GEOTECHNICAL INVESTIGATION REPORT

HOWARD FARMS RESTORATION
WALLACE ROAD & N HOWARD ROAD
JERUSALEM TOWNSHIP, OH
MSG JOB NO: D1310012

SEPTEMBER 22, 2020

REVISED OCTOBER 27, 2020

PREPARED FOR:

DUCKS UNLIMITED INC.
7322 NEWMAN BLVD., BUILDING 1
DEXTER, MICHIGAN 48130

Mannik Smith GROUP

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*PREPARED BY: _____

TEJ H. RAVAL
GEOTECHNICAL ENGINEER

*REVIEWED BY: _____

JOHN S. BROWNING III, PE
EXECUTIVE VICE PRESIDENT

Mannik Smith GROUP

October 27, 2020

Mr. Brian Nicholson, PE, CFM
Ducks Unlimited, Inc.
7322 Newman Blvd., Building 1
Dexter, MI 48130
Office: (734) 263-2000

RE: Geotechnical Investigation Report
Howard Farms Restoration
Jerusalem Township, Lucas County, Ohio

Dear Mr. Nicholson:

The Mannik & Smith Group, Inc. (MSG) has finalized our geotechnical investigation for the restoration of the Howard Farms site in Jerusalem Township, Ohio. The Geotechnical Investigation Report presents the findings of our subsurface investigation and our geotechnical recommendations for subgrade preparation, earthwork, and slab on grade, sheet pile walls, foundation design and initial pavement design.

We trust that this report addresses your project needs. We appreciate the opportunity to work with you on this very important project and look forward to providing additional services in the future. Please contact us if you have any questions or if we can be of further assistance.

Sincerely,

The Mannik & Smith Group, Inc.

Tej H. Raval
Geotechnical Engineer

John S. Browning III, PE
Executive Vice President

Submitted: One (1) Electronic Copy via email
File

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EXECUTIVE SUMMARY

The Mannik & Smith Group, Inc. (MSG) was retained by Ducks Unlimited, Inc. to perform a geotechnical investigation for the Howard Farms Cell No.2 Restoration located between the Cedar Point wetland and Lake Erie at the northwest intersection of Wallace Road in Jerusalem Township, Lucas County, Ohio (Site location). The site location referenced to nearby roads and major topographical features is presented as *Figure 1: Site Location Map*.

Based on the information obtained from our geotechnical subsurface investigation the site can be developed for the proposed project and the following considerations were identified:

- All the borings were performed on a farm field. Borings SB-01, SB-02 and SB-05 indicated no apparent signs of topsoil. However borings SB-03 and SB-04 consisted of approximately 12 inches of topsoil at the near surface. Removal of at least 12 inches of topsoil material should be anticipated during construction (Refer to Section 3.1).
- Generally soils consisted of brown and/or mottled with gray lacustrine clays in borings SB-01, SB-02, SB-04 and SB-05 extending to 18.5 feet below existing grade. At SB-02 high plasticity lacustrine clay layer (USCS classification of CH) was encountered from 3 feet extending to 5 feet below existing grade. The glacial clay was encountered at a depth of 18.5 feet below existing grade extending to 38.5 feet below existing grade. A transition layer of clay was encountered up to a depth of 43.5 feet below existing grade. Very hard till layer was encountered beneath the glacial clay (Refer to Section 3.1)
- Groundwater was encountered at borings, SB-02 and SB-04 at depth of 2 feet and 43 feet, respectively. Moisture contents for the low plasticity soils generally ranged from 10.2 percent to 33.0 percent with an average of 20 percent. The soils are considered very moist to wet. Even though groundwater was not encountered in the remaining boreholes, it should be noted that the silty clay material present is not amenable to recharge of groundwater during the typical drill timeframe and may hold pockets of water. If necessary, the contractor should be equipped to utilize sump pit and pumping methods to dewater excavations, and should be prepared to stabilize subgrades, where necessary.
- Undercuts should be performed per Section 4.4 as noted in this report.
- Based upon our review of the existing soil conditions in the planned foundation areas in the vicinity of Borings SB-04, it is recommended that the foundations bear within the natural medium stiff soils or well compacted engineered fill be designed for an allowable bearing capacity of 1,500 psf. The exterior footings and footings in unheated areas should bear just below the frost depth for the site which is generally 42 inches below grade in this region of Ohio.
- Based on the existing materials and a subgrade prepared as outlined above, for slab-on-grade design, an estimated modulus for subgrade reaction on top of the existing subgrade of 100 pounds per cubic inch (pci) may be used. It is recognized that the use of stabilized base increases the modulus of subgrade reaction appreciably. Design of the slabs was not included in MSG's scope of work for the geotechnical investigation.
- The recommended California Bearing Ratio (CBR) value is 6 based on the limited laboratory testing and the silty clay soils encountered at the site. Pavement Recommendations (Section 4.4) provides specific recommendations for the pavement.

This Executive Summary articulates selective findings and recommendations and is provided solely for the purposes of overview and should not be counted upon to provide details in its entirety for the design and construction of the proposed structure, but rather as a reference for recommendations and other design considerations.

1.0 INTRODUCTION AND PROJECT DESCRIPTION

The Mannik & Smith Group, Inc. (MSG) was retained by Ducks Unlimited, Inc. to perform a geotechnical investigation for the restoration of Howard Farms Cell No.2 in Jerusalem Township, Ohio (Site location). The Site location as referenced to nearby roads and major topographical features is presented as *Figure 1: Site Location Map*.

We understand that Ducks Unlimited, Inc. is working with Toledo MetroParks and Smith Group JJR to perform restoration on the Howards Farm site. The project includes of a similar berm system as previously performed as part of Phase 1 analyses including with a proposed concrete pump station set on concrete risers. The purpose of this geotechnical investigation is to evaluate subsurface conditions for the proposed restoration activities. This investigation involved the completion of five (5) soil borings. This report describes the geotechnical investigative and testing procedures, presents the subsurface conditions encountered, and provides evaluations and recommendations relative to the project considerations.

This work was completed in accordance with our proposal No: OP191685, dated November 7, 2019.

2.0 INVESTIGATION PROCEDURES

Our investigation consisted of a field investigation and laboratory testing programs. Details of these programs are presented below.

2.1 Field Exploration

Our field investigation consisted of drilling five (5) test borings locations, advanced to a maximum depth of 45 feet below ground surface (bgs). The locations and depths of borings were provided to MSG as part of the RFP dated October 28, 2019. A total of two (2) borings were drilled to a maximum depth of 45 feet bgs and the remainder three (3) borings to a maximum depth of 10 feet bgs. The boring locations and depths were selected by Ducks Unlimited and were included as the RFP. The boring locations were field marked using a measuring wheel and measuring from existing site features. The locations of the borings are shown on *Figure 2: Soil Boring Location Plan.*

2.1.1 Drilling

The drilling operations for this investigation were performed on December 4 and 5, 2019. The soil borings were performed using a track-mounted Geoprobe 7822DT drill rig. The borings were advanced by hydraulically pushing a 3.25-inch inner diameter steel casing. Upon completion, the borehole was backfilled to the surface using bentonite mixed with soil cuttings.

2.1.2 Standard Penetration Test (SPT)

The Standard Penetration Test was conducted in accordance with ASTM D1586 procedures and was completed at 2.5 feet intervals for the first 10 feet and 5 feet intervals thereafter. During the SPT testing, soil samples were obtained with a 2-inch outer diameter split spoon sampler driven 18 inches into the soil with blows of a 140-pound hammer falling 30 inches. The sampler is generally driven in three successive 6-inch increments with the blows for each 6-inch increment being recorded. The number of blows required to advance the sampler through 12 inches after an initial penetration of 6 inches is termed as the Standard Penetration Test resistance (N-value) and is presented graphically in the Appendix B Soil Boring Logs.

2.1.3 Sampling

Soil samples were recovered using a split-spoon sampling procedure in general accordance with ASTM D1586 Standard ("Standard Method for Penetration Tests and Split Barrel Sampling of Soils"). In general, samples were obtained at a regular interval of 2.5 feet for the upper 10 feet of the boreholes, then at 5 feet intervals to the bottom of the borings. All collected samples were labeled with the soil boring designation and

a unique sample number. The samples were sealed in glass jars in the field to protect the soil and maintain the soil's natural moisture content. In addition, four (4) thin walled Shelby Tubes were pushed at different depths in the soil. All samples were transferred to MSG's laboratory for further analysis and testing.

The soil samples collected from this investigation will be retained in our laboratory for a period of 30 days after the date of submission of the final report, after which they will be discarded unless we are notified otherwise. A sample storage charge will apply for samples requested to be stored beyond 30 days.

2.1.4 Groundwater Level Observation Procedures

Whenever possible, groundwater level observations were made during the drilling operations and are shown on the Soil Boring Logs. In addition, prior to backfilling, each open borehole was observed again for groundwater. During drilling, the depth at which free water was observed, where drill cuttings became saturated or where saturated samples were collected, was indicated as the groundwater level during drilling. In particular, in pervious soils (granular soils), the indicated water levels are considered relatively reliable when solid or hollow-stem augers are used for drilling. However, in cohesive soils as applicable to this site, groundwater observations are not necessarily indicative of the static water table due to low permeability rates of the soils and due to the sealing off of natural paths of groundwater during drilling operations. It should be noted that seasonal variations and recent rainfall conditions may influence the groundwater table significantly.

2.2 Laboratory Testing

Each of the split spoon and thin wall samples recovered from the borings was examined and visually classified by a geotechnical professional. This examination was performed to verify conditions identified within the field boring logs, perform visual-manual classification of samples not subjected to further laboratory testing and select samples for laboratory testing. Based on the review of the test boring logs and visual examination of the collected samples, we completed a laboratory testing program on selected samples. Our laboratory testing program consisted of the following:

- Five moisture content tests performed in accordance with ASTM D2216;
- Eight sieve analyses and hydrometer tests performed in accordance with ASTM D422;
- Eight Atterberg limit tests performed in accordance with ASTM D4318; and,
- Two unconfined compression tests performed in accordance with ASTM D2166.

All soil samples were classified in general accordance with the Unified Soil Classification System (USCS). The USCS group symbol determined from visual-manual classification is shown in parentheses at the end of the sample description for each layer shown on the Soil Boring Logs.

The results for the soil classification and the laboratory test results are included on the Soil Boring Logs and soil laboratory test data, which are presented in Appendices B and C, respectively. Also included in Appendix B are General Soil Sample Notes, and Boring/Well Log Key that illustrates the soil classification criteria and terminology used on the Soil Boring Logs.

3.0 SUBSURFACE CONDITIONS

3.1 Subsurface -Classification

The subsurface soil and groundwater conditions encountered in the -borings drilled at the site are presented in the Soil Boring Logs and the Generalized Soil Profile Sheets contained in *Appendix B*. Notes and symbols illustrating the soil classification criteria and terminology used in the boring logs are also included in *Appendix B*.

The following sections describe the subsurface conditions in terms of major soil strata for the purposes of geotechnical exploration. The soil boundaries indicated are inferred from non-continuous sampling, drilling operations and/or sampling resistance. The subsurface conditions discussed in the following paragraphs and those shown on the boring logs represent an estimate of the subsurface conditions based on interpretation of the field and laboratory data using normally accepted geotechnical engineering judgments and common engineering practice standards. The subsurface conditions described herein may vary between and beyond the borings locations and at different times of the year. A generalized soil profiled of the subsurface conditions encountered across the site, beginning at the ground surface and extended downward is as follows:

Surficial Materials – Topsoil
All the borings were performed on a farm field. Borings SB-01, SB-02 and SB-05 indicated no apparent signs of topsoil. However borings SB-03 and SB-04 consisted of approximately 12 inches of topsoil at the near surface. Removal of at least 12 inches of topsoil material should be anticipated during construction.

Stratum 1 – Very Soft to Very Stiff Silty Clay
Generally these soils consisted of brown and/or mottled with gray lacustrine clays in borings SB-01, SB-02, SB-04 and SB-05 extending to 18.5 feet below existing grade. At SB-01 a soft brown layer was encountered with variable amounts of sand and gravel from 2.5 feet below existing grade extending to 7.5 feet below existing grade. At SB-02 very soft layer of this material was encountered at the surface extending to 3 feet below existing grade. Beneath this layer a very stiff layer high plasticity lacustrine clay layer (USCS classification of CH) was encountered from 3 feet extending to 5 feet below existing grade. At SB-04 and SB-05 this layer was sandwiched between a glacial clay (Stratum 2) in the upper 18.5 feet and from 38.5 feet below existing grade extending to 43.5 feet below existing grade underlain in to a hard bearing till (Stratum 3). The SPT N value or blow counts for these soils ranged from 2 to15 with an average of 7 blows per foot. The USCS classification of this soil is CL.

Stratum 2 – Hard Silty Clay
Identical layers of hard gray glacial clays were encountered in SB-04 and SB-05 underlain by lacustrine clays from Stratum 1. The glacial clay was encountered at a depth of 18.5 feet below existing grade extending to 38.5 feet below existing grade. A transition layer of clay was encountered up to a depth of 43.5 feet below existing grade. The SPT N value or blow counts for these soils ranged from 29 to 52 with an average of 40 blows per foot. The USCS classification of this soil is CL.

Stratum 3 – Very Hard Till
At SB-04 and SB-05 a very hard till layer was encountered beneath glacial clay in Stratum 2 at a depth of 43.5 feet below existing grade extending to the final explored depth of 45 feet below existing grade. The SPT N value or blow counts for these soils over 50 blows per foot.

3.2 Groundwater

Groundwater was encountered during the drilling operations as summarized below in Table 3.2.1 below. Typically, the level where the soil color changes from brown to gray is generally indicative of the long term groundwater level. Water levels reported are accurate only for the time and date the borings were drilled. The borings were backfilled and sealed

the same day that they were completed. Long term monitoring of the boreholes was not included as part of the scope of our subsurface investigation.

Table 3.2.1
SUMMARY OF ENCOUNTERED GROUNDWATER CONDITIONS

Boring No.	Depth (ft.) At Time of Drilling	Depth (ft.) End of Drilling	Depth (ft.) After Drilling
SB-02	2.0	-	-
SB-04	43.0	-	-

It should be noted that the elevation of the natural groundwater table, and the elevation and quantity of the perched groundwater, is likely to vary throughout the year depending on the amount of precipitation, runoff, evaporation and percolation in the area, as well as on the water level in the surface water bodies in the vicinity affecting the groundwater flow pattern. Long term monitoring with monitoring wells or piezometers would be necessary to accurately assess the groundwater levels and fluctuation patterns at the site. Even though groundwater was not encountered in the remaining boreholes, it should be noted that the silty clay material present is not amenable to recharge of groundwater during the typical drill timeframe and may hold pockets of water. Moisture contents for the low plasticity soils generally ranged from 10.2 percent to 33.0 percent with an average of 20 percent. The soils are considered very moist to wet. If deemed necessary, may require methods of controlling water during construction. The transition of soils in coloration from brown to gray is a possible indicator of the static groundwater table.

4.0 ANALYSES AND RECOMMENDATIONS

4.1 General

The following evaluations and conclusions are based on interpretations of field and laboratory data obtained during the geotechnical investigation and MSG's experience with similar soils and subsurface conditions. Where comments are made on construction or regarding the proposed development, they are provided in order to highlight aspects of construction that could potentially affect the design of the project. Contractors bidding on or undertaking the work should make their own interpretations of the factual results of the investigation as it affects their construction methods, equipment capabilities, costs, schedule, sequencing and similar issues.

This report and evaluation reflects only the geotechnical aspects of the subsurface conditions at the site. Review and evaluation of environmental aspects of subsurface conditions is beyond the scope of this report.

While borings were select and the geotechnical scope was limited, other areas of the site may require undercutting at the time of construction. The contractor, designer and parties involved in the planning and execution phase should be prepared to remediate the site if warranted. Undercut fill requirements should be performed in accordance with Section 4.4 of this report.

4.2 Structure Foundation Recommendations

MSG has developed the foundation recommendations presented herein based on the geotechnical investigation and the silty clay encountered during drilling operations.

4.2.1 Concrete Pump Structures at SB-04

Based upon our review of the existing soil conditions in the planned foundation areas in the vicinity of Borings SB-04, it is recommended that the foundations bear within the natural medium stiff soils or well compacted engineered fill be designed for an allowable bearing capacity of 1,500 psf. This assumes existing elevation is

currently approximately 572.0 feet and the proposed footing for the pump is approximately at elevation 562.0 feet, which results in a 10 foot difference. By utilizing proper construction techniques, the total settlement (i.e. from immediate settlement and primary and secondary consolidation) in the soil layers should be limited to 1 inch and the differential settlement should not exceed ¾ of the total settlement. Primary consolidation is anticipated to occur in the cohesive soil layers over a period of 6 to 8 months after completion of construction. Secondary consolidation is anticipated to occur indefinitely in the cohesive layers but is anticipated to be minimal. The recommended values take into account variation in shear strength of the underlying soil likely to be encountered within portions of the site and should provide economical shallow footing sizes for the type of structures proposed with an adequate factor of safety. This evaluation was based on footing elevations with regards to existing site elevations. Foundation subgrades should be evaluated by a geotechnical engineer to determine the undercut locations. Should expansive soil be encountered during construction in localized areas, undercutting at least 5 feet beyond planned bearing depth may be required in the vicinity of the foundations.

The footing sizes should be based upon the anticipated structural loads in comparison to the aforementioned recommended allowable bearing capacity. However, the wall footings should be at least 3.0 feet wide and the column footings should be at least 36 square feet (6 feet by 6 feet). Exterior footing bottoms and footings in unheated areas should bear just below the frost depth for the site which is generally 42 inches below final exterior grade in this region of Ohio. This will provide protection against possible frost damage. Interior footings, which should not be subject to frost action, may bear at shallower depths, provided they are supported on native compact soil or engineered fill capable of supporting the design load. MSG recommends the interior shallow foundations bear no less than 24 inches below final floor subgrade.

A qualified geotechnical consultant, prior to the placement of reinforcing steel and concrete, should evaluate foundation excavations to verify that an adequate bearing material is present, and that all debris, mud, and loose, frozen or water-softened soils are removed. All footings should bear in the undisturbed natural soils or in well-compacted fill soils. MSG recommends that the floor of all foundation excavations be compacted. In addition, MSG recommends that a cone penetrometer test (ASTM D3441), or similar field analysis, be performed by the geotechnical engineer representative to assure a suitable bearing capacity for all foundations prior to concrete placement.

Foundations should be constructed as soon as is practical after foundation excavation activities. If the foundation excavations will be left open for an extended period of time, a thin mat of lean concrete should be placed over the bottom to minimize damage to the bearing surface from weather or construction activities. Water should not be allowed to pond in any excavation. Foundation concrete should not be placed on frozen or flooded subgrade.

4.3 Slabs-on-Grade

The subgrade soils will consist of natural low to medium plasticity silty clay or engineered fill. The subgrade should be inspected and tested to assure proper preparation. The concrete pad area shall be proof rolled as described in Section 4.2. Based on observations made during proof rolling operations, soft/yielding areas should be undercut and backfilled as described in Section 4.3. Localized undercuts of unsuitable bearing material (e.g. soft soils) may be required in any areas where failing proof rolls are observed.

Based on the existing materials and a subgrade prepared as outlined above, for slab-on-grade design, an estimated modulus for subgrade reaction on top of the existing subgrade (low plasticity soils) of 100 pounds per cubic inch (pci) may be used. The use of stabilized base increases the modulus of subgrade reaction appreciably. The slab should be a minimum of 5 inches thick. However, the final design thickness of the slabs, the joint spacing and slab reinforcement

should be determined by the structural engineer based on the above recommended subgrade modulus and the anticipated floor loading conditions. Design of the slabs was not included in MSG's scope of work for the geotechnical investigation.

In order to minimize the potential impacts caused by differential settlement, the slab-on-grade should be kept structurally separate from walls and columns and saw cut control joints should be provided at suitable intervals.

4.4 Site Preparation

The following are our recommendations for the site soil preparation based on the geotechnical investigation performed for this project. These recommendations should be incorporated into the project specifications.

Before proceeding with construction, surface soils, vegetation, topsoil, root systems, refuse, asphalt, concrete including any existing abandoned buried foundations, and other deleterious materials should be stripped from the proposed construction areas. Depending on the time of year of construction and the Contractor's Means and Methods at controlling surface water, it may be possible that portions of the upper 12 to 18 inches of site material including the surface soils will be considered unsuitable and will be required to be stripped during site preparation activities. The on-site cohesive soils are moisture sensitive (10 percent to 33 percent with an average of 20 percent) and could become unstable if proper site water controls are not implemented and/or if they are subject to construction traffic. Every effort should be taken to minimize disturbance during compaction or over excavation and where possible, free standing water should be diverted away from the construction perimeter or pumped out using a sump to accommodate the proper compaction techniques.

Generally, areas exposed by stripping operations on which subgrade preparations are to be performed should be compacted in place to 98 percent of Standard Proctor or 95 percent of Modified Proctor. If there are areas where the building floor slab will be located partially on a fill area and partially on a cut area, it is recommended that the depth of subgrade compaction in the cut area be increased to 18 inches, to provide uniform support of the rigid slab.

It is recommended that the prepared subgrade for pavement and slab-on-grade areas be proof rolled to detect any unstable areas. Proof rolling should be accomplished by making a minimum of two complete passes in each of two perpendicular directions with a fully-loaded tandem-axle dump truck, or other approved pneumatic-tired vehicle, with a minimum weight of 20 tons. If proof rolling reveals the presence of unstable areas within the subgrade, certain remedial measures will be required to stabilize the subgrade. Depending on the severity of distress encountered during proof rolling, undercutting of 24 to 36 inches below subgrade and backfilling with engineered fill as outlined in Section 4.4 may be performed. If an undercut and replacement of the top 24 to 36 inches fails to stabilize the subgrade, use of granular backfill with geogrid stabilization may be required. Undercuts may be reduced to 12 to 18 inches if geogrid and granular backfill is utilized. Alternately, chemical stabilization of the upper 12 to 18 inches with cement or lime may be performed.

Based on a combinations of field investigations, visual assessment and laboratory test data, the following observations were noted:

Undercutting may be required in the proposed parking areas, roadway areas where unsuitable bearing material is not achieved such as in the vicinity of borings SB-01 and SB-02 where soft soils are encountered in the upper 3 feet. We anticipate up to 2,000 cy of undercuts may be required in select locations upon the outcome of proofroll observations.

Suitability of bearing should be determined in shallow foundation bearing structures (i.e. bearing at 3.5 feet below existing grade). Deeper undercuts up to 5 feet may be warranted upon a case by case basis. For deeper bearing structures such as the Pump Structure Profile, Sheet GLARO-XX0-000-206, "Enlarged Pump Plan", dated November 2018, it is our understanding the existing subgrade elevation is currently approximately 572.0 feet and the proposed footing for the pump is approximately at elevation 562.0 feet, thus resulting in approximately 10 foot difference. This

means the foundation will likely bear on medium stiff soils. Therefore we recommend all pump structure foundations undercut additional 8 feet beyond the planned bearing depth into hard bearing soils (18.5 feet below existing grade).

