February 13, 2025 CT Project No. 230264

City of Willoughby
1 E Spaulding St,
Willoughby, OH 44094

Geotechnical Subsurface Investigation
EQ Basin
City of Willoughby, Ohio

Following is the report of the geotechnical subsurface investigation performed by CT Consultants, Inc. (CT) for the referenced project. This study was performed for the City of Willoughby in support of design services for the Proposed EQ Basin Project.

This report contains the results of our study, our engineering interpretation of the results with respect to the project characteristics, design and construction recommendations for foundations, floor slabs, below-grade walls, and pavements.

Soil samples collected during this investigation will be stored at our laboratory for 90 days from the date of this report. The samples will be discarded after this time unless you request that they be saved or delivered to you.

Should you have any questions regarding this report or require additional information, please contact our office.

Sincerely,

CT Consultants, Inc.

Imad El Hajjar, EI
Geotechnical Project Manager

Curtis E. Roupe, P.E.
Vice President

T:\Projects\230264 - City of Willoughby - Lakeshore East Equalization Basin, Eastlake, OH\Reports and Other Deliverables\230264 - City of Willoughby - Lakeshore East Equalization Basin, Eastlake, OH.docx

GEOTECHNICAL SUBSURFACE INVESTIGATION
EQ BASIN
CITY OF WILLOUGHBY, OHIO

FOR

CITY OF WILLOUGHBY
1 E SPAULDING ST.
WILLOUGHBY, OH 44094

SUBMITTED

FEBRUARY 13, 2025
CT PROJECT NO. 230264

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1.0 INTRODUCTION

This geotechnical subsurface investigation report has been prepared for the proposed EQ Basin project in Willoughby, Ohio. The new basin is proposed on a vacant lot located along Forest Drive roughly halfway between its intersection with Portage Drive and E. Island Drive. The general project area is shown on the Site Location Map (Plate 1.0).

This study was performed for the City of Willoughby in support of design services for the proposed EQ Basin project.

This report summarizes our understanding of the proposed construction, describes the investigative and testing procedures, presents the findings, discusses our evaluations and conclusions, and provides our design and construction recommendations for tank support and below-grade walls.

The purpose of this investigation was to evaluate the subsurface conditions and laboratory data relative to the design and construction of basin foundations at the referenced site. This investigation included four (4) test borings, field and laboratory soil testing, and a geotechnical engineering evaluation of the test results. This report includes:

- A description of the subsurface soil and groundwater conditions encountered in the borings.
- Design recommendations related to the proposed underground equalization basin.
- Recommendations concerning soil- and groundwater-related construction procedures such as site preparation, earthwork, pavement subgrade preparation, and related field testing.

This investigation did not include an environmental assessment of the subsurface materials at this site.

2.0 INVESTIGATIVE PROCEDURES

This subsurface investigation included three (3) test borings drilled by CT on April 17, 2023., and an additional boring on October 8, 2024. The test borings were located in the field by CT in accordance with a proposed boring location plan submitted with the proposal of this study. The approximate locations of the borings are shown on the Test Boring Location Plan (Plate 2.0).

The test borings were performed in general accordance with geotechnical investigative procedures outlined in ASTM Standard D 1452. The test borings performed during this investigation were drilled with a track-mounted drill rig with utilizing 3¼-inch diameter hollow-stem augers. Borings B-1 and B-3 were advanced to 20 feet below existing grades and Boring B-2 to 30 feet. The additional boring, B-4, was advanced to 65 feet below existing ground surface. Ground Surface Elevations were depicted from Google Earth and are reported to the nearest foot.

During auger advancement, soil samples were collected at 2½-foot intervals to 10 feet and at 5-foot intervals thereafter using 18-inch drives. Split-spoon (SS) samples were obtained by the Standard Penetration Test (SPT) Method (ASTM D 1586), which consists of driving a 2-inch outside diameter split-barrel sampler into the soil with a 140-pound weight falling freely through a distance of 30 inches. The sampler was driven in three successive 6-inch increments with the number of blows per increment being recorded. The sum of the number of blows required to advance the sampler the second and third 6-inch increments is termed the Standard Penetration Resistance (N-value) and is presented on the Logs of Test Borings attached to this report. The samples were sealed in jars and shipped to our laboratory for further classification and testing. Additionally, a long-term groundwater monitoring well was installed in Boring B-4.

