fresh state			UC = 5,300 psi Good quality UC = 2,400 psi
350													
	90												

Log of Boring EL-B-4 (continued)

GeoEngineers

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County, Illinois

Project Number: 18782-011-01

Figure A-6

Sheet 3 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 4/17/2015 End 4/18/2015	Total Depth (ft) 90.5	Logged By RMB Checked By NAA	Driller Geotechnology, Inc.	Drilling Method Hollow Stem Auger	
Surface Elevation (ft) Vertical Datum 439	Hammer Data Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment CME-750 ATV Mounted			
Latitude 39º 46' 59" N Longitude 90º 32' 37" W	System Datum Geographic	Groundwater Date Measured / Depth to Water (ft) / Elevation (ft): N/A			

Notes: Upon completion, borehole backfilled with cement-bentonite grout.

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		8	3		S1			SP-SM	Brown fine sand with silt (very loose, moist)			
													Water observed at 2.5 feet bgs
435			18	WOH		S2				Grades to black			
	5												
			18	3		S3				Becomes brown fine sand with silt lenses			
430			6	3		S4				With fine to medium sand			% Fine = 9
	10												
425			13	WOH		S5							
	15												
420			7	5		S6			SP	Brown fine to coarse sand with gravel (loose, moist)			
	20												
415			11	7		S7				Becomes gray			
	25												
410			12	10		S8				With medium to coarse sand and becomes medium dense			% Fine = 2 % Gravel = 21
	30												
405			13	10		S9							
	35												

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring EL-B-5

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County,Illinois

Project Number: 18782-011-01

Figure A-7
Sheet 1 of 3

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
400	40		12	20		S10							
395	45		12	14		S11				With fine to medium sand and occasional gravel			
390	50		11	11		S12				Becomes medium to coarse sand			Lost drilling fluid returns
385	55		11	21		S13							% Fine = 2 % Gravel = 14
380	60		18	63		S14				Becomes very dense			Chatter drilling action
375	65		17	36		S15				Becomes dense			
370	70		20	72		R1			Limestone	Gray fine grained limestone, horizontal bedding, open fractures, visually fresh state			Fair quality
			60	92		R2							Excellent quality UC = 12,100 psi
365	75		60	100		R3				With sediment filled fractures			Excellent quality

Log of Boring EL-B-5 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County,Illinois

Project Number: 18782-011-01

Figure A-7
Sheet 2 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
360													
	80		60	90		R4				With horizontal and subhorizontal bedding, open 0° fractures			Excellent quality
355													
	85		54	72		R5							UC = 14,700 psi Fair quality
350													
	90		12	60		R6							Fair quality

Log of Boring EL-B-5 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County,Illinois

Project Number: 18782-011-01

Figure A-7

Sheet 3 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 4/20/2015 End 4/21/2015	Total Depth (ft) 95	Logged By RMB Checked By NAA	Driller Geotechnology, Inc.	Drilling Method Hollow Stem Auger	
Surface Elevation (ft) Vertical Datum 444	Hammer Data Automatic 140 (lbs) / 30 (in) Drop	Drilling Equipment CME-750 ATV Mounted			
Latitude 39° 46' 53.886" N Longitude 90° 32' 32.345" W	System Datum Geographic	Groundwater Date Measured	Depth to Water (ft) N/A	Elevation (ft)	
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		18	2		S1			SM	Brown silty fine to medium sand (very loose, moist)			
440	5		15	3		S2				Becomes wet			
			17	4		S3				Becomes loose			
435	10		18	3		S4				Becomes very loose			% Fine = 24
430	15		16	3		S5				Becomes gray silty fine sand with silt lenses			
425	20		13	5		S6			SP-SM	Gray fine to medium sand with silt (loose, wet)			
420	25		12	6		S7							
415	30		11	8		S8				Becomes brown			
410	35		14	20		S9				With occasional gravel and becomes medium dense			% Fine = 5 % Gravel = 10

Log of Boring EL-B-6

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County,Illinois

Project Number: 18782-011-01

Figure A-8

Sheet 1 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
405			15	26		S10				With fine to medium sand			
	40												
400			10	14		S11				Becomes gray medium to coarse sand with occasional gravel			
	45												
395			11	22		S12				Without gravel			% Fine = 3
	50												
390			9	20		S13							
	55												
385			15	25		S14							
	60												
380			11	26		S15							
	65												
375			10	41		S16				Becomes dense			
	70												
370			24	76		R1			Limestone	Gray fine grained limestone, horizontal bedding, open 0º fractures, visually fresh state			Good quality
	75		50	85		R2							Good quality

Log of Boring EL-B-6 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

Project Location: Scott County,Illinois

Project Number: 18782-011-01

Figure A-8

Sheet 2 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
365													
	80		60	98		R3							UC = 7,300 psi Mohs = 4 Excellent quality
360													
	85		60	94		R4							Excellent quality
355													
	90		60	68		R5							Fair quality
350													
	95												

Log of Boring EL-B-6 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Illinois River East Levee HDD

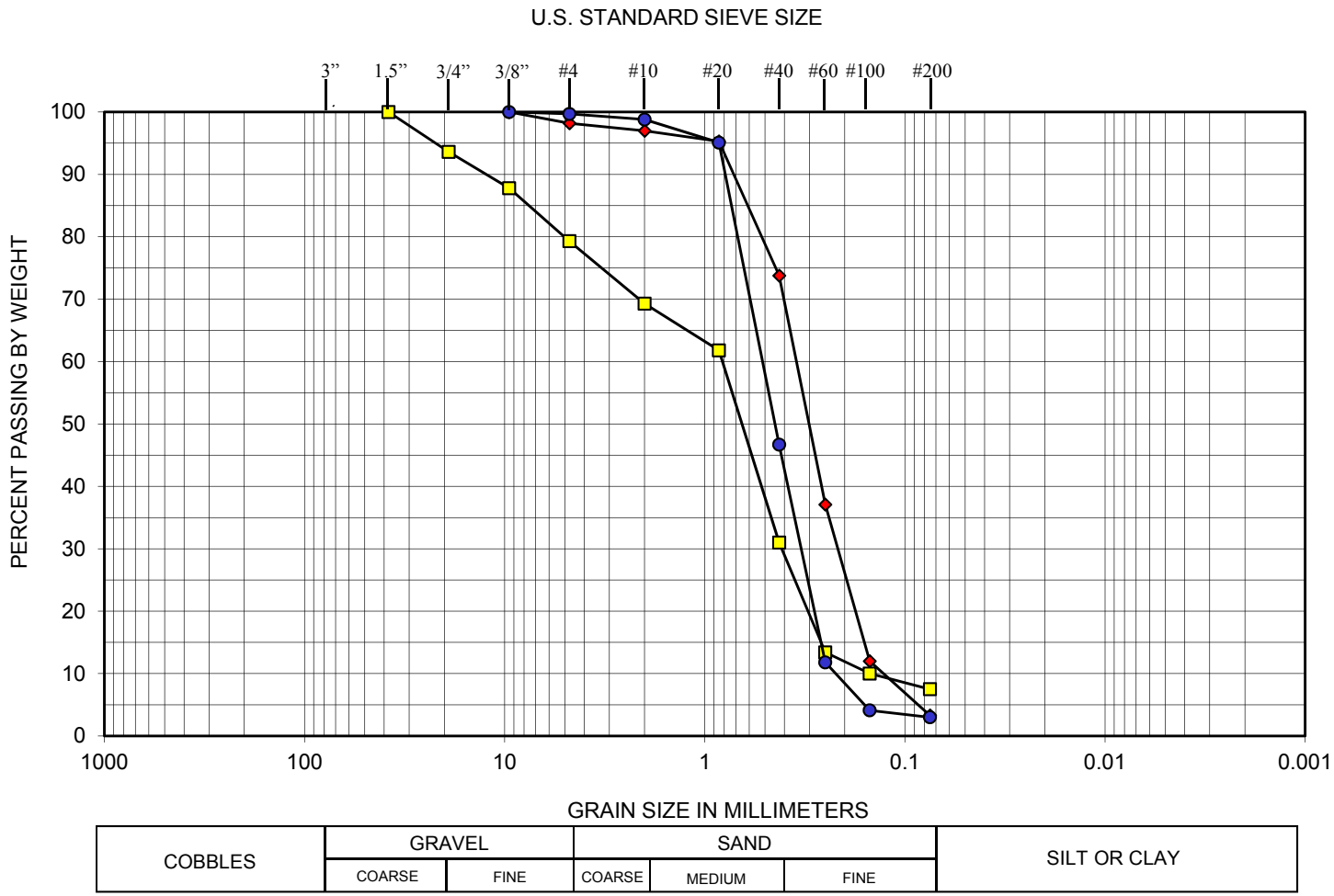
Project Location: Scott County,Illinois

Project Number: 18782-011-01

Figure A-8

Sheet 3 of 3

Springfield: Date:6/9/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate:LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	EL-B-1	23.5 – 25.0	Brown poorly graded SAND (SP)
■	EL-B-1	58.5 – 60.0	Gray poorly graded SAND with gravel (SP)
●	EL-B-2	33.5 – 35.0	Gray poorly graded SAND (SP)

Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River East Levee HDD
Scott County, Illinois

GEOENGINEERS

Figure A-9

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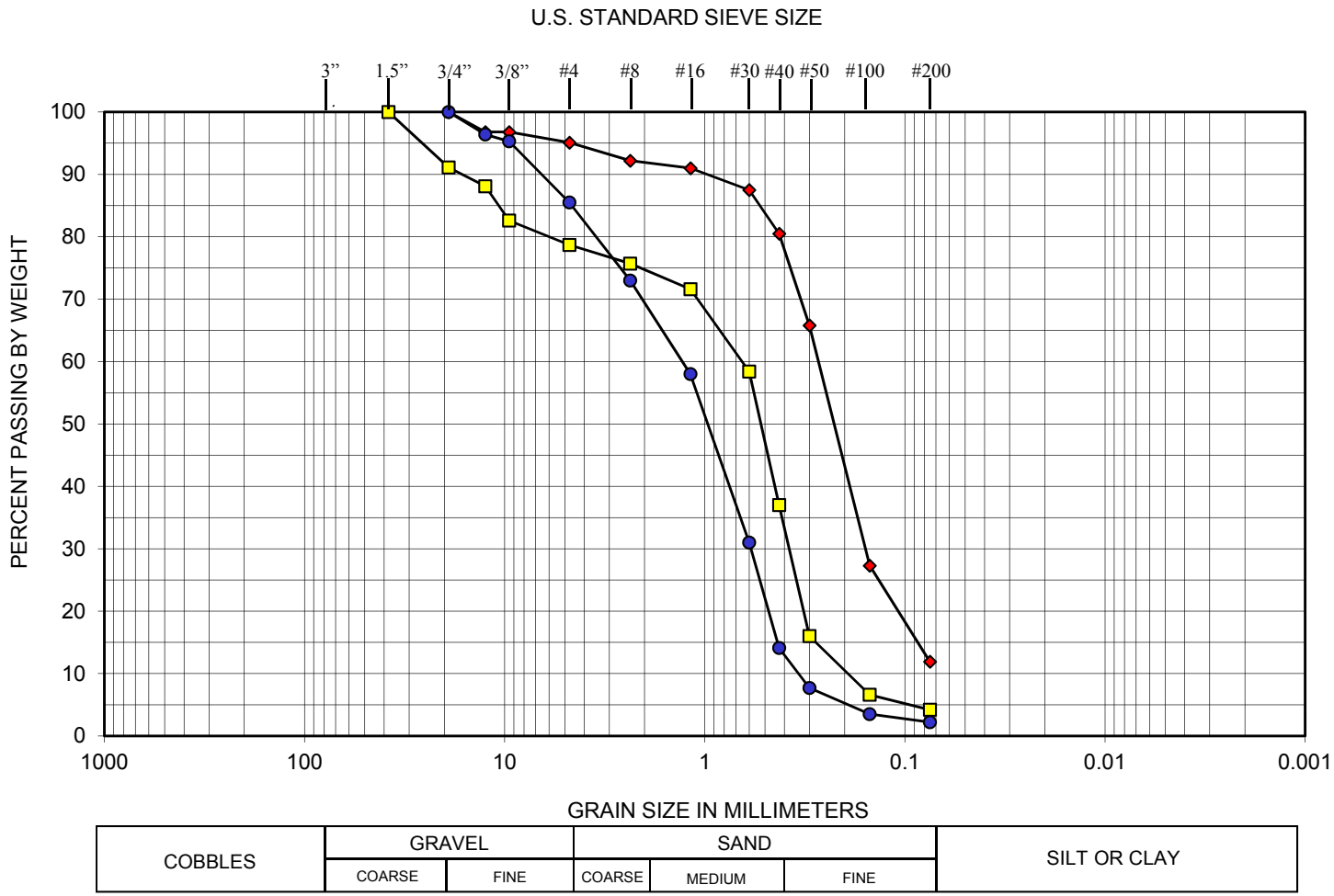

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	EL-B-3	38.5 – 40.0	Gray fine to medium SAND with silt and trace gravel (SP-SM)
□	EL-B-3	68.5 – 70.0	Gray poorly graded SAND with gravel (SP)
●	EL-B-4	38.5 – 40.0	Gray poorly graded SAND with gravel (SP)

Notes: The geotechnical laboratory testing results were provided by SCI Engineering, Inc.
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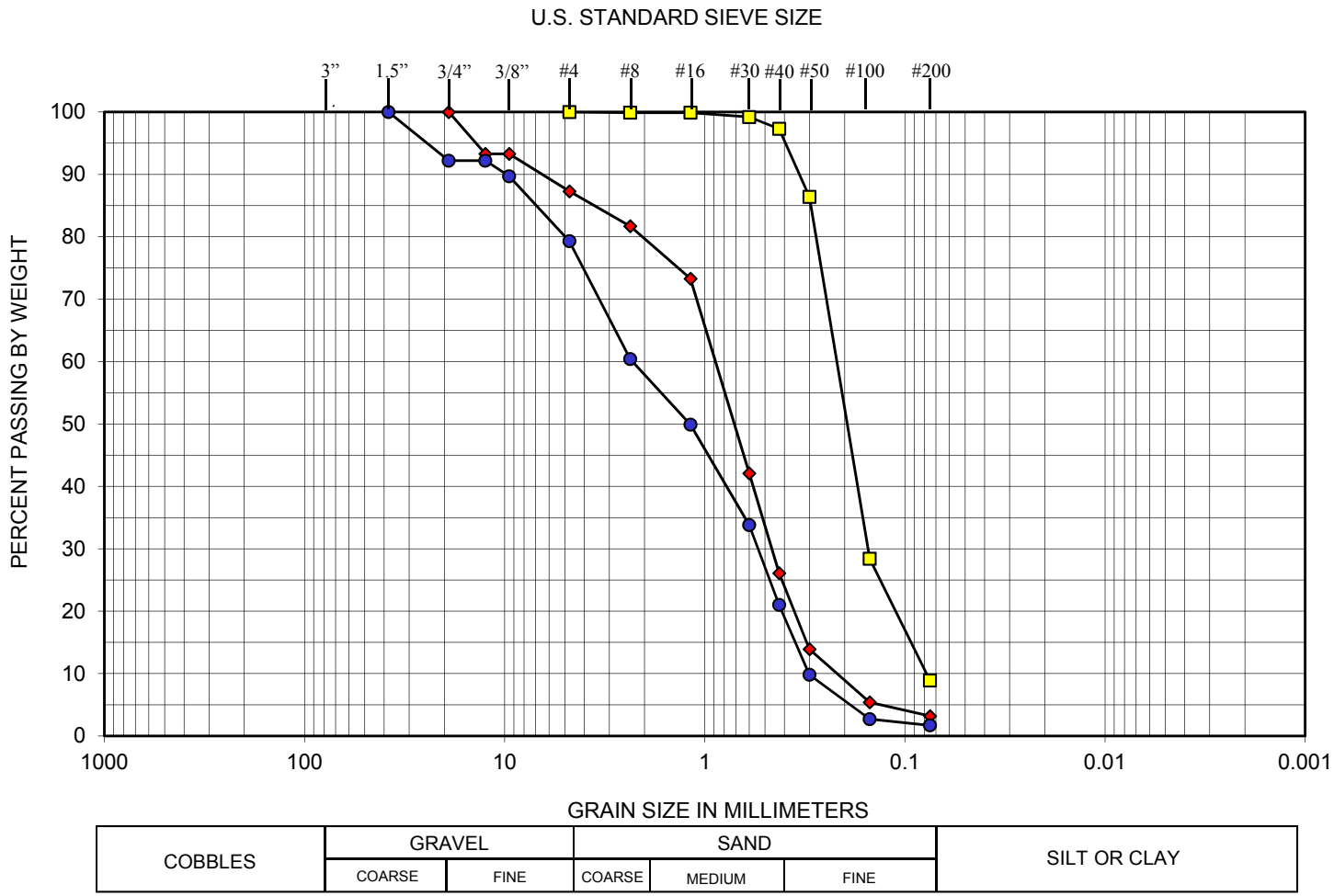
Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River East Levee HDD
Scott County, Illinois

GEOENGINEERS

Figure A-10



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	EL-B-4	63.5 – 65.0	Gray poorly graded SAND with occasional gravel (SP)
□	EL-B-5	8.5 – 10.0	Brown fine SAND with silt (SP-SM)
●	EL-B-5	28.5 – 30.0	Gray poorly graded SAND with gravel (SP)

Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River East Levee HDD
Scott County, Illinois

GEOENGINEERS

Figure A-11

Notes: The geotechnical laboratory testing results were provided by SCI Engineering, Inc.
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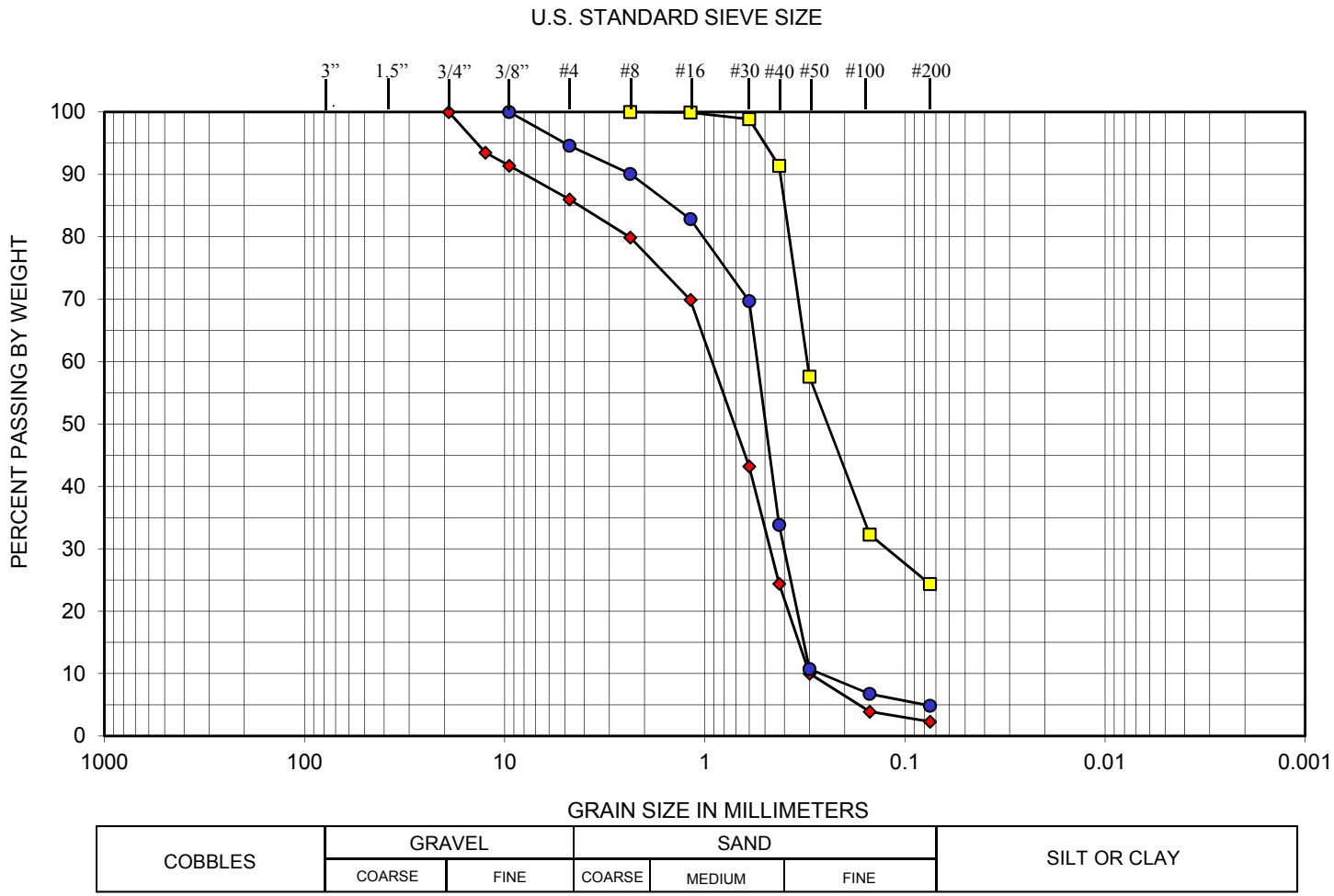

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	EL-B-5	53.5 – 55.0	Gray poorly graded SAND with occasional gravel (SP)
□	EL-B-6	8.5 – 10.0	Brown silty fine to medium SAND (SM)
●	EL-B-6	33.5 – 35.0	Gray fine to coarse SAND with occasional gravel (SP-SM)

Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River East Levee HDD
Scott County, Illinois