The actual undercut depths and/or subgrade remediation measures required should be determined by the on-site Geotechnical Engineer or his/her designated representative.

Due to the past use of the subject site, existing abandoned utilities within the project site may be encountered during construction. Such utilities should be removed and relocated or abandoned in place. If abandoned in place, it is recommended that the utility pipe be filled with cement grout to avoid potential collapse in the future. Should the utility lines be removed from the site, the resultant trench excavations should be backfilled with well-compacted granular material, placed and compacted in accordance with the recommendations of Section 4.3.

4.5 Fill Placement and Engineered Fill Requirements

Any fill placed in areas which will support new foundations, slabs-on-grade and pavement should be free of organics, debris, frozen soils or any other deleterious materials. Portions of the on-site natural and inorganic clay soils are generally considered suitable for reuse as fill but may require moisture conditioning effort. High plasticity clay or organic soils, where encountered such as at boring SB-02 at a depth of 3 feet to a depth of 5 feet, are not considered suitable for reuse as fill. Because the number of boring locations were limited during the geotechnical investigation, it should also be noted other areas of high plasticity clays may be encountered during construction.

The fill material should be verified by an approved testing laboratory or by a geotechnical engineering firm. All fine grained fill soils should be checked for plasticity index and liquid limit before placement. Cohesive fill materials should have a liquid limit less than 40 percent and plasticity index less than 20 percent (i.e., non-expansive).

As described in Section 4.1 above, undercuts will be required depending on the suitability of the soils. The operations (extent, depth, suitability of soils etc.) involving fill material removal and replacement with engineered fill for this project should be performed as directed by the on-site Geotechnical Engineer or his/her designated representative.

Coarse crushed granular material is recommended as fill for utility trench backfill, replacement of undercut areas and as aggregate base material for pavement and slab-on-grade areas. The granular material shall consist of natural aggregate materials that meet the gradation requirements of ODOT 304 (or alternately Structural Backfill Type 1 for slab-on-grade areas), or engineer approved equivalent. Typical lift thickness utilized for this material is 8 inches. In utility trenches, granular backfill material should extend at least two pipe diameters above the pipe's crown. Clay (on-site material) compacted to 95 percent of Modified Proctor or 98 percent Standard Proctor can be used as a backfill for the balance of the trench excavation.

Fill should be compacted to 98 percent of the Standard Proctor or 95 percent Modified Proctor maximum dry density and should be compacted at $\pm$2 percent of optimum moisture content. Fill materials should be placed in horizontal lifts and adequately keyed into stripped and scarified subgrade soils and adjacent fill. Proper drainage should be maintained during and after fill placement to prevent water from impacting compaction efforts or long-term fill integrity. A qualified geotechnical consultant should be retained to monitor fill placement in order to assure compaction requirements are achieved. Soil density testing should be performed during fill placement activities to assure proper fill compaction. A commonly used testing criterion is one test per 2,500 square feet per lift in areas to support proposed structures and one test per 5,000 square feet in parking lots, drive ways, exterior slabs, etc., with a minimum of three tests per lift. Areas that do not achieve compaction requirements after initial placement should be recompacted to meet project requirements.

The actual lift thickness suitable for fill placement is dependent upon the soil type, compaction equipment, and the compaction specification. In general fill should be placed in 9-inch loose thickness lifts; assuming appropriately

weighted and ballasted compaction equipment is utilized. In confined areas where hand operated compaction equipment is required, 4-inch and 6-inch loose thickness lifts should be utilized for hand operated vibratory plate compactors and hand operated vibratory drum rollers weighing at least 1,000 pounds, respectively. Sand fills should be compacted using smooth vibratory rollers. Clay fills should be compacted using a sheep foot compactor. The geotechnical engineer, as part of the construction monitoring, should review the equipment utilized for compaction to confirm suitability relative to the specified loose lift thickness. If necessary, the geotechnical engineer will recommend a revised lift thickness suitable to the equipment performing compaction.

If a working platform for the new building construction is needed, and prior to footing excavation, it is recommended that at least 6 inches of granular base material meeting the gradation requirements of ODOT 304 crushed aggregate be placed and compacted to 95 percent of Modified Proctor maximum dry density or 98 percent of Standard Proctor maximum dry density.

4.6 Excavation and Slope

Familiarity with applicable local state and federal safety regulations, including current OSHA excavation and trench safety is vital. Therefore, it should be a requisite for both the owner and contractor with the contractor by and large being responsible for the safety of the site. Activities at the site, such as utilities or building demolition, may require excavations at significant depth below the ground surface. Slope height, slope inclination, and excavation depth (including utility trench excavations) should in no case exceed those specified in local, state, or federal safety (OSHA Health and Safety Standards for Excavations, 29 CFR Part 1926 Subpart P) regulations. Such regulations are strictly enforced and, if not followed, the Owner, contractor, or earthwork or utility subcontractors could be liable for substantial penalties. Maximum allowable slopes for excavations less than 20 feet based on soil type and angle to horizontal are reflected in Table 4.4.1.

The overburden soils encountered during our investigation were generally composed of medium stiff to very stiff silty clay, which also assumes undercuts have been performed in very soft or soft areas and replaced with engineering fill. Based upon the data obtained, we anticipate OSHA will classify site soils as Type B soil. However, some soils (i.e. soft soils) may warrant a Type C classification. Flatter slopes will be required if seepage conditions occur during construction or if subsurface sand lenses are encountered. For permanent excavations and slopes, the grades should be no steeper than 4H:1V without further geotechnical review of the finalized grading plan. If any excavation, including a utility trench, is extended to a depth of more than 20 feet, OSHA requires that a Professional Engineer design the side slopes of such excavations.

TABLE 4.6.1
ALLOWABLE SLOPES

Soil Type	H:V	Slope Angle
Stable Rock	Vertical	90°
Type A	¾:1	53°
Type B	**1:1**	**45°**
Type C	**1 ½ : 1**	**34°**
Type A (Short-Term) – for a maximum excavation depth of 12 ft.	½:1	63°

4.7 Embankment and Slope Stability Analysis

The slope stability assessment is based on the subsurface conditions observed at the boring locations, laboratory test data obtained, the generic berm profile provided by the client, and our professional experience. The generic berm profile provided was for a berm 10 feet high with a top width of 12 feet and 3:1 slideslopes. Testing performed included grain size analysis, plasticity characteristics, density, water content and unconfined compression. Triaxial compression and consolidation analyses were not performed.

For preliminary design, four (4) scenarios were analyzed for the generic berm profile slope stability. These scenarios included: static slope stability for end of construction conditions; static slope stability for steady-state seepage conditions with water at normal pool; static slope stability for steady-state seepage conditions with water at top of dam; and, static slope stability for rapid drawdown from normal pool. Results are summarized below. These analysis may demonstrate to the client and jurisdictional authority that additional analysis are not necessary. Please see Slope Stability Analysis in Appendix C.

TABLE 4.7.1
SLOPE STABILITY ANALYSIS RESULTS

Static Slope Stability Scenario	Typical Minimum FOS	Calculated FOS
End of Construction	1.3	**6.9**
Steady-state Seepage Condition; Normal Pool	1.5	**6.5**
Steady-state Seepage Condition; Water at Top of Dam	1.3	**6.2**
Rapid Drawdown from Normal Pool	1.3	**2.2**

4.8 Lateral Earth Pressure

Lateral earth pressures (horizontal stresses) are developed during soil displacements (or strains). Lateral earth pressure for design of underground structures and retaining walls is determined utilizing an earth pressure coefficient to relate horizontal stress to vertical stress. Three separate earth pressure coefficients are utilized to determine lateral earth pressure: at rest; active; and passive. Active earth pressure addresses displacement of a vertical soil face away from the retained soil. Passive earth pressure addresses displacement against the retained soil. At rest earth pressure addresses a negligible displacement scenario. Applied horizontal stress can be determined by multiplying the appropriate earth pressure coefficient by the applied vertical stress. Earth pressure coefficients are a direct function of the internal friction of a soil. Laboratory testing to determine internal friction angles for soil was not performed. However, index laboratory and field data obtained can be utilized to approximate earth pressure coefficients based upon empirical relationships.

For remolded clay (i.e. engineered fill), the lateral earth pressure coefficients are: at-rest earth pressure (K_o) = 0.6, active pressure coefficient (K_a) = 0.5, and the passive earth pressure coefficient (K_p) = 2.0. For gravel backfill, the lateral earth pressure coefficients are K_o = 0.5, K_a = 0.3 and K_p = 3.0 (refer to Table 4.8.1).

TABLE 4.8.1

Soil Parameters	Engineered Fill Material Type	
	Granular	Silty Clay
Unit Weight	125	135
Angle of Internal Friction, degrees	30	20
Soil/Concrete Friction Angle, degrees	21	13
At Rest Pressure Coefficient, Ko	0.5	0.6
Active Pressure Coefficient, Ka	0.3	0.5
Passive Pressure Coefficient, Kp *	3.0	2.0

* The passive pressure in the upper 3.0 feet should be neglected

4.9 Site Seismic Classification

According to the International Building Code (IBC) Chapter 16, Tables 1613.5.2 and 1613.5.3, the proposed site is designated as "Site Class D" based on the average Standard Penetration Test for the upper 50 feet of soil, which is the maximum depth the borings were advanced for this geotechnical investigation. It is considered as having a stiff soil profile, as defined by IBC.

4.10 Pavement Recommendations

Subgrade soils should be prepared for pavements as recommended in previous sections of this report. The use of pavement subdrains, in conjunction with free draining backfill, will also improve performance. Such measures should include consultation with a geotechnical engineer to assure soil improvement techniques result in pavement construction with an acceptable service life. Subgrade stability should be verified through proof rolling in accordance with Section 4.2 of this report.

Based on the soil characteristics and blow counts during the geotechnical investigation, a conservative California Bearing Ratio (CBR) value of 6 was estimated for the on-site cohesive soils. MSG recommends that underdrains be utilized around catch basins and in other low areas of the proposed pavements to limit the accumulation of water below the pavement structures. Surface edge drains should also be used at curbs.

Pavement design information was not provided for the proposed pavement areas. The pavement design input parameters are established based on the procedures contained in the 1993 Guide for Design of Pavement Structures by AASHTO. For the basis of the design, MSG assumed a low volume area with a 1.5 daily equivalent 18-kip Equivalent Standard Axle Loading (ESAL) of approximately 100,000 ESALS with 80% reliability, and an analysis period of 15 to 25 years. On that basis we recommend the use of the following pavement sections:

TABLE 4.9.1 RECOMMENDED PAVEMENT THICKNESS (INCHES)

Pavement Materials*	Light-Duty: Parking Lots	Heavy-Duty: Driveways/Dumpster Pads etc.
Surface Course (ODOT Item 448) Type 1	1.5	1.5
Intermediate Course (ODOT 448) Type 2	2.5	3.25
Aggregate Base (ODOT 304)	6	10
OR		
Portland Cement Concrete (PCC) (ODOT Item 452)	6	8
Aggregate Base (ODOT 304)	6	8

* Verify pavement materials with local and state guidelines.

5.0 CONSTRUCTION CONSIDERATIONS

5.1 Ground Water Control

The location of the level of groundwater is of importance in shallow foundations for a number of reasons. Most importantly, the bearing capacity of the soil is affected by the presence of a high water table as encountered in SB-02 at two feet below existing grade, decreasing the bearing capacity.

Groundwater was observed at soil boring locations SB-02 and SB-04 at 2 feet and 43 feet below existing grade, respectively during the on-site drilling activities. Perched water may be present at other locations on the Subject Property. As discussed previously, the groundwater elevation fluctuates and is typically higher during the winter and spring and lower in summer and early fall.

The amount and type of dewatering required during construction will depend on the weather, groundwater levels at the time of construction, and the effectiveness of the contractor's techniques in preventing surface water runoff from entering open excavations and lowering the groundwater table. Given the cohesive nature of the soils encountered on-site, the contractor should be prepared to address general water infiltration (i.e. pumping water from prepared sumps).

5.2 Construction Monitoring

The Mannik & Smith Group, Inc. knows the importance of providing a quality testing program benefits the outcome of the product to be designed and minimizes the potential of major problems before they develop. We recommend the use of our assistance to conduct tests during construction.

6.0 CLOSURE

The evaluations, conclusions and recommendations in this report are based on our interpretation of the field and laboratory data obtained during the geotechnical investigation, our understanding of the project and our experience during previous work, with similar sites and subsurface conditions. Data used during this exploration included:

- Five (5) exploratory borings performed during this study;
- Observations of the project site by our staff; and,
- Results of laboratory soil testing.

The subsurface conditions discussed in this report and those shown on the boring logs represent an estimate of the subsurface conditions based on interpretation of the boring data using normally accepted geotechnical engineering judgments. Although individual test borings are representative of the subsurface conditions at the boring locations on the dates shown, they are not necessarily indicative of subsurface conditions at other locations or at other times. As variations in the soil profile are encountered, additional subsurface sampling and testing may be necessary to provide data required to reevaluate the recommendations of this report. MSG is not responsible for independent conclusions, opinions or recommendations made by others based upon information presented in this report.

The project plans and specifications should be reviewed by the on-site geotechnical engineer to confirm that the geotechnical aspects are generally consistent with the recommendations of this report. In addition, site subgrade preparation, fill compaction activities, and foundation installation activities should be monitored by the geotechnical engineer or his representative.

FIGURES

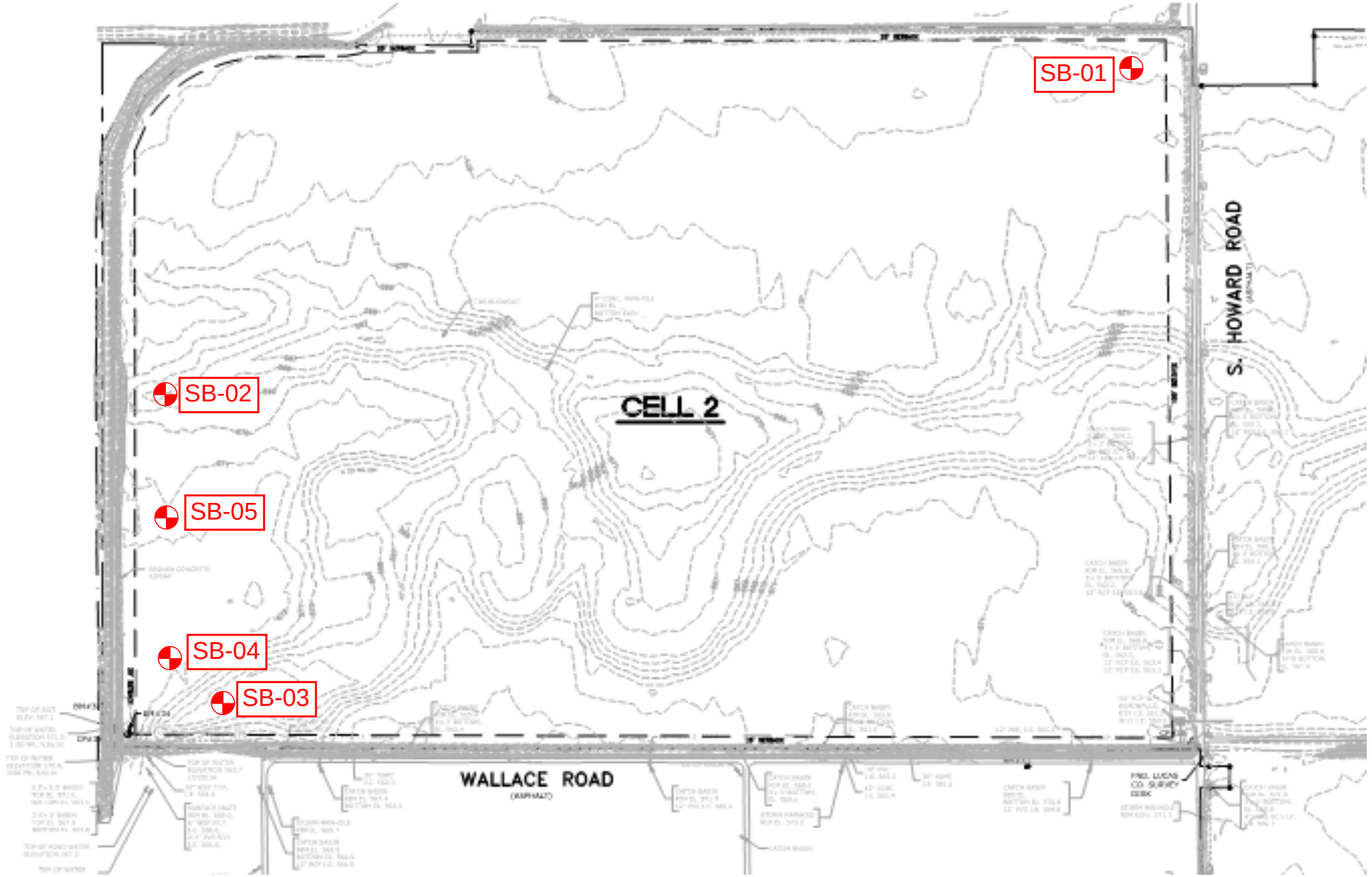
FIGURE 1 – SITE LOCATION MAP
FIGURE 2 – SOIL BORING LOCATION MAP

Mannik Smith GROUP
2365 Haggerty Road South
Canton, Michigan 48188
Tel: 734-397-3100
Fax: 734-397-3131
www.MannikSmithGroup.com

Figure 1: Site Location Map
Howard Farms Restoration
Jerusalem Township, Lucas County, Ohio

Map Adapted from Google Earth 2018 ®

N



Mannik Smith GROUP
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Canton, Michigan 48188
Tel: 734-397-3100
Fax: 734-397-3131
www.MannikSmithGroup.com

Figure 2: Soil Boring Location Plan
Howard Farms Restoration
Jerusalem Township, Lucas County, Ohio
MSG Project No. D1310012

Notes:
Not to Scale
Preliminary Site Plan
Boring Locations are approximate
Soil Borings

N

APPENDIX A
SOIL BORING LOGS

GENERAL SOIL SAMPLE NOTES

Unless noted, all terms utilized herein refer to the Standard Definitions presented in ASTM D653.

Standard Penetration Test (ASTM D1586): A 2.0-inch outside-diameter (O.D.), 1-3/8-inch inside-diameter (I.D.) split barrel sampler is driven into undisturbed soil by means of a 140-pound weight falling freely through a vertical distance of 30 inches. The sampler is normally driven three successive 6-inch increments. The total number of blows required for the final 12 inches of penetration is the Standard Penetration Resistance (N).

COHESIVE SOILS

Consistency	Approximate Range of N	Unconfined Compressive Strength (psf)
Very Soft	0 – 1	Below 500
Soft	2 – 4	500 – 1,000
Medium Stiff	5 – 8	1,000 – 2,000
Stiff	9 – 15	2,000 – 4,000
Very Stiff	16 – 30	4,000 – 8,000
Hard	31 – 50	8,000 – 16,000
Very Hard	Over 50	Over 16,000

COHESIONLESS SOILS

Density Classification	Approximate Range of N
Very Loose	0 – 4
Loose	5 – 10
Medium Dense	11 – 30
Dense	31 – 50
Very Dense	Over 50

CLASSIFICATION

The major soil constituent is the principal noun, i.e. sand, silt, gravel. The second major soil constituent and other minor constituents are reported as follows:

Second Major Constituent (percent by weight)	Minor Constituents (percent by weight)
Trace – 1% to 11%	Trace – 1% to 11%
Adjective – 12% to 35% (clayey, silty, etc.)	Little – 12% to 22%
	Some – 23% to 33%
And – Over 35%	

PARTICLE SIZES

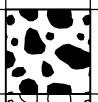
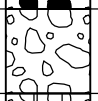
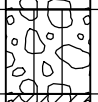
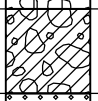
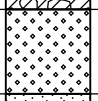
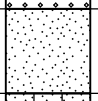
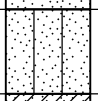
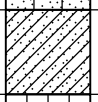
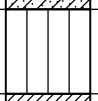
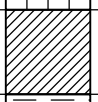
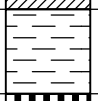
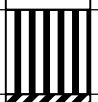
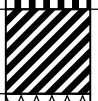
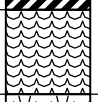
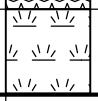
Boulders		- Greater than 12 inches (305 mm)
Cobbles		- 3 inches (76.2 mm) to 12 inches (305 mm)
Gravel:	Coarse	- ¾ inches (19.05 mm) to 3 inches (76.2 mm)
	Fine	- No.4 (4.75 mm) to ¾ inches (19.05 mm)
Sand:	Coarse	- No. 10 (2.00 mm) to No. 4 (4.75 mm)
	Medium	- No. 40 (0.425 mm) to No. 10 (2.00 mm)
	Fine	- No. 200 (0.074 mm) to No. 40 (0.425 mm)
Silt		- 0.005 mm to 0.074 mm
Clay		- Less than 0.005 mm

If clay content is sufficient so that clay dominates soil properties, clay becomes the principal noun with the other major soil constituent as modifier: i.e., silty clay. Other minor soil constituents may be included in accordance with the classification breakdown for cohesionless soils: i.e., silty clay, trace sand, little gravel.

If sand particle size is greater than 11% by weight of the total sample weight, the adjective (i.e., fine, medium or coarse) is added to the soil description for the sand portion of the sample, provided sand is the major or second major constituent.