The samples were sealed in jars and transported to our laboratory for further classification and testing. The conditions encountered in the test borings are presented in the Logs of Test Borings, along with information related to sample data, SPT results (and equivalent SPT results for the hand auger borings), water conditions observed in the borings, and laboratory test data. It should be noted that these logs have been prepared on the basis of soils laboratory classification and testing as well as field logs of the encountered soils.

One (1) Shelby Tube (ST) sample was obtained in Borings B-2 from 6 to 8 feet by hydraulically advancing a 3-inch diameter, thin-walled sampler approximately 24 inches beyond the hollow-stem auger into relatively undisturbed soil, in general accordance with ASTM D 1587. The Shelby tube sample was sealed with end caps and transported to our laboratory, where it was extruded, classified, and tested.

All of the recovered samples of the subsoils were visually or manually classified in accordance with the Unified Soil Classification System (USCS) per ASTM D 2487 and D 2488, and were tested in our laboratory for moisture content (ASTM D 2216). Dry density determinations and unconfined compressive strength tests (ASTM D 2166) were performed on selected intact cohesive samples. Unconfined compressive strength estimates were obtained for the remaining intact cohesive samples using a calibrated hand penetrometer. A particle size analysis (ASTM D 6913 and D 7928) and Atterberg limits test (ASTM D 4318) were performed on representative samples from Boring B-2 (ST-1) and B-3 (SS-5) to determine soil classification and soil index properties. The test results are presented on the Logs of Test Borings, Tabulation of Test Data sheets, and Laboratory Test Results Outputs attached to this report.

Soil conditions encountered in the test borings are presented in the Logs of Test Borings, along with information related to sample data, SPT results, water conditions observed in the borings, and laboratory test data. It should be noted that these logs have been prepared on the basis of laboratory classification and testing as well as field logs of the encountered soils.

Experience indicates that the actual subsoil conditions at a site could vary from those generalized on the basis of test borings made at specific locations. Therefore, it is essential that a geotechnical engineer be retained to provide soil engineering services during the site preparation, excavation, and foundation phases of the proposed project. This is to observe compliance with the design concepts, specifications, and recommendations, and to allow design changes in the event subsurface conditions differ from those anticipated prior to the start of construction.

The test boring data is provided in the following table.

Table 2.0 Test Boring Data			
Boring Number	Ground Surface Elevation (Ft)	Termination Depth (Ft)	Approximate Termination Elevation (Ft)
B-1	612	20	592
B-2	612	30	582
B-3	611	20	591
B-4	612	65	547

3.0 PROPOSED CONSTRUCTION

The proposed project consists of a proposed underground concrete EQ basin in Willoughby, Ohio. The construction will consist of a 1.35-million-gallon concrete tank which is anticipated to bear approximately 15 to 20 feet below existing grades and will be supported on a thickened slab having a 2 to 3 foot wide thickened edge.

We have assumed that final grades will approximate existing grades present at the time of this investigation.

4.0 GENERAL SITE AND SUBSURFACE CONDITIONS

4.1 General Site Conditions

At the time of our investigation, the project area consisted of relatively flat vacant lot covered with grass. Ground surface elevations at the boring locations ranged from Elevs. 612 to 611 feet.

The surface material encountered at all the Borings consisted of topsoil ranging in thickness estimated from 5 to 10 Inches.

4.2 General Site Geology

Published geologic maps from the Ohio Department of Natural Resources (ODNR) indicate that the project site is located within the glaciated portion of Ohio. Quaternary soil deposits within the southern portion of the site consisted of Lacustrine Silts (LL). These soils were deposited in glacial lakes as shallow-water deltas or nearshore bars and sheets; includes many small areas of dunes. Quaternary soil deposits within the norther portion of the site consisted of Beach Ridges (B). These soils were deposited along shores of former glacial lakes and consist of fine sand to coarse gravel and cobble deposits; includes small areas of dunes and nearshore sand.

Bedrock at the site consist of Upper Devonian aged shale of the Ohio shale formation. Seams of siltstone, and very fine-grained sandstone could be found Interbedded within the shale bedrock. Bedrock is anticipated at approximate Elev. 550 feet which is 65 to 75 feet below existing grades.