GEOENGINEERS

Figure A-12

Notes: The geotechnical laboratory testing results were provided by SCI Engineering, Inc.
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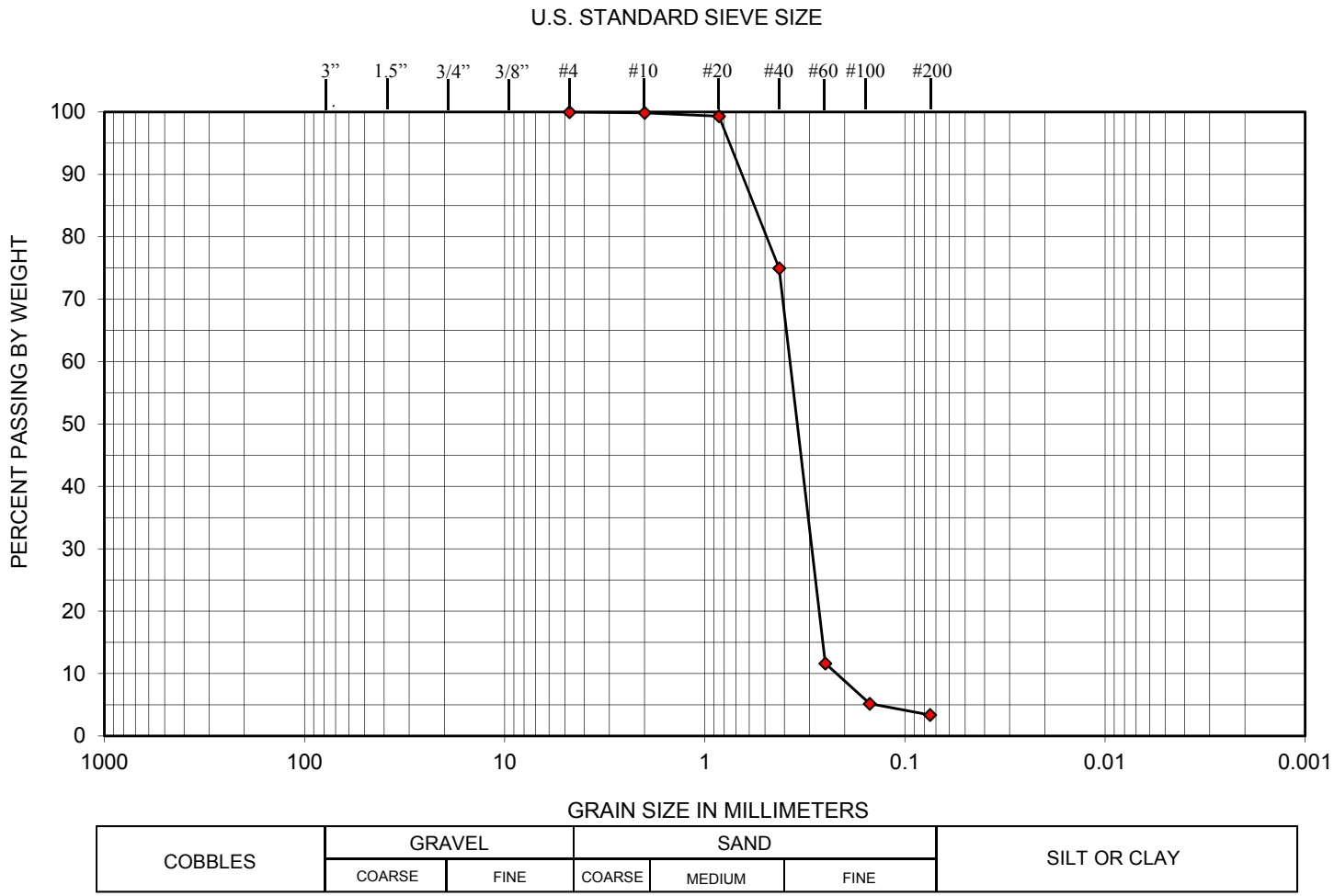

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	EL-B-6	48.5 – 50.0	Gray fine to medium SAND (SP)

Sieve Analysis Results

Dakota Access Pipeline Project – Illinois River East Levee HDD
Scott County, Illinois

GEOENGINEERS

Figure A-13

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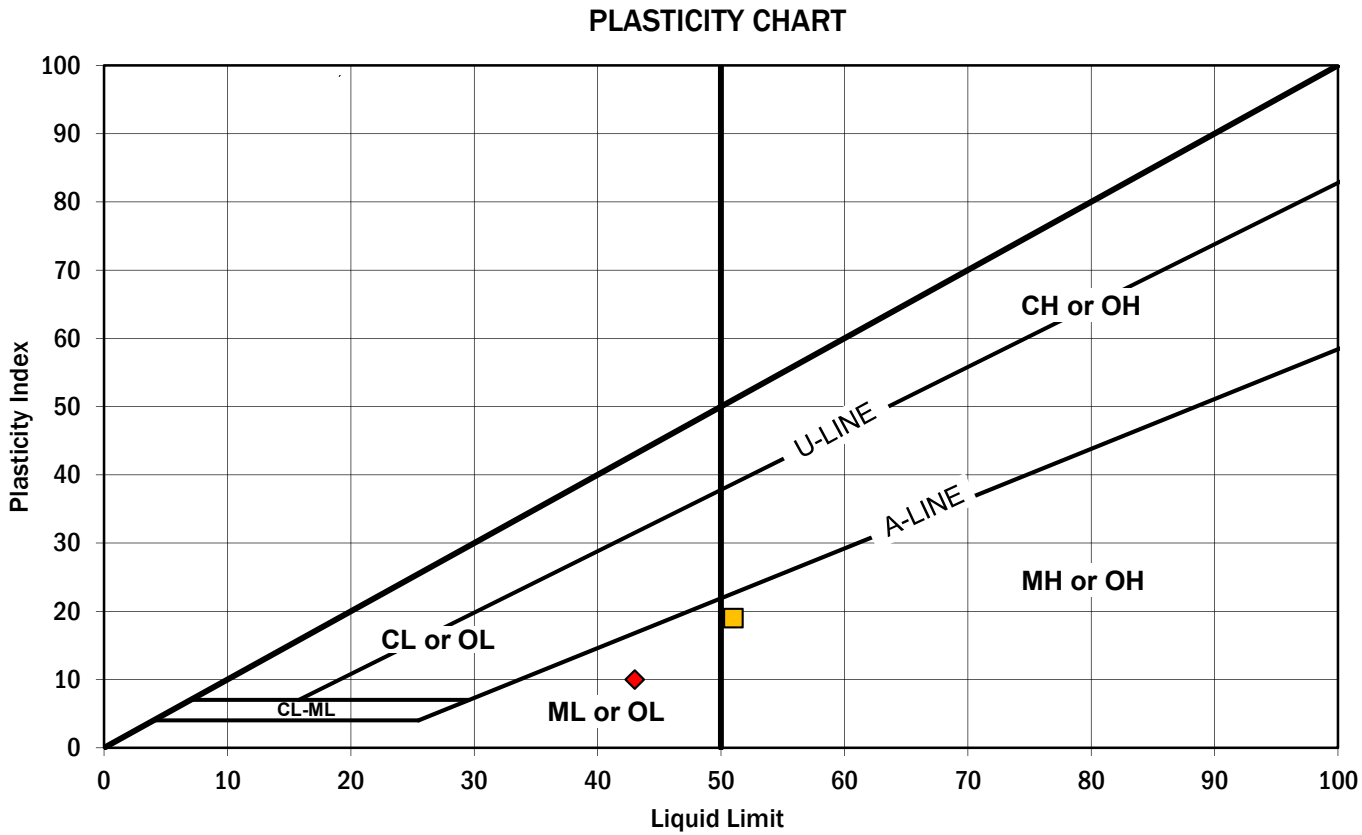

Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆	EL-B-3	8.5 – 10.0	45	43	10	Gray SILT with sand (ML)
■	EL-B-4	13.5 – 15.0	62	51	19	Gray SILT (MH)

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Atterberg Limits Test Results

Dakota Access Pipeline Project – Illinois River East Levee HDD
Scott County, Illinois

GeoEngineers

Figure A-14

BORING	DEPTH (FEET)	RQD (%)	ROCK QUALITY	UNCONFINED COMPRESSIVE STRENGTH (TSF)	UNCONFINED COMPRESSIVE STRENGTH (PSI)
EL-B-2	83.0 – 83.5	88	Good	338	4,700
EL-B-3	80.6 – 80.9	54	Fair	914	12,700
EL-B-4	85.1 – 85.4	76	Good	382	5,300
EL-B-4	86.6 – 86.9	76	Good	173	2,400
EL-B-5	71.6 – 71.9	92	Excellent	871	12,100
EL-B-5	85.0 – 85.3	72	Fair	1,058	14,700
EL-B-6	81.0 – 81.5	98	Excellent	526	7,300

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Rock Core Test Results

Dakota Access Pipeline Project – Illinois River East Levee HDD
Scott County, Illinois

GeoEngineers

Figure A-15

EL-B-2: 77.5' to 86.0'

0 0.5 1.0 Scale In Feet 1.5 2.0

EL-B-3: 77.0' to 87.0'

0 0.5 1.0 Scale In Feet 1.5 2.0

GEOENGINEERS

Dakota Access Pipeline Project
Illinois River East Levee HDD
Rock Core Sample Photos

FIGURE A-16

EL-B-3: 87.0' to 90.0'

0 0.5 1.0 Scale In Feet 1.5 2.0

EL-B-4: 72.0' to 78.6'

0 0.5 1.0 Scale In Feet 1.5 2.0

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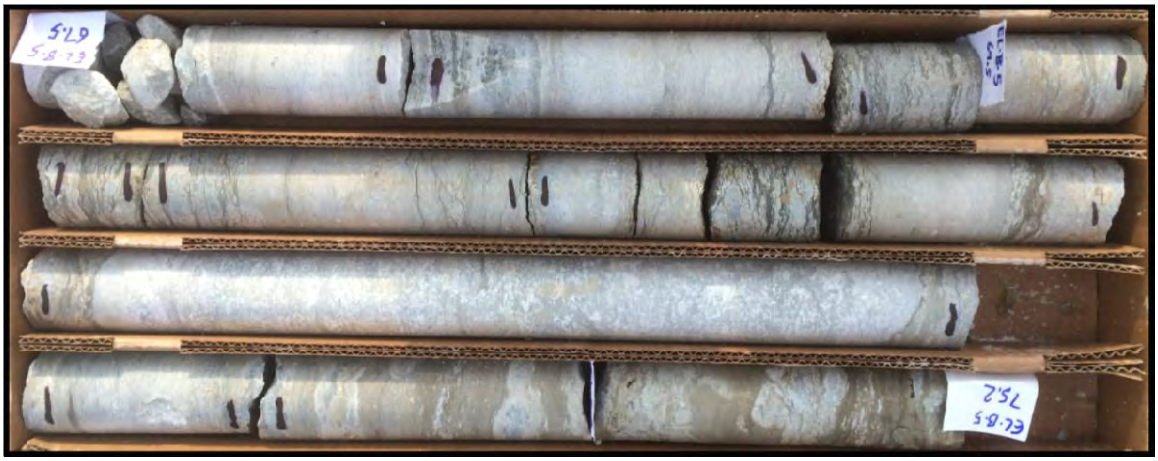
Dakota Access Pipeline Project
Illinois River East Levee HDD
Rock Core Sample Photos

FIGURE A-17

EL-B-4: 78.6' to 88.3'

0 0.5 1.0 Scale In Feet 1.5 2.0

EL-B-5: 67.5' to 75.2'



0 0.5 1.0 Scale In Feet 1.5 2.0

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Dakota Access Pipeline Project
Illinois River East Levee HDD
Rock Core Sample Photos

FIGURE A-18

EL-B-5: 75.2' to 84.5'

0 0.5 1.0 Scale In Feet 1.5 2.0

EL-B-5: 84.5' to 90.5'

0 0.5 1.0 Scale In Feet 1.5 2.0

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Dakota Access Pipeline Project
Illinois River East Levee HDD
Rock Core Sample Photos

FIGURE A-19

EL-B-6: 73.0' to 76.9'

0 0.5 1.0 Scale In Feet 1.5 2.0

EL-B-6: 76.9' to 87.0'

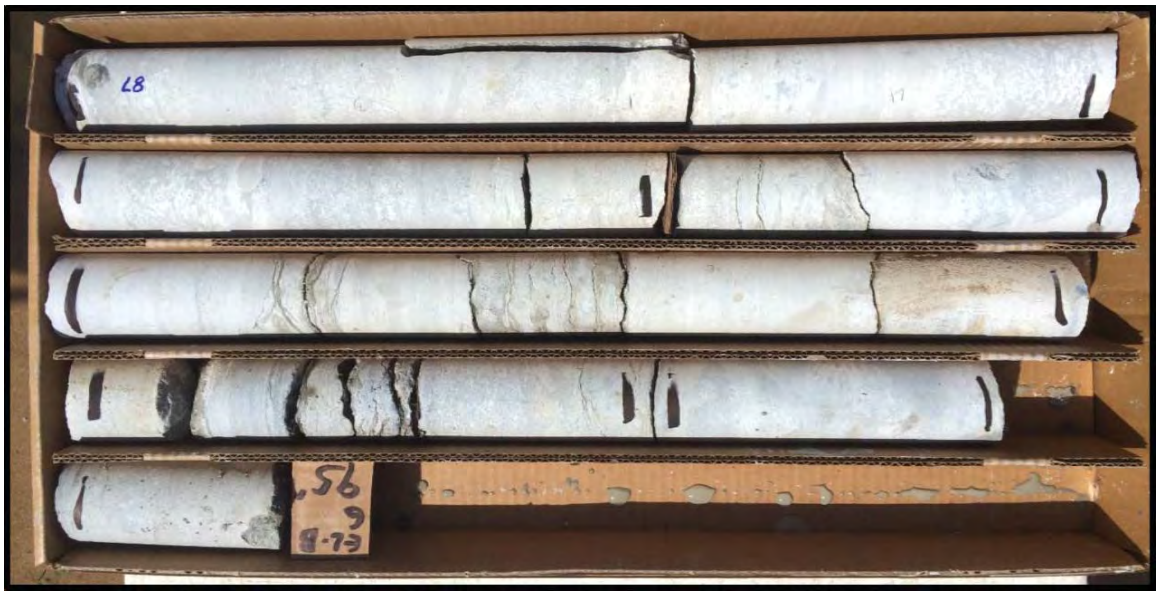
0 0.5 1.0 Scale In Feet 1.5 2.0

GEOENGINEERS

Dakota Access Pipeline Project
Illinois River East Levee HDD
Rock Core Sample Photos

FIGURE A-20

EL-B-6: 87.0’ to 95.0’



0 0.5 1.0 Scale In Feet 1.5 2.0

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Dakota Access Pipeline Project
Illinois River East Levee HDD
Rock Core Sample Photos

FIGURE A-21

APPENDIX B
Report Limitations and Guidelines for Use

APPENDIX B
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geotechnical and Environmental Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of Dakota Access, and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Similarly, an environmental assessment study conducted for a property owner may not fulfill the needs of a prospective purchaser of the same property. Because each study is unique, each report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering or Environmental Report Is Based on a Unique Set of Project-Specific Factors

This report has been prepared for the proposed Illinois River East Levee Horizontal Directional Drill (HDD) located in Scott County, Illinois. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure;

[1] Developed based on material provided by ASFE/The Best People on Earth, Professional Firms Practicing in the Geosciences; www.asfe.org.

- elevation, configuration, location, orientation or weight of the proposed structure;
- composition of the design team; or
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Subsurface Conditions Can Change

This report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, by new releases of hazardous substances, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Top Soil

For the purposes of this report, we consider topsoil to consist of generally fine-grained soil with an appreciable amount of organic matter, based on visual examination, and to be unsuitable for direct support of the proposed improvements. However, the organic content and other mineralogical and gradational characteristics used to evaluate the suitability of soil for use in landscaping and agricultural purposes were not determined, nor were they considered in our analyses. Therefore, the information and recommendations in this report, and our logs and descriptions, should not be used as a basis for estimating the volume of topsoil available for such purposes.

Most Geotechnical and Environmental Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on field observations and laboratory test results from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Geotechnical Engineering Report Recommendations Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient monitoring and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not construction activities are completed in accordance with our

recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A Geotechnical Engineering or Geologic Report Could Be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also, retain GeoEngineers to review pertinent elements of the design team's plans and specifications. If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

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APPENDIX C
Report Limitations and Guidelines for Use

APPENDIX C
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

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Horizontal Directional Drill Design Services

Dakota Access Pipeline Project
Kaskaskia River HDD
Fayette County, Illinois

for
Dakota Access, LLC

August 14, 2015

GeoEngineers
Earth Science + Technology

Horizontal Directional Drill Design Services

Dakota Access Pipeline Project
Kaskaskia River HDD
Fayette County, Illinois

for
Dakota Access, LLC

August 14, 2015

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Horizontal Directional Drill Design Services

Dakota Access Pipeline Project
Kaskaskia River HDD
Fayette County, Illinois

File No. 18782-011-01

August 14, 2015

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14. August. 2015

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EXECUTIVE SUMMARY

This report provides the Horizontal Directional Drill (HDD) design of GeoEngineers, Inc. (GeoEngineers) for the proposed Dakota Access Pipeline Project (DAPL) Kaskaskia River HDD at approximate DAPL milepost (MP) 1,011.3 in Fayette County, Illinois. This report replaces and supersedes previous design reports for this proposed HDD. The location of the site is shown on the Vicinity Map, Figure 1.

We understand that Dakota Access, LLC (Dakota Access) is proposing to construct approximately 1,020 miles of 30-inch-diameter steel pipeline extending from Mountrail Country, North Dakota through eastern South Dakota, Central Iowa, and terminating in Wayne County, Illinois. The proposed Kaskaskia River HDD would cross beneath the Kaskaskia River and a delineated wetland in Fayette County, Illinois. The layout of the proposed HDD and approximate boring locations are shown in the attached design drawings included in Appendix A.

We explored subsurface conditions near the proposed HDD site on October 28 through November 1, 2014 by drilling four geotechnical borings (KSR-B-1, through KSR-B-4) to depths of up to approximately 75 feet below ground surface (bgs) adjacent to the alignment of the proposed HDD at that time. An additional boring (KSR-B-5) was completed on April 27 and 28, 2015 to collect geotechnical data along the revised pipeline alignment. In general, the subsurface conditions encountered in the borings were consistent with the published geology for the area, consisting predominantly of sand with varying amounts of silt, clay and occasional gravel, and silt and clay units with varying amounts of sand. Sandstone and shale deposits were encountered in Borings KSR-B-1, KSR-B-2 and KSR-B-5. Details of our subsurface exploration program are included in our geotechnical data report attached as Appendix B.

Based on the information available at this time, the subsurface conditions observed in our geotechnical explorations and our detailed HDD constructability review, it is our opinion the proposed Kaskaskia River HDD is technically feasible. However, there are some potential risks associated with the HDD method of construction at this crossing location that, if left unmitigated, will likely cause difficulties during construction. The primary risk to this HDD is related to the hydraulic fracture and inadvertent returns (IR). Based on the subsurface conditions encountered in the borings and our experience, it is our opinion there is a generally low to moderate risk of hydraulic fracture and IR along much of the proposed alignment. If such conditions adversely impact the HDD operations, the HDD contractor should be prepared to submit a mitigation plan. In addition, based on the subsurface conditions encountered within the borings, the HDD profile was designed with a bottom tangent having a 0.28 degree slope to avoid drilling into the underlying bedrock and mixed face zones, to help provide adequate cover beneath the Kaskaskia River and a delineated wetland, and reduce the risk of inadvertent drilling fluid returns along the alignment. If such conditions are encountered, we recommend the HDD contractor adjust their penetration rate and steering tools to stay within the vertical pilot hole tolerance as well as build a smooth profile to reduce the risk of the product pipe becoming stuck during the pullback operations. Bedrock may be encountered at locations and depths not observed within the borings.

This Executive Summary should be used only in context of the full report for which it is intended.

1.0 INTRODUCTION

At the request of Dakota Access, LLC (Dakota Access) and in general accordance with our subcontract agreement (No. 07-PSA-0017) GeoEngineers, Inc. (GeoEngineers) is pleased to submit this report which replaces and supersedes previous reports provided for the Horizontal Directional Drill (HDD) design for the proposed Dakota Access Pipeline (DAPL) Kaskaskia River HDD in Fayette County, Illinois. The project site is shown on the Vicinity Map, Figure 1.

We understand that Dakota Access is proposing to construct approximately 1,020 miles of 30-inch-diameter steel pipeline extending from Mountrail County, North Dakota through eastern South Dakota, Central Iowa, and terminating in Wayne County, Illinois. Further, we understand Dakota Access is proposing to construct approximately 151 miles of gathering line, consisting of 12.75-, 20-, 24- and 30-inch-diameter steel pipeline in McKenzie, Mountrail, and Williams Counties, North Dakota.

The proposed Kaskaskia River HDD is a part of 30-inch-diameter DAPL mainline and would cross beneath the Kaskaskia River and a delineated wetland at DAPL milepost (MP) 1,011.3 in Fayette County, Illinois. The layout of the proposed HDD and approximate boring locations are shown in the attached design drawings included in Appendix A.

We explored subsurface conditions near the proposed HDD site on October 28 through November 1, 2014 by drilling four geotechnical borings (KSR-B-1 through KSR-B-4) to depths of up to approximately 75 feet below ground surface (bgs) adjacent to the alignment of the proposed HDD at that time. An additional boring (KSR-B-5) was completed on April 27 and 28, 2015 to collect geotechnical data along the revised pipeline alignment. In general, the subsurface conditions encountered in the borings were consistent with the published geology for the area, consisting predominantly of sand with varying amounts of silt, clay and occasional gravel, and silt and clay units with varying amounts of sand. Sandstone and shale deposits were encountered in Borings KSR-B-1, KSR-B-2 and KSR-B-5. Details of our subsurface exploration program are included in our geotechnical data report attached as Appendix B.

1.1. Basis of Design

Our HDD design has been completed in general accordance with the latest versions of the Code of Federal Regulations (CFR), Title 49, Part 195, American Society of Mechanical Engineers (ASME) B31.4 and generally accepted practices within the pipeline industry. Where more conservative, we analyzed the design per the gas pipeline requirements found in (CFR), Title 49, Part 192 and ASME B31.8. The HDD design engineering was completed based on the parameters presented below in Table 1.

TABLE 1. BASIS OF DESIGN FOR THE 30-INCH KASKASKIA RIVER HDD

Product Pipe Data	Design Parameter
Product pipe Specifications	30 inches x 0.625 inches w.t.[a] API 5L – X70
Horizontal Crossing Length	4,160 feet
Maximum Allowable Operating Pressure	1,440 psig[b]
Maximum Operating Temperature	100 degrees F
Tie-In Temperature	70 degrees F
Design Factor[c]	0.50

Notes:

[a] w.t. – wall thickness

[b] psig – pounds per square inch gauge

[c] As defined in CFR 49, sections 192.5 and 192.111

2.0 HDD CONSTRUCTION RECOMMENDATIONS

2.1. General

Based on the information available at this time, the results of our subsurface exploration and laboratory testing program and our engineering analyses, it is our opinion the proposed Kaskaskia River HDD is technically feasible, provided the construction requirements specified within the Dakota Access Construction Specification, Specification Number: DAPL-WGM-GN000-PRE-SPC-00001 (Construction Specification) dated April 20, 2015 and noted in the design drawing are incorporated into the HDD contractor's drill plan. In addition, the HDD contractor should make all reasonable attempts to utilize "Best Drilling Practices" during all construction phases of the project. This report also provides our construction recommendations that, in our opinion will help mitigate some of the risks inherent with this project and increase the likelihood that the installation will be completed successfully and on schedule. The construction recommendations for consideration by the project team and prospective HDD contractors are provided in Section 2.2. A detailed discussion of the construction risks and general construction considerations is provided in Section 3.0.