SAMPLE DESIGNATIONS

AS	Auger Sample - directly from auger flight	ST	Shelby Tube Sample - 3-inch diameter unless otherwise noted
BS	Miscellaneous Samples - Bottle or Bag	PS	Piston Sample - 3-inch diameter unless otherwise noted
MC	Macro-Core Sample - 2.25-inch O.D., 1.75-inch I.D., 5 feet long polyethylene liner	RC	Rock Core - NX core unless otherwise noted
LB	Large-Bore (Micro-Core) Sample - 1-inch diameter, 2 feet long polyethylene liner	CS	CME Continuous Sample - 5 feet long, 3-inch diameter unless otherwise noted
SS	Split Spoon Sample - 1-inch or 2-inch O.D.	HA	Hand Auger
LS	Split Spoon (SS) Sampler with 3 feet long liner insert	DP	Drive Point
NR	No Recovery	CM	Coring Machine

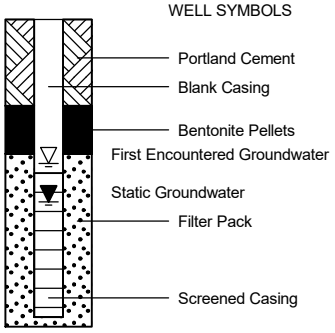
MAJOR DIVISIONS					TYPICAL NAMES
COARSE-GRAINED SOILS MORE THAN HALF IS COARSER THAN NO. 200 SIEVE	GRAVELS MORE THAN HALF COARSE FRACTION IS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS WITH LESS THAN 15% FINES	GW		WELL-GRADED GRAVELS WITH OR WITHOUT SAND
			GP		POORLY-GRADED GRAVELS WITH OR WITHOUT SAND
		GRAVELS WITH 15% OR MORE FINES	GM		SILTY GRAVELS WITH OR WITHOUT SAND
			GC		CLAYEY GRAVELS WITH OR WITHOUT SAND
	SANDS MORE THAN HALF COARSE FRACTION IS FINER THAN NO. 4 SIEVE SIZE	CLEAN SANDS WITH LESS THAN 15% FINES	SW		WELL-GRADED SANDS WITH OR WITHOUT GRAVEL
			SP		POORLY-GRADED SANDS WITH OR WITHOUT GRAVEL
		SANDS WITH 15% OR MORE FINES	SM		SILTY SANDS WITH OR WITHOUT GRAVEL
			SC		CLAYEY SANDS WITH OR WITHOUT GRAVEL
FINE-GRAINED SOILS MORE THAN HALF IS FINER THAN NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT 50% OR LESS		ML		INORGANIC SILTS OF LOW TO MEDIUM PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
			CL		INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
			OL		ORGANIC SILTS OR CLAYS OF LOW TO MEDIUM PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50%		MH		INORGANIC SILTS OF HIGH PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
			CH		INORGANIC CLAYS OF HIGH PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
			OH		ORGANIC SILTS OR CLAYS OF HIGH PLASTICITY WITH OR WITHOUT SAND OR GRAVEL
HIGHLY ORGANIC SOILS			PT		PEAT AND OTHER HIGHLY ORGANIC SOILS

SYMBOLS KEY

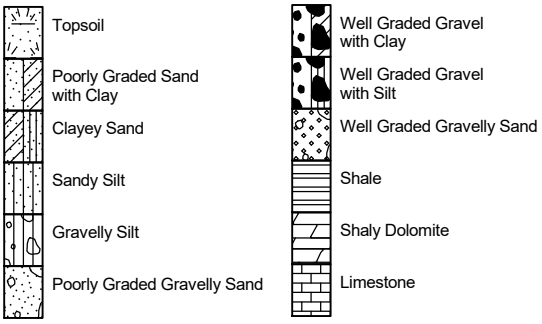
SAMPLE TYPES

- Split Spoon sample, 1 inch or 2 inch outer-diameter.
- Shelby Tube sample - 3 inch diameter unless otherwise noted.

WELL SYMBOLS



OTHER MATERIAL SYMBOLS



The Mannik & Smith Group, Inc.
2365 Haggerty Road South, Canton, MI 48188
ph: (734) 397-3100 fax: (734) 397-3131
www.manniksmithgroup.com

BORING / WELL LOG KEY

BORING / WELL LOG USCS KEY - - 1/23/20 09:43 - W:\PROJECTS\PROJECTS A-E\D1310012\ADMIN\GEOTECH\D1310012 BORING LOGS.GPJ

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ph: (734) 397-3100 fax: (734) 397-3131
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BORING NUMBER SB-01

CLIENT Ducks Unlimited
PROJECT NAME Howard Farms-Geotechnical Investigation
PROJECT NUMBER D1310012
PROJECT LOCATION Lucas County, Ohio
DATE STARTED 12/5/19 **COMPLETED** 12/5/19
GROUND ELEVATION 572.0 **BORING DIAMETER**
DRILLING CONTRACTOR MSG
BORING COORDINATES N/A
DRILLING METHOD Hollow Stem Auger with Split Spoon
WATER LEVEL AT TIME OF DRILLING N/A
LOGGED BY **CHECKED BY** MXS
WATER LEVEL AT END OF DRILLING N/A
NOTES
WATER LEVEL AFTER DRILLING N/A

DEPTH (FEET)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0		(CL) Medium stiff, brown silty CLAY, trace sand and gravel, moist	SS 1	53	2-3-3 (6)	2.5						
		(CL) Soft, brown silty CLAY, trace sand and gravel, wet	SS 2	80	1-1-3 (4)	0.5						
5			SS 3	53	1-1-3 (4)	0.5		33				
		(CL) Medium stiff, brown silty CLAY, trace sand and gravel, moist	SS 4	100	2-3-5 (8)	1.75						
10		Bottom of borehole at 10.0 feet.										

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2365 Haggerty Road South, Canton, MI 48188
ph: (734) 397-3100 fax: (734) 397-3131
www.manniksmithgroup.com

BORING NUMBER SB-02

CLIENT Ducks Unlimited
PROJECT NAME Howard Farms-Geotechnical Investigation
PROJECT NUMBER D1310012
PROJECT LOCATION Lucas County, Ohio
DATE STARTED 12/5/19 **COMPLETED** 12/5/19
GROUND ELEVATION 570.0 **BORING DIAMETER**
DRILLING CONTRACTOR MSG
BORING COORDINATES N/A
DRILLING METHOD Hollow Stem Auger with Split Spoon
WATER LEVEL AT TIME OF DRILLING 2 FEET
LOGGED BY **CHECKED BY** MXS
WATER LEVEL AT END OF DRILLING N/A
NOTES
WATER LEVEL AFTER DRILLING N/A

DEPTH (FEET)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0		(CL) Soft, brown silty clay, trace sand and gravel, moist	SS 1	27	1-1-1 (2)	0.25						
5		(CH) Stiff, mottled brown and gray high plasticity silty CLAY, trace sand, moist * Full Sieve Analysis Completed	ST 1	100		3		27	56	20	36	92
		(CL) Stiff, gray silty CLAY, trace sand and gravel, moist	SS 3	0	2-4-6 (10)	1.50						
10		(CL) Stiff, gray silty CLAY, with sand, trace gravel, moist * Full Sieve Analysis Completed	SS 4	53	2-4-7 (11)	1.75		15	27	15	12	75
		Bottom of borehole at 10.0 feet.										

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BORING NUMBER SB-03

The Mannik & Smith Group, Inc.
2365 Haggerty Road South, Canton, MI 48188
ph: (734) 397-3100 fax: (734) 397-3131
www.manniksmithgroup.com

CLIENT Ducks Unlimited
PROJECT NAME Howard Farms-Geotechnical Investigation
PROJECT NUMBER D1310012
PROJECT LOCATION Lucas County, Ohio
DATE STARTED 12/4/19 **COMPLETED** 12/4/19
GROUND ELEVATION 568.0 **BORING DIAMETER**
DRILLING CONTRACTOR MSG
BORING COORDINATES N/A
DRILLING METHOD Hollow Stem Auger with Split Spoon
WATER LEVEL AT TIME OF DRILLING N/A
LOGGED BY **CHECKED BY** MXS
WATER LEVEL AT END OF DRILLING N/A
NOTES
WATER LEVEL AFTER DRILLING N/A

DEPTH (FEET)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0		TOPSOIL (12 inches)										
		(CL) Medium stiff, brown silty CLAY, trace sand and gravel, moist	SS 1	67	1-2-3 (5)	1.75						
			SS 2	87	1-3-4 (7)	2.75						
5			SS 3	100	2-3-5 (8)	2.25						
		(CL) Medium stiff, gray silty CLAY, trace sand and gravel, moist	SS 4	73	1-3-5 (8)	2		23	39	19	20	97
10		*Full Sieve Analysis Completed										
		Bottom of borehole at 10.0 feet.										

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www.manniksmithgroup.com

BORING NUMBER SB-04

CLIENT Ducks Unlimited
PROJECT NAME Howard Farms-Geotechnical Investigation
PROJECT NUMBER D1310012
PROJECT LOCATION Lucas County, Ohio
DATE STARTED 12/4/19 **COMPLETED** 12/4/19
GROUND ELEVATION 573.0 **BORING DIAMETER**
DRILLING CONTRACTOR MSG
BORING COORDINATES N/A
DRILLING METHOD Hollow Stem Auger with Split Spoon
WATER LEVEL AT TIME OF DRILLING 43 FEET
LOGGED BY **CHECKED BY** MXS
WATER LEVEL AT END OF DRILLING N/A
NOTES
WATER LEVEL AFTER DRILLING N/A

DEPTH (FEET)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0		TOPSOIL (12 inches)										
		(CL) Medium stiff to stiff, brown and/or mottled with gray silty CLAY, trace sand and gravel, moist	SS 1	67	2-4-4 (8)	3.75						
			SS 2	78	2-4-5 (9)	3.25						
5			SS 3	89	1-3-4 (7)	3.5						
			SS 4	100	1-1-4 (5)	1.0						
10												
			ST 5	133		1	96	29	29	17	12	80
15												
		(CL) Hard, gray silty CLAY, trace sand and gravel, moist	SS 6	67	7-12-17 (29)	4.5+						
20												
			SS 7	94	15-25-27 (52)	4.5+						
25												

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BORING NUMBER SB-04

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PROJECT NAME Howard Farms-Geotechnical Investigation
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PROJECT LOCATION Lucas County, Ohio
DATE STARTED 12/4/19 **COMPLETED** 12/4/19
GROUND ELEVATION 573.0 **BORING DIAMETER**
DRILLING CONTRACTOR MSG
BORING COORDINATES N/A
DRILLING METHOD Hollow Stem Auger with Split Spoon
WATER LEVEL AT TIME OF DRILLING 43 FEET
LOGGED BY **CHECKED BY** MXS
WATER LEVEL AT END OF DRILLING N/A
NOTES
WATER LEVEL AFTER DRILLING N/A

DEPTH (FEET)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
25		(CL) Hard, gray silty CLAY, trace sand and gravel, moist *(continued)*										
30			SS 8	83	10-17-20 (37)	4.5+						
35			SS 9	100	11-14-23 (37)	4.5+						
40		(CL) Very Soft, gray silty CLAY, trace sand and gravel, wet	SS 10	100	4-6-8 (14)	0.25		24	31	19	12	100
45			SS 11	61	10-50/5	0						
		Hardpan Refusal at 45.0 feet. Bottom of borehole at 45.0 feet.										

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BORING NUMBER SB-05

CLIENT Ducks Unlimited
PROJECT NAME Howard Farms-Geotechnical Investigation
PROJECT NUMBER D1310012
PROJECT LOCATION Lucas County, Ohio
DATE STARTED 12/5/19 **COMPLETED** 12/5/19
GROUND ELEVATION 571.0 **BORING DIAMETER**
DRILLING CONTRACTOR MSG
BORING COORDINATES N/A
DRILLING METHOD Hollow Stem Auger with Split Spoon
WATER LEVEL AT TIME OF DRILLING N/A
LOGGED BY **CHECKED BY** MXS
WATER LEVEL AT END OF DRILLING N/A
NOTES
WATER LEVEL AFTER DRILLING N/A

DEPTH (FEET)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
0		(CL) Medium stiff to very stiff brown to gray silty CLAY with sand, trace gravel, moist										
			SS 1	53	2-3-4 (7)	2.5						
5			ST 1	80		0.75						
			SS 3	80	2-2-4 (6)	2.75						
			SS 4	100	1-2-3 (5)	1.75						
10			ST 2	100		1.5		23	31	17	14	76
			SS 5	100	0-1-4 (5)	0.75						
15												
		(CL) Hard, gray silty CLAY, with sand, trace gravel, moist * Full Sieve Analysis Completed	SS 6	89	10-16-20 (36)	4.5+		10	26	14	12	84
20												
			SS 7	89	20-25-32 (57)	4.5+						
25												

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CLIENT Ducks Unlimited
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PROJECT NUMBER D1310012
PROJECT LOCATION Lucas County, Ohio
DATE STARTED 12/5/19 **COMPLETED** 12/5/19
GROUND ELEVATION 571.0 **BORING DIAMETER**
DRILLING CONTRACTOR MSG
BORING COORDINATES N/A
DRILLING METHOD Hollow Stem Auger with Split Spoon
WATER LEVEL AT TIME OF DRILLING N/A
LOGGED BY **CHECKED BY** MXS
WATER LEVEL AT END OF DRILLING N/A
NOTES
WATER LEVEL AFTER DRILLING N/A

DEPTH (FEET)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	POCKET PEN. (tsf)	DRY UNIT WT. (pcf)	MOISTURE CONTENT (%)	ATTERBERG LIMITS: LIQUID LIMIT	ATTERBERG LIMITS: PLASTIC LIMIT	ATTERBERG LIMITS: PLASTICITY INDEX	FINES CONTENT (%)
25		(CL) Hard, gray silty CLAY, with sand, trace gravel, moist * Full Sieve Analysis Completed *(continued)*										
30			SS 8	100	11-16-21 (37)	4.5+		11				
35			SS 9	89	12-16-21 (37)	4.5+	130	10				
40		(CL) Very Soft, gray silty CLAY, trace sand and gravel, wet * Full Sieve Analysis Completed	SS 10	94	5-5-10 (15)	0.25		22	29	16	13	99
45			SS 11	67	12-50/6	0						
		Hardpan Refusal at 45.0 feet. Bottom of borehole at 45.0 feet.										

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APPENDIX B
GEOTECHNICAL LABORATORY TEST DATA

LABORATORY TEST PROCEDURES

A brief description of the most common laboratory tests performed at the Geotechnical Engineering Laboratory at the Mannik Smith Group is provided in the following sections.

DESCRIPTION OF SOILS (VISUAL-MANUAL PROCEDURE) (ASTM D2488)
The visual classification of soil samples are performed in accordance with ASTM D2488 standard. Our engineers use this test method to describe each soil sample using visual examination and simple manual tests. Visual classification helps grouping similar soil samples so that only a minimum number of laboratory tests are required for positive soil classification.

POCKET PENETROMETER
In the pocket penetrometer test, the unconfined compressive strength of a cohesive soil sample is estimated by measuring the resistance of the sample to the penetration of a small, calibrated spring-loaded cylinder. The maximum capacity of the penetrometer is 4.5 tons per square foot.

NATURAL MOISTURE CONTENT (ASTM D2216)
Natural moisture content represents the ratio of the weight of water in a given amount of soil to the weight of solid particles. Natural moisture content is expressed as a percentage (%). In this test method the water content is measured in the laboratory by noting the weight loss after drying the soil at specific temperature for 24 hours.

ATTERBERG LIMITS (ASTM D4318)
The Atterberg Limits test is performed in accordance with ASTM D4318. Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) of the soil sample are determined using this test method. The Liquid Limit is the moisture content at which the soil begins to behave as a liquid material and starts to flow. The Plastic Limit is the moisture content at which the soil changes from plastic to semi-solid stage. The Plasticity Index (PI = LL - PL) is the range of moisture content at which the soil is in a plastic stage. Typically, a soil's potential for volume change increases with increase of plasticity indices.

PARTICLE SIZE ANALYSIS (ASTM D421, D422 and D1140)
These tests are performed to determine the partial soil particle size distribution. The soil sample is prepared according to ASTM D421 test method. The amount of material finer than the openings on the No. 200 sieve (0.075 mm) is determined by wash sieve method according to ASTM D1140. The hydrometer test is used to determine particle size distribution of material finer than 0.075 mm according to ASTM D422 test method.

STANDARD PROCTOR COMPACTION TEST (ASTM D698)
The Standard Proctor compaction test is used to determine maximum dry density and optimum moisture content of the soil sample. In this test, the soil is compacted in the Proctor mold in three lifts of equal volume using a standard effort by the free falling of a 5.5 lb rammer from 12 inches above soil surface. The test procedure is repeated on samples at several different moisture contents and a parabolic graph showing the relationship between moisture content and dry density of the soil is established. The maximum dry unit weight of the compacted sample and the respective moisture content is reported as maximum dry density and optimum moisture content of the soil sample.

MODIFIED PROCTOR COMPACTION TEST (ASTM D1557)
Modified Proctor compaction is similar to the Standard Proctor test. In this test, the soil is compacted in the Proctor mold in five lifts of equal volume using a standard effort by the free falling of a 10 lb rammer from 18 inches above the soil surface. The maximum dry unit weight of the compacted sample and the respective moisture content is reported as maximum dry density and optimum moisture content of the soil sample.

LABORATORY CALIFORNIA BEARING RATIO (ASTM D1883)
The CBR value is the ratio of forces required for 0.1-inch penetration of a 2-inch diameter circular plunger at the rate of 0.05 inch/min into a compacted soil sample compared to the same penetration in a certain standard crushed stone.

LOSS ON IGNITION TEST (LOI) (ASTM D2974)
LOI tests are performed on peat or suspected organic soils. An oven-dried sample is ignited in a furnace at 440°C (Method C) or 750°C (Method D). The ash content of the soil sample is determined as a percentage of the weight of the oven-dried sample. The organic content is the loss of weight due to ignition and reported as a percentage of the weight of the oven-dried sample.

ONE-DIMENSIONAL CONSOLIDATION TEST (ASTM D2435)
The consolidation test data is used to estimate the magnitude and rate of both differential and total settlement of a structure. A one-dimensional consolidation test is performed in a consolidation ring that does not allow lateral displacement of the sample. The sample is subjected to various vertical loading and unloading cycles. The deformation of the sample due to loading and unloading is recorded and used for the plotting a void ratio-applied pressure graph. The pre-consolidation pressure for the soil can also be determined from this test.

UNCONFINED COMPRESSION TEST ON ROCK SAMPLES (ASTM D7012)

In the unconfined compression test, the unconfined compressive strength (q_u) of a rock sample is estimated by measuring the resistance of the sample in compression when an axial loading is applied to the cylindrical specimen (with a height to diameter ratio of approximately 2) to reach the failure condition.

UNCONFINED COMPRESSION TEST ON SOIL SAMPLES (ASTM D2166)

In the unconfined compression test, the unconfined compressive strength (q_u) of a cohesive soil sample is estimated by measuring the resistance of the sample in compression when an axial loading is applied to the cylindrical specimen (with a height to diameter ratio of 2 to 2.5) to reach the failure condition or 15 percent (%) of axial deformation, whichever is secured first.

UNCONSOLIDATED-UNDRAINED (UU) TRIAXIAL COMPRESSION TEST (ASTM D2850)

Triaxial Shear tests are used to determine the shear strength of soil samples under various loading conditions. The test is performed on a relatively undisturbed sample extruded from a Shelby tube. In this test method, fluid flow is not permitted into or out of the soil specimen as the load is applied (undrained condition), therefore pore pressure builds up in the sample. The compressive strength of a soil is determined in terms of the total stress. The various confining pressures help determining the shear strength of the soil at different depths.

CONSOLIDATED-UNDRAINED (CU) TRIAXIAL COMPRESSION TEST (ASTM D4767)

The shear characteristics of cohesive samples (collected from relatively undisturbed sample extruded from a Shelby tube) are measured in this test under undrained conditions. This test represents field conditions where fully consolidated soils under one set of stresses are subjected to a sudden change in stress without sufficient time for further consolidation (undrained condition). The data from this test is used to analyze the shear strength parameters of the soil at different depths. The compressive strength of a soil is reported in terms of the effective stress.

WATER SOLUBLE SULFATE, RESISTIVITY AND PH

To evaluate the corrosion potential of the site, MSG performs sulfates (Ohio DOT Supplement 1122), resistivity (ASTM G187), and pH tests (ASTM D4972) on select soil samples.

SPECIFIC GRAVITY (ASTM D854)

Specific gravity is defined as the ratio of the unit weight of soil solids only to unit weight of water at a specific temperature. MSG performs specific gravity tests for soils according to ASTM D854 test procedure.

PERMEABILITY (ASTM D2434 and ASTM D5084)

This test method covers laboratory measurements of the hydraulic conductivity (the coefficient of permeability) of water-saturated granular and cohesive materials. MSG performs multiple methods for permeability tests according to ASTM D2434 and ASTM D5084.

DIRECT SHEAR TEST (ASTM D3080)

The direct shear tests are performed to determine the maximum and residual shear strength. A horizontal load is applied at a constant rate of strain. The soil sample is placed in a box where the lower half of the box is mounted on rollers and is pushed forward at a uniform rate by a motorized apparatus. The upper half of the box bears against a steel proving ring, the deformation of which is shown on a dial gauge indicating the shear force. The various information that can be obtained from the results includes the maximum (peak) shear strength and the ultimate (residual) shear strength.

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SUMMARY OF LABORATORY RESULTS

AASHTO R18

CLIENT Ducks Unlimited **PROJECT NAME** Howard Farms-Geotechnical Investigation

PROJECT NUMBER D1310012 **PROJECT LOCATION** Lucas County, Ohio

Boring No. / Sample No.	Depth	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Size (mm)	%<#200 Sieve	Class-ification	Water Content (%)	Bulk Density (pcf)	Satur-ation (%)	Specific Gravity
SB-01 / SS-3	6.0							33.0			
SB-02 / ST-1	3.0	56	20	36	19	92	CH	27.3			
SB-02 / SS-4	8.5	27	15	12	4.75	75	CL	15.3			
SB-03 / SS-4	8.5	39	19	20	9.525	97	CL	22.7			
SB-04 / ST-5	13.5	29	17	12	19	80	CL	29.5	124.0		
SB-04 / SS-10	38.5	31	19	12	2	100	CL	24.4			
SB-05 / ST-2	10.0	31	17	14	9.525	76	CL	23.2			
SB-05 / SS-6	18.5	26	14	12	9.525	84	CL	10.4			
SB-05 / SS-8	28.5							11.4			
SB-05 / SS-9	33.5							10.2	143.4		
SB-05 / SS-10	38.5	29	16	13	9.525	99	CL	21.7			

LAB SUMMARY - GINT STD US LAB.GDT - 1/23/20 15:03 - W:\PROJECTS\PROJECTS A-E\D1310012\ADMIN\GEOTECH\D1310012 BORING LOGS.GPJ

GRAIN SIZE DISTRIBUTION

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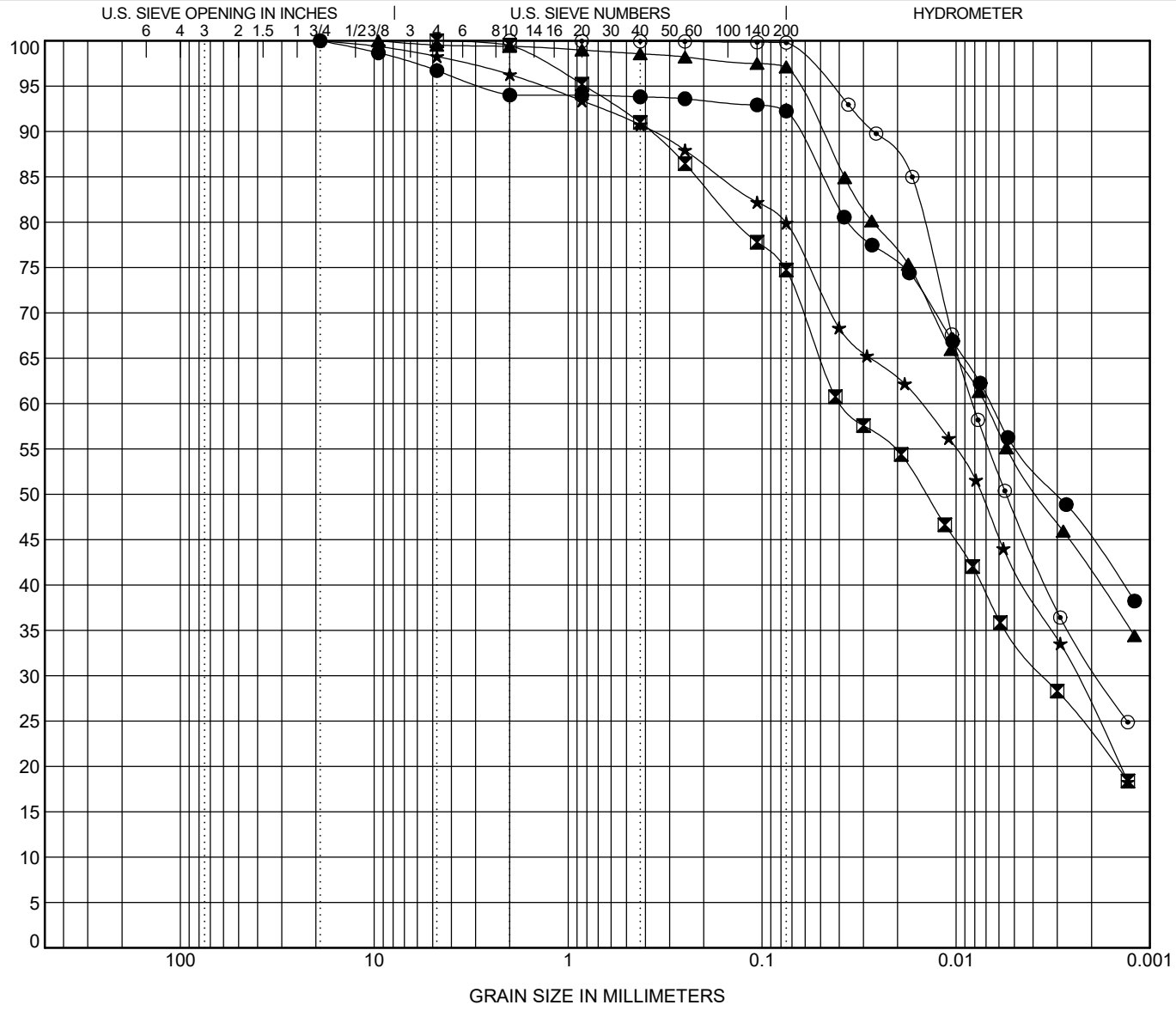
CLIENT Ducks Unlimited **PROJECT NAME** Howard Farms-Geotechnical Investigation