4.3 General Soil Conditions

Based on the results of our field and laboratory tests, the subsoils encountered underlying surface materials consisted of predominantly medium to stiff cohesive lacustrine soils. However, zones of cohesive soils exhibiting very stiff consistency were encountered as well.

These cohesive soils consisted of lean clay (CL) with sand and trace amounts of gravel, as well as Silty Clay (CL-ML) with sand and varying amounts of gravel. Isolated

Seams of Sandy silt with trace amounts of gravel were encountered with the explored subsurface profile and were encountered in Borings B-1 and B-3.

SPT N-values were generally on the order of 5 to 15 blows per foot (bpf). Zones exhibiting very stiff consistency were encountered with SPT N-values ranging from 17 to 32 bpf. Unconfined compressive strengths ranged from 2,460 pounds per square foot (psf) to 9,000 psf, the maximum obtainable reading with a hand penerometer. Moisture contents ranged from 14 to 25 percent.

Liquid limits of 32 and 28 percent, and plasticity indices of 11 and 9 percent were determined for two soil samples obtained from Borings B-2 (ST-1) andB-3 (SS-5) respectively. These values, along with gradation results, are indicative of Lean Clay with sand (CL) in accordance with USCS Soil Classification System.

Additional descriptions of the stratigraphy encountered in the borings are presented on the Logs of Test Borings.

4.4 <u>Groundwater Conditions</u>

Groundwater was not encountered during or upon completion of drilling in the borings. It should be noted that the borings were drilled and backfilled within the same day, and stabilized water levels may not have been established over this limited period.

Upon completing the drilling in Boring B-4, a groundwater monitoring well was installed in an offset borehole location to observe long-term groundwater levels. The well extended to 45 feet below the existing grades using 1-inch-diameter PVC pipes. In the lower 10 feet, a slotted screen was utilized, while solid stems were placed in the upper portion. After installing the pipes, the borehole was backfilled with sand up to roughly 2 feet below the existing grade and sealed with bentonite. Additionally, a riser and a protective cover were installed for extended monitoring duration.

Groundwater levels were observed during four distinct instances spanning from November 2024 to February 2025. Observed water levels in the well ranged from ½ to 4 feet below existing grades. On January 10th, 2025, the water level was bailed down to 14 feet below the ground surface within just one hour without the ability to drain further. Within approximately 30 minutes, the water levels returned to the prior levels.

It appears that the well is reflecting a transient flow condition, possibly due to trapped water in the silty seams which are underlain by relatively impermeable clay layers. These seams of sandy silt material within the predominantly clayey subsurface profile were encountered in Boring B-1 and B-3. The report incorporates a concise overview of the measured water readings, complemented by a hydrograph, which is provided in detail within Appendix E.

Based on the limited data available, such as the soil characteristics, the groundwater conditions encountered in the borings, and the groundwater monitoring well readings, it is our opinion that the "normal" groundwater level may generally be encountered 12 to 14 feet below existing grades, corresponding to approximate elevations of 600 to 597 feet. However, it should be noted that groundwater elevations can fluctuate with seasonal and climatic influences. In particular, "perched" water may be encountered in the silty seams that are underlain by relatively impermeable cohesive clayey materials. Therefore, the groundwater conditions may vary at different times of the year from those encountered during this investigation.

The contractor should be mindful of the likelihood of water percolation through the drain-free granular soils, specifically consisting of sand at the site. This percolation poses the risk of generating an unstable bottom within the excavations dedicated to the construction of the EQ basin and associated underground utilities.

5.0 DESIGN RECOMMENDATIONS

The following conclusions and recommendations are based on our understanding of the proposed construction and on the data obtained during the field investigation. If the project information or location as outlined is incorrect or should change significantly, a review of these recommendations should be made by CT. These recommendations are subject to the satisfactory completion of the recommended site and subgrade preparation and fill placement operations described in Section 6.0, "Construction Recommendations".

5.1 Structure Foundation

We understand that the proposed EQ Basin structure will be constructed underground, with a base slab bearing at approximately 15 to 20 feet below existing grade (Elevs. 597± to 592±). Based on the results of the field and laboratory testing for the borings performed for this investigation, the soils encountered at the anticipated foundation bearing depth are expected to consist of predominantly medium stiff to stiff native cohesive lacustrine soils.