2.2. Construction Recommendations

This section provides GeoEngineers' construction recommendations that in our opinion should be considered by the prospective HDD contractors and the project team to increase the likelihood that the pipeline can be successfully installed without damage, significant construction difficulties or delays. Our recommendations are not meant to be exhaustive and do not relieve the contractor from the responsibility of reviewing all of the information related to the proposed crossing and developing their own plan to install the crossing without damage to the product pipe or unplanned delay.

We recommend that the risks we identify along with any other risks the contractor perceives be discussed prior to construction. In this manner the project team will be able to identify and quantify costs associated with project risk. The implementation of our recommendations may, in some instances, increase the initial cost estimates for construction. However, in our experience, the higher initial estimates can be much more reflective of ultimate project costs and reduce the budget uncertainty related to construction risk. We recommend the construction bid packages require that prospective HDD contractors supply unit costs for

risk mitigation items so they can be better evaluated in the bid selection phase. In the event that some of these measures are deemed necessary after award of the contract, their associated costs will have already been negotiated.

TABLE 2. GEOENGINEERS' CONSTRUCTION RECOMMENDATIONS

General Recommendations
We recommend the prospective contractors visit the site and evaluate the designated access routes to determine what improvements might be necessary and what considerations may be needed to mobilize their equipment to the site.
We recommend the prospective contractors visit the workspace areas to determine the extent of preconstruction site preparation necessary for HDD activities.
The drilling fluid properties should be tested a minimum of three (3) times per shift so that the suitability of the drilling fluid for the given conditions can be determined.
Pilot Hole Recommendations
We recommend the contractor consider using the pilot hole intersect method to complete the pilot hole as it could potentially reduce the risk of experiencing high downhole annular drilling fluid pressures, hydraulic fracture and inadvertent drilling fluid returns along the HDD alignment.
We recommend the secondary survey wires be placed at least as wide as the survey probe is deep plus an allowance for the vertical pilot hole tolerance. As a result, the depth of the HDD profile will require the coil to increase in width from approximately 20 feet wide near the entry and exit locations to a minimum of approximately 66 feet wide through portions of the drill profile.
We recommend the contractor consider using the pilot hole intersect method to complete the pilot hole as it could potentially reduce the risk of experiencing high downhole annular drilling fluid pressures, hydraulic fracture and inadvertent drilling fluid returns along the HDD alignment.
We recommend the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system.
We recommend that a downhole annular pressure tool be utilized during pilot hole operations.
We recommend the HDD contractor's as-built drawing be reviewed by GeoEngineers prior to storing the data in the project file.
Reaming and Swabbing Recommendation
We recommend the HDD contractor consider conducting reaming operations from entry to exit (low side to high side).
We recommend the HDD contractor develop a contingency plan in the event that hole instabilities through the dry hole section is expected or encountered. This could include the installation of large diameter casing or excavation of the overlying soils from the dry hole portion.
We recommend the HDD contractor adjust the penetration and/or pump rates while conducting reaming operations to maintain an annular solids content of 30 percent or less.

Installation Recommendations
We recommend a minimum bending radius of 1,000 feet while stringing and handling the product pipe to provide additional protection against pipe damage while moving the product pipe into position for pullback.
We recommend the HDD contractor utilize a drill rig that provides a factor of safety of at least 2.0 between the drill rig capacity and the pull loads they anticipate.
Because of the significant reduction in pull forces from using buoyancy control, we recommend that buoyancy control measures be utilized during pullback operations.
We recommend the HDD contractor be required to provide the maximum anticipated pull force required to install the product pipe and the maximum allowable pull force that can be applied to their downhole tooling.

3.0 HDD CONSTRUCTION RISKS AND CONSIDERATIONS

3.1. Construction Risks

The contractor's means and methods during construction are critical to the successful completion of the HDD. Because the subsurface conditions can vary between borings, we recommend GeoEngineers be on-site to document the drilling process in real time to mitigate risks and increase the potential for a successful installation of this HDD. At a minimum, we recommend contacting GeoEngineers immediately if subsurface conditions are claimed to be different than presented in this report. The following items should be considered during preconstruction planning and during construction operations to increase the likelihood of the successful installation of this HDD:

- Based on the subsurface conditions encountered in the borings and our experience, it is our opinion that there is a generally low to moderate risk of hydraulic fracture and IR along much of the proposed alignment.
- The HDD profile was designed with a bottom tangent having a 0.28 degree slope to avoid drilling into the underlying bedrock and mixed face zones. If such conditions are encountered while advancing the pilot hole, we recommend the HDD contractor adjust their penetration rate and steering tools to stay within the vertical pilot hole tolerance as well as build a smooth profile to reduce the risk of the product pipe becoming stuck during pullback operations.
- The exit point is approximately 9 feet higher than the entry point creating approximately 60 feet of "dry hole" located on the exit side of the crossing.
- Hole instabilities may be experienced within the dry section of the hole because much of this section is located within sand with silt and gravel units of soil which will increase the risk of stuck tooling downhole, the product pipe becoming stuck during pullback operations, ground subsidence, and sinkhole formation along the HDD alignment. We recommend the HDD contractor consider excavating along the alignment down to the drill profile, removing the material that may cause instability and hole collapse.

3.1.1. Hydraulic Fracture and Inadvertent Drilling Fluid Returns

Hydraulic Fracture

Hydraulic fracture is a term used to describe the situation in which the downhole fluid pressure exceeds the overburden pressure and shear strength of the soil and rock formation above a drill path. Hydraulic fracture typically occurs when the drill path passes through relatively weak cohesive soils or loose granular

soils with low shear strength. Very loose to loose sands and silty sands and soft to medium stiff silts and clays typically have a higher hydraulic fracture potential. Medium dense to very dense sands and very stiff to hard silts and clays typically have a low to moderate hydraulic fracture potential. Unfractured rock, because of its high shear strength, typically has a very low potential for hydraulic fracture. HDD installations with greater depth or drill paths in formations with higher shear strength may reduce the potential for hydraulic fracturing.

Our qualitative hydraulic fracture evaluation considers the soil types encountered in the borings completed at the site, the relative density or consistency of the soils, the elevation of entry and exit with respect to features of interest, and the relative pumping pressures required to move drilling fluid from the cutting tool to the entry and/or exit points.

Inadvertent Drilling Fluid Returns IR

Inadvertent drill fluid returns (IR) occur when drilling fluid emerges at the ground surface. IR have the potential for releasing relatively large volumes of drilling fluid over a short period of time, particularly if the high-pressure drilling fluid pumps are not immediately disengaged.

In practice, IR typically occur in close proximity to the entry and exit points where the depth of cover decreases and near the exit point where annular pressures are at their greatest. IR potential also increases at locations along a drill path where there are low strength soils, where the alignment is at a relatively shallow depth, or along pre-existing fractures or voids. Other locations where IR potential is elevated include preferential pathways such as exploratory boring locations, and along the sides of existing structures such as piles or utility poles.

The HDD contractor's construction procedures constitute another important factor influencing when and where fluid loss occurs. If the contractor operates with inadequate pump volumes, less than ideal drilling fluid properties or excessive rates of penetration, the annulus may become blocked through an accumulation of drill cuttings falling out of suspension. If the accumulation creates a blockage downhole, the annulus may become over-pressurized, leading to hydraulic fracturing and potentially IR.

Our qualitative IR evaluation considers soil types encountered by exploratory borings, and the susceptibility of those material types to hydraulic fracture, and/or difficulty removing cuttings of those materials from the drilled hole. We also consider the relative pump pressures that will be required to move solids laden drilling fluid from the cutting tool to the entry and/or exit pits and the elevations of entry and exit with respect to features of interest. Based on these considerations, and our HDD construction experience, we developed a qualitative opinion on the relative risk of IR along the proposed HDD.

Qualitative Risk Analysis of Hydraulic Fracture and Inadvertent Drilling Fluid Returns

Based on the subsurface conditions encountered in the borings and our experience, it is our opinion that there is a generally low to moderate risk of hydraulic fracture and IR along much of the proposed alignment including under the Kaskaskia River, wetland and the places where sandy soil are encountered. However, based on our experience, the risk of IR during construction is elevated within approximately 100 feet of the entry and exit points regardless of subsurface conditions because of the relatively thin soil cover. Near the exit point, the risk level is often exacerbated due to the relatively high pump pressures required to maintain drilling fluid returns to the entry side of the HDD during pilot hole operations.

The contractor's means and methods will be critical to limiting IR during construction. Specifically, the contractor should limit penetration rates during drilling of the HDD such that the drill bit does not "outrun" the removal of cuttings from the pilot hole. In addition, the contractor should maintain drilling fluid properties that are conducive to removing cuttings from the hole, and also maintain drilling fluid returns at all times during the HDD process. When drilling fluid returns are not maintained during HDD operations, the risk of hydraulic fracture and IR increases significantly. If desired, annular pressure can be monitored through the use of an annular pressure tool as part of the bottom hole assembly (BHA). An annular pressure tool can indicate when downhole annular pressures increase dramatically and that hydraulic fracture is likely to occur so that drilling practices can be amended to reduce the potential for IR.

The planned HDD alignment crosses the Kaskaskia River and a delineated wetland, which could be adversely affected by IR. We recommend that the contractor submit a drilling plan that addresses how they will attempt to reduce the potential for hydraulic fracture and IR and includes a contingency plan for responding to inadvertent surface returns.

3.1.2. Drill Hole Stability

In general, soil conditions encountered in the exploration borings near the proposed HDD alignment were consistent with published geology for the area, consisting predominantly of sand with varying amounts of silt, clay and occasional gravel, and silt and clay units with varying amounts of sand. Sandstone and shale deposits were encountered in Borings KSR-B-1, KSR-B-2 and KSR-B-5.

The difference in elevation between the entry and exit points of the proposed HDD (approximately 9 feet) will cause the drilling fluid within the hole to come to equilibrium at the lower of the two points, causing a portion of the hole to be situated above the drilling fluid equilibrium elevation. This condition creates a dry section within the hole, which will increase the risk of hole collapse and poor cuttings removal from the annulus during reaming operations which, in turn may lead to additional risks (ground settlement and loss of drilling fluid returns). As designed, approximately 60 feet of the exit tangent will be dry hole. The subsurface units along this section of the profile are likely to consist sand with varying amount of silt and occasional gravel. In our opinion, the risk of hole instabilities is low. The HDD contractor should develop a mitigation plan in the event of hole instability. We recommend the HDD contractor consider excavating along the alignment down to the drill profile, removing the material that may cause instability and hole collapse. If excavation to the depth is not feasible, large diameter casing could be installed through the dry hole section.

3.1.3. Mixed Face Conditions

Based on the subsurface conditions encountered within the borings, the HDD profile was designed with a bottom tangent having a 0.28 degree slope to avoid drilling into the underlying bedrock and mixed face zones, to help provide adequate cover beneath the Kaskaskia River and a delineated wetland, and reduce the risk of inadvertent drilling fluid returns along the alignment. The HDD contractor should be aware of the risk of encountering mixed face conditions while advancing the pilot hole. We recommend the contactor adjust their penetration rate and steering tools to stay within the vertical pilot hole tolerance as well as build a smooth profile to reduce the risk of the product pipe becoming stuck during pullback operations. Bedrock may be encountered at locations and depths not observed in the borings.

3.2. Construction Considerations

3.2.1. Site Access

The proposed HDD entry workspace will most likely be accessed pipeline right-of-way (ROW) and an approved access route from County Road 900 North, north of the site.

The HDD exit and product pipe stringing and fabrication workspaces may be accessed via the pipeline ROW from Country Road 375 East, west of the site.

Depending upon conditions at the time of construction, load-dispersing materials such as timber mats or quarry rock may be required to maintain stabilization of the equipment entering the locations. We recommend the prospective contractors visit the site and evaluate the designated access routes to determine what improvements might be necessary and what considerations may be needed to mobilize their equipment to the site.

3.2.2. Workspace Considerations

The temporary workspace at entry includes a rectangular-shaped area measuring 200 feet wide by 250 feet in length with the entry point positioned 75 feet from the front (west side) of the workspace. The entry workspace is located in an agricultural area such that clearing should not be needed prior to mobilization of equipment to the site. The ground surface within the entry workspace is relatively flat and grading is not likely to be needed prior to mobilization of equipment to the site.

The temporary workspace at exit includes a rectangular-shaped area measuring 200 feet wide by 250 feet in length with the exit point positioned 75 feet from the front (east side) of the workspace. The exit workspace is located in a native grassy area with some deciduous trees such that minor clearing should be needed prior to mobilization of equipment to the site. The ground surface within the entry workspace is moderately sloped and minor grading likely be needed prior to mobilization of equipment to the site.

The proposed product pipe stringing and fabrication workspace will extend 4,260 feet west of the temporary workspace at exit as depicted in the HDD design drawings in Appendix A. The product pipe stringing and fabrication workspace is of sufficient length to string the product pipe in one continuous section during pullback operations. However, the product pipe pull section may have to be fabricated in two strings that are divided by County Road 375 East to maintain through traffic on County Road 375 East. The two strings of pipe could be welded together immediately prior to pullback operations.

We recommend that the prospective contractors visit the workspace areas to determine the extent of clearing and grading necessary to prepare the site for HDD activities.

3.2.3. Proposed HDD Plan and Profile

A plan and profile design drawings for the proposed Kaskaskia River HDD is included in Appendix A. The design drawings include the necessary geometric information required to complete the pilot hole and the site specific construction requirements. Detailed calculations for minimum allowable radius of curvature, operating stresses and installation loads and stresses are also included for reference in Appendix A.

The proposed Kaskaskia River HDD is 4,160 feet long as measured along the HDD centerline, with a length of approximately 4,167 feet as measured along the drill profile. The radius of curvature for the entry and

exit vertical curves is 3,000 feet. The HDD was designed with a bottom tangent having a 0.28 degree slope to avoid drilling into the underlying bedrock, help provide adequate cover beneath the Kaskaskia River and a delineated wetland, and reduce the risk of inadvertent drilling fluid returns along the alignment.

3.2.4. Pilot Hole Considerations

Pilot Hole Survey

We recommend the HDD contractor provide and maintain all times instrumentation to document and accurately locate the pilot hole. This effort should include the use of a downhole steering tool as well as a secondary survey system (TruTrack, ParaTrack or equivalent). We recommend the HDD contractor not be allowed to drill any portion of the pilot hole without the use of a secondary survey system or a gyroscopic steering tool unless agreed to in advance by the Company. If the HDD contractor elects to use the wire coil grids with these secondary survey systems, we recommend the secondary survey wires be placed at least as wide as the survey probe is deep plus an allowance for the vertical pilot hole tolerance. As a result, the depth of the HDD profile will require the coil to increase in width from approximately 20 feet wide near the entry and exit locations to a minimum of approximately 66 feet wide through a portion of the drill profile. The placement of the coils is limited to areas where ground surface conditions, permit requirements, and agreements with landowners allow and as such, we recommend the contractor review the project plans and workspace limitations to determine the most appropriate configuration for the secondary survey system. After surveying the secondary survey wire, the HDD contractor should report any lack of closure that may indicate incorrectly located entry and/or exit points or any other potential discrepancy with the design information provided on the design drawing.

Tolerances

Based on the design geometry and proposed product pipe specifications, the minimum allowable three-joint vertical radius over any consecutive three-joint section shall not be less than 2,050 feet. The three-joint radius should be calculated for each three-joint (for Range 2 drill pipe) section (approximately 90 feet) drilled during pilot hole operations. The horizontal pilot hole tolerances are no more than 10 feet left and 10 feet right of the designed alignment. The vertical pilot hole tolerances are no more than 2 feet above and 10 feet below the designed profile. We recommend that the pilot hole not be accepted if its location would result in the pipeline being installed in violation of the right-of-way and permit stipulations section of the contract, any federal, state or local permit requirements, or required clearances between Dakota Access and foreign owned utilities and structures. For the entry and exit point tolerances please refer to the HDD design drawings in Appendix A.

We recommend that, upon completion of the pilot hole, GeoEngineers have the opportunity to review the pilot hole survey data prior to the start of reaming operations.

Pilot Hole As-Built

We recommend the HDD contractor be required to produce and submit an as-built drawing of the pilot hole survey data within two weeks of the completion of pullback operations. This should include a tabulation of the supporting as-built survey data used to generate the drawing. We recommend that the HDD contractor's as-built drawing be reviewed by GeoEngineers prior to storing the data in the project file.

3.2.5. Reaming and Swabbing Considerations

Reaming

During reaming operations we anticipate the HDD contractor will likely ream the hole to a minimum final hole diameter of approximately 42 inches. If pull ream passes from exit to entry are conducted, a drilling fluid recycling system and high pressure drilling fluid pump operating from the exit side of the crossing would be advantageous to facilitate circulating drilling fluid downhole and recycling of the drilling fluid returns on that side of the crossing. Generally accepted best management practices (BMPs) within the HDD industry recommend an annular solids percentage of 30 percent or less, which requires pumping a volume of drilling fluid greater than 3 times the volume of soil cuttings being generated. We recommend that the HDD contractor adjust the penetration and/or pump rates while conducting reaming operations to maintain an annular solids content of 30 percent or less.

Hole Swabbing

Swabbing the hole after the completion of reaming operations is generally one of the best methods to evaluate if the hole is in a condition to receive the product pipe. Irregularities in the hole, zones of instability and areas where drill cuttings may have accumulated can often be detected during the swab pass. In the event that any of these conditions are detected or suspected, mitigation measures can be employed prior to pullback operations to increase the likelihood of successfully installing the product pipe without damage. Mitigation measures may include additional reaming or swab passes.

The HDD contractor complete at a minimum one (1) swab pass to evaluate the condition of the hole prior to pullback operations. The HDD contractor should review the data collected during the reaming and swab passes with Dakota Access before pullback operations begin.

3.2.6. Pullback Considerations

Handling of the Product Pipe

We recommend the contractor be required to supply a pullback lifting procedure as part of their final HDD Work Plan. The minimum allowable radius of curvature for handling and positioning the product pipe in preparation for pullback operations is approximately 800 feet (See Appendix A for detailed calculations of overbend radius). This radius of curvature results in a bending stress of approximately 67 percent (46,700 pounds per square inch [psi]) of the specified minimum yield stress (SMYS). We recommend the overbend radius be limited to at least 1,000 feet to reduce the risk of damaging the product pipe during pullback operations.

Installation Loads

For the proposed HDD, we analyzed the anticipated pull loads for the as-designed HDD geometry based upon different drilling fluid weights in the hole and with and without the use of buoyancy control inside the product pipe. The proposed 30-inch-diameter steel product pipe will be positively buoyant in the anticipated drilling fluid weights. We recommend the contractor should consider adding water to the product pipe in an effort to reduce positive buoyancy during pullback. Our analyses include a range of cases with differing drilling fluid densities in the hole during pullback and with and without the use of buoyancy control. Installation load and stress calculation results are attached in Appendix A.

The five cases analyzed are as follows:

1. The annulus contains 9.5 pounds per gallon (lb/gal) drilling fluid and the product pipe is empty.
2. The annulus contains 9.5 lb/gal drilling fluid and the product pipe is full of water.
3. The annulus contains 12 lb/gal drilling fluid and the product pipe is empty.
4. The annulus contains 12 lb/gal drilling fluid and the product pipe is full of water.
5. The annulus contains 10 lb/gal drilling fluid and the product pipe is neutrally buoyant.

The following table presents a summary of the calculated installation loads for the crossing.

TABLE 3. INSTALLATION LOADS FOR THE 30-INCH PIPELINE KASKASKIA RIVER HDD[a]

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Effective Pipe Weight[b] (lb/ft)	Pullback Force[c] (lb)
9.5	Empty	-152	469,000
9.5	Full	129	374,000
12	Empty	-244	596,000
12	Full	37	284,000
10	Neutral	0	257,000

Notes:

a Assumes the as-designed HDD profile. See Appendix A for detailed calculations.

[b] Negative values indicate upward force (positive buoyancy).

[c.] Assumes a fully open drilled hole with no obstructions.

We recommend the HDD contractor utilize a drill rig that provides a factor of safety of at least 2.0 between the drill rig capacity and the pull loads they anticipate. Based on our analysis of the installation loads (see Table 3), the pullback force during installation of the 30-inch-diameter product pipe may be as high as approximately 596,000 pounds depending on the weight of the drilling fluid in the hole at the time of pullback and buoyancy control measures utilized by the HDD contractor. Because of the reduction in pull forces from using buoyancy control, we recommend that buoyancy control measures be utilized during pullback operations. The calculated safe pull force for this installation is in excess of 2,000,000 pounds such that the limiting pull force will depend on the capacity of the tooling the HDD contractor intends to utilize during pullback operations. We recommend the HDD contractor be required to provide the maximum anticipated pull force required to install the product pipe and the maximum allowable pull force that can be applied to their downhole tooling.

Pneumatic Hammer Usage

In some instances, a pneumatic hammer can be utilized to assist with the installation of the product pipe. The contractor should not employ the use of a pneumatic hammer without prior approval from Dakota Access.

Drilling Fluid Displacement

During pullback operations, the product pipe will displace approximately 153,000 gallons of drilling fluid. Because of the geometry of the HDD profile we anticipate that much of the displaced drilling fluid will likely flow to the entry point on the east side of the crossing.

4.0 OPERATING CONDITIONS

For our analysis of the operating stresses, the installation and operating temperatures utilized for the 30-inch pipeline were 70 and 100 degrees Fahrenheit, respectively. We can further evaluate different installation and operating temperatures, if necessary. Also, the operating stresses are based on a minimum allowable pilot hole radius of curvature of 2,050 feet. If the as-built minimum radius of the pilot hole is less than 2,050 feet, the operating stresses will be increased. The following table presents a summary of the operating stresses for the product pipe specifications proposed for the HDD.

TABLE 4. OPERATING STRESSES FOR THE 30-INCH KASKASKIA RIVER HDD[a]

Stress Component	Stress (psi)	Percent SMYS[b] (%)	Maximum Allowable Percent SMYS[b] (%)
Longitudinal Bending Stress	17,900	26	-
Hoop Stress	34,600	49	50[c]
Longitudinal Tensile Stress from Hoop Stress	10,400	15	-
Longitudinal Stress from Thermal Expansion	-5,700	8	90[d]
Maximum Net Longitudinal Stress	22,500	32	67[d]
Maximum Shear Stress	23,900	34	45[e]
Maximum Combined Effective Stress	47,800	68	90[d]

Notes:
[a] Operating stresses are based on an allowable minimum radius of 2,050 feet
[b] Specified minimum yield stress
[c.] Limited by design factor from design basis
[d.] Limited by section 402.3.2 of ASME B31.4
[e.] Limited by section 402.3.1 of ASME B31.4

5.0 LIMITATIONS

We have prepared this report for use by Dakota Access and their authorized agents and other approved members of the design team involved with this project. The report is not intended for use by others, and the information contained herein is not applicable to other sites. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. To increase the likelihood of a successful installation, the conclusions and recommendations in this report should be applied in their entirety.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or

procedures, except as specifically described in our report for consideration in developing an HDD Work Plan.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. No warranty or other conditions, express, written, or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, and will serve as the official document of record.