PROJECT NUMBER D1310012 **PROJECT LOCATION** Lucas County, Ohio



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification			Classification	LL	PL	PI	Cc	Cu
●	SB-02 / ST-1	3.0	FAT CLAY (CH)	56	20	36		
⊠	SB-02 / SS-4	8.5	LEAN CLAY with SAND (CL)	27	15	12		
▲	SB-03 / SS-4	8.5	LEAN CLAY (CL)	39	19	20		
★	SB-04 / ST-5	13.5	LEAN CLAY with SAND (CL)	29	17	12		
⊙	SB-04 / SS-10	38.5	LEAN CLAY (CL)	31	19	12		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	SB-02 / ST-1	3.0	19	0.007			3.3	4.5	47.3	44.9
⊠	SB-02 / SS-4	8.5	4.75	0.039	0.003		0.0	25.3	51.2	23.5
▲	SB-03 / SS-4	8.5	9.525	0.007			0.5	2.4	55.8	41.4
★	SB-04 / ST-5	13.5	19	0.015	0.002		1.7	18.4	53.4	26.5
⊙	SB-04 / SS-10	38.5	2	0.008	0.002		0.0	0.2	68.7	31.1

GRAIN SIZE - GINT STD US LAB.GDT - 1/23/20 15:02 - W:\PROJECTS\PROJECTS A-E\D1310012\ADMIN\GEOTECH\D1310012 BORING LOGS.GPJ

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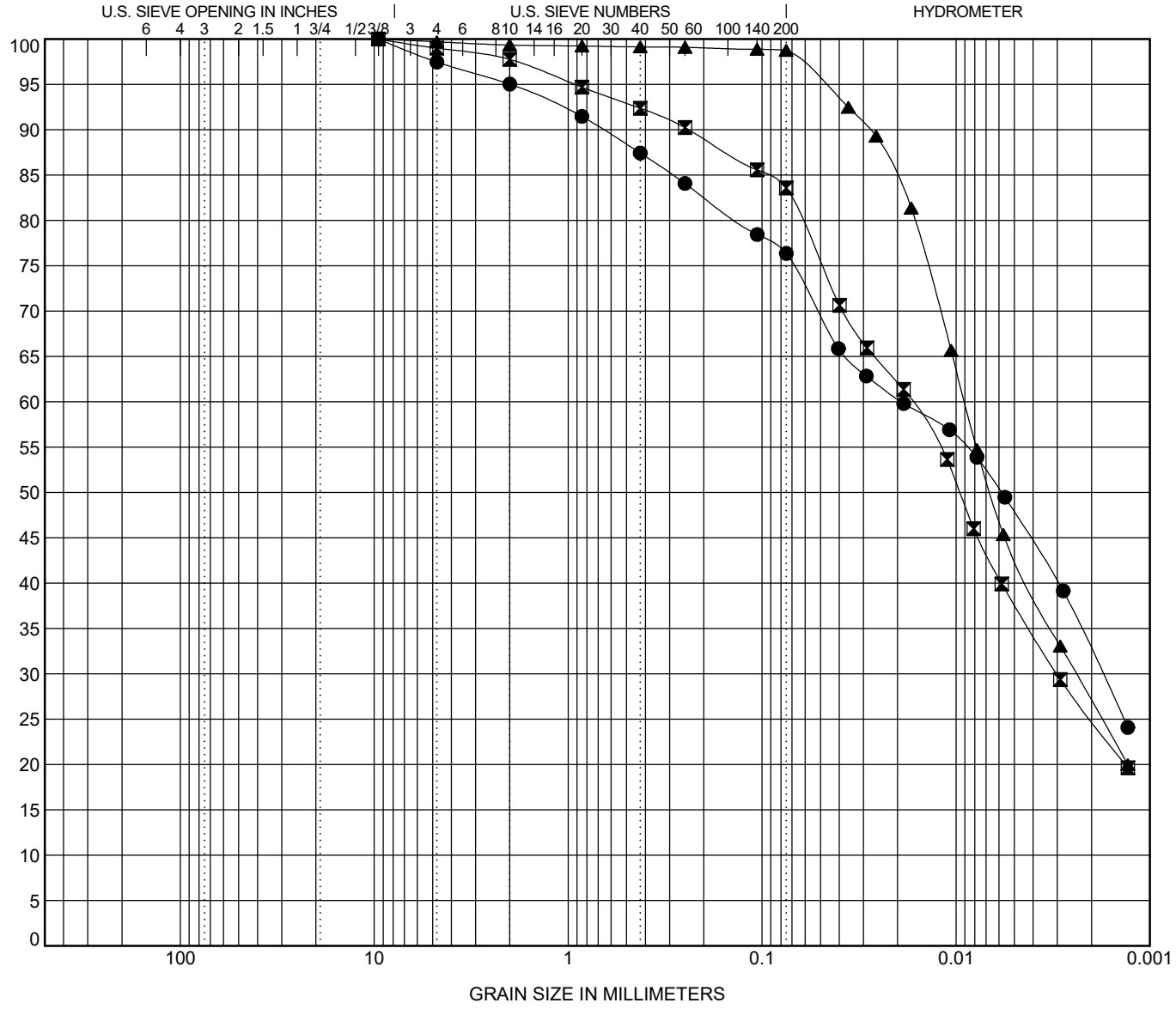
CLIENT Ducks Unlimited **PROJECT NAME** Howard Farms-Geotechnical Investigation

PROJECT NUMBER D1310012 **PROJECT LOCATION** Lucas County, Ohio



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Specimen Identification		Classification	LL	PL	PI	Cc	Cu
● SB-05 / ST-2	10.0	LEAN CLAY with SAND (CL)	31	17	14		
⊠ SB-05 / SS-6	18.5	LEAN CLAY with SAND (CL)	26	14	12		
▲ SB-05 / SS-10	38.5	LEAN CLAY (CL)	29	16	13		

Specimen Identification		D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● SB-05 / ST-2	10.0	9.525	0.019	0.002		2.5	21.1	43.8	32.5
⊠ SB-05 / SS-6	18.5	9.525	0.017	0.003		1.0	15.4	58.7	24.9
▲ SB-05 / SS-10	38.5	9.525	0.009	0.002		0.3	0.9	71.7	27.0

GRAIN SIZE - GINT STD US LAB.GDT - 1/23/20 15:02 - W:\PROJECTS\PROJECTS A-E\D1310012\ADMIN\GEOTECH\D1310012 BORING LOGS.GPJ

ATTERBERG LIMITS' RESULTS

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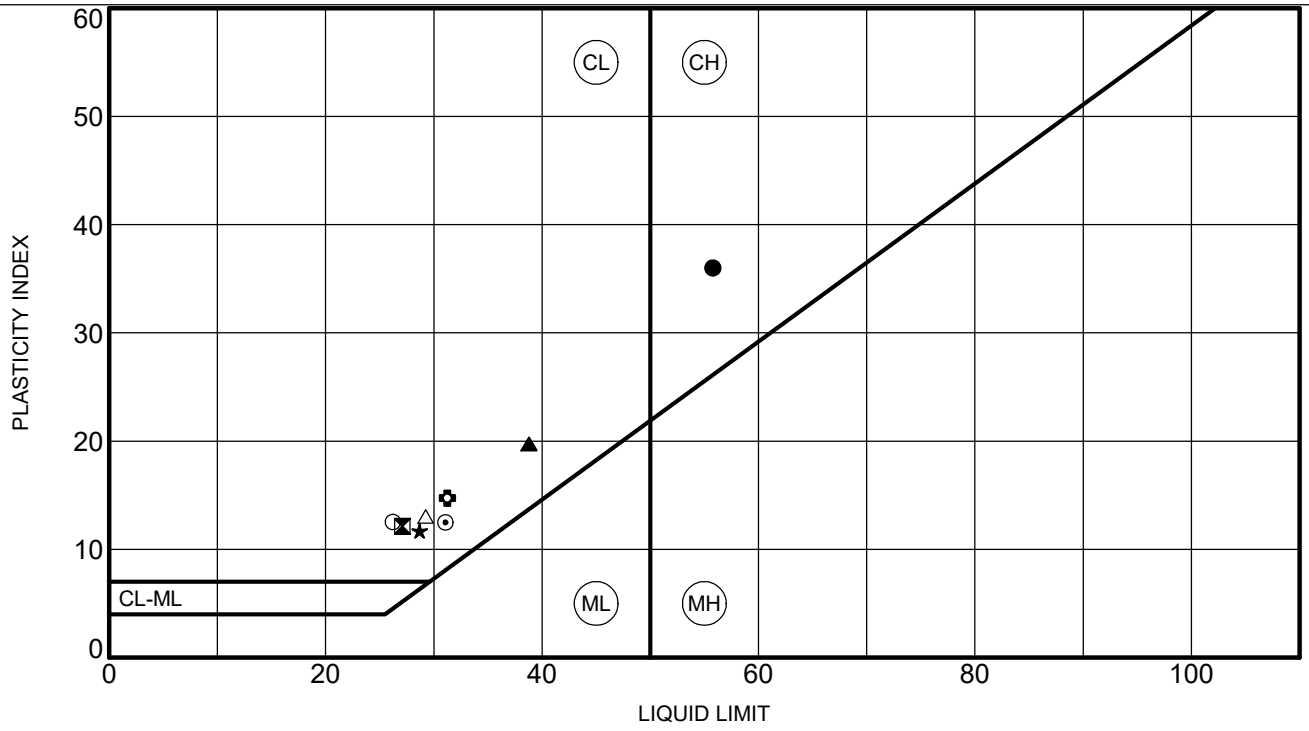
AASHTO R18

CLIENT Ducks Unlimited **PROJECT NAME** Howard Farms-Geotechnical Investigation

PROJECT NUMBER D1310012 **PROJECT LOCATION** Lucas County, Ohio



	Specimen Identification		LL	PL	PI	Fines	Classification
●	SB-02 / ST-1	3.0	56	20	36	92	FAT CLAY (CH)
⊠	SB-02 / SS-4	8.5	27	15	12	75	LEAN CLAY with SAND (CL)
▲	SB-03 / SS-4	8.5	39	19	20	97	LEAN CLAY (CL)
★	SB-04 / ST-5	13.5	29	17	12	80	LEAN CLAY with SAND (CL)
⊙	SB-04 / SS-10	38.5	31	19	12	100	LEAN CLAY (CL)
✿	SB-05 / ST-2	10.0	31	17	14	76	LEAN CLAY with SAND (CL)
○	SB-05 / SS-6	18.5	26	14	12	84	LEAN CLAY with SAND (CL)
△	SB-05 / SS-10	38.5	29	16	13	99	LEAN CLAY (CL)

ATTERBERG LIMITS - GINT STD US LAB.GDT - 1/23/20 15:01 - W:\PROJECTS\PROJECTS A-E\D1310012\ADMIN\GEOTECH\D1310012 BORING LOGS.GPJ

UNCONFINED COMPRESSION TEST

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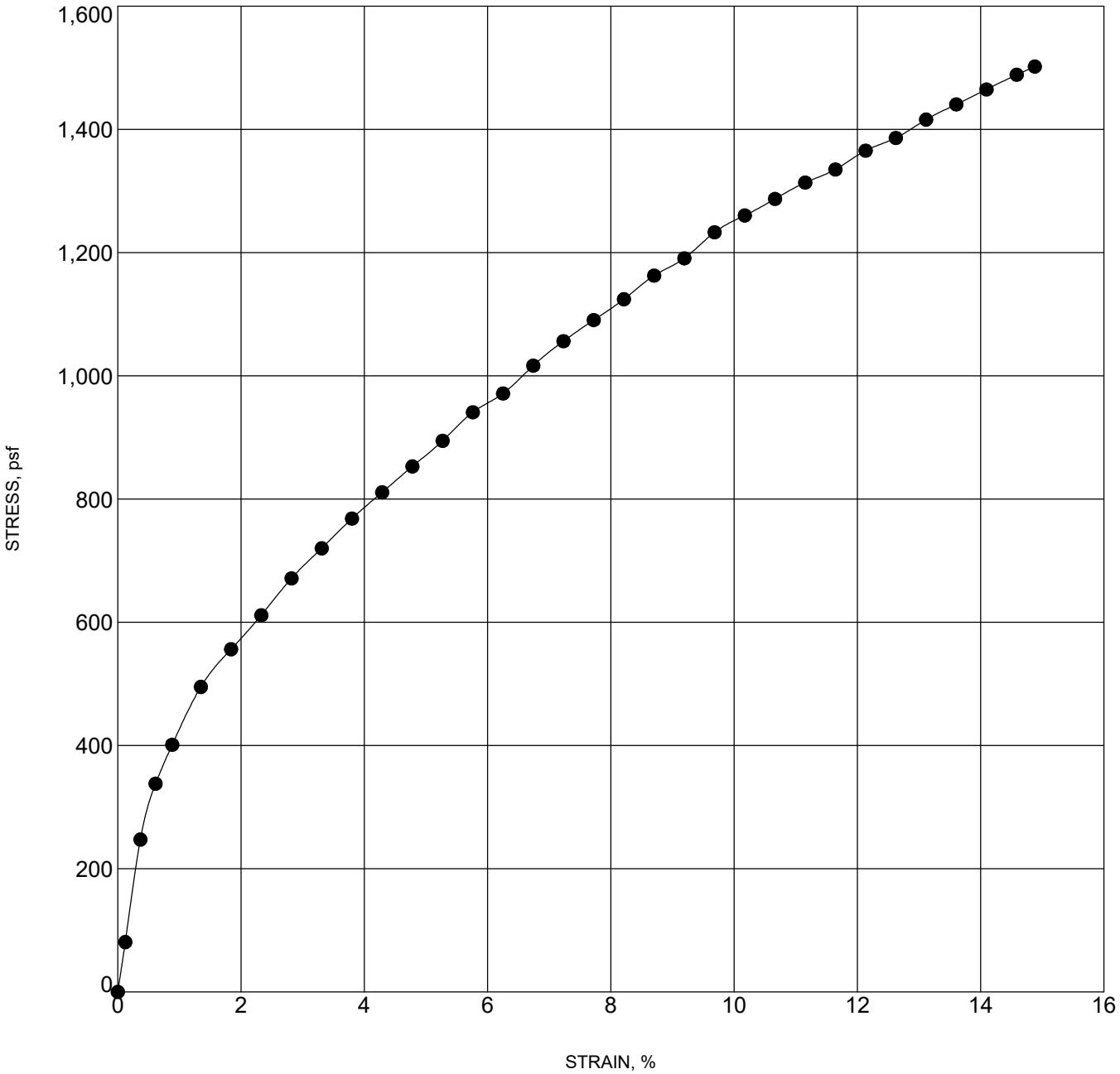
AASHTO R18

CLIENT Ducks Unlimited **PROJECT NAME** Howard Farms-Geotechnical Investigation

PROJECT NUMBER D1310012 **PROJECT LOCATION** Lucas County, Ohio



Specimen Identification	Classification	γ_d	MC%
● SB-04 / ST-5 13.5	**LEAN CLAY with SAND (CL)**	**96**	**29**

UNCONFINED - GINT STD US LAB.GDT - 1/23/20 15:01 - W:\PROJECTS\PROJECTS A-E\D1310012\ADMIN\GEOTECH\D1310012 BORING LOGS.GPJ

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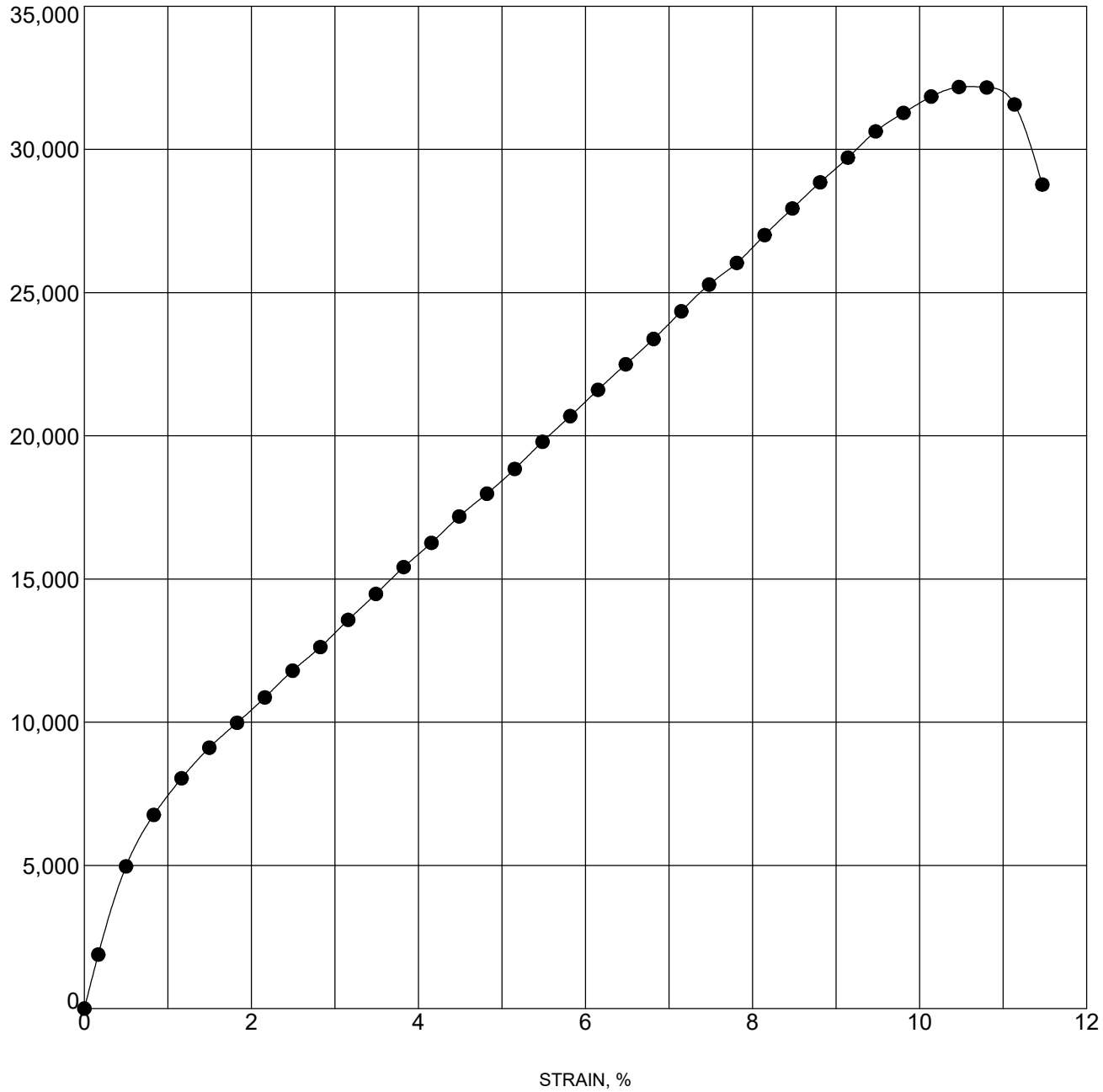
PROJECT NUMBER D1310012 **PROJECT LOCATION** Lucas County, Ohio



Specimen Identification	Classification	γ_d	MC%
● SB-05 / SS-9 33.5	**LEAN CLAY with SAND (CL)**	**130**	**10**

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APPENDIX C
SLIDE SLOPE STABILITY DATA

Slide Analysis Information

Slope Stability Analysis

Project Summary

File Name:	Slope Stability Analysis.slmd
Slide Modeler Version:	8.023
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	10/22/2020, 11:32:33 AM

Currently Open Scenarios

Group Name	Scenario Name	Global Minimum	Compute Time
Static Slope Stability	End of Construction	Bishop Simplified: 7.255830 Janbu Simplified: 6.969410	00h:00m:00.275s
	Normal Pool	Bishop Simplified: 6.830650 Janbu Simplified: 6.576970	00h:00m:00.337s

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

All Open Scenarios	
Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
	Janbu simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

All Open Scenarios	
Groundwater Method:	Steady State FEA
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Tolerance:	1e-06
Maximum number of iterations:	500
Use negative pore pressure cutoff:	No
Advanced Groundwater Method:	None
Mesh Element Type:	3 noded triangles
Number of Elements:	642
Number of Nodes:	379

Random Numbers

All Open Scenarios	
Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

All Open Scenarios	
Surface Type:	Circular
Search Method:	Grid Search
Radius Increment:	10
Composite Surfaces:	Disabled
Reverse Curvature:	Invalid Surfaces
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic Loading

All Open Scenarios	
Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Materials

Property	Embankment Material	Native Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	130	125
Cohesion [psf]	2000	1000
Friction Angle [°]	23	20
Unsaturated Shear Strength Angle [°]	0	0
Air Entry Value [psf]	0	0
Ks [feet/second]	1e-07	1e-07
K2/K1	1	1
K Angle [°]	0	0
Groundwater Model	Simple	Simple
GW Model Properties	Soil Type: General	Soil Type: Clay
Unsat. Shear Strength Phi b [°]	0	0
Unsat. Shear Strength Air Entry Value [psf]	0	0