Following satisfactory completion of the site preparation and excavation inspections, the proposed substructures may be supported on shallow foundations (i.e., slab with a thickened edge). We recommend a gross allowable bearing capacity (q_a) of 2,750 pounds per square foot (tsf). The bearing materials should be field-verified as being lean clay (CL) exhibiting an unconfined compressive strength of 2,000 psf or greater. If the hand penetrometer readings are marginal, a Shelby tube sample could be obtained and transported to a soils laboratory for minimum verification from a one-point unconsolidated-undrained (UU) triaxial compressive strength test resulting a minimum undrained shear strength of 1,000 psf.

Utilizing the above allowable bearing pressure and proper foundation inspection techniques, the total settlement associated with the structure should not exceed ½ inch. Differential settlement from center to edge of the slab will also depend on the rigidity of the mat. In any case, the differential settlement from center to edge of the basin should generally not exceed ½ of the total settlement, likely less for an essentially rigid mat and presumed near-uniform loading.

Due to the possible varying bearing materials, we strongly recommend that the bearing surface at the bottom of all footing excavations be inspected during construction by a CT geotechnical engineer or qualified representative. Inspection should be performed to verify that the exposed soil conditions at the bearing elevations are consistent with the subsurface conditions encountered in the test borings and are suitable for foundation bearing. Additionally, the presence of our engineer will help facilitate the timely remediation of unsuitable soil conditions.

5.2 Lateral Earth Pressure

Based on the conditions encountered in the borings performed for this investigation, the soils along below-grade walls are anticipated to consist of native cohesive soils. We recommend the soil profile be modeled simply as a predominantly cohesive soil layer for lateral earth pressure considerations as well as the likelihood of the presence of backfill material due to construction operations and excavation considerations.

Below-grade structure walls are anticipated to be restrained from rotation and are considered rigid and non-yielding. As such, lateral earth pressures should be assumed for "at-rest" conditions. For the encountered subsurface soils, an at-rest lateral earth pressure coefficient (k_o) of 0.5 should be used along with a total soil unit weight of 130 pounds per cubic foot (pcf) in determining the lateral pressure acting on the walls. Alternately, an equivalent fluid weight of 65 pcf may be used for the at-rest case design. For retaining walls and temporary sheetpile walls that are not restrained from rotation, lateral earth pressures should be assumed for "active" conditions. For the encountered subsurface soils, an active lateral earth pressure coefficient (ka) of 0.33 should be used along with a total soil unit weight of 130 pcf in determining the lateral pressure acting on the walls. Alternately, an equivalent fluid weight of 45 pcf may be used for the active case design.

Lateral loading due to hydrostatic pressures below the design groundwater depth should be included in design of below-grade walls, unless drainage is provided as discussed below. Depending on the design methodology, total lateral pressures would be the resultant of the hydrostatic pressures in combination with submerged (or "effective") unit weights of the soil. An effective unit weight of 70 pcf should be used for lateral earth pressure design below the design groundwater depth.

It should be noted that the above k-parameter may be used for general design of subsurface structures associated with the project. However, certain types of braced excavations may account for method-specific earth pressure distributions, for which the above parameters should be reviewed and utilized in the proper context of the design method/system.

It should be noted that the above k-parameters may be used for general design of subsurface structures, retaining walls, and possible excavation support systems associated with the project. However, certain types of braced excavations may account for method-specific earth pressure distributions, for which the above parameters should be reviewed and utilized in the proper context of the design method/system.

A passive earth pressure coefficient (k_p) of 3.0 may be utilized for the portion of temporary walls (e.g., sheet pile walls) that is below the excavation bottom. In the case of permanent structures, a k_p value of 3.0 should only be utilized below the frost depth of 3½ feet below toe grades. It should be noted that some wall movement or horizontal displacement is typically needed to mobilize the full passive pressure of the soil. We recommend a maximum passive earth pressure for the toe of the retaining wall of 300 pounds per square foot per foot of depth bearing in at least medium stiff native soils below finish grade on the toe side of the wall. If the design includes passive pressure above the frost line, the contribution of passive resistance to sliding or overturning stability should be evaluated in conjunction with the design factor of safety. These values are based on footings poured in intimate contact with at least medium stiff lean clay. It should be noted that some wall/foundation movement or horizontal displacement is needed to mobilize the full passive pressure of the soil. Because of this consideration, some design methods incorporate a higher required factor of safety (e.g., F. S. = 2.0) when using passive pressure contribution to stability, as compared to sliding resistance on the base only (typically, F.S. = 1.5).