Please refer to Appendix C, titled "Report Limitations and Guidelines for Use," for additional information pertaining to use of this report.

6.0 REFERENCES

From the CFR Title 49, Part 192 and 195

- Code of Federal Regulations (2013), "Design Factor for Steel Pipe," CFR Transportation, Title 49 Part 192.111
- Code of Federal Regulations (2013), "Design Factor for Steel Pipe," CFR Transportation, Title 49 Part 195.106

From ASME, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids (B31.4)

- The American Society of Mechanical Engineers (2012), "Allowable Stress Values," ASME Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids, B31.4 Part 402.3.1
- The American Society of Mechanical Engineers (2012), "Limits of Calculated Stresses Due to Suspended Loads and Thermal Expansion," ASME Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids, B31.4 Part 402.3.2

From ASME, Gas Transmission and Distribution Piping Systems (B31.8)

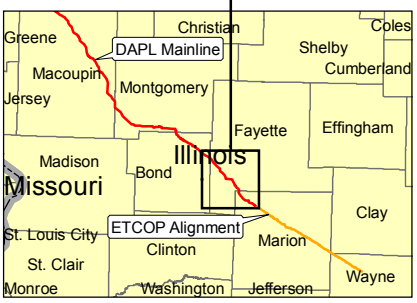
- The American Society of Mechanical Engineers (2010), "Summation of Longitudinal Stress in Restrained Pipe," ASME Gas Transmission and Distribution Piping Systems, B31.8 Part 833.3
- The American Society of Mechanical Engineers (2010), "Combined Stress for Restrained Pipe," ASME Gas Transmission and Distribution Piping Systems, B31.8 Part 833.4

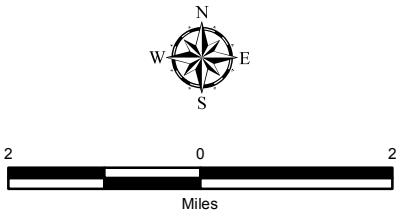
Pipeline Research Committee International (PRCI) of the American Gas Association "Installation of Pipelines by Horizontal Directional Drilling, An Engineering Design Guide," November, 2008.

Dakota Access, LLC, Pipeline Construction Plan Document No. DAPL-WGM-GN000-PRE-SPC-0001, Project No. 10395700, Revision C, Issue Date: April 20, 2015.

FIGURES

GeoEngineers





Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Imagery from ESRI Data Online.
Projection: NAD 1983, UTM Zone 16 North.

DAKOTA ACCESS PIPELINE PROJECT
VICINITY MAP

PROPOSED 30" PIPELINE
KASKASKIA RIVER HDD
FAYETTE COUNTY, ILLINOIS

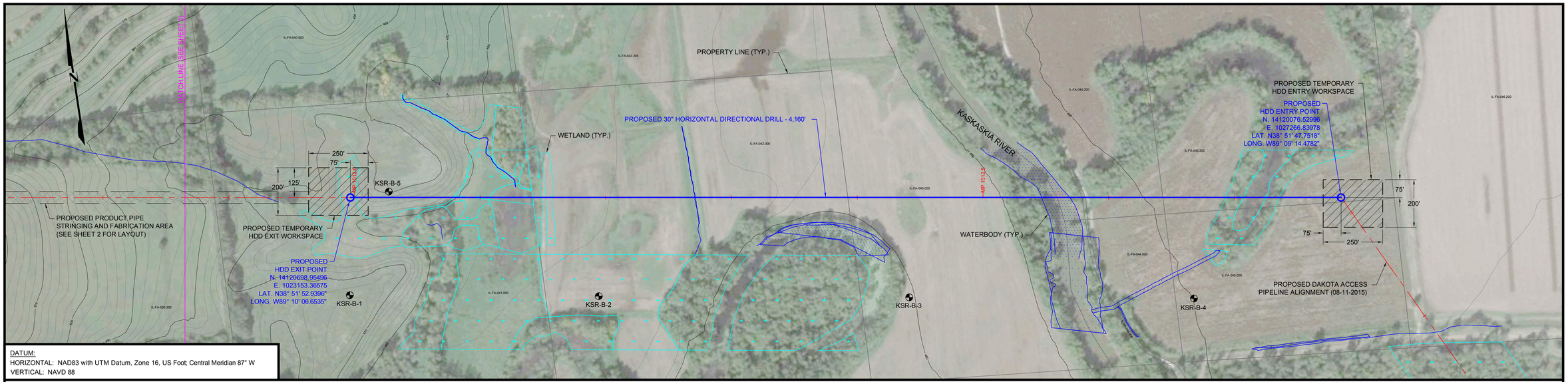
GEOENGINEERS

Figure 1

Office: SPR Path: P:\18\1878201101\GIS\Vicinity Maps\Illinois\Kaskaskia River HDD.mxd Map Revised: 24 June 2015 mclevenger

GeoEngineers

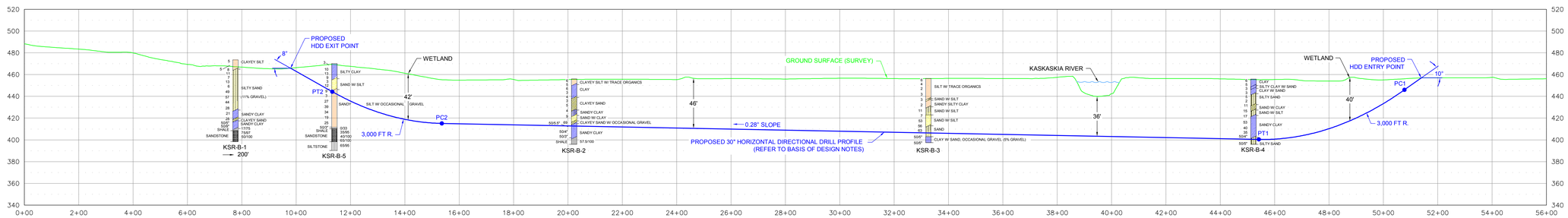
APPENDIX A
HDD Design Drawings and Calculations



DATUM:
HORIZONTAL: NAD83 with UTM Datum, Zone 16, US Foot; Central Meridian 87° W
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN
200' 0 200'
SCALE IN FEET



PROFILE
200' 0 200'
HORIZONTAL SCALE IN FEET
50' 0 50'
VERTICAL SCALE IN FEET

DIRECTIONAL DRILL DATA KASKASKIA RIVER HDD		
DESCRIPTION	STATION * (FT)	ELEVATION (FT)
ENTRY @ 10°	51+39.56	456.96
P C 1 (10.28° @ 3,000 FT R.)	50+77.22	445.97
P T 1	45+41.62	400.43
P C 2 (7.72° @ 3,000 FT R.)	15+35.88	415.12
P T 2	11+33.02	444.28
EXIT @ 8°	9+79.56	465.85
HORIZONTAL DISTANCE = 4,160.00 FT		
DIRECTIONAL DRILL PIPE LENGTH = 4,166.52 FT		

* STATIONING IS BASED ON AN ARBITRARY REFERENCE POINT.

RECOMMENDED TOLERANCES	
ITEM	TOLERANCE
PILOT HOLE ENTRY ANGLE	INCREASE ANGLE UP TO 1° (STEEPER), BUT NO DECREASE IN ANGLE ALLOWED.
PILOT HOLE ENTRY LOCATION	WITHIN 5 FEET OF ENTRY POINT AS SHOWN ON DRAWING. WITH NO CHANGES WITHOUT COMPANY APPROVAL.
PILOT HOLE EXIT ANGLE	INCREASE ANGLE UP TO 1° (STEEPER) OR DECREASE UP TO 2° (FLATTER).
PILOT HOLE EXIT LOCATION	UP TO 30 FEET BEYOND THE EXIT STAKE. BETWEEN 10 FEET LEFT AND 10 FEET RIGHT OF CENTERLINE.
PILOT HOLE DEPTH	UP TO 2 FEET ABOVE THE DESIGN DRILL PROFILE ALLOWED. UP TO 10 FEET BELOW THE DESIGN DRILL PROFILE ALLOWED.
PILOT HOLE ALIGNMENT	SHALL REMAIN WITHIN 10 FEET LEFT OR RIGHT OF THE HDD ALIGNMENT.

LEGEND

SPT (N) — TYPE OF SOIL (% GRAVEL)
TYPE OF ROCK — RQD/%REC

BORING LOCATION
MAJOR CONTOUR - 10' INTERVAL
MINOR CONTOUR - 2' INTERVAL

BASIS OF DESIGN:

1. PRODUCT PIPE WILL CONSIST OF 30" O.D. X 0.625" W.T., API-5L X-70 PIPE WITH 14-16 MILS OF FUSION BONDED EPOXY (FBE) AND A MINIMUM OF 40 MILS OF ABRASION RESISTANT OVERLAY (ARO).
2. THE MAXIMUM ALLOWABLE OPERATING PRESSURE (MAOP) = 1,440 psi.
3. THE ASSUMED MAXIMUM OPERATING TEMPERATURE = 100° FAHRENHEIT.
4. THE MINIMUM ALLOWABLE THREE JOINT RADIUS SHALL NOT BE LESS THAN 2,050 FEET.

ISSUED FOR BID

NOTES:

1. CONTRACTOR SHALL ADHERE TO THE SPECIFICATIONS AND REQUIREMENTS PER DAKOTA ACCESS, LLC SPECIFICATIONS, CONTRACT DOCUMENTS AND SPECIAL PERMIT CONDITIONS, EXCEPT AS NOTED ON THIS DRAWING.
2. CONTRACTOR IS RESPONSIBLE FOR CALLING ILLINOIS ONE-CALL AND LOCATING ALL UNDERGROUND UTILITIES PRIOR TO BEGINNING CONSTRUCTION. IF ANY UTILITY IS LOCATED WITHIN 15 FEET OF THE DESIGNED HDD PROFILE AND ALIGNMENT, CONTRACTOR SHALL OBTAIN APPROVAL FROM DAKOTA ACCESS, LLC PRIOR TO INITIATING HDD OPERATIONS.
3. IT IS THE CONTRACTOR'S RESPONSIBILITY TO IDENTIFY AND PROTECT ANY FOREIGN UTILITY THAT MAY BE AFFECTED BY THE HDD OPERATIONS.
4. PLACEMENT OF THE HDD RIG IS NOT FIXED BY THE DESIGNATION OF THE ENTRY AND EXIT POINTS. THE USE OF DUAL HDD RIGS DURING CONSTRUCTION MAY BE AT THE DISCRETION OF THE HDD CONTRACTOR, TO BE APPROVED BY DAKOTA ACCESS, LLC.
5. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
6. WORK SPACE: MAXIMUM WORK SPACE LIMITS ARE DEPICTED. RESTRICT CLEARING TO THE WORK SPACE INDICATED AT THE ENTRY AND EXIT POINTS AND PRODUCT PIPE STRINGING AND FABRICATION AREA ALONG THE CONSTRUCTION RIGHT-OF-WAY. CLEARING BETWEEN THE ENTRY AND EXIT POINTS REQUIRES PRIOR APPROVAL FROM THE ENVIRONMENTAL INSPECTOR AND IS LIMITED TO THE AMOUNT NECESSARY TO STRING SURVEY WIRES AND INSTALL PUMPS AND PIPING TO OBTAIN WATER (WHERE APPROVED).
7. WATER SOURCE: DRILL WATER AND HYDROSTATIC TEST WATER SHALL BE OBTAINED FROM AN APPROVED SOURCE.
8. HYDROSTATIC TEST: PRE-INSTALLATION AND POST-INSTALLATION HYDROSTATIC TESTS SHALL BE CONDUCTED IN ACCORDANCE WITH THE HYDROSTATIC TEST PLAN. TEST WATER SHALL BE SAMPLED AND TESTED IN ACCORDANCE WITH PERMIT REQUIREMENTS. THE TEST WATER SHALL BE DISCHARGED IN AN UPLAND AREA INTO AN EROSION CONTROL STRUCTURE OF STRAW BALES AND/OR SILT FENCES, GEOTEXTILE FILTER BAG, OR COLLECTED IN A TRUCK AND HAULED TO AN APPROVED DISPOSAL SITE. UPON COMPLETION OF DEWATERING AND DRYING, A CALIPER PIG SURVEY SHALL BE COMPLETED IN ACCORDANCE WITH THE CONTRACT DOCUMENTS.
9. SPILL-PREVENTION: REFUELING OF ALL EQUIPMENT SHALL BE COMPLETED IN ACCORDANCE WITH THE SPCC PLAN.
10. EROSION AND SEDIMENT CONTROL: CONTRACTOR SHALL SUPPLY, INSTALL AND MAINTAIN SEDIMENT CONTROL STRUCTURES IN ACCORDANCE WITH CONTRACT DOCUMENTS. CONTRACTOR SHALL INSTALL ADDITIONAL EROSION CONTROL STRUCTURES AS DIRECTED BY THE ENVIRONMENTAL INSPECTOR.
11. INSTALLATION: THE PIPE SECTION FOR THE DRILLED CROSSING SHALL BE MADE UP WITHIN THE APPROVED CONSTRUCTION RIGHT-OF-WAY AT THE DRILL EXIT POINT AS SHOWN. AFTER THE PILOT HOLE IS COMPLETE, CONTRACTOR'S ACTUAL DRILL PROFILE SHALL BE SUBMITTED TO DAKOTA ACCESS, LLC FOR APPROVAL. CONTRACTOR SHALL ASSESS THE NEED FOR AND SUPPLY APPROPRIATE BALLAST DURING PULLBACK.
12. DRILLING FLUID DISPOSAL: CONTRACTOR SHALL DISPOSE OF EXCESS DRILLING FLUID AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS. UNDER NO CIRCUMSTANCES SHALL DRILLING FLUID BE DISPOSED OF IN WATER BODIES OR WETLANDS. ANY DRILLING FLUID WHICH INADVERTENTLY SURFACES AT POINTS OTHER THAN THE ENTRY OR EXIT POINTS SHALL BE CONTAINED AND COLLECTED TO THE EXTENT PRACTICAL AND DISPOSED OF AS DIRECTED BY THE COMPANY REPRESENTATIVE IN ACCORDANCE WITH PERMIT CONDITIONS.
13. CLEANUP/STABILIZATION/RESTORATION: ALL DISTURBED AREAS SHALL BE RETURNED TO THE ORIGINAL CONTOURS. DISTURBED AREAS SHALL BE SEEDED AS SPECIFIED IN THE CLEAN-UP AND RESTORATION REQUIREMENTS. IF THE TERRAIN ALLOWS AND ACCESS IS PERMITTED, CONTRACTOR SHALL UTILIZE LOW GROUND PRESSURE EQUIPMENT OR OTHER EQUIPMENT APPROVED BY OWNER, TO FACILITATE CONTAINMENT AND CLEAN-UP OF ANY INADVERTENT RETURNS THAT OCCUR DURING THE HDD INSTALLATION PROCESS.
14. GEOTECHNICAL DATA: BORE HOLES ARE OFFSET FROM THE PIPELINE CENTERLINE AS SHOWN ON THE PLAN VIEW. THE GEOTECHNICAL INFORMATION PROVIDED ON THIS DRAWING IS A GENERAL SUMMARY. REFER TO THE APPLICABLE GEOTECHNICAL REPORT IN THE CONTRACT DOCUMENTS FOR MORE DETAILED INFORMATION.
15. AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO © 2015, LICENSED TO GEOENGINEERS, INC., IMAGE DATED 09/14/11. GROUND SURFACE DEM (1/3 ARC SECOND) DOWNLOADED FROM HTTP://VIEWER.NATIONALMAP.GOV/VIEWER/. GROUND SURFACE SURVEY PROVIDED BY WOOD GROUP MUSTANG, INC.
16. SHAPE FILES PROVIDED BY CONTRACT LAND STAFF, LLC.

REFERENCES	
DRAWING NUMBER	REFERENCE DRAWING TITLE

REVISIONS					
NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
A	ISSUED FOR BID	BTL	06/12/15	MAM	JLR
B	ISSUED FOR BID	MWC	06/12/15	MAM	JLR
C	ISSUED FOR BID	TJB	06/26/15	MAM	JLR
D	ISSUED FOR BID	TJB	08/14/15	MAM	JLR

CGM Design	04/09/15 Date
MWC Drawn	04/09/15 Date
MAM Checked	04/14/15 Date
JLR Approved	04/14/15 Date

GEOENGINEERS
3050 South Delaware
Springfield, MO 65804
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DAKOTA ACCESS PIPELINE PROJECT
SITE PLAN AND PROFILE
PROPOSED 30" PIPELINE
KASKASKIA RIVER HDD
FAYETTE COUNTY, ILLINOIS

Project No. 18782-011-01
Drawing No. W_29004_C100078
Sheet 1 of 2

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DATUM:
HORIZONTAL: NAD83 with UTM Datum, Zone 16, US Foot; Central Meridian 87° W
VERTICAL: NAVD 88

NOTE: THIS IS A FULL SIZE DRAWING THAT IS INTENDED TO BE PRINTED ON A 24" X 36" SHEET OF PAPER.

PLAN

200' 0 200'
SCALE IN FEET

ISSUED FOR BID

LEGEND
- BORING LOCATION
- MAJOR CONTOUR - 10' INTERVAL
- MINOR CONTOUR - 2' INTERVAL

NOTES:

1. ALL EQUIPMENT MUST ACCESS THE SITE ALONG THE CONSTRUCTION RIGHT-OF-WAY OR FROM APPROVED ACCESS ROADS.
2. AERIAL IMAGE TAKEN FROM GOOGLE EARTH PRO © 2015, LICENSED TO GEOENGINEERS, INC., IMAGE DATED 09/14/11. GROUND SURFACE DEM (1/3 ARC SECOND) DOWNLOADED FROM HTTP://VIEWER.NATIONALMAP.GOV/VIEWER/.
3. SHAPE FILES PROVIDED BY CONTRACT LAND STAFF, LLC.

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REFERENCES

DRAWING NUMBER	REFERENCE DRAWING TITLE

REVISIONS

NO.	DESCRIPTION	BY	DATE	CHK'D	APP'D
A	ISSUED FOR BID	BTL	06/12/15	MAM	JLR
B	ISSUED FOR BID	MWC	06/12/15	MAM	JLR
C	ISSUED FOR BID	TJB	06/26/15	MAM	JLR
D	ISSUED FOR BID	TJB	08/14/15	MAM	JLR

CGM Design	04/09/15 Date
MWC Drawn	04/09/15 Date
MAM Checked	04/14/15 Date
JLR Approved	04/14/15 Date

GEOENGINEERS
3050 South Delaware
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DAKOTA ACCESS PIPELINE PROJECT
STRINGING WORKSPACE

PROPOSED 30" PIPELINE
KASKASKIA RIVER HDD
FAYETTE COUNTY, ILLINOIS

Project No. 18782-011-01
Drawing No. W_29004_C100079
Sheet 2 of 2

HDD Design Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Design Parameters

Pipe Diameter = 30.000 in
Pipe Material = Steel
Yield Stress = 70,000 psi
Wall Thickness = 0.625 in
Assumed Installation Temp = 70 °F
Assumed Operating Temp= 100 °F
Design Factor = 0.5
MAOP = 1,440 psi

Drill Data Box

Point	Station (ft)	Elevation (ft)
ENTRY @ 10°	5,139.56	456.96
P C 1 (10.28° @ 3,000 ft R.)	5,077.22	445.97
P T 1	4,541.62	400.43
P C 2 (7.72° @ 3,000 ft R.)	1,535.88	415.12
P T 2	1,133.02	444.28
EXIT @ 8°	979.56	465.85

Horizontal Alignment Length = 4,160.00 ft

Profile Segment Information

Segment Name	Segment Type	Segment Length (ft)
Entry Tangent	Straight	63.30
Entry Curve	Vertical Curve	538.26
Bottom Tangent	Straight	3,005.77
Exit Curve	Vertical Curve	404.22
Exit Tangent	Straight	154.97

Pipe Length = 4,166.52 ft

Installation Load Summary

Drilling Fluid Weight (lb/gal)	Buoyancy Condition	Buoyancy Control (lb/ft)	Effective Pipe Weight (lb/ft)	Total Installation Force (lb)
9.50	Empty	0.00	-152.27	469,000
9.50	Full	281.31	129.04	374,000
12.00	Empty	0.00	-244.07	596,000
12.00	Full	281.31	37.24	284,000
10.00	Neutral	170.63	0.00	257,000

GeoEngineers

Minimum Radius Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Design Parameters:

Pipe Diameter = 30.000 in **MAOP =** 1,440 psi **Factor of Safety =** 2.00

Wall Thickness = 0.625 in **SMYS =** 70,000 psi

D/t Ratio = 48.00 **Modulus of Elasticity (E) =** 2.93E+007 psi

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 34,560 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 17,280 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 35,000 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 17,720 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 2,046 ft

GeoEngineers

Operating Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Design Parameters

Pipe diameter =	30.000 in	**Minimum Radius of Curvature =**	2,050 ft
Wall Thickness =	0.625 in	**Coefficient of Thermal Expansion =**	6.5E-06 in/in/°F
SMYS =	70,000 psi	**Assumed Installation Temperature =**	70 °F
MAOP =	1,440 psi	**Assumed Operating Temperature =**	100 °F
Poissons's Ratio =	0.30	**Temperature Derating Factor =**	1.00
Young's Modulus (E) =	2.93E+007 psi	**Groundwater Table Head =**	0.00 ft
Design Factor =	0.5		