Materials In Use

Material	End of Construction	Normal Pool
Embankment Material	✓	✓
Native Clay	✓	✓

Global Minimums

Static Slope Stability - End of Construction

Method: bishop simplified

FS	7.255830
Center:	27.342, 34.872
Radius:	32.842
Left Slip Surface Endpoint:	1.194, 15.000
Right Slip Surface Endpoint:	58.402, 24.199
Resisting Moment:	3.60211e+06 lb-ft
Driving Moment:	496444 lb-ft
Total Slice Area:	746.635 ft2
Surface Horizontal Width:	57.2084 ft
Surface Average Height:	13.0512 ft

Method: janbu simplified

FS	6.969410
Center:	27.342, 36.059
Radius:	33.574
Left Slip Surface Endpoint:	1.193, 15.000
Right Slip Surface Endpoint:	58.713, 24.096
Resisting Horizontal Force:	87313.8 lb
Driving Horizontal Force:	12528.1 lb
Total Slice Area:	730.38 ft2
Surface Horizontal Width:	57.5197 ft
Surface Average Height:	12.6979 ft

Static Slope Stability - Normal Pool

Method: bishop simplified

FS	6.830650
Center:	27.342, 34.872
Radius:	32.842
Left Slip Surface Endpoint:	1.194, 15.000
Right Slip Surface Endpoint:	58.402, 24.199
Resisting Moment:	3.39103e+06 lb-ft
Driving Moment:	496444 lb-ft
Total Slice Area:	746.635 ft2
Surface Horizontal Width:	57.2084 ft
Surface Average Height:	13.0512 ft

Method: janbu simplified

FS	6.576970
Center:	28.530, 36.059
Radius:	34.456
Left Slip Surface Endpoint:	1.258, 15.000
Right Slip Surface Endpoint:	60.602, 23.466
Resisting Horizontal Force:	85227.9 lb
Driving Horizontal Force:	12958.5 lb
Total Slice Area:	803.883 ft2
Surface Horizontal Width:	59.3445 ft
Surface Average Height:	13.5461 ft

Entity Information

Group: Static Slope Stability

Shared Entities

Type	Coordinates	
	X	**Y**
External Boundary	100	0
	100	13
	100	15
	86	15
	64.9593	22.0136
	56	25
	44	25
	35.0082	22.0027
	14	15
	0	15
	0	14.9288
	0	13
	0	0

Material Boundary	**X**	**Y**
	14	15
	86	15

Valid/Invalid Surfaces

Static Slope Stability - End of Construction

Method: bishop simplified

Number of Valid Surfaces: 4697
Number of Invalid Surfaces: 154

Error Codes:

Error Code -103 reported for 34 surfaces
Error Code -108 reported for 120 surfaces

Method: janbu simplified

Number of Valid Surfaces: 4587
Number of Invalid Surfaces: 264

Error Codes:

Error Code -103 reported for 34 surfaces
Error Code -108 reported for 183 surfaces
Error Code -111 reported for 47 surfaces

Static Slope Stability - Normal Pool

Method: bishop simplified

Number of Valid Surfaces: 4697
Number of Invalid Surfaces: 154

Error Codes:

Error Code -103 reported for 34 surfaces
Error Code -108 reported for 120 surfaces

Method: janbu simplified

Number of Valid Surfaces: 4578
Number of Invalid Surfaces: 273

Error Codes:

Error Code -103 reported for 34 surfaces
Error Code -108 reported for 182 surfaces
Error Code -111 reported for 57 surfaces

Error Codes

The following errors were encountered during the computation:

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.
-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).
-111 = safety factor equation did not converge

Slice Data

Static Slope Stability - End of Construction

- **Global Minimum Query (bishop simplified) - Safety Factor: 7.25583**

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	1.13689	100.416	-51.1843	Native Clay	1000	20	151.71	1100.78	276.901	-80.7088	276.901	88.3175	88.3175
2	1.13689	290.917	-48.1164	Native Clay	1000	20	159.427	1156.77	433.668	2.93905	430.729	255.882	252.943
3	1.13689	462.414	-45.2228	Native Clay	1000	20	162.514	1179.17	570.513	78.2442	492.269	406.731	328.486
4	1.13689	617.773	-42.4701	Native Clay	1000	20	165.322	1199.55	694.713	146.459	548.254	543.381	396.922
5	1.13689	759.105	-39.8341	Native Clay	1000	20	167.879	1218.1	807.736	208.516	599.22	667.696	459.18
6	1.13689	888.021	-37.2958	Native Clay	1000	20	170.206	1234.98	910.738	265.122	645.616	781.096	515.974
7	1.13689	1005.78	-34.8408	Native Clay	1000	20	172.322	1250.34	1004.63	316.83	687.796	884.677	567.847
8	1.13689	1113.39	-32.457	Native Clay	1000	20	174.242	1264.27	1090.15	364.08	726.067	979.326	615.246
9	1.13689	1211.66	-30.135	Native Clay	1000	20	175.978	1276.87	1167.92	407.231	760.693	1065.77	658.538
10	1.13689	1301.27	-27.8664	Native Clay	1000	20	177.543	1288.22	1238.46	446.576	791.88	1144.59	698.01
11	1.13689	1382.76	-25.6444	Native Clay	1000	20	178.944	1298.39	1302.17	482.359	819.812	1216.26	733.906
12	1.13689	1471.77	-23.4632	Native Clay	1000	20	180.874	1312.39	1373.07	514.784	858.286	1294.56	779.778
13	1.13689	1592.42	-21.3175	Native Clay	1000	20	184.402	1337.99	1472.63	544.021	928.613	1400.67	856.653
14	1.13689	1708.08	-19.2027	Native Clay	1000	20	187.864	1363.11	1567.85	570.217	997.637	1502.42	932.206
15	1.13689	1817.1	-17.1148	Native Clay	1000	20	191.177	1387.15	1657.18	593.496	1063.68	1598.31	1004.81
16	1.13689	1919.71	-15.0502	Native Clay	1000	20	194.346	1410.14	1740.82	613.958	1126.86	1688.56	1074.6
17	1.13689	2016.1	-13.0054	Native Clay	1000	20	197.375	1432.12	1818.93	631.689	1187.24	1773.34	1141.66
18	1.13689	2106.43	-10.9773	Native Clay	1000	20	200.267	1453.1	1891.65	646.761	1244.89	1852.81	1206.05
19	1.13689	2190.85	-8.96307	Native Clay	1000	20	203.024	1473.11	1959.08	659.228	1299.86	1927.06	1267.83
20	1.13689	2269.46	-6.95997	Native Clay	1000	20	205.648	1492.15	2021.31	669.147	1352.16	1996.21	1327.06
21	1.13689	2342.35	-4.9654	Native Clay	1000	20	208.14	1510.23	2078.4	676.567	1401.84	2060.32	1383.75
22	1.13689	2409.58	-2.97685	Native Clay	1000	20	210.501	1527.36	2130.4	681.496	1448.91	2119.46	1437.96
23	1.13689	2471.19	-0.991885	Native Clay	1000	20	212.732	1543.55	2177.33	683.947	1493.38	2173.65	1489.7
24	1.13689	2527.2	0.991885	Native Clay	1000	20	214.832	1558.78	2219.19	683.947	1535.25	2222.91	1538.97
25	1.13689	2577.61	2.97685	Native Clay	1000	20	216.799	1573.06	2255.97	681.506	1574.47	2267.25	1585.74
26	1.13689	2622.39	4.9654	Native Clay	1000	20	218.635	1586.38	2287.65	676.59	1611.06	2306.65	1630.06
27	1.13689	2661.52	6.95997	Native Clay	1000	20	220.338	1598.73	2314.17	669.163	1645.01	2341.07	1671.9
28	1.13689	2694.93	8.96307	Native Clay	1000	20	221.904	1610.1	2335.45	659.227	1676.22	2370.45	1711.22
29	1.13689	2722.53	10.9773	Native Clay	1000	20	223.33	1620.44	2351.41	646.755	1704.65	2394.73	1747.97
30	1.13689	2744.21	13.0054	Native Clay	1000	20	224.613	1629.75	2361.91	631.684	1730.23	2413.79	1782.11
31	1.13689	2759.84	15.0502	Native Clay	1000	20	225.749	1638	2366.84	613.958	1752.89	2427.55	1813.59
32	1.13689	2769.25	17.1148	Native Clay	1000	20	226.734	1645.14	2366.01	593.5	1772.51	2435.83	1842.33
33	1.13689	2772.25	19.2027	Native Clay	1000	20	227.56	1651.14	2359.2	570.219	1788.98	2438.46	1868.24
34	1.13689	2768.6	21.3175	Native Clay	1000	20	228.221	1655.94	2346.19	544.021	1802.17	2435.25	1891.23
35	1.13689	2758.02	23.4632	Native Clay	1000	20	228.709	1659.47	2326.67	514.785	1811.89	2425.94	1911.16
36	1.13689	2740.19	25.6444	Native Clay	1000	20	229.013	1661.68	2300.32	482.358	1817.96	2410.26	1927.9
37	1.13689	2714.7	27.8664	Native Clay	1000	20	229.122	1662.47	2266.7	446.575	1820.13	2387.85	1941.27
38	1.13689	2677.71	30.135	Native Clay	1000	20	228.876	1660.68	2222.45	407.23	1815.22	2355.31	1948.08
39	1.13689	2591.34	32.457	Native Clay	1000	20	226.663	1644.63	2135.18	364.08	1771.1	2279.34	1915.26
40	1.13689	2483.73	34.8408	Native Clay	1000	20	223.705	1623.17	2028.98	316.831	1712.14	2184.69	1867.86
41	1.13689	2365.97	37.2958	Native Clay	1000	20	220.49	1599.84	1913.16	265.123	1648.04	2081.11	1815.98
42	1.13689	2237.06	39.8341	Native Clay	1000	20	216.986	1574.41	1786.71	208.517	1578.19	1967.72	1759.2
43	1.13689	2095.73	42.4701	Native Clay	1000	20	213.155	1546.62	1648.28	146.46	1501.82	1843.4	1696.94
44	1.13689	1940.37	45.2228	Native Clay	1000	20	208.947	1516.08	1496.17	78.2428	1417.93	1706.75	1628.51
45	1.13689	1768.87	48.1164	Native Clay	1000	20	204.293	1482.31	1328.08	2.93913	1325.14	1555.9	1552.96
46	1.13689	1578.37	51.1843	Native Clay	1000	20	195.286	1416.96	1145.59	-80.7088	1145.59	1388.34	1388.34
47	1.22789	1458.27	54.6166	Embankment Material	2000	23	318.855	2313.56	738.695	-178.742	738.695	1187.64	1187.64
48	1.22789	1160.25	58.5181	Embankment Material	2000	23	302.063	2191.72	451.662	-295.245	451.662	944.933	944.933
49	1.22789	778.619	62.9232	Embankment Material	2000	23	280.625	2036.16	85.197	-432.744	85.197	634.133	634.133
50	1.22789	277.155	68.1568	Embankment Material	2000	23	252.06	1828.9	-403.077	-603.254	-403.077	225.742	225.742

- **Global Minimum Query (janbu simplified) - Safety Factor: 6.96941**

Static Slope Stability - Normal Pool

- **Global Minimum Query (bishop simplified) - Safety Factor: 6.83065**

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	1.13689	100.416	-51.1843	Native Clay	1000	20	159.28	1087.99	286.311	44.5673	241.744	88.3175	43.7502
2	1.13689	290.917	-48.1164	Native Clay	1000	20	162.775	1111.86	437.402	130.071	307.331	255.882	125.811
3	1.13689	462.414	-45.2228	Native Clay	1000	20	165.907	1133.26	573.933	207.816	366.117	406.731	198.915
4	1.13689	617.773	-42.4701	Native Clay	1000	20	168.663	1152.08	697.775	279.944	417.831	543.386	263.442
5	1.13689	759.105	-39.8341	Native Clay	1000	20	171.111	1168.8	810.438	346.662	463.776	667.701	321.039
6	1.13689	888.021	-37.2958	Native Clay	1000	20	173.314	1183.84	913.103	407.996	505.107	781.094	373.098
7	1.13689	1005.78	-34.8408	Native Clay	1000	20	175.274	1197.23	1006.68	464.783	541.893	884.673	419.89
8	1.13689	1113.39	-32.457	Native Clay	1000	20	176.961	1208.76	1091.88	518.324	573.552	979.326	461.002
9	1.13689	1211.66	-30.135	Native Clay	1000	20	178.437	1218.84	1169.35	568.086	601.261	1065.76	497.679
10	1.13689	1301.27	-27.8664	Native Clay	1000	20	179.757	1227.86	1239.62	613.585	626.038	1144.58	530.996
11	1.13689	1382.76	-25.6444	Native Clay	1000	20	180.849	1235.32	1303.08	656.559	646.524	1216.26	559.703
12	1.13689	1471.77	-23.4632	Native Clay	1000	20	182.479	1246.45	1373.76	696.645	677.119	1294.56	597.914
13	1.13689	1592.42	-21.3175	Native Clay	1000	20	185.833	1269.36	1473.2	733.129	740.071	1400.68	667.552
14	1.13689	1708.08	-19.2027	Native Clay	1000	20	189.107	1291.72	1568.29	766.787	801.499	1502.42	735.635
15	1.13689	1817.1	-17.1148	Native Clay	1000	20	192.203	1312.87	1657.5	797.894	859.604	1598.31	800.42
16	1.13689	1919.71	-15.0502	Native Clay	1000	20	195.157	1333.05	1741.04	825.996	915.043	1688.56	862.568
17	1.13689	2016.1	-13.0054	Native Clay	1000	20	197.949	1352.12	1819.07	851.628	967.441	1773.35	921.722
18	1.13689	2106.43	-10.9773	Native Clay	1000	20	200.594	1370.19	1891.72	874.627	1017.09	1852.81	978.179
19	1.13689	2190.85	-8.96307	Native Clay	1000	20	203.096	1387.28	1959.09	895.054	1064.04	1927.06	1032.01
20	1.13689	2269.46	-6.95997	Native Clay	1000	20	205.454	1403.38	2021.28	913.005	1108.28	1996.2	1083.2
21	1.13689	2342.35	-4.9654	Native Clay	1000	20	207.672	1418.53	2078.36	928.455	1149.9	2060.32	1131.86
22	1.13689	2409.58	-2.97685	Native Clay	1000	20	209.751	1432.74	2130.36	941.425	1188.93	2119.45	1178.03
23	1.13689	2471.19	-0.991885	Native Clay	1000	20	211.693	1446	2177.31	951.937	1225.37	2173.64	1221.7
24	1.13689	2527.2	0.991885	Native Clay	1000	20	213.497	1458.33	2219.21	959.974	1259.24	2222.91	1262.93
25	1.13689	2577.61	2.97685	Native Clay	1000	20	215.164	1469.71	2256.06	965.542	1290.52	2267.25	1301.71
26	1.13689	2622.39	4.9654	Native Clay	1000	20	216.692	1480.15	2287.82	968.618	1319.2	2306.65	1338.03
27	1.13689	2661.52	6.95997	Native Clay	1000	20	218.086	1489.67	2314.44	969.082	1345.36	2341.06	1371.98
28	1.13689	2694.93	8.96307	Native Clay	1000	20	219.336	1498.21	2335.85	967.039	1368.82	2370.45	1403.41
29	1.13689	2722.53	10.9773	Native Clay	1000	20	220.442	1505.76	2351.97	962.403	1389.57	2394.73	1432.33
30	1.13689	2744.21	13.0054	Native Clay	1000	20	221.399	1512.3	2362.66	955.131	1407.53	2413.8	1458.66
31	1.13689	2759.84	15.0502	Native Clay	1000	20	222.208	1517.83	2367.8	945.079	1422.72	2427.54	1482.47
32	1.13689	2769.25	17.1148	Native Clay	1000	20	222.854	1522.24	2367.2	932.368	1434.84	2435.83	1503.46
33	1.13689	2772.25	19.2027	Native Clay	1000	20	223.343	1525.58	2360.67	916.663	1444.01	2438.46	1521.8
34	1.13689	2768.6	21.3175	Native Clay	1000	20	223.659	1527.73	2347.97	898.039	1449.93	2435.25	1537.21
35	1.13689	2758.02	23.4632	Native Clay	1000	20	223.791	1528.64	2328.81	876.383	1452.43	2425.95	1549.56
36	1.13689	2740.19	25.6444	Native Clay	1000	20	223.738	1528.28	2302.85	851.426	1451.42	2410.26	1558.83
37	1.13689	2714.7	27.8664	Native Clay	1000	20	223.482	1526.52	2269.68	823.072	1446.61	2387.84	1564.77
38	1.13689	2677.71	30.135	Native Clay	1000	20	222.851	1522.22	2225.95	791.17	1434.78	2355.31	1564.14
39	1.13689	2591.34	32.457	Native Clay	1000	20	220.136	1503.67	2139.33	755.492	1383.84	2279.34	1523.85
40	1.13689	2483.73	34.8408	Native Clay	1000	20	216.638	1479.78	2033.89	715.719	1318.17	2184.69	1468.97
41	1.13689	2365.97	37.2958	Native Clay	1000	20	212.876	1454.08	1918.96	671.388	1247.58	2081.11	1409.72
42	1.13689	2237.06	39.8341	Native Clay	1000	20	208.808	1426.29	1793.53	622.299	1171.23	1967.72	1345.42
43	1.13689	2095.73	42.4701	Native Clay	1000	20	204.397	1396.16	1656.3	567.843	1088.45	1843.4	1275.55
44	1.13689	1940.37	45.2228	Native Clay	1000	20	199.59	1363.33	1505.6	507.352	998.247	1706.75	1199.4
45	1.13689	1768.87	48.1164	Native Clay	1000	20	194.319	1327.32	1339.2	439.887	899.313	1555.9	1116.01
46	1.13689	1578.37	51.1843	Native Clay	1000	20	188.476	1287.41	1154.05	364.39	789.659	1388.33	1023.94
47	1.22789	1458.27	54.6166	Embankment Material	2000	23	321.38	2195.23	735.139	275.203	459.936	1187.64	912.439
48	1.22789	1160.25	58.5181	Embankment Material	2000	23	309.623	2114.93	439.315	168.565	270.75	944.932	776.367
49	1.22789	778.619	62.9232	Embankment Material	2000	23	293.918	2007.65	59.194	41.1699	18.0241	634.134	592.964
50	1.22789	277.155	68.1568	Embankment Material	2000	23	265.644	1814.52	-436.963	-119.09	-436.963	225.744	225.744

- **Global Minimum Query (janbu simplified) - Safety Factor: 6.57697**

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	1.16218	99.2689	-49.623	Native Clay	1000	20	157.62	1098.52	270.686	-82.161	270.686	85.3315	85.3315
2	1.16218	287.953	-46.6474	Native Clay	1000	20	165.579	1153.99	423.076	-1.11378	423.076	247.69	247.69
3	1.16218	458.399	-43.828	Native Clay	1000	20	168.774	1176.26	556.365	72.1013	484.264	394.358	322.257
4	1.16218	613.166	-41.1366	Native Clay	1000	20	171.626	1196.13	677.442	138.577	538.865	527.53	388.953
5	1.16218	754.173	-38.5517	Native Clay	1000	20	174.221	1214.22	787.709	199.144	588.565	648.87	449.726
6	1.16218	882.904	-36.0568	Native Clay	1000	20	176.582	1230.67	888.204	254.439	633.765	759.642	505.203
7	1.16218	1000.53	-33.6389	Native Clay	1000	20	178.726	1245.61	979.776	304.965	674.811	860.856	555.891
8	1.16218	1108	-31.2873	Native Clay	1000	20	180.668	1259.15	1063.13	351.127	712.003	953.337	602.21
9	1.16218	1206.08	-28.993	Native Clay	1000	20	182.42	1271.36	1138.82	393.256	745.567	1037.73	644.478
10	1.16218	1295.41	-26.7487	Native Clay	1000	20	183.995	1282.33	1207.33	431.625	775.703	1114.59	682.968
11	1.16218	1376.51	-24.5479	Native Clay	1000	20	185.399	1292.12	1269.06	466.462	802.603	1184.39	717.924
12	1.16218	1477.97	-22.3851	Native Clay	1000	20	187.934	1309.79	1349.09	497.957	851.137	1271.69	773.733
13	1.16218	1602.41	-20.2555	Native Clay	1000	20	191.699	1336.03	1449.51	526.271	923.239	1378.77	852.496
14	1.16218	1719.77	-18.1548	Native Clay	1000	20	195.303	1361.15	1543.8	551.543	992.255	1479.76	928.213
15	1.16218	1830.31	-16.0791	Native Clay	1000	20	198.751	1385.18	1632.16	573.887	1058.27	1574.87	1000.98
16	1.16218	1934.25	-14.0248	Native Clay	1000	20	202.048	1408.15	1714.78	593.397	1121.39	1664.31	1070.92
17	1.16218	2031.79	-11.9889	Native Clay	1000	20	205.196	1430.09	1791.83	610.153	1181.67	1748.25	1138.1
18	1.16218	2123.09	-9.96817	Native Clay	1000	20	208.199	1451.02	1863.39	624.226	1239.16	1826.8	1202.57
19	1.16218	2208.25	-7.95993	Native Clay	1000	20	211.059	1470.96	1929.6	635.66	1293.94	1900.09	1264.43
20	1.16218	2287.4	-5.96151	Native Clay	1000	20	213.778	1489.9	1990.52	644.518	1346	1968.19	1323.68
21	1.16218	2360.6	-3.97034	Native Clay	1000	20	216.356	1507.87	2046.2	650.829	1395.38	2031.19	1380.36
22	1.16218	2427.91	-1.98398	Native Clay	1000	20	218.796	1524.88	2096.69	654.597	1442.09	2089.11	1434.51
23	1.16218	2489.37	0	Native Clay	1000	20	221.096	1540.91	2141.99	655.845	1486.15	2141.99	1486.15
24	1.16218	2544.97	1.98398	Native Clay	1000	20	223.256	1555.97	2182.1	654.602	1527.5	2189.84	1535.24
25	1.16218	2594.72	3.97034	Native Clay	1000	20	225.275	1570.04	2217.01	650.847	1566.16	2232.64	1581.8
26	1.16218	2638.57	5.96151	Native Clay	1000	20	227.154	1583.13	2246.66	644.537	1602.12	2270.38	1625.84
27	1.16218	2676.48	7.95993	Native Clay	1000	20	228.888	1595.21	2271	635.664	1635.34	2303.01	1667.34
28	1.16218	2708.37	9.96817	Native Clay	1000	20	230.475	1606.27	2289.94	624.22	1665.72	2330.44	1706.22
29	1.16218	2734.13	11.9889	Native Clay	1000	20	231.911	1616.28	2303.38	610.149	1693.23	2352.62	1742.48
30	1.16218	2753.65	14.0248	Native Clay	1000	20	233.193	1625.22	2311.17	593.395	1717.77	2369.42	1776.02
31	1.16218	2766.76	16.0791	Native Clay	1000	20	234.316	1633.05	2313.16	573.889	1739.28	2380.7	1806.81
32	1.16218	2773.28	18.1548	Native Clay	1000	20	235.274	1639.72	2309.16	551.544	1757.62	2386.31	1834.77
33	1.16218	2772.97	20.2555	Native Clay	1000	20	236.06	1645.2	2298.95	526.271	1772.68	2386.06	1859.79
34	1.16218	2765.58	22.3851	Native Clay	1000	20	236.666	1649.42	2282.23	497.957	1784.27	2379.71	1881.75
35	1.16218	2750.78	24.5479	Native Clay	1000	20	237.082	1652.32	2258.7	466.461	1792.24	2366.98	1900.52
36	1.16218	2728.21	26.7487	Native Clay	1000	20	237.296	1653.81	2227.96	431.624	1796.33	2347.56	1915.93
37	1.16218	2696.6	28.993	Native Clay	1000	20	237.259	1653.56	2188.89	393.255	1795.63	2320.37	1927.11
38	1.16218	2618.83	31.2873	Native Clay	1000	20	235.361	1640.33	2110.42	351.127	1759.29	2253.45	1902.32
39	1.16218	2511.36	33.6389	Native Clay	1000	20	232.339	1619.27	2006.39	304.966	1701.42	2160.98	1856.02
40	1.16218	2393.73	36.0568	Native Clay	1000	20	229.057	1596.39	1893.01	254.44	1638.57	2059.77	1805.33
41	1.16218	2265	38.5517	Native Clay	1000	20	225.485	1571.5	1769.33	199.146	1570.18	1949.02	1749.87
42	1.16218	2123.99	41.1366	Native Clay	1000	20	221.588	1544.34	1634.14	138.578	1495.56	1827.69	1689.11
43	1.16218	1969.23	43.828	Native Clay	1000	20	217.32	1514.59	1485.92	72.0999	1413.82	1694.53	1622.43
44	1.16218	1798.78	46.6474	Native Clay	1000	20	212.562	1481.43	1322.72	-1.11363	1322.72	1547.87	1547.87
45	1.16218	1610.1	49.623	Native Clay	1000	20	203.353	1417.25	1146.39	-82.161	1146.39	1385.52	1385.52
46	1.04436	1264.87	52.622	Embankment Material	2000	23	334.109	2328.54	773.997	-167.453	773.997	1211.34	1211.34
47	1.04436	1068.26	55.6704	Embankment Material	2000	23	320.681	2234.95	553.519	-257.819	553.519	1023.1	1023.1
48	1.04436	838.097	58.9802	Embankment Material	2000	23	304.97	2125.46	295.572	-359.72	295.572	802.73	802.73
49	1.04436	539.697	62.6496	Embankment Material	2000	23	284.91	1985.66	-33.7905	-476.899	-33.7905	517.024	517.024
50	1.04436	189.502	66.8576	Embankment Material	2000	23	260.864	1818.07	-428.603	-616.126	-428.603	181.731	181.731