It should also be noted that the above earth pressure coefficient is based on a level backfill condition behind the retaining wall. In areas where appreciable sloping materials behind the top of the wall, surcharge loading or equivalent higher earth pressure coefficients should be evaluated, based on the sloping material, backfill slope, and proximity to the wall. In general, 50 percent of the vertical surcharge load should be used for lateral loading in the design of the wall. Additionally, design should include surcharge loads associated with shallower bearing footings as well as traffic, if present in close proximity to the walls.

In order to alleviate the build-up of hydrostatic pressure behind the walls, a minimum of 2 feet of clean free-draining granular fill (i.e., #57 gravel) is typically placed full depth behind the walls. As discussed in Section 4.4, the “normal” groundwater level may be on the order of 12 to 14 feet below existing grades (Elev. 600± to Elev. 597±). These retaining walls are anticipated to extend below the groundwater table, so significant pumping would be required to allow for design without hydrostatic pressures. In this case, it may not be economical to provide drainage and design should instead consider hydrostatic pressures.

For removal of groundwater and the associated hydrostatic pressure, we recommend the granular fill be wrapped with a geotextile separation fabric (ODOT Item 712.09, Type A, or approved equal) to reduce the potential for migration of fines into the free-draining material. If granular fill other than #57 gravel is used, it should not have more than 8% (by weight) passing the #200 screen, and should be compacted to 95% of the maximum dry density as determined by ASTM D 698 (Standard Proctor). Where below-grade structures can be suitably “drained” behind the wall, a perforated corrugated drain tile, wrapped with filter fabric, should be placed along the perimeter at the base of the wall(s). A clay cap (minimum 1-foot thick) should be placed overtop granular backfill, if utilized, to deter inflow of the surface water. The drainage system should properly outlet to a sewer, a properly sized sump pump system, or daylight to an adequate drainage channel.

Where gravity drainage or a sump/pump system is operational, the 2 feet of free-draining material placed behind the wall alleviates the formation of hydrostatic pressures. However, unless this free-draining granular backfill is placed beyond the slip plane associated with the at-rest or active earth pressure, it has little influence on the overall lateral earth pressure acting on the wall which will be governed by the general soil type. If free-draining granular fill is to be placed beyond the slip plane (β=45° for at-rest conditions; β=45°+ϕ/2 for active conditions), a design total unit weight of 125 pcf could be used with the values presented above, thus lowering the earth pressures on the wall. Such excavation may not be feasible in some areas due to the proximity of the new construction to existing structures and roadways, as well as associated sheetpiling systems anticipated to reduce excavation layback.

5.3 Design Groundwater Table

As mentioned in Section 4.3, based on the soil characteristics and groundwater conditions encountered in the borings, it is our opinion that the "normal" groundwater level may be generally encountered at Elevs. 600± to 597±, corresponding to depths ranging from 12 to 14 feet below existing grades at the boring locations performed in this area. It should be noted that these water levels are for long-term, stabilized post-construction conditions. This does not mean that excessive groundwater seepage will occur as soon as construction excavations extend below the noted ground water elevation. In general, the soil profile consists of predominantly cohesive soils which were not found to be freely draining. It should be noted that these water levels are for long-term, stabilized post-construction conditions.

5.4 Groundwater Control and Slab Subgrade Considerations

As previously mentioned, the "normal" groundwater level may be present on the order of Elevs. 600± to 597±, corresponding to depths ranging from 12 to 14 feet below existing grades at the boring locations performed in this area. Even for normal groundwater conditions, installation of the proposed below grade walls is expected to require excavation below the "normal" groundwater level. Although the soils below the groundwater table are expected to be predominantly native cohesive soils with very low permeabilities, some groundwater seepage into excavations should be anticipated.

Management of groundwater is generally anticipated to be feasible by pumping from prepared sumps. In any case, it is our experience that adequate control of groundwater seepage or surface water run-off into shallow excavations that do not extend more than a couple feet below the water level in predominantly clay profiles should be achievable by minor dewatering systems, such as pumping from prepared sumps.