Stress Analyses

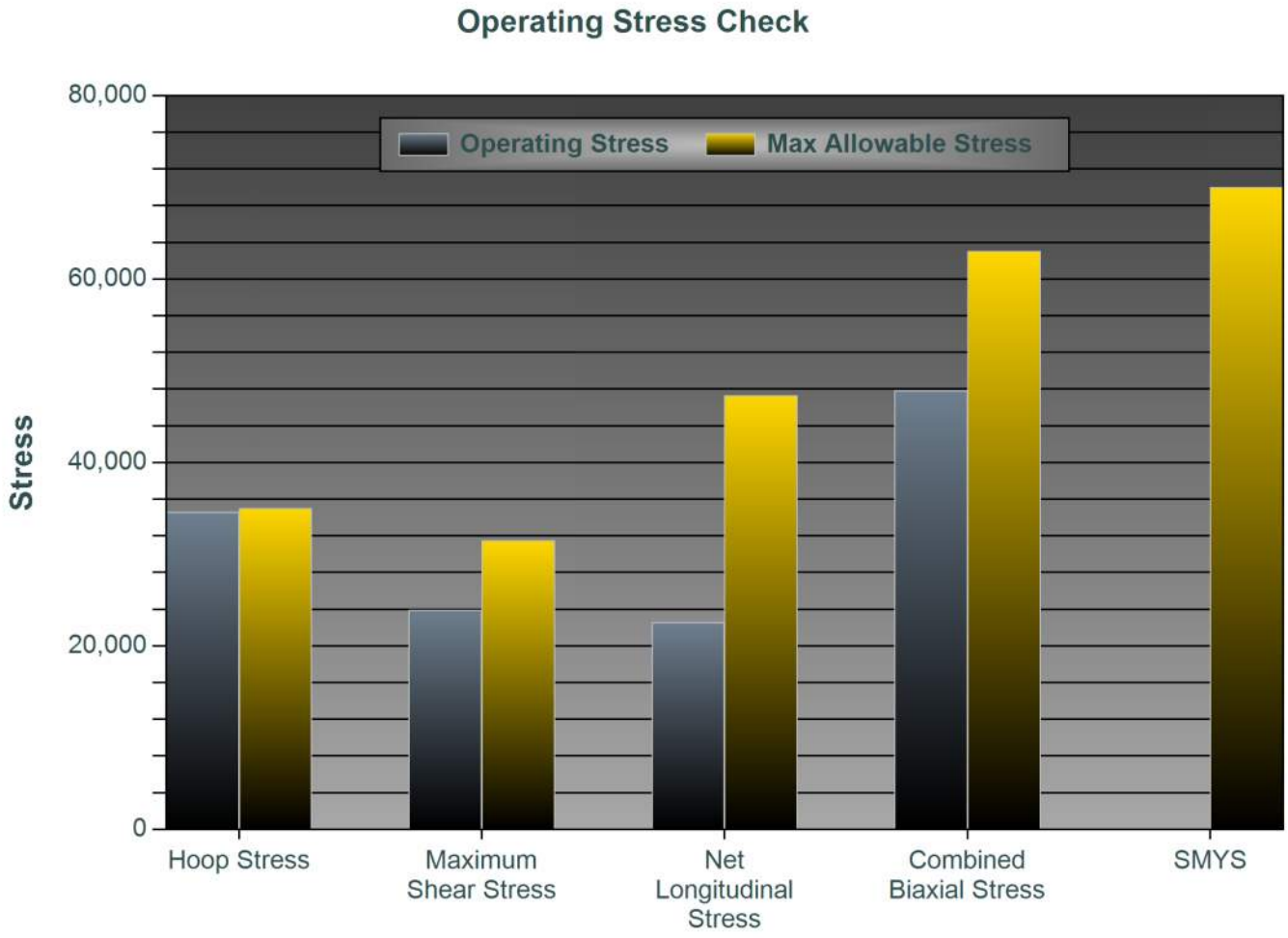
Longitudinal Stress from Bending =	17,893 psi	
Percent SMYS =	25.56 %	
Hoop Stress =	34,560 psi	
Percent SMYS =	49.37 %	Limited by Design Factor (0.5) according to 49 CFR 195.106
Longitudinal Tensile Stress from Hoop Stress =	10,368 psi	
Percent SMYS =	14.81 %	
Longitudinal Stress from Thermal Expansion =	-5,722 psi	
Percent SMYS =	8.17 %	Limited to 90% SMYS by ASME/ANSI B31.4 section 402.3.2
Net Longitudinal Stress (Comp. side of Curve) =	-13,247 psi	
Percent SMYS =	18.92 %	Limited to 67.5% SMYS by ASME/ANSI B31.4 section 402.3.2
Net Longitudinal Stress (Tension side of Curve) =	22,539 psi	
Percent SMYS =	32.20 %	Limited to 67.5% SMYS by ASME/ANSI B31.4 section 402.3.2
Maximum Shear Stress =	23,903 psi	
Percent SMYS =	34.15 %	Limited to 45% SMYS by ASME/ANSI B31.4 section 402.3.1
Combined BiaxialSress Check =	47,807 psi	
Percent SMYS =	68.30 %	Limited to 90% SMYS by AMSE/ANSI B31.4 section 402.3.2

GeoEngineers

Operating Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015



Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,167 ft
Moment of Inertia =	6,224 in^4
Pipe Face Area =	57.68 in^2
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	4.91 ft^3/ft
Displaced Fluid Weight =	348.84 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	-152.27 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	154.97 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	8,763 lb
Friction Force =	7,010 lb
Segment Weight =	3,284 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	19,058 lb
Cumulative Force =	**19,058 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	330 psi	
Cumulative Axial Stress =	330 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	255 psi	7,384 psi
Combined Stress =	0.0059	< 1.0
Total Stress =	0.0013	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	7.72 deg
Segment Length =	404.22 ft	Center Displacement =	6.81 ft

Segment Force Components

Normal Force =	47,982 lb
Drag Force =	22,858 lb
Friction Force =	14,395 lb
Segment Weight =	4,444 lb
Tension =	75,148 lb
Average Tension =	47,103 lb
Segment Force =	56,091 lb
Cumulative Force =	**75,148 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	972 psi	
Cumulative Axial Stress =	1,303 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	601 psi	7,384 psi
Combined Stress =	0.4102	< 1.0
Total Stress =	0.1342	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	3,005.77 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	169,972 lb
Friction Force =	137,309 lb
Segment Weight =	2,237 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	309,518 lb
Cumulative Force =	**384,667 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	5,366 psi	
Cumulative Axial Stress =	6,669 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	775 psi	7,384 psi
Combined Stress =	0.1191	< 1.0
Total Stress =	0.0307	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	10.28 deg
Segment Length =	538.26 ft	Center Displacement =	12.06 ft

Segment Force Components

Normal Force =	94,485 lb
Drag Force =	30,438 lb
Friction Force =	28,346 lb
Segment Weight =	-7,343 lb
Tension =	464,453 lb
Average Tension =	424,560 lb
Segment Force =	79,786 lb
Cumulative Force =	**464,453 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,383 psi	
Cumulative Axial Stress =	8,053 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	775 psi	7,384 psi
Combined Stress =	0.5308	< 1.0
Total Stress =	0.2444	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	63.30 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	3,580 lb
Friction Force =	2,848 lb
Segment Weight =	-1,674 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	4,754 lb
Cumulative Force =	**469,206 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	82 psi	
Cumulative Axial Stress =	8,135 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	235 psi	7,384 psi
Combined Stress =	0.1453	< 1.0
Total Stress =	0.0243	< 1.0

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Installation Case:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,167 ft
Moment of Inertia =	6,224 in⁴
Pipe Face Area =	57.68 in²
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	4.91 ft³/ft
Displaced Fluid Weight =	348.84 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	129.04 lb/ft

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full

Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	154.97 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	8,763 lb
Friction Force =	5,941 lb
Segment Weight =	-2,783 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	11,921 lb
Cumulative Force =	**11,921 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	207 psi	
Cumulative Axial Stress =	207 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	31 psi	7,384 psi
Combined Stress =	0.0037	< 1.0
Total Stress =	0.0000	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	7.72 deg
Segment Length =	404.22 ft	Center Displacement =	6.81 ft

Segment Force Components

Normal Force =	-23,824 lb
Drag Force =	22,858 lb
Friction Force =	7,147 lb
Segment Weight =	-3,766 lb
Tension =	45,308 lb
Average Tension =	28,614 lb
Segment Force =	33,387 lb
Cumulative Force =	**45,308 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	579 psi	
Cumulative Axial Stress =	786 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	73 psi	7,384 psi
Combined Stress =	0.4010	< 1.0
Total Stress =	0.1104	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	3,005.77 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	169,972 lb
Friction Force =	116,356 lb
Segment Weight =	-1,895 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	284,433 lb
Cumulative Force =	**329,740 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	4,931 psi	
Cumulative Axial Stress =	5,717 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	94 psi	7,384 psi
Combined Stress =	0.1021	< 1.0
Total Stress =	0.0112	< 1.0

Installation Load Calculations

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	10.28 deg
Segment Length =	538.26 ft	Center Displacement =	12.06 ft

Segment Force Components

Normal Force =	60 lb
Drag Force =	30,438 lb
Friction Force =	18 lb
Segment Weight =	6,222 lb
Tension =	366,437 lb
Average Tension =	348,088 lb
Segment Force =	36,696 lb
Cumulative Force =	**366,437 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	636 psi	
Cumulative Axial Stress =	6,353 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	95 psi	7,384 psi
Combined Stress =	0.5004	< 1.0
Total Stress =	0.1870	< 1.0

Installation:9.50 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	63.30 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	3,580 lb
Friction Force =	2,413 lb
Segment Weight =	1,418 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	7,411 lb
Cumulative Force =	**373,848 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	128 psi	
Cumulative Axial Stress =	6,482 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	29 psi	7,384 psi
Combined Stress =	0.1157	< 1.0
Total Stress =	0.0136	< 1.0

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty

Product Pipe Parameters	
Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,167 ft
Moment of Inertia =	6,224 in⁴
Pipe Face Area =	57.68 in²
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	4.91 ft³/ft
Displaced Fluid Weight =	440.64 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	-244.07 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	154.97 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	8,763 lb
Friction Force =	11,237 lb
Segment Weight =	5,264 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	25,264 lb
Cumulative Force =	**25,264 lb**

Segment Installation Stress Checks		
Stress Component	Calculated	Allowable
Segment Axial Stress =	438 psi	
Cumulative Axial Stress =	438 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	323 psi	7,384 psi
Combined Stress =	0.0078	< 1.0
Total Stress =	0.0021	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	7.72 deg
Segment Length =	404.22 ft	Center Displacement =	6.81 ft

Segment Force Components

Normal Force =	71,888 lb
Drag Force =	22,858 lb
Friction Force =	21,566 lb
Segment Weight =	7,123 lb
Tension =	98,377 lb
Average Tension =	61,820 lb
Segment Force =	73,113 lb
Cumulative Force =	**98,377 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,268 psi	
Cumulative Axial Stress =	1,706 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	759 psi	7,384 psi
Combined Stress =	0.4174	< 1.0
Total Stress =	0.1467	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	3,005.77 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	169,972 lb
Friction Force =	220,087 lb
Segment Weight =	3,585 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	393,645 lb
Cumulative Force =	**492,022 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	6,825 psi	
Cumulative Axial Stress =	8,531 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	979 psi	7,384 psi
Combined Stress =	0.1523	< 1.0
Total Stress =	0.0496	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	10.28 deg
Segment Length =	538.26 ft	Center Displacement =	12.06 ft

Segment Force Components

Normal Force =	133,398 lb
Drag Force =	30,438 lb
Friction Force =	40,019 lb
Segment Weight =	-11,770 lb
Tension =	590,729 lb
Average Tension =	541,375 lb
Segment Force =	98,707 lb
Cumulative Force =	**590,729 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	1,711 psi	
Cumulative Axial Stress =	10,242 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	979 psi	7,384 psi
Combined Stress =	0.5699	< 1.0
Total Stress =	0.2966	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Empty — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	63.30 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	3,580 lb
Friction Force =	4,565 lb
Segment Weight =	-2,683 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	5,461 lb
Cumulative Force =	**596,190 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	95 psi	
Cumulative Axial Stress =	10,337 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	297 psi	7,384 psi
Combined Stress =	0.1846	< 1.0
Total Stress =	0.0391	< 1.0

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Installation Case:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full

Product Pipe Parameters

Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,167 ft
Moment of Inertia =	6,224 in^4
Pipe Face Area =	57.68 in^2
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations

Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft^3
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft^3
Pipe Exterior Volume =	4.91 ft^3/ft
Displaced Fluid Weight =	440.64 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft^3/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft^3
Effective Weight of Pipe =	37.24 lb/ft

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	154.97 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	8,763 lb
Friction Force =	1,714 lb
Segment Weight =	-803 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	9,674 lb
Cumulative Force =	**9,674 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	168 psi	
Cumulative Axial Stress =	168 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	98 psi	7,384 psi
Combined Stress =	0.0030	< 1.0
Total Stress =	0.0002	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	7.72 deg
Segment Length =	404.22 ft	Center Displacement =	6.81 ft

Segment Force Components

Normal Force =	-1,450 lb
Drag Force =	22,858 lb
Friction Force =	435 lb
Segment Weight =	-1,087 lb
Tension =	32,316 lb
Average Tension =	20,995 lb
Segment Force =	22,641 lb
Cumulative Force =	**32,316 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	393 psi	
Cumulative Axial Stress =	560 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	231 psi	7,384 psi
Combined Stress =	0.3970	< 1.0
Total Stress =	0.1119	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	3,005.77 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	169,972 lb
Friction Force =	33,578 lb
Segment Weight =	-547 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	203,003 lb
Cumulative Force =	**235,319 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	3,520 psi	
Cumulative Axial Stress =	4,080 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	298 psi	7,384 psi
Combined Stress =	0.0729	< 1.0
Total Stress =	0.0083	< 1.0

Installation Load Calculations

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	10.28 deg
Segment Length =	538.26 ft	Center Displacement =	12.06 ft

Segment Force Components

Normal Force =	19,324 lb
Drag Force =	30,438 lb
Friction Force =	5,797 lb
Segment Weight =	1,796 lb
Tension =	279,147 lb
Average Tension =	257,233 lb
Segment Force =	43,828 lb
Cumulative Force =	**279,147 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	760 psi	
Cumulative Axial Stress =	4,840 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	299 psi	7,384 psi
Combined Stress =	0.4734	< 1.0
Total Stress =	0.1709	< 1.0

Installation:12.00 lb/gal Drilling Fluid With the Pipe Annulus Full — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	63.30 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	3,580 lb
Friction Force =	696 lb
Segment Weight =	409 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	4,685 lb
Cumulative Force =	**283,832 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	81 psi	
Cumulative Axial Stress =	4,921 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	91 psi	7,384 psi
Combined Stress =	0.0879	< 1.0
Total Stress =	0.0084	< 1.0

Installation Load Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Installation Case:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy

Product Pipe Parameters	
Pipe Diameter =	30.000 in
Wall Thickness =	0.625 in
SMYS =	70,000 psi
Young's Modulus =	2.90E+007 psi
Total Pipe Length =	4,167 ft
Moment of Inertia =	6,224 in⁴
Pipe Face Area =	57.68 in²
D/t Ratio =	48.00
Poisson Ratio =	0.30
Coefficient of Soil Friction =	0.30
Fluid Drag Coefficient =	0.05

Effective Weight Calculations	
Total Empty Pipe Weight In Air=	196.56 lb/ft
Pipe Interior Volume =	4.51 ft³
Coating Thickness =	0.00 in
Coating Density =	0.00 lb/ft³
Pipe Exterior Volume =	4.91 ft³/ft
Displaced Fluid Weight =	367.20 lb/ft
B.C. Line(s) Weight =	0.00 lb/ft
B.C. Line(s) Volume =	0.00 ft³/ft
Unit Weight of B.C. Fluid =	62.40 lb/ft³
Effective Weight of Pipe =	0.00 lb/ft

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 1 of 5

Segment Parameters

Segment Name =	Exit Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	154.97 ft	Center Displacement =	0.00 ft

Segment Force Components	
Normal Force =	0 lb
Drag Force =	8,763 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	8,763 lb
Cumulative Force =	**8,763 lb**

Segment Installation Stress Checks		
Stress Component	Calculated	Allowable
Segment Axial Stress =	152 psi	
Cumulative Axial Stress =	152 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	269 psi	7,384 psi
Combined Stress =	0.0027	< 1.0
Total Stress =	0.0013	< 1.0

Installation Load Calculations

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 2 of 5

Segment Parameters

Segment Name =	Exit Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	7.72 deg
Segment Length =	404.22 ft	Center Displacement =	6.81 ft

Segment Force Components

Normal Force =	8,037 lb
Drag Force =	22,858 lb
Friction Force =	2,411 lb
Segment Weight =	0 lb
Tension =	36,443 lb
Average Tension =	22,603 lb
Segment Force =	27,680 lb
Cumulative Force =	**36,443 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	480 psi	
Cumulative Axial Stress =	632 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	632 psi	7,384 psi
Combined Stress =	0.3983	< 1.0
Total Stress =	0.1272	< 1.0

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 3 of 5

Segment Parameters

Segment Name =	Bottom Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	3,005.77 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	169,972 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	169,972 lb
Cumulative Force =	**206,416 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	2,947 psi	
Cumulative Axial Stress =	3,579 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	816 psi	7,384 psi
Combined Stress =	0.0639	< 1.0
Total Stress =	0.0192	< 1.0

Installation Load Calculations

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 4 of 5

Segment Parameters

Segment Name =	Entry Curve	Radius of Curvature =	3,000 ft
Segment Type =	Vertical Curve	Angle Turned =	10.28 deg
Segment Length =	538.26 ft	Center Displacement =	12.06 ft

Segment Force Components

Normal Force =	28,324 lb
Drag Force =	30,438 lb
Friction Force =	8,497 lb
Segment Weight =	0 lb
Tension =	253,848 lb
Average Tension =	230,132 lb
Segment Force =	47,432 lb
Cumulative Force =	**253,848 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	822 psi	
Cumulative Axial Stress =	4,401 psi	56,000 psi
Bending Stress =	17,683 psi	45,696 psi
Hoop Stress =	816 psi	7,384 psi
Combined Stress =	0.4656	< 1.0
Total Stress =	0.1877	< 1.0

Installation:10.00 lb/gal Drilling Fluid With Neutral Pipe Buoyancy — Segment 5 of 5

Segment Parameters

Segment Name =	Entry Tangent	Radius of Curvature =	0 ft
Segment Type =	Straight	Angle Turned =	0.00 deg
Segment Length =	63.30 ft	Center Displacement =	0.00 ft

Segment Force Components

Normal Force =	0 lb
Drag Force =	3,580 lb
Friction Force =	0 lb
Segment Weight =	0 lb
Tension =	0 lb
Average Tension =	0 lb
Segment Force =	3,580 lb
Cumulative Force =	**257,428 lb**

Segment Installation Stress Checks

Stress Component	Calculated	Allowable
Segment Axial Stress =	62 psi	
Cumulative Axial Stress =	4,463 psi	56,000 psi
Bending Stress =	0 psi	45,696 psi
Hoop Stress =	248 psi	7,384 psi
Combined Stress =	0.0797	< 1.0
Total Stress =	0.0087	< 1.0

Overbend Radius Calculations

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Design Parameters:

Pipe Diameter = 30.000 in **MAOP =** 0 psi **Factor of Safety =** 1.50

Wall Thickness = 0.625 in **SMYS =** 70,000 psi

D/t Ratio = 48.00 **Modulus of Elasticity (E) =** 2.93E+007 psi

Hoop Stress:

Calculated Hoop Stress = (MAOP * Pipe Diameter) / (2 * Wall Thickness) = 0 psi

Longitudinal Stress:

Calculated Longitudinal Stress = Hoop Stress / 2 = 0 psi

Allowable Stress:

Calculated Allowable Stress = SMYS / Factor of Safety = 46,667 psi

Bending Stress:

Calculated Bending Stress = Allowable Stress - Longitudinal Stress = 46,667 psi

Minimum Radius:

Calculated Minimum Radius = (E * Pipe Diameter) / (2 * Bending Stress) = 777 ft

GeoEngineers

Overbend Stress Summary

Project Name: Dakota Access Pipeline Project **HDD Name:** Kaskaskia River HDD **Owner:** Dakota Access, LLC.

Project No: 18782-011-01 **By:** CGM **Ck'd By:** MAM **Location:** Fayette County, Illinois **Date:** Friday, June 19, 2015

Design Parameters

Pipe diameter = 30.000 in

Wall Thickness = 0.625 in

SMYS = 70,000 psi

Internal Pressure = 0 psi

Poissons's Ratio = 0.30

Young's Modulus (E) = 2.93E+007 psi

Factor of Safety = 1.50

Overbend Radius of Curvature = 777 ft

Assumed Installation Temperature = 70 °F

Stress Analyses

Longitudinal Stress from Bending = 47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Hoop Stress = 0 psi

Percent SMYS = 0 %

Longitudinal Tensile Stress from Hoop Stress = 0 psi

Percent SMYS = 0 %

Longitudinal Stress from Thermal Expansion = 0 psi

Percent SMYS = 0 %

Net Longitudinal Stress (Comp. side of Curve) = -47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Net Longitudinal Stress (Tension side of Curve) = 47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Maximum Shear Stress = 23,610 psi

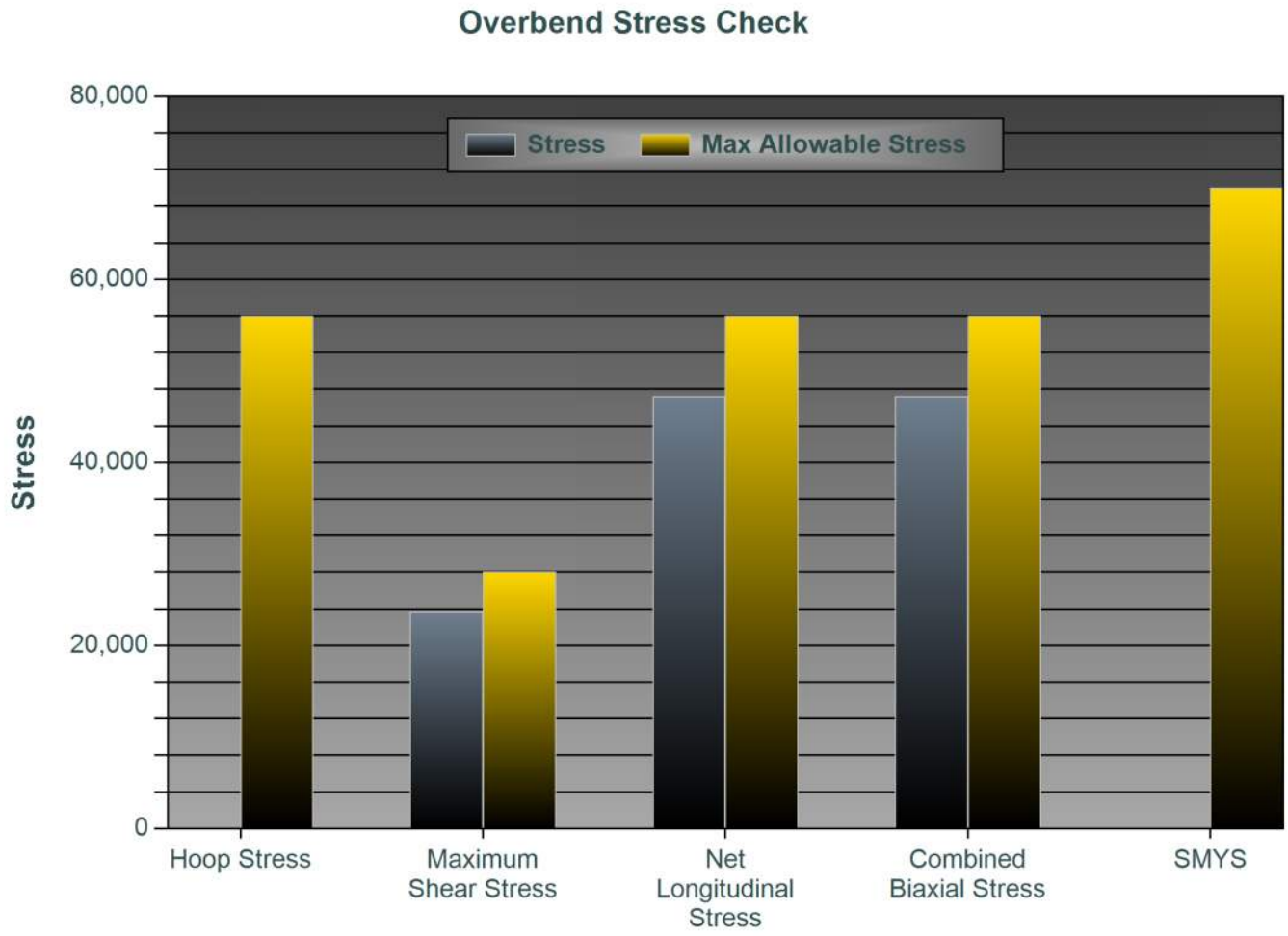
Percent SMYS = 33.73 % Limited to 40% SMYS

Combined Biaxial Stress Check = 47,221 psi

Percent SMYS = 67.46 % Limited to 80% SMYS

Overbend Stress Summary

Project Name:	Dakota Access Pipeline Project	**HDD Name:**	Kaskaskia River HDD	**Owner:**	Dakota Access, LLC.
Project No:	18782-011-01 **By:** CGM **Ck'd By:** MAM	**Location:**	Fayette County, Illinois	**Date:**	Friday, June 19, 2015



APPENDIX B
Geotechnical Data Report

Geotechnical Data Report

Dakota Access Pipeline Project
Kaskaskia River HDD
Fayette County, Illinois

for
Dakota Access, LLC

June 19, 2015

GeoEngineers

3050 South Delaware Avenue
Springfield, Missouri 65804
417.831.9700

Geotechnical Data Report

Dakota Access Pipeline Project
Kaskaskia River HDD
Fayette County, Illinois

File No. 18782-011-01

June 19, 2015

Prepared for:

Dakota Access, LLC
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1.0 INTRODUCTION

At the request of Dakota Access, LLC (Dakota Access), and in general accordance with our contract agreement (No. 07-PSA-0017), GeoEngineers, Inc. (GeoEngineers) is pleased to submit this geotechnical data report for the proposed Dakota Access Pipeline (DAPL) Project Kaskaskia River Horizontal Directional Drill (HDD) near DAPL Milepost (MP) 1,011 in Fayette County, Illinois. The general location of the proposed HDD along with the proposed DAPL pipeline route in the area is noted on the attached Vicinity Map, Figure 1.