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	1.18573	107.614	-50.7664	Native Clay	1000	20	165.76	1090.2	293.672	45.8503	247.822	90.6739	44.8236
2	1.18573	311.938	-47.7413	Native Clay	1000	20	169.517	1114.91	449.566	133.852	315.714	262.999	129.147
3	1.18573	496.166	-44.8836	Native Clay	1000	20	172.876	1137	590.551	214.143	376.408	418.375	204.232
4	1.18573	663.254	-42.162	Native Clay	1000	20	175.841	1156.5	718.53	288.537	429.993	559.299	270.762
5	1.18573	815.4	-39.5532	Native Clay	1000	20	178.458	1173.71	835.004	357.732	477.272	687.616	329.884
6	1.18573	954.286	-37.0393	Native Clay	1000	20	180.829	1189.31	941.212	421.089	520.123	804.753	383.664
7	1.18573	1081.23	-34.6063	Native Clay	1000	20	182.916	1203.03	1038.03	480.209	557.819	911.813	431.604
8	1.18573	1197.29	-32.2428	Native Clay	1000	20	184.708	1214.82	1126.21	536.005	590.203	1009.7	473.694
9	1.18573	1303.33	-29.9394	Native Clay	1000	20	186.308	1225.35	1206.43	587.303	619.129	1099.13	511.827
10	1.18573	1400.05	-27.6882	Native Clay	1000	20	187.695	1234.47	1279.2	635.009	644.19	1180.71	545.697
11	1.18573	1490	-25.4826	Native Clay	1000	20	188.947	1242.7	1346.63	679.816	666.811	1256.57	576.759
12	1.18573	1613.72	-23.3169	Native Clay	1000	20	192.027	1262.96	1443.67	721.201	722.473	1360.91	639.705
13	1.18573	1746.58	-21.1859	Native Clay	1000	20	195.755	1287.48	1548.84	758.997	789.839	1472.96	713.966
14	1.18573	1871.96	-19.0853	Native Clay	1000	20	199.268	1310.58	1647.65	794.352	853.299	1578.71	784.354
15	1.18573	1990.18	-17.011	Native Clay	1000	20	202.621	1332.63	1740.4	826.491	913.909	1678.41	851.919
16	1.18573	2101.46	-14.9595	Native Clay	1000	20	205.808	1353.59	1827.26	855.764	971.495	1772.27	916.505
17	1.18573	2206.04	-12.9275	Native Clay	1000	20	208.824	1373.43	1908.39	882.415	1025.98	1860.46	978.044
18	1.18573	2304.07	-10.9119	Native Clay	1000	20	211.681	1392.22	1983.96	906.333	1077.62	1943.15	1036.81
19	1.18573	2395.71	-8.90988	Native Clay	1000	20	214.384	1409.99	2054.05	927.591	1126.45	2020.44	1092.85
20	1.18573	2481.08	-6.91881	Native Clay	1000	20	216.932	1426.75	2118.76	946.261	1172.49	2092.43	1146.17
21	1.18573	2560.26	-4.9361	Native Clay	1000	20	219.33	1442.53	2178.15	962.321	1215.83	2159.21	1196.89
22	1.18573	2633.31	-2.95931	Native Clay	1000	20	221.578	1457.31	2232.28	975.828	1256.45	2220.82	1244.99
23	1.18573	2700.29	-0.986047	Native Clay	1000	20	223.679	1471.13	2281.17	986.742	1294.43	2277.32	1290.58
24	1.18573	2761.22	0.986047	Native Clay	1000	20	225.632	1483.97	2324.81	995.112	1329.7	2328.7	1333.59
25	1.18573	2816.09	2.95931	Native Clay	1000	20	227.437	1495.85	2363.22	1000.89	1362.33	2374.98	1374.09
26	1.18573	2864.88	4.9361	Native Clay	1000	20	229.099	1506.77	2396.35	1004	1392.35	2416.14	1412.14
27	1.18573	2907.55	6.91881	Native Clay	1000	20	230.608	1516.7	2424.14	1004.51	1419.63	2452.12	1447.61
28	1.18573	2944.04	8.90988	Native Clay	1000	20	231.964	1525.62	2446.53	1002.4	1444.13	2482.9	1480.5
29	1.18573	2974.25	10.9119	Native Clay	1000	20	233.168	1533.54	2463.43	997.533	1465.9	2508.38	1510.85
30	1.18573	2998.06	12.9275	Native Clay	1000	20	234.216	1540.43	2474.71	989.889	1484.82	2528.47	1538.58
31	1.18573	3015.34	14.9595	Native Clay	1000	20	235.096	1546.22	2480.23	979.503	1500.73	2543.04	1563.54
32	1.18573	3025.9	17.011	Native Clay	1000	20	235.81	1550.91	2479.81	966.188	1513.62	2551.96	1585.77
33	1.18573	3029.54	19.0853	Native Clay	1000	20	236.348	1554.45	2473.25	949.902	1523.35	2555.02	1605.12
34	1.18573	3026	21.1859	Native Clay	1000	20	236.701	1556.78	2460.31	930.577	1529.73	2552.05	1621.47
35	1.18573	3015	23.3169	Native Clay	1000	20	236.863	1557.84	2440.67	908.022	1532.65	2542.76	1634.74
36	1.18573	2996.17	25.4826	Native Clay	1000	20	236.818	1557.55	2414.02	882.178	1531.84	2526.89	1644.71
37	1.18573	2941.44	27.6882	Native Clay	1000	20	235.304	1547.59	2357.27	852.779	1504.49	2480.74	1627.96
38	1.18573	2844.78	29.9394	Native Clay	1000	20	232.062	1526.26	2265.58	819.679	1445.9	2399.23	1579.55
39	1.18573	2738.75	32.2428	Native Clay	1000	20	228.578	1503.35	2165.63	782.68	1382.95	2309.81	1527.13
40	1.18573	2622.69	34.6063	Native Clay	1000	20	224.838	1478.75	2056.79	741.427	1315.36	2211.93	1470.5
41	1.18573	2495.74	37.0393	Native Clay	1000	20	220.806	1452.24	1938.24	695.738	1242.51	2104.87	1409.13
42	1.18573	2356.85	39.5532	Native Clay	1000	20	216.465	1423.68	1808.97	644.905	1164.07	1987.75	1342.85
43	1.18573	2204.71	42.162	Native Clay	1000	20	211.755	1392.7	1667.69	588.741	1078.95	1859.44	1270.7
44	1.18573	2037.62	44.8836	Native Clay	1000	20	206.626	1358.97	1512.74	526.481	986.26	1718.53	1192.05
45	1.18573	1853.39	47.7413	Native Clay	1000	20	201.009	1322.03	1341.94	457.174	884.768	1563.17	1105.99
46	1.18573	1649.07	50.7664	Native Clay	1000	20	194.795	1281.16	1152.3	379.806	772.491	1390.85	1011.05
47	1.20017	1409.51	54.0241	Embankment Material	2000	23	331.56	2180.66	717.846	292.246	425.6	1174.6	882.357
48	1.20017	1071.51	57.5849	Embankment Material	2000	23	317.116	2085.66	393.6	191.794	201.806	893.003	701.209
49	1.20017	688.913	61.5412	Embankment Material	2000	23	300.525	1976.54	19.7909	75.0518	-55.2609	574.239	499.187
50	1.20017	242.484	66.0993	Embankment Material	2000	23	276.831	1820.71	-422.387	-66.9861	-422.387	202.297	202.297

Interslice Data

Static Slope Stability - End of Construction

- Global Minimum Query (bishop simplified) - Safety Factor: 7.25583

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	1.19406	15	0	0	0
2	2.33094	13.5868	563.789	0	0
3	3.46783	12.319	1294.84	0	0
4	4.60472	11.1732	2133.26	0	0
5	5.7416	10.1325	3044.18	0	0
6	6.87849	9.18418	4001.06	0	0
7	8.01538	8.31824	4983.2	0	0
8	9.15226	7.52688	5974.12	0	0
9	10.2892	6.8038	6960.47	0	0
10	11.426	6.14384	7931.31	0	0
11	12.5629	5.54275	8877.58	0	0
12	13.6998	4.99696	9791.72	0	0
13	14.8367	4.50349	10674.9	0	0
14	15.9736	4.05984	11537.9	0	0
15	17.1105	3.66388	12372.3	0	0
16	18.2474	3.3138	13169.7	0	0
17	19.3842	3.00811	13922.8	0	0
18	20.5211	2.74552	14624.8	0	0
19	21.658	2.525	15269.7	0	0
20	22.7949	2.34569	15851.8	0	0
21	23.9318	2.2069	16366.1	0	0
22	25.0687	2.10813	16808	0	0
23	26.2056	2.04901	17173.2	0	0
24	27.3424	2.02933	17457.9	0	0
25	28.4793	2.04901	17658.5	0	0
26	29.6162	2.10813	17771.6	0	0
27	30.7531	2.2069	17794.2	0	0
28	31.89	2.34569	17723.5	0	0
29	33.0269	2.525	17557	0	0
30	34.1638	2.74552	17292.3	0	0
31	35.3007	3.00811	16927.5	0	0
32	36.4375	3.3138	16460.6	0	0
33	37.5744	3.66388	15890.1	0	0
34	38.7113	4.05984	15214.6	0	0
35	39.8482	4.50349	14433.2	0	0
36	40.9851	4.99696	13545	0	0
37	42.122	5.54275	12549.9	0	0
38	43.2589	6.14384	11447.9	0	0
39	44.3957	6.8038	10241.3	0	0
40	45.5326	7.52688	8955.12	0	0
41	46.6695	8.31824	7603.8	0	0
42	47.8064	9.18418	6197.76	0	0
43	48.9433	10.1325	4749.99	0	0
44	50.0802	11.1732	3276.99	0	0
45	51.2171	12.319	1800.28	0	0
46	52.354	13.5868	348.768	0	0
47	53.4908	15	-1048.18	0	0
48	54.7187	16.7289	-1933.78	0	0
49	55.9466	18.734	-2468.55	0	0
50	57.1745	21.1359	-2328.62	0	0
51	58.4024	24.1992	0	0	0

- Global Minimum Query (janbu simplified) - Safety Factor: 6.96941

Static Slope Stability - Normal Pool

- Global Minimum Query (bishop simplified) - Safety Factor: 6.83065

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	1.19406	15	0	0	0
2	2.33094	13.5868	585.693	0	0
3	3.46783	12.319	1325.29	0	0
4	4.60472	11.1732	2171.49	0	0
5	5.7416	10.1325	3089.38	0	0
6	6.87849	9.18418	4052.5	0	0
7	8.01538	8.31824	5040.22	0	0
8	9.15226	7.52688	6036.12	0	0
9	10.2892	6.8038	7026.81	0	0
10	11.426	6.14384	8001.39	0	0
11	12.5629	5.54275	8950.88	0	0
12	13.6998	4.99696	9867.69	0	0
13	14.8367	4.50349	10753	0	0
14	15.9736	4.05984	11617.9	0	0
15	17.1105	3.66388	12453.9	0	0
16	18.2474	3.3138	13252.6	0	0
17	19.3842	3.00811	14006.7	0	0
18	20.5211	2.74552	14709.4	0	0
19	21.658	2.525	15354.6	0	0
20	22.7949	2.34569	15936.8	0	0
21	23.9318	2.2069	16450.9	0	0
22	25.0687	2.10813	16892.2	0	0
23	26.2056	2.04901	17256.6	0	0
24	27.3424	2.02933	17540.2	0	0
25	28.4793	2.04901	17739.2	0	0
26	29.6162	2.10813	17850.4	0	0
27	30.7531	2.2069	17870.8	0	0
28	31.89	2.34569	17797.5	0	0
29	33.0269	2.525	17628	0	0
30	34.1638	2.74552	17360	0	0
31	35.3007	3.00811	16991.3	0	0
32	36.4375	3.3138	16520	0	0
33	37.5744	3.66388	15944.7	0	0
34	38.7113	4.05984	15263.9	0	0
35	39.8482	4.50349	14476.4	0	0
36	40.9851	4.99696	13581.7	0	0
37	42.122	5.54275	12579.2	0	0
38	43.2589	6.14384	11468.9	0	0
39	44.3957	6.8038	10253.2	0	0
40	45.5326	7.52688	8956.59	0	0
41	46.6695	8.31824	7593.34	0	0
42	47.8064	9.18418	6173.63	0	0
43	48.9433	10.1325	4710.1	0	0
44	50.0802	11.1732	3218.79	0	0
45	51.2171	12.319	1720.64	0	0
46	52.354	13.5868	243.695	0	0
47	53.4908	15	-1172.95	0	0
48	54.7187	16.7289	-2049.31	0	0
49	55.9466	18.734	-2550.04	0	0
50	57.1745	21.1359	-2331.33	0	0
51	58.4024	24.1992	0	0	0

- Global Minimum Query (janbu simplified) - Safety Factor: 6.57697

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	1.1935	15	0	0	0
2	2.35567	13.6333	553.035	0	0
3	3.51785	12.4023	1266.19	0	0
4	4.68003	11.2868	2082.91	0	0
5	5.8422	10.2716	2969.98	0	0
6	7.00438	9.34547	3901.89	0	0
7	8.16655	8.49934	4858.56	0	0
8	9.32873	7.72605	5823.82	0	0
9	10.4909	7.01979	6784.54	0	0
10	11.6531	6.37577	7729.86	0	0
11	12.8153	5.79002	8650.8	0	0
12	13.9774	5.25921	9539.79	0	0
13	15.1396	4.78055	10403.9	0	0
14	16.3018	4.35168	11248.2	0	0
15	17.464	3.97059	12063.4	0	0
16	18.6261	3.6356	12841	0	0
17	19.7883	3.3453	13573.5	0	0
18	20.9505	3.09851	14254.1	0	0
19	22.1127	2.89426	14876.6	0	0
20	23.2748	2.73175	15435.3	0	0
21	24.437	2.61039	15925.2	0	0
22	25.5992	2.52973	16341.6	0	0
23	26.7614	2.48947	16680.2	0	0
24	27.9235	2.48947	16937	0	0
25	29.0857	2.52973	17108.5	0	0
26	30.2479	2.61039	17191.4	0	0
27	31.4101	2.73175	17182.6	0	0
28	32.5722	2.89426	17079.4	0	0
29	33.7344	3.09851	16879.4	0	0
30	34.8966	3.3453	16580.4	0	0
31	36.0588	3.6356	16180.3	0	0
32	37.2209	3.97059	15677.6	0	0
33	38.3831	4.35168	15070.9	0	0
34	39.5453	4.78055	14359.2	0	0
35	40.7075	5.25921	13541.7	0	0
36	41.8696	5.79002	12618.2	0	0
37	43.0318	6.37577	11588.8	0	0
38	44.194	7.01979	10454.7	0	0
39	45.3562	7.72605	9237.62	0	0
40	46.5183	8.49934	7956	0	0
41	47.6805	9.34547	6620.35	0	0
42	48.8427	10.2716	5243.63	0	0
43	50.0049	11.2868	3842.16	0	0
44	51.167	12.4023	2436.94	0	0
45	52.3292	13.6333	1055.59	0	0
46	53.4914	15	-274.923	0	0
47	54.5358	16.3671	-984.251	0	0
48	55.5801	17.8963	-1495.98	0	0
49	56.6245	19.6331	-1690.96	0	0
50	57.6688	21.6521	-1325.32	0	0
51	58.7132	24.0956	0	0	0

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	1.25774	15	0	0	0
2	2.44347	13.5479	622.912	0	0
3	3.62921	12.2429	1410.51	0	0
4	4.81494	11.062	2312.81	0	0
5	6.00068	9.98824	3292.73	0	0
6	7.18641	9.00895	4321.96	0	0
7	8.37214	8.11416	5378.47	0	0
8	9.55788	7.29598	6444.56	0	0
9	10.7436	6.54805	7505.81	0	0
10	11.9293	5.86514	8550.52	0	0
11	13.1151	5.24292	9568.92	0	0
12	14.3008	4.6778	10553.9	0	0
13	15.4865	4.16673	11519.3	0	0
14	16.6723	3.70715	12463.1	0	0
15	17.858	3.29689	13375.3	0	0
16	19.0438	2.93413	14246.8	0	0
17	20.2295	2.61731	15069.6	0	0
18	21.4152	2.34514	15836.5	0	0
19	22.601	2.11655	16541	0	0
20	23.7867	1.93066	17176.9	0	0
21	24.9724	1.78677	17738.9	0	0
22	26.1582	1.68437	18221.9	0	0
23	27.3439	1.62307	18621.3	0	0
24	28.5296	1.60266	18933	0	0
25	29.7154	1.62307	19153	0	0
26	30.9011	1.68437	19277.7	0	0
27	32.0868	1.78677	19303.8	0	0
28	33.2726	1.93066	19228.4	0	0
29	34.4583	2.11655	19048.5	0	0
30	35.644	2.34514	18761.7	0	0
31	36.8298	2.61731	18365.8	0	0
32	38.0155	2.93413	17858.7	0	0
33	39.2012	3.29689	17238.6	0	0
34	40.387	3.70715	16504.1	0	0
35	41.5727	4.16673	15653.9	0	0
36	42.7584	4.6778	14687.3	0	0
37	43.9442	5.24292	13603.7	0	0
38	45.1299	5.86514	12415.9	0	0
39	46.3156	6.54805	11143.8	0	0
40	47.5014	7.29598	9794.95	0	0
41	48.6871	8.11416	8378.63	0	0
42	49.8728	9.00895	6906.01	0	0
43	51.0586	9.98824	5391.06	0	0
44	52.2443	11.062	3851.4	0	0
45	53.43	12.2429	2309.87	0	0
46	54.6158	13.5479	796.889	0	0
47	55.8015	15	-645.495	0	0
48	57.0017	16.6534	-1434.59	0	0
49	58.2019	18.5434	-1798.09	0	0
50	59.402	20.7577	-1481.37	0	0
51	60.6022	23.4659	0	0	0

Slide Analysis Information

Slope Stability Analysis

Project Summary

File Name:	Slope Stability Analysis.slmd
Slide Modeler Version:	8.023
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	10/22/2020, 11:32:33 AM

Currently Open Scenarios

Group Name	Scenario Name	Global Minimum	Compute Time
Static Slope Stability	Top of Dam	Bishop Simplified: 6.586030 Janbu Simplified: 6.219070	00h:00m:00.305s
Rapid Drawdown Slope Stability	7 Feet Rapid Drawdown	Bishop Simplified: 2.506230 Janbu Simplified: 2.266160	00h:00m:00.238s

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Data Output:	Standard
Failure Direction:	Right to Left

Analysis Options

All Open Scenarios	
Slices Type:	Vertical
Analysis Methods Used	
	Bishop simplified
	Janbu simplified
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Static Slope Stability	
Groundwater Method:	Steady State FEA
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Tolerance:	1e-06
Maximum number of iterations:	500
Use negative pore pressure cutoff:	No
Advanced Groundwater Method:	None
Mesh Element Type:	3 noded triangles
Number of Elements:	642
Number of Nodes:	379

Rapid Drawdown Slope Stability	
Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Use negative pore pressure cutoff:	Yes
Maximum negative pore pressure [psf]:	0
Advanced Groundwater Method:	Rapid Drawdown
Rapid Drawdown Method:	Duncan, Wright, Wong 3 Stage (1990)

Random Numbers

All Open Scenarios	
Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

All Open Scenarios	
Surface Type:	Circular
Search Method:	Grid Search
Radius Increment:	10
Composite Surfaces:	Disabled
Reverse Curvature:	Invalid Surfaces
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic Loading

All Open Scenarios	
Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Materials

Property	Embankment Material	Native Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	130	125
Cohesion [psf]	2000	1000
Friction Angle [°]	23	20
Water Surface	Assigned per scenario	Assigned per scenario
Hu Value	1	1
Rapid Drawdown Undrained Behaviour	Yes	Yes
RD Shear Strength Envelope Properties	CR: 300 PhiR: 12	CR: 300 PhiR: 12

Materials In Use

Material	Top of Dam	7 Feet Rapid Drawdown
Embankment Material	✓	✓
Native Clay	✓	✓

Global Minimums

Static Slope Stability

Method: bishop simplified

FS	6.586030
Center:	28.530, 36.059
Radius:	34.456
Left Slip Surface Endpoint:	1.258, 15.000
Right Slip Surface Endpoint:	60.602, 23.466
Left Slope Intercept:	1.258 15.000
Right Slope Intercept:	60.602 25.000
Resisting Moment:	3.56252e+06 lb-ft
Driving Moment:	540921 lb-ft
Total Slice Area:	807.413 ft2
Surface Horizontal Width:	59.3445 ft
Surface Average Height:	13.6055 ft