However, due to the possible transient flow detected in the ground water monitoring well, planned excavations may experience unstable trench bottom. To prevent this situation, a sufficient dewatering system must be designed and implemented in the subject areas. The water level must be lowered at least to the depth of two feet below the trench bottom to allow workability. Sometimes, due to a large water influx from rain or snow (depending on the permeability characteristics of the soils) this operation might be very difficult. If that is the case, a different method of trench bottom stabilization must be considered such as undercutting and replacement with 12-inch or more (depends of the severity of the situation) thick layer of coarse aggregate (#1's and #2's) wrapped in Geofabric or Geogrid (full overlap on the top). The depth of the undercut will be determined to allow installation of sufficient thickness of the coarse stone aggregate (pillow) and placement of the designed pipe stone bedding.

If excavations below the normal groundwater table are required, or if seasonally elevated groundwater conditions are prevalent at the time of construction, diligent dewatering using point wells will be required for groundwater management during construction. In the event excessive seepage is encountered during construction, CT may be notified to evaluate whether other dewatering methods are required. Installation of the proposed site utilities is expected to require excavation below the "normal" groundwater level and groundwater seepage into excavations should be anticipated.

5.5 Excavations and Slopes

The sides of temporary excavations for installation of the proposed below-grade structures should be adequately sloped to provide stable sides and safe working conditions. Otherwise, the excavations must be properly braced against lateral movements. Soils-related design parameters for temporary support of excavation systems, such as sheetpiling, are presented in Section 5.2.

Design of the temporary support of excavation should be the responsibility of the contractor, since their installation and performance is integrally tied to the contractor's means and methods of construction. In any case, applicable Occupational Safety and Health Administration (OSHA) standards must be followed. It is the responsibility of the installation contractor to develop appropriate installation methods and equipment specifications prior to commencement of work, and to obtain the services of a qualified engineer to design or approve sloped or benched excavations and/or lateral bracing systems as required by OSHA criteria. **In addition, OSHA requires that excavations with open-cut slopes higher than 20 feet, or braced excavation support systems such as sheetpiling be reviewed and designed by a registered professional engineer.**

If the excavation is to be performed with sloped banks, adequate stable slopes must be provided in accordance with the criteria presented below. The soils encountered in the test boring within the anticipated depth of excavation may be classified as the following OSHA designations:

- Type A soils (cohesive soils with unconfined compressive strengths greater than 3,000 pounds per square foot (psf),
- Type B soils (cohesive soils with unconfined compressive strengths greater than 1,000 pounds per square foot (psf) but less than 3,000 psf), and
- Type C soils (cohesive soils with unconfined compressive strengths of 1,000 psf or less).

For temporary excavations in Type A, B and C soils, side slopes must be no steeper than ¾ horizontal to 1 vertical (¾H:1V), 1H:1V, and 1½H:1V, respectively. For situations where a higher strength soil is underlain by a lower strength soil and the excavation extends into the lower strength soil, the slope of the entire excavation is governed by that required for the lower strength soil. In all cases, flatter slopes may be required if lower strength soils or adverse seepage conditions are encountered during construction.

Although not anticipated for this project, it should be noted that, for permanent excavation slopes, we recommend that grades be no steeper than 3H:1V without a more extensive geotechnical evaluation of the proposed construction plans and site conditions.

5.6 Construction (General)

Construction traffic and excavated material stockpiles should be kept away from the excavation a minimum distance equal to the full depth of the excavation. In all cases, pertinent OSHA requirements must be followed, and adequate protection for workers must be provided.

Where existing buildings or structures, including underground utilities, are located within a distance from the excavation equal to approximately twice its depth, an adequate system of sheet piling and/or lateral bracing may be required to prevent lateral movements that could cause settlement. Any retaining system proposed by the contractor should be reviewed by a registered professional engineer prior to approval for installation and use.

It is also suggested that a condition survey (i.e., preconstruction documentation) of any existing structures and transportation infrastructure located in the vicinity of the proposed underground utilities alignment be completed. For general below-grade underground utilities installation, we recommend the condition survey extend a distance from the proposed installation extents equal to the depth of the excavation, but not less than 100 feet. The condition survey should identify existing cracks and other forms of distress to the structures before the start of construction operations. This procedure will be helpful to evaluate possible effects the construction operations may have on nearby structures and to mitigate potential disputes with property owners.