We understand that Dakota Access is proposing to construct approximately 1,020 miles of 30-inch-diameter steel pipeline extending from Mountrail County, North Dakota through eastern South Dakota, Central Iowa, and terminating in Wayne County, Illinois. The proposed Kaskaskia River HDD would cross beneath the Kaskaskia River and a delineated wetland in Fayette County, Illinois. The conceptual plan and profile of the proposed HDD along with the conceptual HDD stringing area are shown in the attached Conceptual Site Plan and Profile and Conceptual Stringing Workspace drawings, Figures 2A and 2B, respectively.

This final geotechnical data report follows up and supersedes our previously-provided geotechnical data report (Dakota Access Pipeline Project, Geotechnical Data Report, Kaskaskia River HDD, dated January 28, 2015). The purpose of this revision is to provide the details and results of the additional geotechnical exploration and laboratory testing program performed to further characterize the subsurface conditions in the area of the proposed HDD crossing. Our geotechnical services included completing a subsurface soil exploration program by drilling one additional boring near the proposed trenchless crossing alignment located roughly 400 feet north of the previous proposed trenchless crossing alignment and preparing this final geotechnical data report.

2.0 SCOPE OF SERVICES

The purpose of our services was to evaluate the existing surface and subsurface soil and groundwater conditions and to prepare a geotechnical data report. The specific scope of services provided by GeoEngineers included the following:

1. Contacted the Illinois “One-Call” utility locating agency to locate utilities in the project area prior to the start of the exploratory borings.
2. Explored subsurface conditions by drilling five borings to depths of up to approximately 80 feet below ground surface (bgs) using hollow stem auger, mud rotary, and NQ-sized rock coring drilling techniques. GeoEngineers’ field staff directed the drilling completed Geotechnology, Inc. using All-Terrain-Vehicle (ATV) mounted drilling equipment.
3. Obtained soil and rock samples at representative intervals from the borings, and:
    - Classified the soil and rock encountered in the borings in general accordance with ASTM International (ASTM) D2488 and ASTM D5878, respectively; and
    - Observed groundwater conditions encountered in the borings, where possible.
4. Completed a laboratory-testing program on selected soil and rock samples obtained from the borings to evaluate pertinent engineering properties. The tests included the following:

- moisture content (ASTM D2216);
- Atterberg limits determination (ASTM D4318);
- Particle-size (sieve) analysis (ASTM D422); and
- unconfined compressive strength of rock (ASTM D7012).

5. Prepared logs of the borings which included the following:
    - SPT values as an indication of in-situ soil density;
    - Index and classification properties of soil and rock, as applicable;
    - Rock quality designation (RQD,) percent recovery, and Mohs hardness; and
    - Other soil, rock, and groundwater properties as applicable.
6. Prepared and submitted to Dakota Access this data report summarizing the results of the geotechnical investigation.

3.0 SITE DESCRIPTION

3.1. Geology

3.1.1. Regional Geologic Setting

In the area of the Kaskaskia River, and stretching back west along the proposed DAPL alignment, the alignment crosses the Springfield Plain subsection of the Till Plains section. The Springfield Plain includes the level portion of the Illinoian drift-sheet in central and south-central Illinois. It is distinguished mainly by its flatness and by shallow entrenchment of drainage as compared with the more sharply incised valleys of the Galesburg Plain located to the northwest. Although the greater part of the district is a flat till plain, the morainic features in the western part of the region are much more conspicuous than elsewhere on the Illinoian drift-sheet. The moraines are low and broad, but they are readily recognized because of their continuity and the associated kames and kame terraces. Drainage systems are well developed, and the district as a whole is in a late youthful stage of dissection. The uplands are low with respect to the master streams, and the valleys are relatively shallow. Most of the principal streams have low gradients and occupy broad alluviated and terraced valleys; the secondary tributaries have wide V-shaped valleys; and the headwaters, flowing essentially on the till plain, have broad shallow valleys and low gradients. The Illinoian drift is moderately thick and is underlain by older drift except in areas where the bedrock is close to the surface. Only the larger valleys and uplands of the bedrock surface are reflected in the present topography. Along the southeast side of the Illinois Valley there is a belt of thick loess, with dune-contours characterizing the bluff-margin, but this body of loess thins rapidly to the southeast (Leighton et al., 1948).

3.1.2. Site Geology

Geologic mapping indicates that Quarternary Age (2.6 million years to present) Cahokia alluvium is present at the Kaskaskia River HDD site, within floodplain of the Kaskaskia River. The Cahokia consists mostly of poorly sorted sand, silt or clay containing local deposits of sandy gravel. In many places the Cahokia overlies well-sorted glacial outwash of the Henry Formation. The Vandalia Member of the Glasford Formation may be encountered beneath the alluvium, consisting of hard, compact sandy till with sand and gravel. Mapping indicates the total thickness of till above bedrock ranges from 50 to 200 feet at the Kaskaskia River HDD Site (Lineback, 1979).

Geologic mapping indicates that Pennsylvanian Age (318 to 299 million years ago) Bond Formation may also be encountered at depth. The Bond Formation consists primarily of limestone and sandstone with some coal (Kolata, 2005).

3.1.3. Surficial Soils

Mapping indicates the soil types likely to be encountered at the Kaskaskia River crossing site are primarily silt loam and silty clay loam residual from alluvium. Glacial deposits and bedrock as described above will likely to be encountered below these surficial soils (NRCS Soil Survey).

3.2. Surface Conditions

3.2.1. General

We evaluated the surface conditions in the vicinity of the proposed trenchless crossing during our geotechnical exploration program on October 28 through November 1, 2014, and April 27 through 28, 2015. Photographs of site surface conditions along the Kaskaskia River HDD alignment are included in the attached Site Photographs, Figure 3.

3.2.2. Surface Description

The proposed HDD alignment trends east to west (proposed entry to proposed exit), crossing beneath the Kaskaskia River and a delineated wetland as shown in the Conceptual Site Plan and Profile, Figure 2A. The conceptual entry point is located approximately 800 feet east of the Kaskaskia River, in an open relatively flat agricultural field, at an approximate elevation of 457 feet (North American Vertical Datum [NAVD] 88). Moving westward from the conceptual entry point, the ground surface along the proposed HDD alignment remains relatively flat as it approaches the east bank of the Kaskaskia River. From the west bank of the Kaskaskia River the ground surface continues westward remaining relatively flat before gradually rising in elevation toward the conceptual exit point in an open field at an approximate elevation of 466 feet NAVD 88. The conceptual HDD exit point is roughly 2,800 feet west of Kaskaskia River.

3.3. Subsurface Conditions

3.3.1. General

Subsurface conditions were explored at the site on October 28 through November 1, 2014, and April 27 through April 28, 2015, by drilling five (5) geotechnical borings (KSR-B-1 through KSR-B-5). The borings were drilled to depths of up to 80 feet bgs using ATV-mounted drilling equipment. In order to characterize the subsurface conditions for trenchless crossing design, the borings were drilled near the alignment of the proposed crossing.

Soil samples were generally obtained from the borings at 5-foot depth intervals using 1.5-inch inside-diameter (I.D.) split spoon samplers. Below the bedrock contact, rock core samples were obtained continuously using a 2-inch I.D. NQ core barrel. GeoEngineers staff managed the geotechnical explorations and logged the borings on a full-time basis. Soil and rock samples were visually classified and collected. Other pertinent drilling information was also documented. Laboratory tests, including moisture content determinations, sieve analyses, and rock core strength tests were completed on selected samples from the borings. A description of the field exploration and laboratory testing procedures, logs of the borings, and graphs and tables of our laboratory testing results are presented in Appendix A.

3.3.2. Subsurface Description

Boring KSR-B-1 was drilled on October 31 and November 1, 2014, with ATV-mounted drilling equipment to a depth of approximately 75 feet bgs. From the ground surface, the boring encountered approximately 8½ feet of medium stiff to stiff silt and sandy silt overlying approximately 40 feet of loose to very dense silty sand with varying amounts of gravel, 5 feet of very stiff sandy low plasticity clay, 5 feet of medium dense clayey sand, and 4½ feet of hard sandy low plasticity clay (weathered shale). Bedrock was encountered at approximately 63 feet bgs and continuous NQ-sized rock coring techniques were used to advance the boring to the termination depth at approximately 75 feet bgs. Rock encountered consisted primarily of very poor quality shale and poor to fair quality sandstone.

Boring KSR-B-2 was drilled on October 30 and October 31, 2014, with ATV-mounted drilling equipment to a depth of approximately 60 feet bgs. From the ground surface, the boring encountered approximately 6 feet of medium stiff silt overlying approximately 12½ feet of soft to medium stiff low plasticity clay, 10 feet of very loose to loose clayey sand, 5 feet of medium stiff sandy low plasticity clay, 5 feet of loose sand with clay, 5 feet of very dense clayey sand with gravel (glacial till), and roughly 10½ feet of hard sandy clay (decomposed shale). Bedrock was encountered at approximately 54 feet bgs and continuous NQ-sized rock coring techniques were used to advance the boring to the termination depth at approximately 60 feet bgs. Rock encountered consisted primarily of fair quality shale.

Boring KSR-B-3 was drilled on October 29, 2014, with ATV-mounted drilling equipment to a depth of approximately 59 feet bgs. From the ground surface, the boring encountered approximately 18½ feet of soft to medium stiff silt overlying approximately 1½ feet of very loose sand with silt, 6 feet of soft sandy silty clay, 7½ feet of medium dense sand with silt, 10 feet of loose to very dense sand, and roughly 15½ feet of hard sandy clay.

Boring KSR-B-4 was drilled on October 28, 2014, with ATV-mounted drilling equipment to a depth of approximately 60 feet bgs. From the ground surface, the boring encountered approximately 6 feet of medium stiff low plasticity clay overlying approximately 2½ feet of soft silty clay with sand, 5 feet of soft clay with sand, 10 feet of very loose to loose silty sand, 5 feet of medium dense sand with clay, 5 feet of medium dense sand with silt, 20 feet of very stiff to hard sandy clay, and roughly 6½ feet of very dense silty sand.

Boring KSR-B-5 was drilled on April 27 and April 28, 2015, with ATV-mounted drilling equipment to a depth of approximately 80 feet bgs. From the ground surface, the boring encountered approximately 13½ feet of soft to stiff low plasticity clay with varying amounts of sand overlying approximately 10 feet of very loose to medium dense sand with silt and gravel, 15 feet of soft to very stiff clayey silt with varying amounts of sand and gravel, and 20 feet of medium dense to dense silty sand with occasional gravel. Bedrock was encountered at approximately 58½ feet bgs and continuous NQ-sized rock coring techniques were used to advance the boring to the termination depth at approximately 80 feet bgs. Rock encountered consisted primarily of poor to fair quality shale, sandstone, and siltstone.

3.3.3. Groundwater Conditions

At the time of drilling, the groundwater level was observed at approximately 13 feet bgs in boring KSR-B-1, approximately 18 feet bgs in Boring KSR-B-2, and approximately 12 feet bgs in Boring KSR-B-4. Due to the drilling techniques used, the groundwater level can be difficult to measure and will also fluctuate over time due to seasonal variations in precipitation and the level of the Kaskaskia River.

4.0 LIMITATIONS

We have prepared this data report for use by Dakota Access, their authorized agents and other approved members of the design team involved with this project. The data report is not intended for use by others, and the information contained herein is not applicable to other sites. The data and report should be provided to prospective contractors, but our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions. A trenchless feasibility assessment for this location will be delivered separately with our conclusions and recommendations based on our subsurface exploration program, design recommendations are not covered in this data report.

Variations in subsurface conditions are possible between the explorations. Subsurface conditions may also vary with time. A contingency for unanticipated conditions should be included in the project budget and schedule for such an occurrence. We recommend that sufficient monitoring, testing and consultation be provided by GeoEngineers during construction to evaluate that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether earthwork and pipeline installation activities comply with contract plans and specifications.

The scope of our services does not include services related to construction safety precautions. Our recommendations are not intended to direct the contractor's methods, techniques, sequences or procedures, except as specifically described in our report for consideration in design.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in this area at the time the report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, express, written or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any attachments are only a copy of the original document. The original document is stored by GeoEngineers, and will serve as the official document of record.

Please refer to Appendix B, titled “Report Limitations and Guidelines for Use,” for additional information pertaining to use of this report.

5.0 REFERENCES

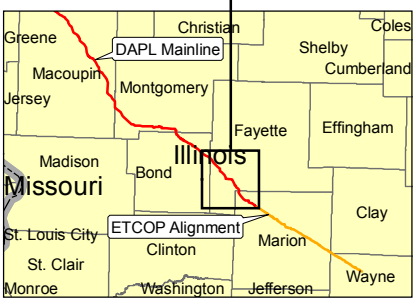
ASTM International. 2010. “Annual Book of ASTM Standards, Soil and Rock,” Volume 04.08.

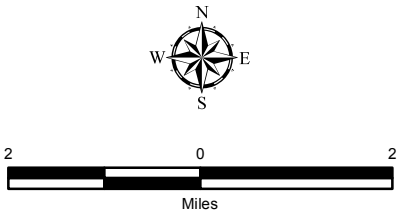
Kolata, D.R., 2005, “Bedrock Geology of Illinois,” Illinois State Geological Survey, Scale 1:500,000.

Leighton, M.M., Ekblaw, G.E. and Horberg, L., 1948, “Physiographic Divisions of Illinois,” Illinois State Geological Survey, Publication RI 129.

Lineback, J.A., 1979, “Quaternary Deposits of Illinois,” Illinois State Geological Survey, Scale 1:500,000.

National Cooperative Soil Survey, Natural Resources Conservation Service, United States Department of Agriculture, (http://websoilsurvey.nrcs.usda.gov).





Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
Data Sources: ESRI Data & Maps, Street Maps 2008.
Imagery from ESRI Data Online.
Projection: NAD 1983, UTM Zone 16 North.

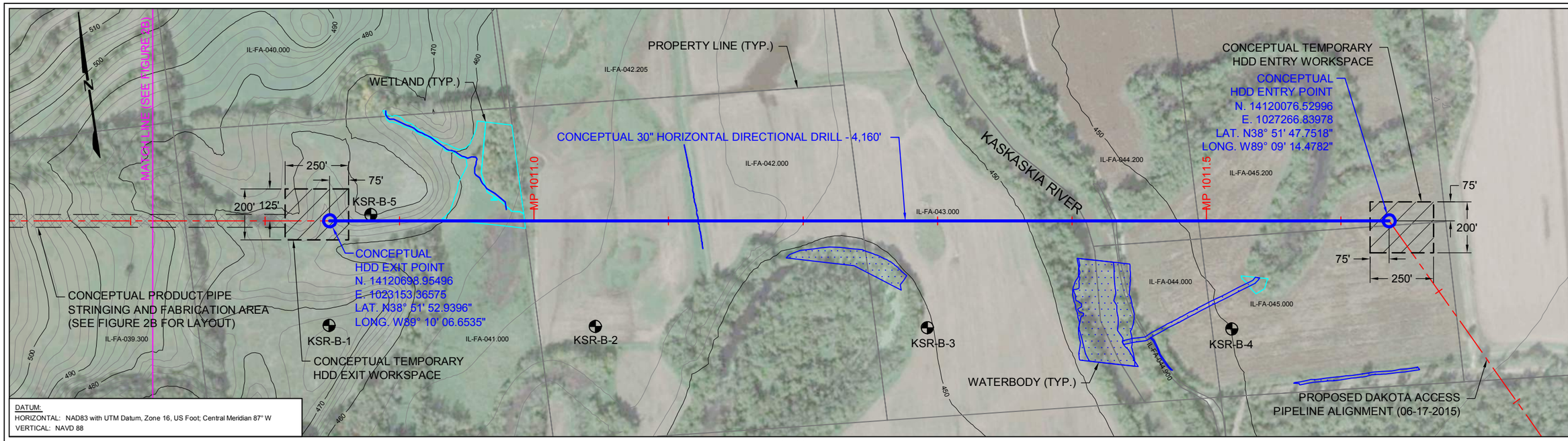
DAKOTA ACCESS PIPELINE PROJECT
VICINITY MAP

PROPOSED 30" PIPELINE
KASKASKIA RIVER HDD
FAYETTE COUNTY, ILLINOIS

GEOENGINEERS

Figure 1

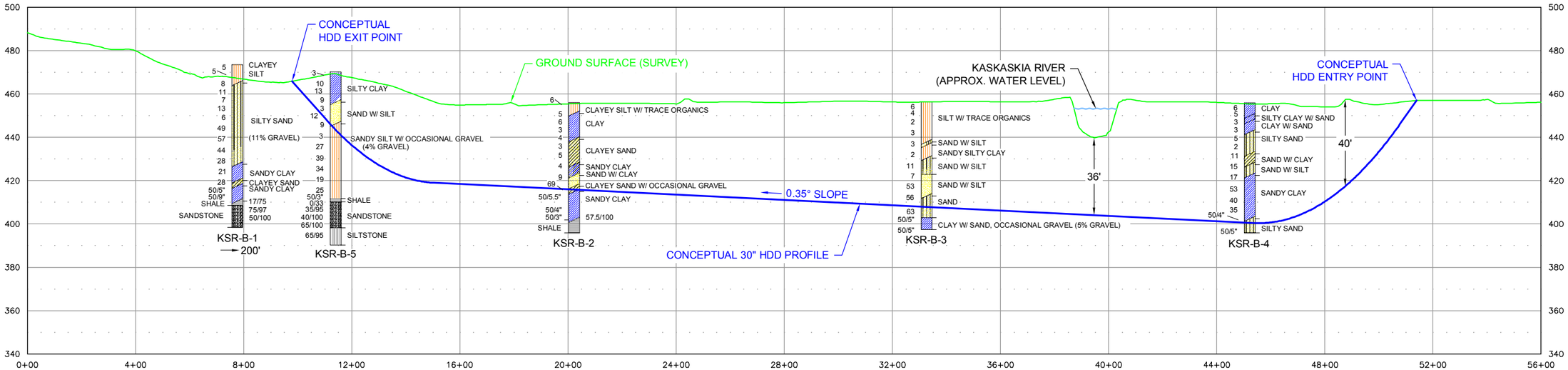
Office: SPR Path: P:\18\1878201101\GIS\Vicinity Maps\Illinois\Kaskaskia River HDD.mxd Map Revised: 17 June 2015 mclevenger



PLAN

400' 0 400'

SCALE IN FEET



PROFILE

400' 0 400'

HORIZONTAL SCALE IN FEET

50' 0 50'

VERTICAL SCALE IN FEET

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. Refer to the boring logs in the accompanying report for more detailed soil descriptions.
4. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Ground surface DEM (1/3 Arc Second) downloaded from http://NationalMap.Gov. Ground surface survey provided by Wood Group Mustang, Inc. Aerial image taken from Google Earth Pro © 2015, licensed to GeoEngineers, Inc., image dated 09/14/11. Shape files provided by Contract Land Staff, LLC.

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

LEGEND:

SPT (N) | TYPE OF SOIL (% GRAVEL)
TYPE OF ROCK | RQD/ % REC

Boring Location
Major Contour - 10' Interval
Minor Contour - 2' Interval

DAKOTA ACCESS PIPELINE PROJECT
CONCEPTUAL SITE PLAN AND PROFILE

PROPOSED 30" PIPELINE
KASKASKIA RIVER HDD
FAYETTE COUNTY, ILLINOIS

GEOENGINEERS

FIGURE 2A

ISSUED DATE: JUNE 19, 2015

MAM : TJB

P:\18\1878201\01\CAD\Crossings\Illinois\Kaskaskia River\Drawings\Kaskaskia River HDD Figure 2.dwg\TAB:Figure 2A modified on Jun 19, 2015 - 1:23pm

DATUM:
HORIZONTAL: NAD83 with UTM Datum, Zone 16, US Foot; Central Meridian 87° W
VERTICAL: NAVD 88

Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. can not guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.
3. GeoEngineers, Inc. has not verified the field location of the existing utilities.