Method: janbu simplified

FS	6.219070
Center:	29.717, 37.246
Radius:	36.072
Left Slip Surface Endpoint:	1.322, 15.000
Right Slip Surface Endpoint:	62.748, 22.751
Left Slope Intercept:	1.322 15.000
Right Slope Intercept:	62.748 25.000
Resisting Horizontal Force:	86596.7 lb
Driving Horizontal Force:	13924.4 lb
Total Slice Area:	868.269 ft2
Surface Horizontal Width:	61.4263 ft
Surface Average Height:	14.1351 ft

Rapid Drawdown Slope Stability

Method: bishop simplified

FS	2.506230
Center:	26.155, 36.059
Radius:	29.567
Left Slip Surface Endpoint:	5.401, 15.000
Right Slip Surface Endpoint:	53.576, 25.000
Resisting Moment:	854190 lb-ft
Driving Moment:	340827 lb-ft
Total Slice Area:	593.985 ft2
Surface Horizontal Width:	48.1751 ft
Surface Average Height:	12.3297 ft

Method: janbu simplified

FS	2.266160
Center:	26.155, 33.685
Radius:	27.943
Left Slip Surface Endpoint:	5.377, 15.000
Right Slip Surface Endpoint:	52.715, 25.000
Resisting Horizontal Force:	24435.5 lb
Driving Horizontal Force:	10782.8 lb
Total Slice Area:	612.833 ft2
Surface Horizontal Width:	47.3375 ft
Surface Average Height:	12.946 ft

Entity Information

Group: Static Slope Stability

Shared Entities

Type	Coordinates

External Boundary

X	Y
100	0
100	13
100	15
86	15
64.9593	22.0136
56	25
44	25
35.0082	22.0027
14	15
0	15
0	14.9288
0	13
0	0

Material Boundary

X	Y
14	15
86	15

Group: Rapid Drawdown Slope Stability

Shared Entities

Type	Coordinates

External Boundary

X	Y
100	0
100	15
86	15
56	25
44	25
14	15
0	15
0	0

Material Boundary

X	Y
14	15
86	15

Scenario-based Entities

Type	Coordinates	7 Feet Rapid Drawdown
Water Table	X: 0, 35, 86, 100 Y: 22, 22, 15, 15	Assigned to materials: Embankment Material Native Clay
Drawdown Line	X: 0, 86, 100 Y: 15, 15, 15	✓

Valid/Invalid Surfaces

Static Slope Stability

Method: bishop simplified

Number of Valid Surfaces: 4697
Number of Invalid Surfaces: 154

Error Codes:

Error Code -103 reported for 34 surfaces
Error Code -108 reported for 120 surfaces

Method: janbu simplified

Number of Valid Surfaces: 4578
Number of Invalid Surfaces: 273

Error Codes:

Error Code -103 reported for 34 surfaces
Error Code -108 reported for 182 surfaces
Error Code -111 reported for 57 surfaces

Rapid Drawdown Slope Stability

Method: bishop simplified

Number of Valid Surfaces: 4647
Number of Invalid Surfaces: 204

Error Codes:

Error Code -103 reported for 34 surfaces
Error Code -108 reported for 170 surfaces

Method: janbu simplified

Number of Valid Surfaces: 4338
Number of Invalid Surfaces: 513

Error Codes:

Error Code -103 reported for 34 surfaces
Error Code -108 reported for 327 surfaces
Error Code -111 reported for 152 surfaces

Error Codes

The following errors were encountered during the computation:

-103 = Two surface / slope intersections, but one or more surface / nonslope external polygon intersections lie between them. This usually occurs when the slip surface extends past the bottom of the soil region, but may also occur on a benched slope model with two sets of Slope Limits.
-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).
-111 = safety factor equation did not converge

Slice Data

Static Slope Stability

- **Global Minimum Query (bishop simplified) - Safety Factor: 6.58603**

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	1.18573	107.614	-50.7664	Native Clay	1000	20	165.505	1090.02	293.44	46.1013	247.339	90.7532	44.6519
2	1.18573	311.938	-47.7413	Native Clay	1000	20	169.205	1114.39	449.296	135.013	314.283	263.073	128.06
3	1.18573	496.166	-44.8836	Native Clay	1000	20	172.487	1136	590.23	216.565	373.665	418.443	201.878
4	1.18573	663.254	-42.162	Native Clay	1000	20	175.34	1154.79	718.136	292.842	425.294	559.359	266.517
5	1.18573	815.4	-39.5532	Native Clay	1000	20	177.818	1171.11	834.529	364.403	470.126	687.67	323.267
6	1.18573	954.286	-37.0393	Native Clay	1000	20	180.057	1185.86	940.68	430.038	510.642	804.804	374.766
7	1.18573	1081.23	-34.6063	Native Clay	1000	20	181.986	1198.56	1037.44	491.893	545.545	911.865	419.972
8	1.18573	1197.29	-32.2428	Native Clay	1000	20	183.586	1209.1	1125.55	551.045	574.5	1009.74	458.698
9	1.18573	1303.33	-29.9394	Native Clay	1000	20	185.004	1218.44	1205.72	605.565	600.158	1099.17	493.607
10	1.18573	1400.05	-27.6882	Native Clay	1000	20	186.188	1226.24	1278.45	656.864	621.581	1180.74	523.879
11	1.18573	1490	-25.4826	Native Clay	1000	20	187.213	1232.99	1345.84	705.697	640.139	1256.61	550.912
12	1.18573	1613.72	-23.3169	Native Clay	1000	20	190.062	1251.75	1442.86	751.18	691.68	1360.94	609.76
13	1.18573	1746.58	-21.1859	Native Clay	1000	20	193.56	1274.79	1548.01	793.034	754.977	1472.99	679.955
14	1.18573	1871.96	-19.0853	Native Clay	1000	20	196.811	1296.2	1646.83	833.025	813.805	1578.74	745.71
15	1.18573	1990.18	-17.011	Native Clay	1000	20	199.914	1316.64	1739.59	869.637	869.956	1678.43	808.795
16	1.18573	2101.46	-14.9595	Native Clay	1000	20	202.842	1335.92	1826.48	903.545	922.94	1772.29	868.742
17	1.18573	2206.04	-12.9275	Native Clay	1000	20	205.588	1354.01	1907.67	935.034	972.634	1860.48	925.444
18	1.18573	2304.07	-10.9119	Native Clay	1000	20	208.172	1371.03	1983.29	963.901	1019.39	1943.16	979.259
19	1.18573	2395.71	-8.90988	Native Clay	1000	20	210.596	1386.99	2053.46	990.209	1063.25	2020.45	1030.24
20	1.18573	2481.08	-6.91881	Native Clay	1000	20	212.864	1401.93	2118.27	1013.98	1104.29	2092.44	1078.46
21	1.18573	2560.26	-4.9361	Native Clay	1000	20	214.983	1415.89	2177.78	1035.15	1142.63	2159.21	1124.06
22	1.18573	2633.31	-2.95931	Native Clay	1000	20	216.95	1428.84	2232.05	1053.81	1178.24	2220.83	1167.02
23	1.18573	2700.29	-0.986047	Native Clay	1000	20	218.773	1440.84	2281.08	1069.87	1211.21	2277.32	1207.45
24	1.18573	2761.22	0.986047	Native Clay	1000	20	220.446	1451.87	2324.91	1083.41	1241.5	2328.7	1245.29
25	1.18573	2816.09	2.95931	Native Clay	1000	20	221.978	1461.95	2363.5	1094.3	1269.2	2374.97	1280.67
26	1.18573	2864.88	4.9361	Native Clay	1000	20	223.368	1471.11	2396.84	1102.47	1294.37	2416.13	1313.66
27	1.18573	2907.55	6.91881	Native Clay	1000	20	224.612	1479.3	2424.86	1107.98	1316.88	2452.12	1344.14
28	1.18573	2944.04	8.90988	Native Clay	1000	20	225.705	1486.5	2447.5	1110.86	1336.64	2482.88	1372.02
29	1.18573	2974.25	10.9119	Native Clay	1000	20	226.653	1492.74	2464.67	1110.87	1353.8	2508.36	1397.49
30	1.18573	2998.06	12.9275	Native Clay	1000	20	227.458	1498.04	2476.23	1107.88	1368.35	2528.44	1420.56
31	1.18573	3015.34	14.9595	Native Clay	1000	20	228.094	1502.23	2482.07	1102.2	1379.87	2543.02	1440.82
32	1.18573	3025.9	17.011	Native Clay	1000	20	228.571	1505.37	2482	1093.49	1388.51	2551.93	1458.44
33	1.18573	3029.54	19.0853	Native Clay	1000	20	228.881	1507.42	2475.8	1081.68	1394.12	2554.99	1473.31
34	1.18573	3026	21.1859	Native Clay	1000	20	229.009	1508.26	2463.25	1066.82	1396.43	2552.01	1485.19
35	1.18573	3015	23.3169	Native Clay	1000	20	228.955	1507.9	2444.04	1048.59	1395.45	2542.72	1494.13
36	1.18573	2996.17	25.4826	Native Clay	1000	20	228.694	1506.18	2417.85	1027.12	1390.73	2526.85	1499.73
37	1.18573	2941.44	27.6882	Native Clay	1000	20	226.98	1494.9	2361.58	1001.86	1359.72	2480.69	1478.83
38	1.18573	2844.78	29.9394	Native Clay	1000	20	223.546	1472.28	2270.43	972.85	1297.58	2399.18	1426.33
39	1.18573	2738.75	32.2428	Native Clay	1000	20	219.866	1448.04	2171.06	940.075	1230.99	2309.75	1369.68
40	1.18573	2622.69	34.6063	Native Clay	1000	20	215.934	1422.14	2062.87	903.038	1159.84	2211.87	1308.83
41	1.18573	2495.74	37.0393	Native Clay	1000	20	211.701	1394.27	1945.05	861.805	1083.25	2104.81	1243
42	1.18573	2356.85	39.5532	Native Clay	1000	20	207.184	1364.52	1816.57	815.062	1001.51	1987.68	1172.62
43	1.18573	2204.71	42.162	Native Clay	1000	20	202.285	1332.25	1676.19	763.329	912.859	1859.36	1096.04
44	1.18573	2037.62	44.8836	Native Clay	1000	20	196.949	1297.11	1522.3	706	816.302	1718.45	1012.45
45	1.18573	1853.39	47.7413	Native Clay	1000	20	191.131	1258.79	1352.72	641.702	711.022	1563.08	921.376
46	1.18573	1649.07	50.7664	Native Clay	1000	20	184.684	1216.33	1164.59	570.219	594.368	1390.76	820.541
47	1.20017	1419.94	54.0241	Embankment Material	2000	23	319.957	2107.25	742.349	489.687	252.662	1183.12	693.435
48	1.20017	1111.5	57.5849	Embankment Material	2000	23	306.655	2019.64	443.195	396.932	46.2633	926.124	529.192
49	1.20017	758.86	61.5412	Embankment Material	2000	23	291.021	1916.68	95.3865	291.688	-196.302	632.301	340.613
50	1.20017	342.392	66.0993	Embankment Material	2000	23	271.873	1790.57	-328.202	165.197	-493.399	285.296	120.099

- **Global Minimum Query (janbu simplified) - Safety Factor: 6.21907**

Rapid Drawdown Slope Stability

- **Global Minimum Query (bishop simplified) - Safety Factor: 2.50623**

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	0.965307	54.8758	-43.2971	Native Clay	377.467	0	150.611	377.467	198.762	28.3776	170.385	56.8476	28.47
2	0.965307	159.98	-40.7767	Native Clay	389.37	0	155.361	389.37	299.724	82.7315	216.993	165.73	82.9988
3	0.965307	256.284	-38.3488	Native Clay	400.265	0	159.708	400.265	391.846	132.534	259.312	265.495	132.961
4	0.965307	344.672	-36	Native Clay	410.239	0	163.688	410.239	475.985	178.243	297.742	357.059	178.816
5	0.965307	425.853	-33.7193	Native Clay	419.366	0	167.329	419.366	552.834	220.225	332.609	441.158	220.933
6	0.965307	500.407	-31.4977	Native Clay	427.706	0	170.657	427.706	622.961	258.78	364.181	518.391	259.611
7	0.965307	568.812	-29.3279	Native Clay	435.31	0	173.691	435.31	686.837	294.155	392.682	589.255	295.1
8	0.965307	631.466	-27.2033	Native Clay	442.222	0	176.449	442.222	744.856	326.556	418.3	654.16	327.604
9	0.965307	688.876	-25.1186	Native Clay	448.5	0	178.954	448.5	797.533	356.157	441.376	713.634	357.477
10	0.965307	764.722	-23.0689	Native Clay	457.329	0	182.477	457.329	869.922	383.104	486.818	792.206	409.102
11	0.965307	852.318	-21.0501	Native Clay	467.789	0	186.65	467.789	954.786	407.522	547.264	882.951	475.429
12	0.965307	935.231	-19.0583	Native Clay	477.659	0	190.589	477.659	1034.68	429.518	605.167	968.843	539.325
13	0.965307	1013.63	-17.0901	Native Clay	486.958	0	194.299	486.958	1109.8	449.182	660.62	1050.06	600.883
14	0.965307	1087.68	-15.1426	Native Clay	495.703	0	197.788	495.703	1180.3	466.592	713.703	1126.77	660.178
15	0.965307	1157.49	-13.2128	Native Clay	503.908	0	201.062	503.908	1246.29	481.813	764.481	1199.09	717.275
16	0.965307	1223.18	-11.2982	Native Clay	511.586	0	204.126	511.586	1307.93	494.902	813.023	1267.14	772.241
17	0.965307	1284.83	-9.39632	Native Clay	518.747	0	206.983	518.747	1365.26	505.903	859.359	1331.01	825.107
18	0.965307	1342.52	-7.50484	Native Clay	525.397	0	209.636	525.397	1418.39	514.854	903.534	1390.77	875.917
19	0.965307	1396.3	-5.62156	Native Clay	531.544	0	212.089	531.544	1467.36	521.787	945.575	1446.49	924.699
20	0.965307	1446.23	-3.74436	Native Clay	537.192	0	214.343	537.192	1512.23	526.722	985.509	1498.2	971.481
21	0.965307	1492.32	-1.87118	Native Clay	542.342	0	216.398	542.342	1553.02	529.677	1023.34	1545.95	1016.27
22	0.965307	1534.6	0	Native Clay	546.996	0	218.255	546.996	1589.75	530.661	1059.09	1589.75	1059.09
23	0.965307	1573.08	1.87118	Native Clay	551.154	0	219.914	551.154	1622.43	529.677	1092.75	1629.62	1099.94
24	0.965307	1607.74	3.74436	Native Clay	554.813	0	221.374	554.813	1651.03	526.722	1124.31	1665.52	1138.8
25	0.965307	1638.58	5.62156	Native Clay	557.969	0	222.633	557.969	1675.55	521.787	1153.77	1697.47	1175.68
26	0.965307	1665.55	7.50484	Native Clay	560.617	0	223.689	560.617	1695.94	514.854	1181.09	1725.41	1210.56
27	0.965307	1688.62	9.39632	Native Clay	562.749	0	224.54	562.749	1712.15	505.903	1206.25	1749.31	1243.41
28	0.965307	1707.72	11.2982	Native Clay	564.356	0	225.181	564.356	1724.11	494.902	1229.21	1769.1	1274.2
29	0.965307	1722.79	13.2128	Native Clay	565.426	0	225.608	565.426	1731.74	481.813	1249.93	1784.71	1302.9
30	0.965307	1733.74	15.1426	Native Clay	565.946	0	225.816	565.946	1734.94	466.592	1268.35	1796.05	1329.46
31	0.965307	1740.45	17.0901	Native Clay	566.177	0	225.908	566.177	1733.55	449.182	1284.37	1803	1353.82
32	0.965307	1742.81	19.0583	Native Clay	571.053	0	227.853	571.053	1726.72	429.518	1297.21	1805.44	1375.92
33	0.965307	1740.65	21.0501	Native Clay	576.705	0	230.109	576.705	1714.64	407.522	1307.12	1803.21	1395.68
34	0.965307	1733.81	23.0689	Native Clay	582.145	0	232.279	582.145	1697.19	383.104	1314.09	1796.12	1413.02
35	0.965307	1722.08	25.1186	Native Clay	587.494	0	234.413	587.494	1674.07	356.157	1317.92	1783.97	1427.82
36	0.965307	1705.22	27.2033	Native Clay	591.916	0	236.178	591.916	1645.11	326.556	1318.56	1766.51	1439.96
37	0.965307	1682.95	29.3279	Native Clay	595.372	0	237.557	595.372	1609.97	294.155	1315.82	1743.43	1449.28
38	0.965307	1654.92	31.4977	Native Clay	597.806	0	238.528	597.806	1568.24	258.78	1309.46	1714.4	1455.62
39	0.965307	1620.75	33.7193	Native Clay	599.15	0	239.064	599.15	1519.44	220.225	1299.22	1679	1458.77
40	0.965307	1579.94	36	Native Clay	599.311	0	239.128	599.311	1462.98	178.243	1284.74	1636.72	1458.48
41	0.965307	1511.18	38.3488	Native Clay	591.842	0	236.148	591.842	1378.67	132.534	1246.13	1565.49	1432.96
42	0.965307	1414.88	40.7767	Native Clay	577.408	0	230.389	577.408	1267.02	82.7315	1184.29	1465.73	1383
43	0.965307	1309.77	43.2971	Native Clay	563.997	0	225.038	563.997	1144.8	28.3776	1116.43	1356.85	1328.47
44	0.988987	1219.94	45.9609	Embankment Material	513.921	0	205.057	513.921	1021.47	0	1021.47	1233.52	1233.52
45	0.988987	1081.58	48.7943	Embankment Material	493.761	0	197.013	493.761	868.628	0	868.628	1093.63	1093.63
46	0.988987	928.189	51.7987	Embankment Material	470.962	0	187.917	470.962	699.737	0	699.737	938.526	938.526
47	0.988987	756.538	55.0201	Embankment Material	444.808	0	177.481	444.808	511.305	0	511.305	764.963	764.963
48	0.90365	522.089	58.3612	Embankment Material	404.41	0	161.362	404.41	315.864	0	315.864	577.756	577.756
49	0.90365	336.582	61.8891	Embankment Material	347.296	0	138.573	347.296	113.064	0	113.064	372.47	372.47
50	0.90365	118.611	65.8917	Embankment Material	278.777	0	111.234	278.777	-117.311	0	-117.311	131.258	131.258

- **Global Minimum Query (janbu simplified) - Safety Factor: 2.26616**

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	1.23457	115.09	-50.3853	Native Clay	1000	20	175.913	1094.01	305.733	47.4338	258.299	93.2019	45.7681
2	1.23457	333.77	-47.3987	Native Clay	1000	20	179.938	1119.05	466.006	138.929	327.077	270.334	131.405
3	1.23457	531.213	-44.5735	Native Clay	1000	20	183.496	1141.17	611.046	223.181	387.865	430.262	207.081
4	1.23457	710.477	-41.8799	Native Clay	1000	20	186.608	1160.53	742.783	301.74	441.043	575.468	273.728
5	1.23457	873.848	-39.2959	Native Clay	1000	20	189.278	1177.13	862.696	376.025	486.671	707.797	331.772
6	1.23457	1023.08	-36.8042	Native Clay	1000	20	191.715	1192.29	972.12	443.807	528.313	828.677	384.87
7	1.23457	1159.56	-34.3912	Native Clay	1000	20	193.762	1205.02	1071.86	508.572	563.284	939.228	430.656
8	1.23457	1284.4	-32.0461	Native Clay	1000	20	195.482	1215.72	1162.71	570.033	592.682	1040.34	470.312
9	1.23457	1398.5	-29.7598	Native Clay	1000	20	197.03	1225.35	1245.43	626.292	619.135	1132.77	506.478
10	1.23457	1502.61	-27.5246	Native Clay	1000	20	198.266	1233.03	1320.42	680.169	640.247	1217.1	536.928
11	1.23457	1614.97	-25.334	Native Clay	1000	20	200.11	1244.5	1402.85	731.103	671.745	1308.11	577.009
12	1.23457	1764.51	-23.1825	Native Clay	1000	20	204.026	1268.85	1516.61	777.958	738.656	1429.24	651.284
13	1.23457	1908.05	-21.065	Native Clay	1000	20	207.815	1292.41	1625.55	822.151	803.396	1545.5	723.353
14	1.23457	2043.54	-18.9774	Native Clay	1000	20	211.397	1314.69	1727.96	863.35	864.606	1655.26	791.91
15	1.23457	2171.32	-16.9156	Native Clay	1000	20	214.807	1335.9	1824.08	901.21	922.874	1758.76	857.546
16	1.23457	2291.64	-14.8762	Native Clay	1000	20	217.991	1355.7	1914.13	936.837	977.291	1856.22	919.385
17	1.23457	2404.73	-12.8559	Native Clay	1000	20	220.998	1374.4	1998.26	969.6	1028.66	1947.83	978.227
18	1.23457	2510.78	-10.8517	Native Clay	1000	20	223.825	1391.99	2076.63	999.66	1076.97	2033.72	1034.06
19	1.23457	2609.94	-8.86098	Native Clay	1000	20	226.48	1408.49	2149.35	1027.02	1122.33	2114.04	1087.02
20	1.23457	2702.34	-6.88095	Native Clay	1000	20	228.966	1423.96	2216.52	1051.71	1164.81	2188.88	1137.17
21	1.23457	2788.06	-4.90916	Native Clay	1000	20	231.284	1438.37	2278.19	1073.77	1204.42	2258.32	1184.55
22	1.23457	2867.19	-2.94318	Native Clay	1000	20	233.443	1451.8	2334.42	1093.12	1241.3	2322.41	1229.29
23	1.23457	2939.76	-0.980677	Native Clay	1000	20	235.438	1464.21	2385.23	1109.83	1275.4	2381.2	1271.37
24	1.23457	3005.81	0.980677	Native Clay	1000	20	237.279	1475.65	2430.64	1123.79	1306.85	2434.7	1310.91
25	1.23457	3065.33	2.94318	Native Clay	1000	20	238.964	1486.13	2470.62	1134.99	1335.63	2482.91	1347.92
26	1.23457	3118.3	4.90916	Native Clay	1000	20	240.494	1495.65	2505.15	1143.38	1361.77	2525.81	1382.43
27	1.23457	3164.67	6.88095	Native Clay	1000	20	241.86	1504.14	2534.19	1149.07	1385.12	2563.38	1414.31
28	1.23457	3204.37	8.86098	Native Clay	1000	20	243.07	1511.67	2557.64	1151.84	1405.8	2595.53	1443.69
29	1.23457	3237.3	10.8517	Native Clay	1000	20	244.124	1518.23	2575.42	1151.6	1423.82	2622.22	1470.62
30	1.23457	3263.35	12.8559	Native Clay	1000	20	245.011	1523.74	2587.39	1148.42	1438.97	2643.31	1494.89
31	1.23457	3282.35	14.8762	Native Clay	1000	20	245.721	1528.15	2593.43	1142.34	1451.09	2658.7	1516.36
32	1.23457	3294.12	16.9156	Native Clay	1000	20	246.255	1531.48	2593.35	1133.12	1460.23	2668.24	1535.12
33	1.23457	3298.44	18.9774	Native Clay	1000	20	246.609	1533.68	2586.93	1120.67	1466.26	2671.74	1551.07
34	1.23457	3295.04	21.065	Native Clay	1000	20	246.767	1534.66	2573.93	1104.96	1468.97	2668.98	1564.02
35	1.23457	3277.48	23.1825	Native Clay	1000	20	246.442	1532.64	2549.23	1085.81	1463.42	2654.76	1568.95
36	1.23457	3202.29	25.334	Native Clay	1000	20	243.624	1515.11	2478.52	1063.26	1415.26	2593.86	1530.6
37	1.23457	3107.55	27.5246	Native Clay	1000	20	240.099	1493.19	2392	1036.96	1355.04	2517.12	1480.16
38	1.23457	3003.44	29.7598	Native Clay	1000	20	236.345	1469.85	2297.66	1006.76	1290.9	2432.79	1426.03
39	1.23457	2889.34	32.0461	Native Clay	1000	20	232.34	1444.94	2194.93	972.479	1222.45	2340.38	1367.9
40	1.23457	2764.5	34.3912	Native Clay	1000	20	228.065	1418.36	2083.15	933.726	1149.42	2239.25	1305.53
41	1.23457	2628.02	36.8042	Native Clay	1000	20	223.473	1389.8	1961.5	890.553	1070.95	2128.71	1238.16
42	1.23457	2478.79	39.2959	Native Clay	1000	20	218.516	1358.97	1829	842.755	986.249	2007.83	1165.08
43	1.23457	2315.42	41.8799	Native Clay	1000	20	213.222	1326.04	1684.32	788.533	895.791	1875.5	1086.97
44	1.23457	2136.16	44.5735	Native Clay	1000	20	207.434	1290.04	1525.94	729.043	796.892	1730.3	1001.26
45	1.23457	1930.04	47.3987	Native Clay	1000	20	200.74	1248.42	1345.06	662.532	682.523	1563.35	900.817
46	1.23457	1678.45	50.3853	Native Clay	1000	20	192.317	1196.03	1127.22	588.624	538.592	1359.57	770.942
47	1.159	1318.54	53.4697	Embankment Material	2000	23	333.791	2075.87	687.103	508.367	178.736	1137.7	629.331
48	1.159	1037.52	56.6927	Embankment Material	2000	23	320.665	1994.24	407.204	420.774	-13.5702	895.235	474.461
49	1.159	721.77	60.223	Embankment Material	2000	23	305.716	1901.27	88.4972	321.091	-232.594	622.804	301.713
50	1.159	358.355	64.1915	Embankment Material	2000	23	288.121	1791.84	-286.529	203.858	-490.387	309.251	105.393