Where underground utilities will be installed beneath pavement areas, future structure areas, or future pavement areas, the backfill material should be placed in uniform layers not more than 8 inches thick and compacted to 100 percent of the maximum dry density as determined by ASTM D 698 (Standard Proctor). Backfill placed in pavement areas should consist of dense-graded aggregate, such as ODOT Item 304 material. In order to achieve the desired compaction, the backfill material should be within 3 percent of the optimum moisture content. Alternatively, flowable controlled-density fill could be used to backfill the excavated trenches.

We emphasize the need for placing the fill in lifts and compacting each lift to the specified density, especially where the trench will be directly beneath roadway pavement. The installation contractor should not be allowed to push or end-dump several feet of backfill into the trench as a single layer or lift, because the lower portion of a thick lift will not achieve proper densification from compaction equipment operating at the surface of that lift. If backfill is not properly placed and compacted, undesirable trench backfill settlement may occur.

It is recommended that all earthwork and site preparation activities be conducted under adequate specifications and properly monitored in the field by a CT geotechnical engineer or qualified representative.

6.0 QUALIFICATION OF RECOMMENDATIONS

Our evaluation of foundation and below grade walls design and construction conditions has been based on the data obtained during our field investigation and our understanding of the furnished site and project information. general subsurface conditions were based on interpretation of the subsurface data at specific boring locations. Regardless of the thoroughness of a subsurface investigation, there is the possibility that conditions between borings will differ from those at the boring locations, that conditions are not as anticipated by the designers, or that the construction process has altered the soil conditions. This is especially true for previously developed sites. Therefore, experienced geotechnical engineers should observe earthwork and foundation construction to confirm that the conditions anticipated in design are noted. Otherwise, CT assumes no responsibility for construction compliance with the design concepts, specifications, or recommendations.

The design recommendations in this report have been developed on the basis of the previously described project characteristics and subsurface conditions. If project criteria or locations change, a qualified geotechnical engineer should be permitted to determine whether the recommendations must be modified. The findings of such a review will be presented in a supplemental report.

The nature and extent of variations between the borings may not become evident until the course of construction. If such variations are encountered, it will be necessary to reevaluate the recommendations of this report after on-site observations of the conditions.

Our professional services have been performed, our findings derived, and our recommendations prepared in accordance with generally accepted geotechnical engineering principles and practices. This warranty is in lieu of all other warranties either expressed or implied. CT is not responsible for the conclusions, opinions, or recommendations of others based on this data.