Reference: Ground surface DEM (1/3 Arc Second) downloaded from http://NationalMap.Gov.
Aerial image taken from Google Earth Pro © 2015, licensed to GeoEngineers, Inc., image dated 09/14/11.
Shape files provided by Contract Land Staff, LLC.

PLAN
400' 0 400'
SCALE IN FEET

NOT FOR CONSTRUCTION
FOR DISCUSSION ONLY

LEGEND:
- Boring Location
- Major Contour - 10' Interval
- Minor Contour - 2' Interval

DAKOTA ACCESS PIPELINE PROJECT
CONCEPTUAL STRINGING WORKSPACE

PROPOSED 30" PIPELINE
KASKASKIA RIVER HDD
FAYETTE COUNTY, ILLINOIS

GEOENGINEERS

FIGURE 2B

ISSUED DATE: JUNE 19, 2015

MAM : TJB

P:\18\1878201\01\CAD\Crossings\Illinois\Kaskaskia River\Drawings\Kaskaskia River HDD Figure 2.dwg\TAB:Figure 2B modified on Jun 19, 2015 - 1:25pm

Looking North Toward The Proposed Pipeline Alignment Near Boring KSR-B-2

Looking North Toward The Proposed Pipeline Alignment From Boring KSR-B-3

GEOENGINEERS

Dakota Access Pipeline Project – Kaskaskia River HDD
Site Photographs

FIGURE 3

APPENDIX A
Field Explorations and Laboratory Testing

APPENDIX A
FIELD EXPLORATIONS AND LABORATORY TESTING

Field Explorations

Subsurface conditions were explored at the site on October 28 through November 1, 2014, and April 27 through April 28, 2015, by drilling five (5) geotechnical borings using an All-Terrain-Vehicle (ATV) mounted drill rig. The Illinois State "One-Call" utility locating agency was contacted to locate utilities in the project area prior to the start of the exploratory borings. The borings were drilled near the alignment of the proposed trenchless crossing in order to characterize the subsurface conditions.

The drilling operations were monitored by GeoEngineers staff who examined and classified the soils and rock encountered, obtained representative samples, observed groundwater conditions where possible and prepared a detailed log of each exploration. The soils encountered were classified visually in general accordance with ASTM International (ASTM) D2488, which is described in Figure A-1. The rock encountered was classified in accordance with the rock classification system described on Figure A-2. The approximate locations of the explorations are shown in the Conceptual Site Plan and Profile and Conceptual Stringing Workspace drawings, Figures 2A and 2B.

In general, soil samples were obtained from the borings at 5-foot-depth intervals using a 1.5-inch inside-diameter (I.D.) split spoon standard penetration test (SPT) sampler. The SPT sampler was driven 18 inches, using a 140-pound hammer with a 30-inch drop. The number of hammer blows required to drive the sampler the final 12-inches was recorded on field logs. Bedrock core samples were obtained using a 2-inch I.D. NQ core barrel. Each boring was backfilled full depth with cement-bentonite grout.

The relative density of the SPT samples recovered at each interval was evaluated based on correlations with lab and field observations in general accordance with the values outlined in Table A-1 below.

TABLE A-1 CORRELATION BETWEEN BLOW COUNTS AND RELATIVE DENSITY[1]

Cohesive Soils (Clay/Silt)						
Parameter	Very Soft	Soft	Medium Stiff	Stiff	Very Stiff	Hard
Blows, N	< 2	2 – 4	4 – 8	8 – 16	16 – 32	>32
Cohesionless Soils (Gravel/Sand/Silty Sand)[2]						
Parameter	Very Loose	Loose	Medium Dense	Dense	Very Dense	
Blows, N	0 – 4	4 – 10	10 – 30	30 – 50	> 50	

Notes:

[1] After Terzaghi, K and Peck, R.B., "Soil Mechanics in Engineering Practice," John Wiley & Sons, Inc., 1962.

[2] Classification applies to soils containing additional constituents; that is, organic clay, silty or clayey sand, etc.

The Rock Quality Designation (RQD) of the rock core samples recovered from each core run was evaluated and are presented on the exploration logs in Figures A-3 through A-7. The rock quality descriptions are correlated to RQD (%) as outlined in Table A-2, below.

TABLE A-2 ROCK QUALITY DESIGNATION

RQD (%)	Rock Quality Description
0-25	Very Poor
26-50	Poor
51-75	Fair
76-90	Good
91-100	Excellent

The exploration logs are presented in Figures A-3 through A-7. The logs are based on our interpretation of the field data and indicate the various types of soils encountered. They also indicate the approximate depths at which the subsurface conditions change.

Laboratory Testing

General

Soil samples obtained from the explorations were transported to our Springfield, Missouri office and examined to confirm or modify field classifications. Representative samples were selected for laboratory testing consisting of moisture content determinations, sieve analyses, Atterberg limits tests and an unconfined compression test. The laboratory testing procedures are discussed in more detail below.

Moisture Content Testing

Moisture content tests were completed for representative soil samples obtained from the explorations in general accordance with ASTM D2216. The results of these tests are presented on the exploration logs in Figures A-3 through A-7 at the depths at which the samples were obtained.

Sieve Analyses

Sieve analyses were performed on selected samples in general accordance with ASTM D422. The results of the sieve analyses were plotted and classified in general accordance with the Unified Soil Classification System (USCS) and are presented in Figures A-8 and A-10. The sample gravel content (% Gravel) and percentage passing the U.S. No. 200 sieve (% Fine) are shown on the boring logs at the respective sample depths.

Atterberg Limits Testing

Atterberg Limits were performed on selected fine grained soil samples in general accordance with ASTM D4318. The tests were used to classify the soil as well as to evaluate its index properties. The results of the Atterberg Limits testing are shown in Figures A-11 through A-12.

Unconfined Compression Testing

An unconfined compression (UC) test was performed on a selected rock sample obtained from the borings. The test was used to evaluate shear strength characteristics and was completed in general accordance with the ASTM D7012 test procedure. The result of the testing is presented on the respective boring log at the respective sample depth and is summarized in tabular form in Figure A-13. Rock core photographs are presented in Figures A-14 through A-16.

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS MORE THAN 50% RETAINED ON NO. 200 SIEVE	GRAVEL AND GRAVELLY SOILS MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
		GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
	SAND AND SANDY SOILS MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
		SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	TS	Topsoil/ Forest Duff/Sod

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Continuous Coring

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig.

Laboratory / Field Tests

%F	Percent fines
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
OC	Organic content
PM	Permeability or hydraulic conductivity
PI	Plasticity index
PP	Pocket penetrometer
PPM	Parts per million
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen
NT	Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS

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FIGURE A-1

UNIFIED ROCK CLASSIFICATION SYSTEM (URCS)*

BASIC ELEMENTS

DEGREE OF WEATHERING

WEATHERED		ALTERED	REPRESENTATIVE	
SAND SIZE COMPLETELY DECOMPOSED STATE (CDS) E	GRAVEL SIZE PARTLY DECOMPOSED STATE (PDS) D	STAINED STATE (STS) C	VISUALLY FRESH STATE (VFS) B	MICRO FRESH STATE (HAND LENSE) (MFS) A
PLASTIC NON-PLASTIC	PLASTIC NON-PLASTIC	COMPARE TO FRESH STATE	UNIT WEIGHT, RELATIVE ABSORPTION	

ESTIMATED STRENGTH

REMOLDING		REACTION TO IMPACT OF 1 LB. BALLPEEN HAMMER		
"MOLDABLE" (FRIABLE) (MBL) E	"CRATERS" (SHEARS) (CQ) D	"DENTS" (COMPRESSIVE) (DQ) C	"PITS" (TENSIONAL) (PQ) B	"REBOUNDS" (ELASTIC) (RQ) A
<1,000 PSI (<7 MPa)	1,000 to 3,000 PSI (7 to 21 Ma)	3,000 to 8,000 PSI (21 to 55 MPa)	3,000 to 15,000 PSI (55 to 103 MPA)	>15,000 PSI (>103 MPa)

DISCONTINUITIES

TRANSMITS WATER						
YES	NO	YES	NO	LATENT PLANES OF SEPARATION (LPS) C	SOLID-PREFERRED BREAKAGE (SPB) B	SOLID-RANDOM BREAKAGE (SRB) A
3-DIMENSIONAL PLANES OF SEPARATION (3D) E		2-DIMENSIONAL PLANES OF SEPARATION (2D) D				
INTERLOCK		ATTITUDE				

UNIT WEIGHT

LESS THAN 130 LBS/CU FT (2.10 Mg/CU M) (<130) E	130 TO 140 LBS/CU FT (2.10 TO 2.25 Mg/CU M) (130) D	140 TO 150 LBS/CU FT (2.25 TO 2.40 Mg/CU M) (140) C	150 TO 160 LBS/CU FT (2.40 TO 2.55 Mg/CU M) (150) B	GREATER THAN 160 LBS/CU FT (2.55 Mg/CU M) (>160) A

DESIGN NOTATION

WEATHERING	STRENGTH	DISCONTINUITY	WEIGHT
A-E	A-E	A-E	A-E

* Williamson, Douglas A., 1984, Unified Rock Classification System: Association of Engineering Geologists Bulletin, Vol. XXI, No. 3, pp. 345-354

GEOENGINEERS

ROCK CLASSIFICATION SYSTEM

FIGURE A-2

Drilled Start 10/31/2014 End 11/1/2014	Total Depth (ft) 75	Logged By MJP Checked By MAF	Driller Geotechnology, Inc.	Drilling Method HSA/Mud Rotary	
Surface Elevation (ft) Vertical Datum 473.0		Hammer Data Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment CME-750 ATV Mounted	
Latitude 38° 51' 48.919" N Longitude 89° 10' 07.335" W		System Datum Geographic		Groundwater Date Measured	Depth to Water (ft) N/A / Elevation (ft)
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		14	5		S1			ML	Brown to light brown silt (medium stiff, moist)	24		
470			18	5		S2							
	5		18	8		S3				Becomes light brown sandy silt and stiff			
465			16	11		S4			SM	Light gray silty fine sand (medium dense, moist)	18		
	10												
460			15	7		S5				Becomes brown silty fine to coarse sand and loose	18		Water observed at 13 feet bgs
	15												
455			18	13		S6				Grades to orange to brown and becomes medium dense	16		
	20												
450			2	6		S7				Becomes loose			Gravel stuck in shoe Hard drilling
	25												
445			16	49		S8				Grades to gray and becomes dense	12		
	30												
440			18	57		S9				With occasional gravel and becomes very dense	10		% Fine = 41 % Gravel = 11
	35												

Log of Boring KSR-B-1

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-3
Sheet 1 of 2

Springfield: Date:6/19/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
435	35												
			14	44		S10				Becomes dense	12		
430	40												
			8	28		S11				Becomes medium dense	12		
425	45												
			18	21		S12			CL	Bluish gray sandy clay (very stiff, moist)	24		LL = 37 PI = 21
420	50												
			18	28		S13			SC	Bluish gray clayey fine sand (medium dense, moist)	18		
415	55												
			17	50/5"		S14			CL	Gray sandy clay (hard, moist) (weathered shale)	14		
410	60												
			0	50/9"		S15			Shale	No recovery			
			18	17		R1				Gray shale, stained state, rebound quality, solid random breakage			
405	65		58	75		R2			Sandstone	Gray sandstone, stained state, rebound quality, solid random breakage			Fair quality
400	70		60	50		R3				With clay lenses			Poor quality UC = 1,780 psi Mohs = 3
	75												

Springfield: Date:6/19/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring KSR-B-1 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-3
Sheet 2 of 2

Drilled Start 10/30/2014 End 10/31/2014	Total Depth (ft) 60	Logged By MJP Checked By MAF	Driller Geotechnology, Inc.	Drilling Method HSA/Mud Rotary	
Surface Elevation (ft) Vertical Datum 455.0		Hammer Data Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment CME-750 ATV Mounted	
Latitude 38° 51' 47.577" N Longitude 89° 09' 54.230" W		System Datum Geographic		Groundwater Date Measured	Depth to Water (ft) N/A / Elevation (ft)
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		12	6		S1			ML	Brown silt with trace organics (medium stiff, moist)	25		
			14	5		S2				Becomes light brown silt			
450	5		18	6		S3			CL	Light brown clay (medium stiff, moist)			
			18	3		S4				Becomes soft	29		
445	10												
			18	4		S5				Becomes gray, medium stiff and wet	28		
440	15												
			12	3		S6			SC	Gray clayey fine sand with organics (very loose, moist)	25		Water observed at 18 feet bgs % Fine = 48 % Gravel = 0
435	20												
			18	5		S7				Becomes loose and wet	31		
430	25												
			12	4		S8			CL	Gray sandy clay (medium stiff, wet)	27		LL = 26 PI = 7
425	30												
			12	9		S9			SP	Gray fine to coarse sand with clay (loose, moist)	16		
420	35												

Springfield: Date:6/19/15 Path:P:\18\18782011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring KSR-B-2

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-4

Sheet 1 of 2

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												Slow drilling
415	40		17	69		S10			SC	Gray clayey fine to medium sand with occasional gravel (very dense, moist to wet) (glacial till)	15		
410	45		5.5	50/5.5"		S11			CL	Gray sandy clay (hard, moist to dry) (decomposed shale)	14		
405	50		4	50/4"		S12					14		
400	55		3 60	50/3" 58		S13 R1			Shale	Gray shale, partially decomposed state, dent quality, 2D discontinuities	14		Switched to rock coring at 55 feet bgs Fair quality
395	60												

Log of Boring KSR-B-2 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-4
Sheet 2 of 2

Springfield: Date:6/19/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 10/29/2014 End 10/29/2014	Total Depth (ft) 59	Logged By MJP Checked By MAF	Driller Geotechnology, Inc.	Drilling Method HSA/Mud Rotary	
Surface Elevation (ft) Vertical Datum 450.0		Hammer Data Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment CME-750 ATV Mounted	
Latitude 38° 51' 45.903" N Longitude 89° 09' 37.887" W		System Datum Geographic		Groundwater Date Measured	Depth to Water (ft) N/A / Elevation (ft)
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		14	6		S1			ML	Brown silt with trace organics (medium stiff, moist)	24		
445	5		14	4		S2				Grades to light brown			
440	10		18	2		S3				Becomes sandy and soft	25		
435	15		18	3		S4					22		% Fine = 50 % Gravel = 0
430	20		18	3		S5			SP-SM	Brownish gray fine to medium sand with silt (very loose, moist)	22		
425	25		12	2		S6			CL-ML	Gray sandy silty clay (soft, moist)	24		% Fine = 57 % Gravel = 0 LL = 22 PI = 6
420	30		16	11		S7			SP-SM	Gray fine to coarse sand with silt (medium dense, moist)	16		Hard drilling
415	35		8	7		S8			SP	Gray fine to coarse sand (loose, moist)	17		

Log of Boring KSR-B-3

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-5

Sheet 1 of 2

Springfield: Date:6/19/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
			0	53		S9				Becomes very dense No recovery			Possible cobble or boulder, likely glacial till
410	40												Slow drilling
			18	56		S10			CL	Gray fine to coarse sandy clay with occasional fine gravel (hard, moist)	11		% Fine = 64 % Gravel = 5 LL = 22 PI = 8
405	45												
			16	63		S11					12		
400	50												
			5	50/5"		S12				Becomes gray clay with sand	13		
395	55												
			5	50/5"		S13					14		

Log of Boring KSR-B-3 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-5

Sheet 2 of 2

Springfield: Date:6/19/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 10/28/2014 End 10/28/2014	Total Depth (ft) 60	Logged By MJP Checked By MAF	Driller Geotechnology, Inc.	Drilling Method HSA/Mud Rotary	
Surface Elevation (ft) Vertical Datum 450.0		Hammer Data Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment CME-750 ATV Mounted	
Latitude 38° 51' 44.367" N Longitude 89° 09' 22.902" W		System Datum Geographic		Groundwater Date Measured	Depth to Water (ft) N/A / Elevation (ft)
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		12	6		S1			CL	Light brown clay (medium stiff, moist)	23		
445	5		8	5		S2				With trace sand			
			15	3		S3			ML/CL	Brown silty clay with sand (soft, moist)			
440	10		18	3		S4			CL	Brownish gray clay with sand (soft, moist)	27		Water observed at 12 feet bgs
435	15		18	5		S5			SM	Brown silty fine to medium sand (loose, moist)	18		% Fine = 12 % Gravel = 0
430	20		18	2		S6				Grades to gray and becomes very loose	24		
425	25		18	11		S7			SP-SC	Gray fine to coarse sand with clay (medium dense, moist)	26		
420	30		16	15		S8			SP-SM	Gray fine to coarse sand with silt (medium dense, moist)	14		
415	35		9	17		S9			CL	Gray sandy clay (very stiff, moist)	12		

Springfield: Date:6/19/15 Path:P:\18\18782011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Log of Boring KSR-B-4

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-6

Sheet 1 of 2

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	35												
410	40		18	53		S10				Becomes hard	13		LL = 23 PI = 8
405	45		18	40		S11					12		
400	50		18	35		S12					12		
395	55		10	50/4"		S13			SM	Gray silty fine sand (very dense, moist)	16		
390	60		11	50/5"		S14					11		

Log of Boring KSR-B-4 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-6
Sheet 2 of 2

Springfield: Date:6/19/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Drilled Start 4/27/2015 End 4/28/2015	Total Depth (ft) 80	Logged By RMB Checked By DJJ	Driller Geotechnology, Inc.	Drilling Method HSA/Mud Rotary	
Surface Elevation (ft) Vertical Datum 467.0		Hammer Data Automatic 140 (lbs) / 30 (in) Drop		Drilling Equipment CME-750 ATV Mounted	
Latitude 38° 51' 52.9833" N Longitude 89° 10' 4.5863" W		System Datum Geographic		Groundwater Date Measured	Depth to Water (ft) N/A / Elevation (ft)
Notes: Upon completion, borehole backfilled with cement-bentonite grout.					

FIELD DATA

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
	0		10	3		S1			CL	Brown clay (soft, moist)			
465													
	5		14	10		S2				Becomes gray and stiff			
460			13	13		S3							
	10		17	9		S4				Becomes sandy	19		
455													
	15		17	3		S5			SW-SM	Brown fine to coarse sand with silt and gravel (very loose, wet)	22		
450													
	20		6	12		S6				Becomes medium dense	9		% Fine = 9 % Gravel = 38
445													
	25		13	9		S7			CL-ML	Gray sandy clayey silt with occasional gravel (stiff, moist)	12		
440													
	30		17	3		S8				Becomes soft	13		
435													
	35		14	27		S9				Becomes with out sand, without gravel and very stiff	14		LL = 20 PI = 6

Log of Boring KSR-B-5

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-7

Sheet 1 of 3

Springfield: Date:6/19/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
430	35												
			13	39		S10			SM	Gray silty fine to coarse sand with occasional gravel (dense, moist)	12		
425	40												
			8	34		S11					12		% Fine = 32 % Gravel = 4
420	45												
			18	19		S12				Becomes medium dense	22		
415	50												
			16	25		S13					31		
410	55												
			10	50/3"		S14			Shale	Black shale	15		
			4	0		R1				Weathered shale			
405	60		57	35		R2			Sandstone	Gray fine grained sandstone, horizontal bedding, smooth open 0° fractures, stained state, laminated black organic layers			Poor Quality UC = 780 psi Mohs = 4
											7	137	
400	65		60	40		R3							Poor Quality
													Fair Quality
395	70		60	65		R4							
									Siltstone	Gray fine grained siltstone, horizontal bedding, smooth open and closed 0° fractures, visually fresh state, laminated black organic layers			
	75		57	65		R5					7	143	Fair Quality UC = 1,340 psi Mohs = 4

Log of Boring KSR-B-5 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-7

Sheet 2 of 3

Springfield: Date:6/19/15 Path:P:\18\18782\01\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot RQD %	Collected Sample	Sample/Run Testing/Fractures	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Moisture Content, %	Dry Density, (pcf)	REMARKS
30													
	80												

Log of Boring KSR-B-5 (continued)

GEOENGINEERS

Project: Dakota Access Pipeline Project Kaskaskia River HDD

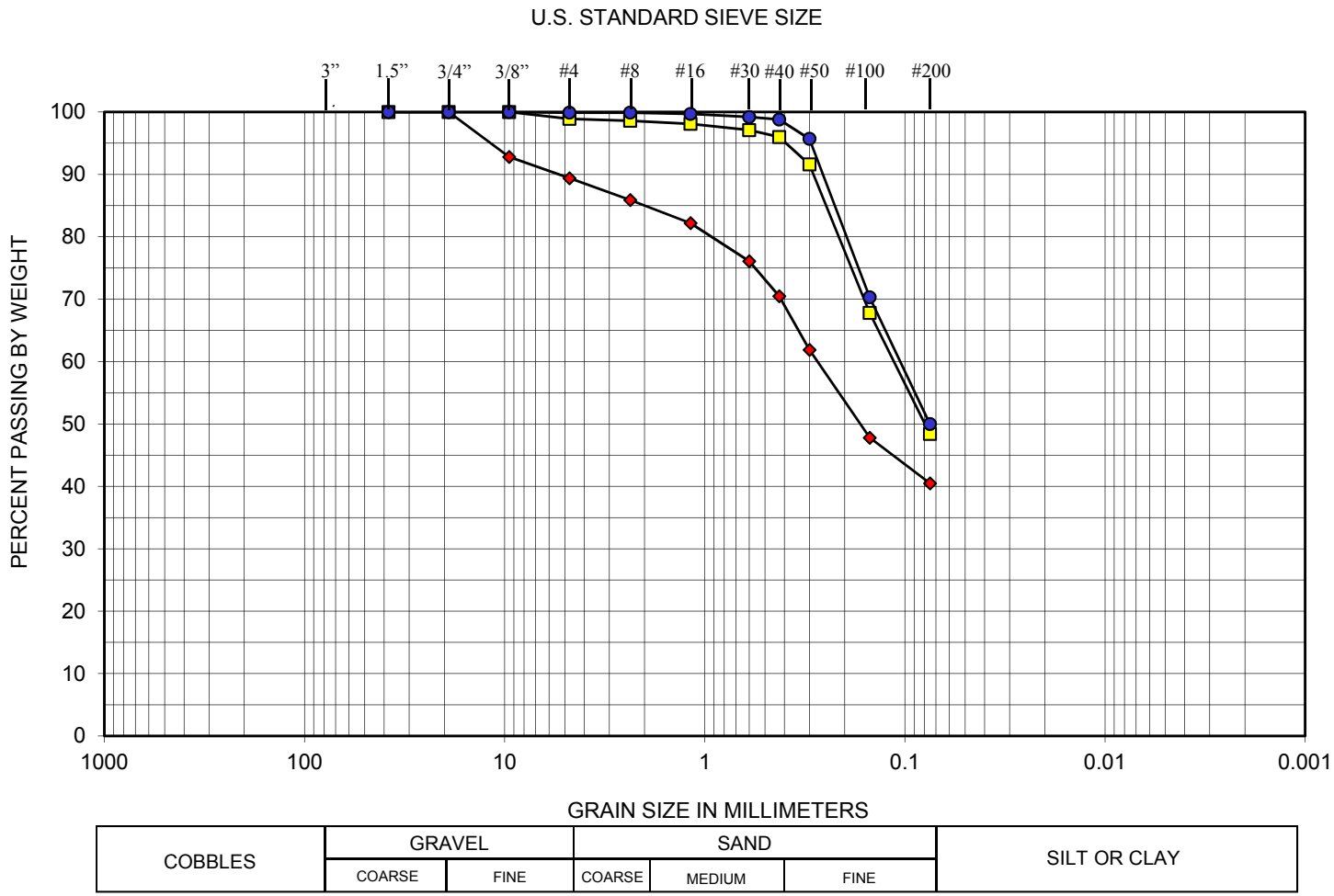
Project Location: Fayette County, Illinois