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]	Base Vertical Stress [psf]	Effective Vertical Stress [psf]
1	0.94445	59.0075	-46.6264	Native Clay	381.924	0	168.534	381.924	240.619	31.1882	209.431	62.2349	31.0467
2	0.94445	171.613	-43.8731	Native Clay	394.686	0	174.165	394.686	348.924	90.7072	258.217	181.479	90.7719
3	0.94445	274.088	-41.242	Native Clay	406.318	0	179.298	406.318	447.191	144.872	302.319	289.995	145.123
4	0.94445	367.65	-38.7132	Native Clay	416.933	0	183.982	416.933	536.54	194.325	342.215	389.073	194.748
5	0.94445	453.243	-36.2711	Native Clay	426.623	0	188.258	426.623	617.856	239.566	378.29	479.713	240.147
6	0.94445	531.618	-33.9033	Native Clay	435.463	0	192.159	435.463	691.852	280.992	410.86	562.71	281.718
7	0.94445	603.381	-31.5998	Native Clay	443.514	0	195.712	443.514	759.108	318.923	440.185	638.706	319.783
8	0.94445	669.029	-29.3519	Native Clay	450.828	0	198.939	450.828	820.104	353.622	466.482	708.227	354.605
9	0.94445	728.974	-27.1528	Native Clay	457.449	0	201.861	457.449	875.241	385.307	489.934	771.709	386.402
10	0.94445	798.194	-24.9961	Native Clay	465.433	0	205.384	465.433	940.766	414.158	526.608	845.011	430.853
11	0.94445	886.035	-22.8767	Native Clay	476.05	0	210.069	476.05	1026.66	440.329	586.333	938.026	497.697
12	0.94445	969.377	-20.79	Native Clay	486.096	0	214.502	486.096	1107.72	463.95	643.77	1026.28	562.331
13	0.94445	1048.1	-18.7318	Native Clay	495.552	0	218.675	495.552	1183.8	485.13	698.668	1109.65	624.515
14	0.94445	1122.38	-16.6984	Native Clay	504.435	0	222.595	504.435	1255.08	503.962	751.121	1188.31	684.346
15	0.94445	1192.37	-14.6864	Native Clay	512.764	0	226.27	512.764	1321.72	520.524	801.195	1262.42	741.892
16	0.94445	1258.19	-12.6928	Native Clay	520.552	0	229.707	520.552	1383.86	534.884	848.979	1332.13	797.243
17	0.94445	1319.95	-10.7148	Native Clay	527.811	0	232.91	527.811	1441.59	547.096	894.495	1397.52	850.424
18	0.94445	1377.73	-8.74959	Native Clay	534.549	0	235.883	534.549	1495.02	557.207	937.816	1458.72	901.512
19	0.94445	1431.6	-6.79472	Native Clay	540.775	0	238.631	540.775	1544.2	565.253	978.951	1515.77	950.519
20	0.94445	1481.63	-4.84778	Native Clay	546.493	0	241.154	546.493	1589.2	571.264	1017.94	1568.75	997.485
21	0.94445	1527.84	-2.90644	Native Clay	551.708	0	243.455	551.708	1630.05	575.259	1054.79	1617.69	1042.43
22	0.94445	1570.26	-0.968445	Native Clay	556.419	0	245.534	556.419	1666.76	577.253	1089.51	1662.61	1085.36
23	0.94445	1608.92	0.968445	Native Clay	560.629	0	247.392	560.629	1699.37	577.253	1122.12	1703.55	1126.3
24	0.94445	1643.8	2.90644	Native Clay	564.334	0	249.027	564.334	1727.85	575.259	1152.59	1740.49	1165.23
25	0.94445	1674.89	4.84778	Native Clay	567.532	0	250.438	567.532	1752.19	571.264	1180.93	1773.43	1202.17
26	0.94445	1702.17	6.79472	Native Clay	570.216	0	251.622	570.216	1772.35	565.253	1207.1	1802.33	1237.08
27	0.94445	1725.6	8.74959	Native Clay	572.379	0	252.577	572.379	1788.28	557.207	1231.08	1827.16	1269.95
28	0.94445	1745.13	10.7148	Native Clay	574.013	0	253.298	574.013	1799.91	547.096	1252.81	1847.84	1300.74
29	0.94445	1760.68	12.6928	Native Clay	575.105	0	253.78	575.105	1807.15	534.884	1272.27	1864.31	1329.43
30	0.94445	1772.16	14.6864	Native Clay	575.641	0	254.016	575.641	1809.9	520.524	1289.38	1876.48	1355.96
31	0.94445	1779.48	16.6984	Native Clay	575.605	0	254	575.605	1808.05	503.962	1304.09	1884.24	1380.28
32	0.94445	1782.5	18.7318	Native Clay	576.207	0	254.266	576.207	1801.24	485.13	1316.11	1887.46	1402.33
33	0.94445	1781.08	20.79	Native Clay	581.773	0	256.722	581.773	1788.51	463.95	1324.56	1885.97	1422.02
34	0.94445	1775.05	22.8767	Native Clay	587.823	0	259.392	587.823	1770.16	440.329	1329.83	1879.6	1439.27
35	0.94445	1764.19	24.9961	Native Clay	592.965	0	261.661	592.965	1746.12	414.158	1331.96	1868.11	1453.96
36	0.94445	1748.25	27.1528	Native Clay	597.166	0	263.514	597.166	1716.11	385.307	1330.81	1851.27	1465.96
37	0.94445	1726.96	29.3519	Native Clay	600.382	0	264.934	600.382	1679.76	353.622	1326.13	1828.75	1475.12
38	0.94445	1699.97	31.5998	Native Clay	602.554	0	265.892	602.554	1636.61	318.923	1317.68	1800.18	1481.26
39	0.94445	1666.86	33.9033	Native Clay	603.602	0	266.355	603.602	1586.13	280.992	1305.14	1765.14	1484.14
40	0.94445	1627.13	36.2711	Native Clay	603.428	0	266.278	603.428	1527.71	239.566	1288.15	1723.11	1483.54
41	0.94445	1579.98	38.7132	Native Clay	601.833	0	265.574	601.833	1460.33	194.325	1266.01	1673.2	1478.87
42	0.94445	1501.87	41.242	Native Clay	591.526	0	261.026	591.526	1361.67	144.872	1216.8	1590.52	1445.65
43	0.94445	1399.4	43.8731	Native Clay	575.566	0	253.983	575.566	1237.86	90.7072	1147.15	1482.04	1391.34
44	0.94445	1286.79	46.6264	Native Clay	560.35	0	247.269	560.35	1101.12	31.1882	1069.93	1362.84	1331.65
45	0.879293	1084.4	49.4225	Embankment Material	505.366	0	223.005	505.366	973.229	0	973.229	1233.62	1233.62
46	0.879293	960.74	52.2821	Embankment Material	484.033	0	213.592	484.033	816.825	0	816.825	1093	1093
47	0.879293	823.07	55.3412	Embankment Material	459.666	0	202.839	459.666	643.072	0	643.072	936.459	936.459
48	0.879293	667.856	58.66	Embankment Material	431.254	0	190.302	431.254	447.463	0	447.463	759.963	759.963
49	1.13227	590.559	62.9465	Embankment Material	374.371	0	165.201	374.371	198.536	0	198.536	522.014	522.014
50	1.13227	213.694	68.6963	Embankment Material	275.497	0	121.57	275.497	-122.595	0	-122.595	189.156	189.156

Interslice Data

Static Slope Stability

- **Global Minimum Query (bishop simplified) - Safety Factor: 6.58603**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	1.25774	15	0	0	0
2	2.44347	13.5479	622.35	0	0
3	3.62921	12.2429	1409.31	0	0
4	4.81494	11.062	2310.85	0	0
5	6.00068	9.98824	3289.83	0	0
6	7.18641	9.00895	4317.92	0	0
7	8.37214	8.11416	5373.13	0	0
8	9.55788	7.29598	6437.72	0	0
9	10.7436	6.54805	7497.23	0	0
10	11.9293	5.86514	8540	0	0
11	13.1151	5.24292	9556.23	0	0
12	14.3008	4.6778	10538.8	0	0
13	15.4865	4.16673	11501.5	0	0
14	16.6723	3.70715	12442.5	0	0
15	17.858	3.29689	13351.5	0	0
16	19.0438	2.93413	14219.6	0	0
17	20.2295	2.61731	15038.7	0	0
18	21.4152	2.34514	15801.7	0	0
19	22.601	2.11655	16501.9	0	0
20	23.7867	1.93066	17133.3	0	0
21	24.9724	1.78677	17690.5	0	0
22	26.1582	1.68437	18168.5	0	0
23	27.3439	1.62307	18562.5	0	0
24	28.5296	1.60266	18868.5	0	0
25	29.7154	1.62307	19082.4	0	0
26	30.9011	1.68437	19200.7	0	0
27	32.0868	1.78677	19220.1	0	0
28	33.2726	1.93066	19137.6	0	0
29	34.4583	2.11655	18950.2	0	0
30	35.644	2.34514	18655.6	0	0
31	36.8298	2.61731	18251.3	0	0
32	38.0155	2.93413	17735.4	0	0
33	39.2012	3.29689	17106	0	0
34	40.387	3.70715	16361.7	0	0
35	41.5727	4.16673	15501.2	0	0
36	42.7584	4.6778	14523.6	0	0
37	43.9442	5.24292	13428.4	0	0
38	45.1299	5.86514	12228.1	0	0
39	46.3156	6.54805	10942.6	0	0
40	47.5014	7.29598	9579.52	0	0
41	48.6871	8.11416	8147.77	0	0
42	49.8728	9.00895	6658.37	0	0
43	51.0586	9.98824	5125.08	0	0
44	52.2443	11.062	3565.16	0	0
45	53.43	12.2429	2000.96	0	0
46	54.6158	13.5479	462.292	0	0
47	55.8015	15	-1009.84	0	0
48	57.0017	16.6534	-1856.69	0	0
49	58.2019	18.5434	-2339.65	0	0
50	59.402	20.7577	-2224.9	0	0
51	60.6022	23.4659	73.4249	0	0

- **Global Minimum Query (janbu simplified) - Safety Factor: 6.21907**

Rapid Drawdown Slope Stability

- **Global Minimum Query (bishop simplified) - Safety Factor: 2.50623**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	5.40117	15	0	0	0
2	6.36648	14.0904	326.174	0	0
3	7.33179	13.2579	725.679	0	0
4	8.29709	12.4942	1179.1	0	0
5	9.2624	11.7929	1670.93	0	0
6	10.2277	11.1486	2188.62	0	0
7	11.193	10.5571	2721.83	0	0
8	12.1583	10.0148	3261.98	0	0
9	13.1236	9.51863	3801.88	0	0
10	14.0889	9.06606	4335.56	0	0
11	15.0542	8.65494	4869.35	0	0
12	16.0195	8.28343	5404.25	0	0
13	16.9849	7.94995	5933.27	0	0
14	17.9502	7.65316	6450.2	0	0
15	18.9155	7.39193	6949.45	0	0
16	19.8808	7.1653	7426	0	0
17	20.8461	6.97244	7875.28	0	0
18	21.8114	6.8127	8293.18	0	0
19	22.7767	6.68553	8675.91	0	0
20	23.742	6.59051	9020.07	0	0
21	24.7073	6.52734	9322.51	0	0
22	25.6726	6.4958	9580.37	0	0
23	26.6379	6.4958	9791.06	0	0
24	27.6032	6.52734	9952.17	0	0
25	28.5685	6.59051	10061.6	0	0
26	29.5338	6.68553	10117.3	0	0
27	30.4992	6.8127	10117.5	0	0
28	31.4645	6.97244	10060.8	0	0
29	32.4298	7.1653	9945.64	0	0
30	33.3951	7.39193	9770.94	0	0
31	34.3604	7.65316	9535.71	0	0
32	35.3257	7.94995	9239.29	0	0
33	36.291	8.28343	8883.41	0	0
34	37.2563	8.65494	8468.51	0	0
35	38.2216	9.06606	7994.98	0	0
36	39.1869	9.51863	7463.64	0	0
37	40.1522	10.0148	6875.36	0	0
38	41.1175	10.5571	6231.55	0	0
39	42.0828	11.1486	5534.21	0	0
40	43.0481	11.7929	4786.08	0	0
41	44.0135	12.4942	3990.87	0	0
42	44.9788	13.2579	3165.95	0	0
43	45.9441	14.0904	2333.48	0	0
44	46.9094	15	1509.44	0	0
45	47.8984	16.0227	667.551	0	0
46	48.8873	17.1522	-118.705	0	0
47	49.8763	18.4089	-812.233	0	0
48	50.8653	19.8224	-1359.42	0	0
49	51.769	21.289	-1676.87	0	0
50	52.6726	22.9807	-1742.9	0	0
51	53.5763	25	0	0	0

- **Global Minimum Query (janbu simplified) - Safety Factor: 2.26616**

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	1.32165	15	0	0	0
2	2.55622	13.5084	673.174	0	0
3	3.7908	12.1659	1520.92	0	0
4	5.02537	10.9496	2490.67	0	0
5	6.25994	9.84265	3543.25	0	0
6	7.49451	8.83231	4648.52	0	0
7	8.72908	7.9086	5783.15	0	0
8	9.96365	7.06355	6928.11	0	0
9	11.1982	6.29072	8068.01	0	0
10	12.4328	5.58482	9190.37	0	0
11	13.6674	4.94147	10284.6	0	0
12	14.9019	4.35699	11351.6	0	0
13	16.1365	3.8283	12405.3	0	0
14	17.3711	3.35279	13434.8	0	0
15	18.6057	2.92824	14429.3	0	0
16	19.8402	2.55278	15379.4	0	0
17	21.0748	2.22483	16276.2	0	0
18	22.3094	1.94308	17112	0	0
19	23.5439	1.70642	17879.8	0	0
20	24.7785	1.51395	18573	0	0
21	26.0131	1.36497	19185.9	0	0
22	27.2477	1.25893	19713	0	0
23	28.4822	1.19545	20149.3	0	0
24	29.7168	1.17432	20490.4	0	0
25	30.9514	1.19545	20731.9	0	0
26	32.1859	1.25893	20870.1	0	0
27	33.4205	1.36497	20901.3	0	0
28	34.6551	1.51395	20822.4	0	0
29	35.8897	1.70642	20630.1	0	0
30	37.1242	1.94308	20322	0	0
31	38.3588	2.22483	19895.4	0	0
32	39.5934	2.55278	19348.3	0	0
33	40.8279	2.92824	18678.6	0	0
34	42.0625	3.35279	17884.7	0	0
35	43.2971	3.8283	16965.4	0	0
36	44.5317	4.35699	15921.9	0	0
37	45.7662	4.94147	14774	0	0
38	47.0008	5.58482	13531.5	0	0
39	48.2354	6.29072	12201.3	0	0
40	49.4699	7.06355	10791.8	0	0
41	50.7045	7.9086	9312.99	0	0
42	51.9391	8.83231	7776.98	0	0
43	53.1737	9.84265	6198.82	0	0
44	54.4082	10.9496	4597.59	0	0
45	55.6428	12.1659	2997.62	0	0
46	56.8774	13.5084	1436.99	0	0
47	58.1119	15	-19.7089	0	0
48	59.2709	16.5646	-729.532	0	0
49	60.4299	18.3285	-1107.13	0	0
50	61.5889	20.3541	-972.358	0	0
51	62.7479	22.7507	157.853	0	0

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	5.37737	15	0	0	0
2	6.32182	14.0003	399.49	0	0
3	7.26627	13.0923	880.583	0	0
4	8.21072	12.2643	1419.98	0	0
5	9.15517	11.5073	1999.66	0	0
6	10.0996	10.8143	2605.42	0	0
7	11.0441	10.1795	3225.79	0	0
8	11.9885	9.59852	3851.44	0	0
9	12.933	9.0674	4474.65	0	0
10	13.8774	8.583	5089	0	0
11	14.8219	8.14267	5696.96	0	0
12	15.7663	7.74417	6304.21	0	0
13	16.7108	7.3856	6903.72	0	0
14	17.6552	7.06534	7489.09	0	0
15	18.5997	6.78202	8054.63	0	0
16	19.5441	6.53448	8595.21	0	0
17	20.4886	6.32177	9106.23	0	0
18	21.433	6.14306	9583.52	0	0
19	22.3775	5.9977	10023.3	0	0
20	23.3219	5.88517	10422.1	0	0
21	24.2664	5.80507	10776.9	0	0
22	25.2108	5.75712	11084.7	0	0
23	26.1553	5.74115	11342.9	0	0
24	27.0997	5.75712	11549.1	0	0
25	28.0442	5.80507	11701.1	0	0
26	28.9886	5.88517	11796.9	0	0
27	29.9331	5.9977	11834.8	0	0
28	30.8775	6.14306	11813.1	0	0
29	31.822	6.32177	11730.3	0	0
30	32.7664	6.53448	11585.3	0	0
31	33.7109	6.78202	11376.8	0	0
32	34.6553	7.06534	11104.1	0	0
33	35.5998	7.3856	10767.1	0	0
34	36.5442	7.74417	10367.9	0	0
35	37.4887	8.14267	9907.15	0	0
36	38.4331	8.583	9385.08	0	0
37	39.3776	9.0674	8802.33	0	0
38	40.322	9.59852	8160.05	0	0
39	41.2665	10.1795	7459.92	0	0
40	42.2109	10.8143	6704.38	0	0
41	43.1554	11.5073	5896.77	0	0
42	44.0998	12.2643	5041.77	0	0
43	45.0443	13.0923	4160.46	0	0
44	45.9887	14.0003	3276.02	0	0
45	46.9332	15	2408.5	0	0
46	47.8125	16.0267	1605.11	0	0
47	48.6918	17.1636	863.977	0	0
48	49.5711	18.4355	224.223	0	0
49	50.4504	19.8794	-254.771	0	0
50	51.5826	22.0964	-508.145	0	0
51	52.7149	25	0	0	0

Ohio Dam Safety Geotechnical Requirements

There is technically no differences in the geotechnical analysis required for Class I and Class II dams. The geotechnical requirements for both classes include:

- A foundation investigation to determine the suitability of the site for the development of the dam. The foundation investigation should define the soil and rock stratigraphy and the groundwater conditions to the satisfaction of the chief. It should consist of borings, test pits, and other subsurface explorations as deemed necessary.
- Laboratory testing of the undisturbed and remolded soil specimens, and rock samples.
- A construction materials investigation to determine the suitability of the material that will be used to construct a dam. The construction materials used to construct the dam must be able to remain stable for all loading conditions and have limited detrimental settlement. The construction materials must be able to limit any detrimental seepage that could impact neighboring properties or destabilize the dam.

In general, Stability, seepage and settlement need to be evaluated as part of the geotechnical analysis. The extent of the geotechnical investigation and the complexity of the geotechnical analysis will depend on the size of the dam and the site subsurface conditions. For example, larger dams will require extensive geotechnical investigation and laboratory testing to assess the subsurface conditions.

The aforementioned geotechnical requirements will be needed for the Permit application. The Dam construction permit is a two-part process. Step one is the submittal of the preliminary design report and step two involves submittal of the final design report including the permit application, statutory filing fee, and surety bond. Below is the **geotechnical requirements for the permit application**:

- For the preliminary design report (Step one):
    1. A preliminary written report of the surficial conditions, i.e., geology, topography, and cultural features, which is based on a field reconnaissance by the applicant's engineer.
    2. Logs of borings and/or test pits in the foundation and in the borrow areas, and results of any seismic and resistivity subsurface investigations.

- For the final design report (Step two):
    1. A report of the field and laboratory investigations of the foundation soils and/or the bedrocks, and the materials that will comprise the dam or levee. Stability and settlement analyses, and seepage and underseepage studies is required, unless the applicant can demonstrate to the satisfaction of the Chief that these analyses are not necessary.
    2. A map that shows the locations of borings, test pits, proposed borrow areas, known farm tiles, utility lines, and other areas pertinent to the design and construction of the structure.

2365 Haggerty Road South, Canton, Michigan 48188 Tel: 734.397.3100 Fax: 734.397.3131 www.MannikSmithGroup.com

References:

Ohio department of Natural Resources, Division of Water Resources, ***Ohio Dam Safety Laws,*** https://ohiodnr.gov/wps/wcm/connect/gov/81785d2b-cc59-4f34-bbe5-63d5c1cd3fd7/Current+Laws+and+Rules+10-17-2019+%281%29.pdf?MOD=AJPERES&CVID=n8LvcVP *(last visited September 15, 2020)*

Ohio department of Natural Resources, Division of Water Resources, ***Dam Safety Regulations,*** https://ohiodnr.gov/wps/portal/gov/odnr/rules-and-regulations/rules-for-landowners/damsafety *(last visited September 15, 2020)*