Project Number: 18782-011-01

Figure A-7

Sheet 3 of 3

Springfield: Date:6/19/15 Path:P:\18\18782\011\01\GINT\DAKOTA ACCESS PIPELINE BORING LOGS.GPJ DBTemplate/LibTemplate:GEOENGINEERS8.GDT/GEI8_GEOTECH_SOIL_ROCK



Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	KSR-B-1	33.5 – 35.0	Gray silty fine to coarse SAND (SM)
□	KSR-B-2	18.5 – 20.0	Gray clayey fine SAND with organics (SC)
●	KSR-B-3	13.5 – 15.0	Brown sandy SILT (ML)

Sieve Analysis Results

Dakota Access Pipeline Project – Kaskaskia River HDD
Fayette County, IL

GEOENGINEERS

Figure A-8

Notes: The geotechnical laboratory testing results were provided by SCI Engineering, Inc.
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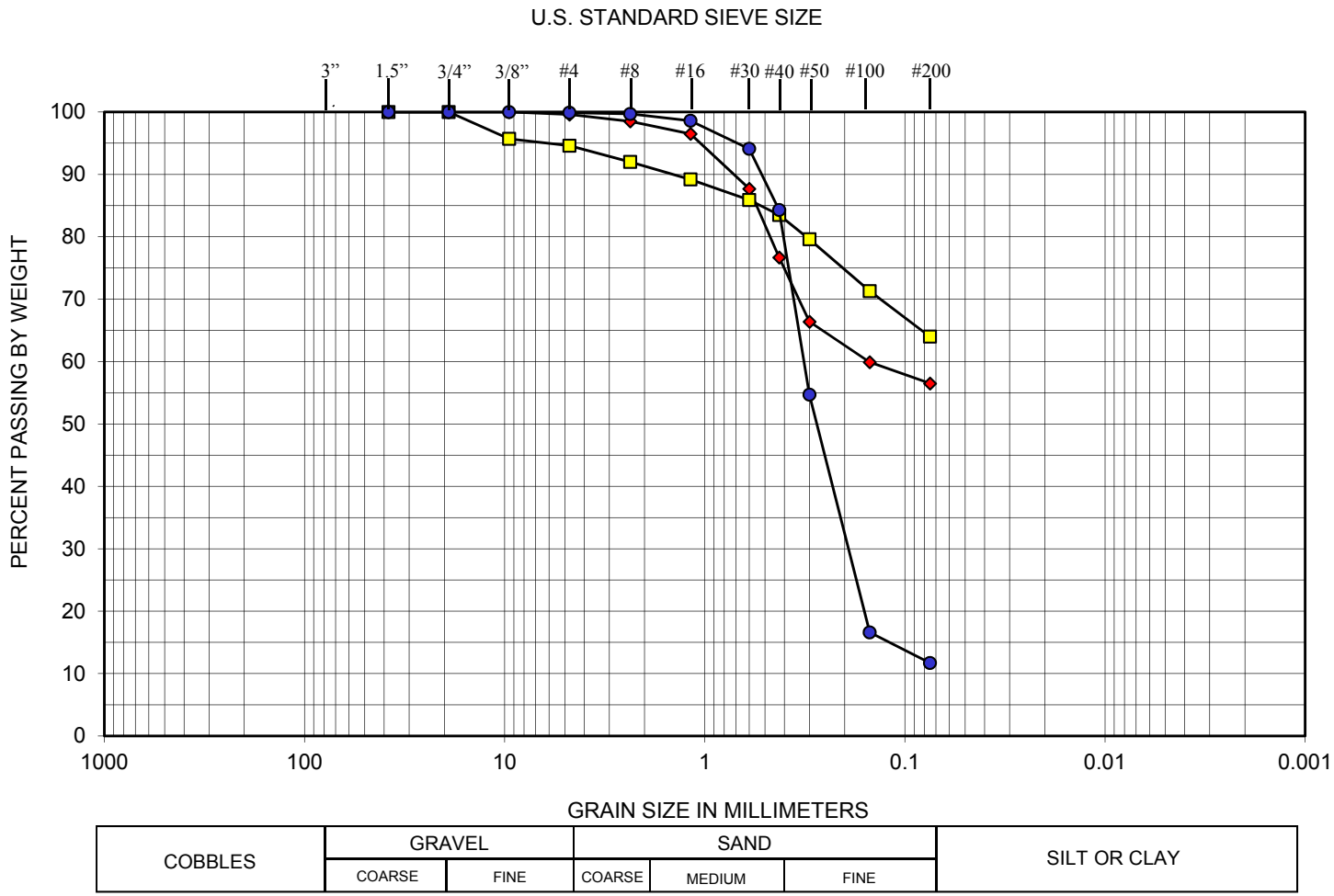

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	KSR-B-3	23.5 – 25.0	Gray sandy siltly CLAY (CL-ML)
□	KSR-B-3	43.5 – 45.0	Gray fine to coarse sandy CLAY (CL)
●	KSR-B-4	13.5 – 15.0	Brown silty fine to medium SAND (SM)

Sieve Analysis Results

Dakota Access Pipeline Project – Kaskaskia River HDD
Fayette County, IL

GEOENGINEERS

Figure A-9

Notes: The geotechnical laboratory testing results were provided by SCI Engineering, Inc.
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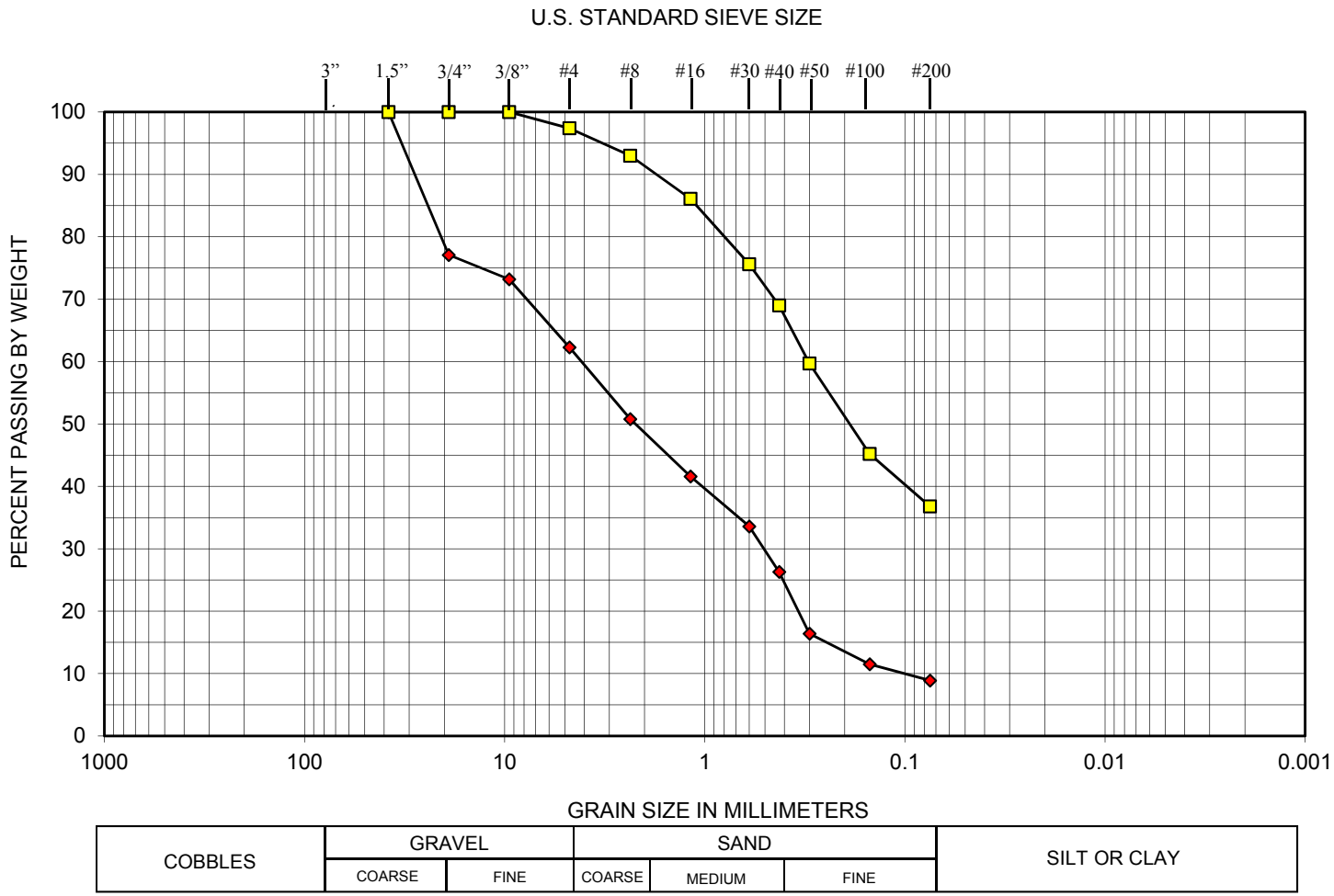

Symbol	Exploration Number	Sample Depth (feet)	Soil Classification
◆	KSR-B-5	18.5 – 20.0	Brown fine to coarse SAND with silt and gravel (SW-SM)
■	KSR-B-5	43.5 – 45.0	Gray silty fine to coarse SAND with occasional gravel (SM)

Notes: The geotechnical laboratory testing results were provided by SCI Engineering, Inc.
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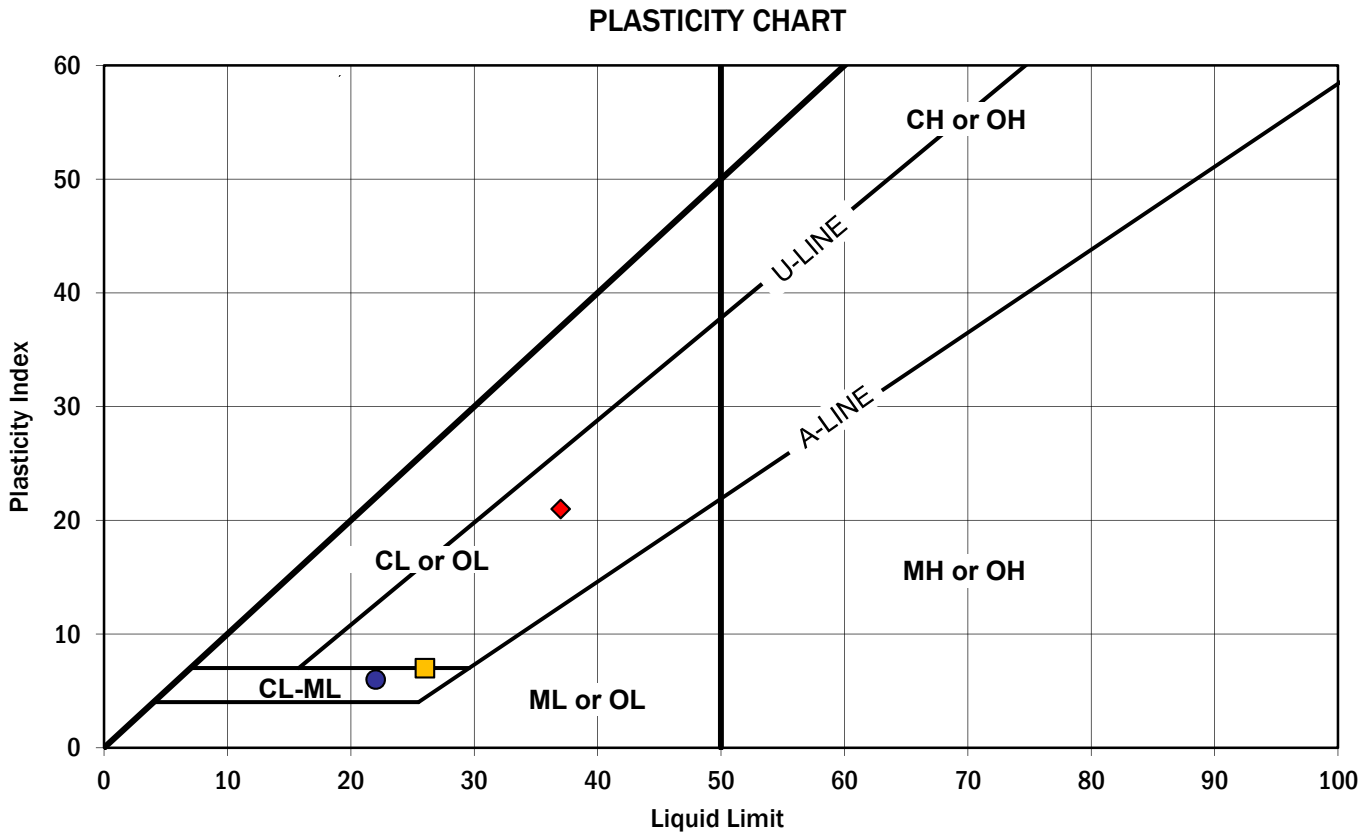
Sieve Analysis Results

Dakota Access Pipeline Project – Kaskaskia River HDD
Fayette County, IL

GEOENGINEERS

Figure A-10



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
◆	KSR-B-1	48.5 - 50.0	24	37	21	Bluish-gray low plasticity sandy CLAY (CL)
■	KSR-B-2	28.5 - 30.0	27	26	7	Gray low plasticity sandy CLAY (CL)
●	KSR-B-3	23.5 - 25.0	24	22	6	Gray sandy silty CLAY (CL-ML)

Notes: The geotechnical laboratory testing results were provided by SCI Engineering, Inc.
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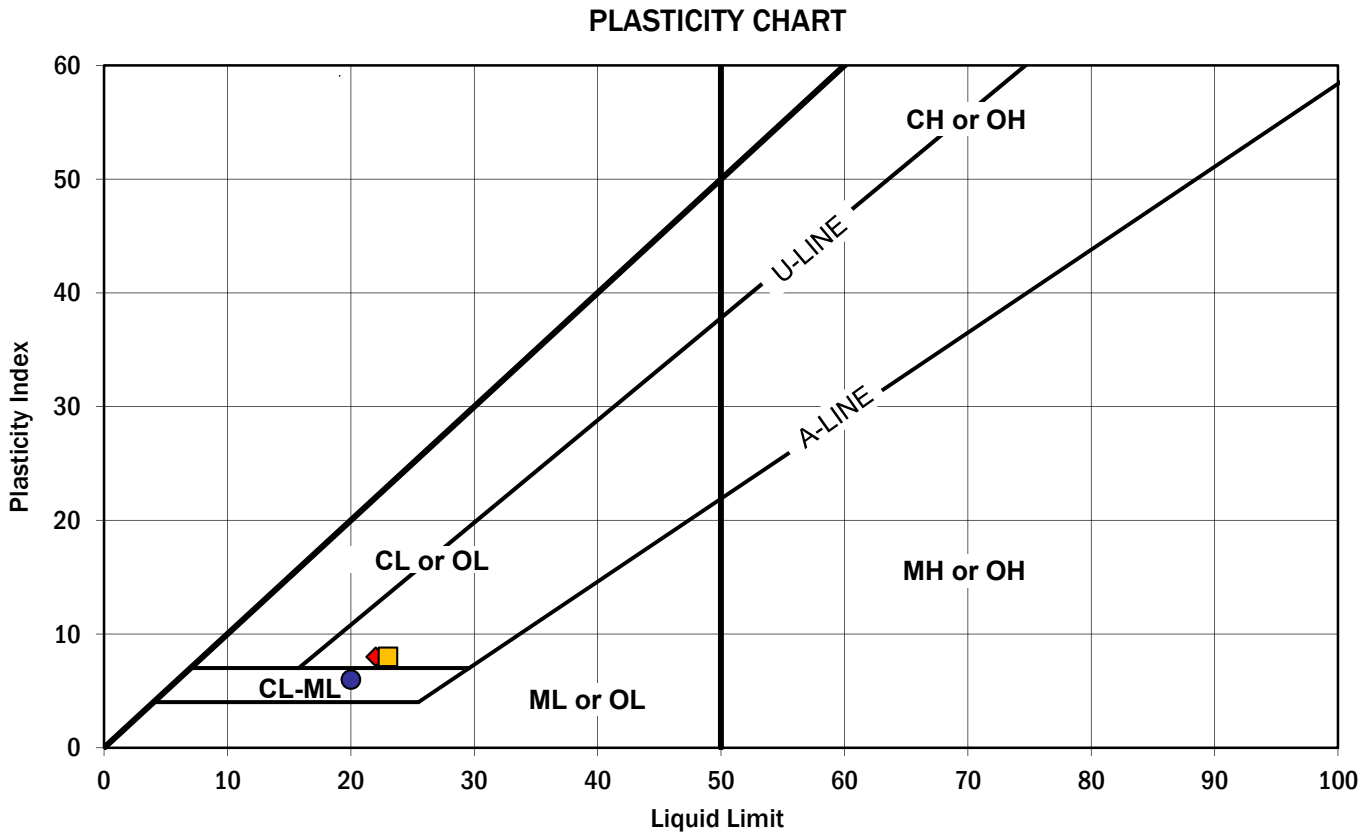
Atterberg Limits Test Results

Dakota Access Pipeline Project – Kaskaskia River HDD
Fayette County, Illinois

GEOENGINEERS

Figure A-11



Symbol	Exploration Number	Sample Depth (feet)	Moisture Content (%)	Liquid Limit (%)	Plasticity Index (%)	Soil Description
♦	KSR-B-3	43.5 - 45.0	11	22	8	Gray low plasticity sandy CLAY (CL)
■	KSR-B-4	38.5 - 40.0	13	23	8	Gray low plasticity sandy CLAY (CL)
●	KSR-B-5	33.5 - 35.0	14	22	6	Gray low plasticity clayey SILT (CL-ML)

Notes: The geotechnical laboratory testing results were provided by SCI Engineering, Inc.
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Atterberg Limits Test Results

Dakota Access Pipeline Project – Kaskaskia River HDD
Fayette County, Illinois

GEOENGINEERS

Figure A-12

BORING	DEPTH (FEET)	RQD (%)	ROCK QUALITY	MOHS' HARDNESS	UNCONFINED COMPRESSIVE STRENGTH (TSF)	UNCONFINED COMPRESSIVE STRENGTH (PSI)
KSR-B-1	72 – 72.5	50	Poor	3	130	1,780
KSR-B-5	60.0 – 62.0	35	Poor	4	56	780
KSR-B-5	75.0 – 77.0	65	Fair	4	96	1,340

Note: This report may not be reproduced, except in full, without written approval of GeoEngineers, Inc. Test results are applicable only to the specific sample on which they were performed, and should not be interpreted as representative of any other samples obtained at other times, depths or locations, or generated by separate operations or processes.

Rock Core Test Results

Dakota Access Pipeline Project - Kaskaskia River HDD
Fayette County, Illinois

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Figure A-13

KSR-B-1: 63' to 70'

KSR-B-1: 70' to 75'

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Dakota Access Pipeline Project – Kaskaskia River HDD
ROCK CORE SAMPLE PHOTOGRAPHS

FIGURE A-14

KSR-B-2: 55’ to 60’

KSR-B-5: 60’ to 70’

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Dakota Access Pipeline Project – Kaskaskia River HDD
ROCK CORE SAMPLE PHOTOGRAPHS

FIGURE A-15

KSR-B-5: 70’ to 80’

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Dakota Access Pipeline Project – Kaskaskia River HDD
ROCK CORE SAMPLE PHOTOGRAPHS

FIGURE A-16

APPENDIX B
Report Limitations and Guidelines for Use

APPENDIX B
REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

Geotechnical and Environmental Services Are Performed for Specific Purposes, Persons and Projects

This report has been prepared for the exclusive use of Dakota Access, and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Similarly, an environmental assessment study conducted for a property owner may not fulfill the needs of a prospective purchaser of the same property. Because each study is unique, each report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted geotechnical practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A Geotechnical Engineering or Environmental Report Is Based on a Unique Set of Project-Specific Factors

This report has been prepared for the proposed Kaskaskia River Horizontal Directional Drill (HDD) located in Fayette County, Illinois. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure;

[1] Developed based on material provided by ASFE/The Best People on Earth, Professional Firms Practicing in the Geosciences; www.asfe.org.

- elevation, configuration, location, orientation or weight of the proposed structure;
- composition of the design team; or
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

Subsurface Conditions Can Change

This report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, by new releases of hazardous substances, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

Top Soil

For the purposes of this report, we consider topsoil to consist of generally fine-grained soil with an appreciable amount of organic matter, based on visual examination, and to be unsuitable for direct support of the proposed improvements. However, the organic content and other mineralogical and gradational characteristics used to evaluate the suitability of soil for use in landscaping and agricultural purposes were not determined, nor were they considered in our analyses. Therefore, the information and recommendations in this report, and our logs and descriptions, should not be used as a basis for estimating the volume of topsoil available for such purposes.

Most Geotechnical and Environmental Findings Are Professional Opinions

Our interpretations of subsurface conditions are based on field observations and laboratory test results from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

Geotechnical Engineering Report Recommendations Are Not Final

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient monitoring and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not construction activities are completed in accordance

with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A Geotechnical Engineering or Geologic Report Could Be Subject to Misinterpretation

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also, retain GeoEngineers to review pertinent elements of the design team's plans and specifications. If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Exploration Logs

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

Give Contractors a Complete Report and Guidance

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

Contractors Are Responsible for Site Safety on Their Own Construction Projects

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

Read These Provisions Closely

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

Geotechnical, Geologic and Environmental Reports Should Not Be Interchanged

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

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APPENDIX C
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Have we delivered World Class Client Service?

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