Plates

Plate 1.0 Site Location Map
Plate 2.0 Test Boring Location Plan

Site Location Map

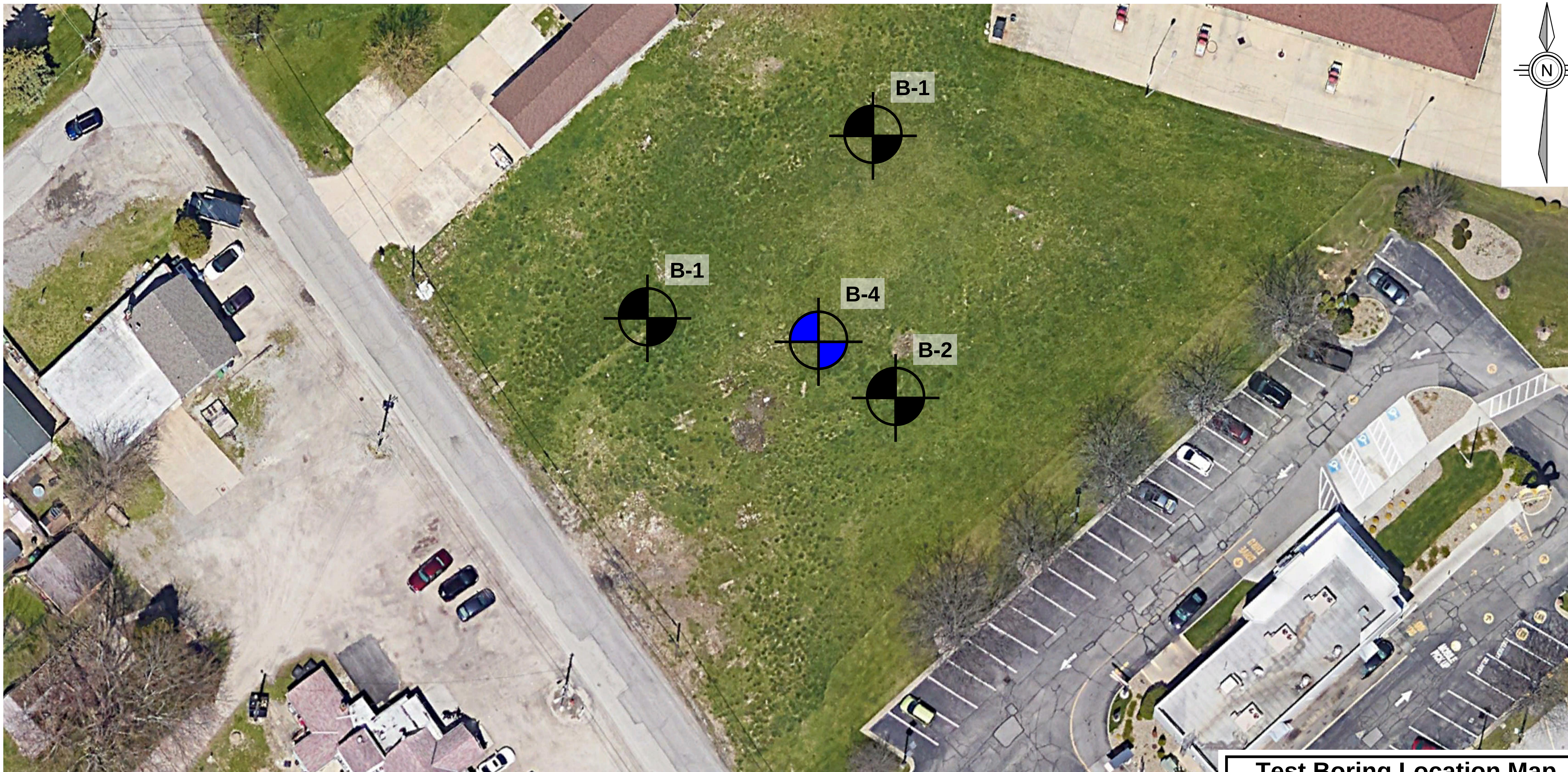
Lakeshore East Equalization Basin
Willoughby, Ohio

City of Willoughby

DRAWN:	IJH 7/05/2023
REVISED:	---
Project No.:	230264
Drawing No.:	Plate 1.0

your trusted advisor consultants engineers architects planners

Notes: Aerial Basemap obtained From Google Earth and dated 04/28/2022



Legend:

B-1 Approximate Test Boring Location

B-4 Approximate Test Boring / Monitoring Well Location

Notes: Aerial Basemap obtained From Google Earth and dated 04/27/2022

Test Boring Location Map

Lakeshore Equalization Basin
Willoughby, Ohio

City of Willoughby

DRAWN: IJH 7/05/2023

Project No.: 230264

Drawing No.: Plate 2.0

CT consultants your trusted advisor engineers architects planners

APPENDIX A

Logs of Test Borings

CT Consultants, Inc.
1915 N 12th Street
Toledo Ohio 43604
Telephone: (419)324-2222

BORING NUMBER B-1

CLIENT City of Willoughby

PROJECT NAME Lake Shore East Equilization Basin

PROJECT NUMBER 230264

PROJECT LOCATION Eastlake, OH

DRILLING CONTRACTOR CT Consultants Inc. TB JP

RIG NO. D70

GROUND ELEVATION 612 ft

DRILLING METHOD 3-1/4 in. HSA

GROUND WATER LEVELS:

DATE STARTED 4/17/23 **COMPLETED** 4/17/23

AT TIME OF DRILLING None

LOGGED BY KKC **CHECKED BY** IEH

AT END OF DRILLING None

NOTES

0hrs AFTER DRILLING Backfilled w/Cuttings and Bentonite Chips

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	MC (PL / MC / LL: 20 40 60 80; ▲ SPT N VALUE ▲: 20 40 60 80)
	0	TOPSOIL - 10 Inches — 0.8'						
610		Moist Medium Stiff Brown SILTY CLAY w/Sand and Trace Gravel (CL-ML) — 3.0'	SS 1	100	2-3-4 (7)	4.50		17
	5	Moist Stiff Brown SANDY SILT w/Trace Gravel (ML) — 6.2'	SS 2	100	4-6-7 (13)	3.42	112	16
605		Moist Very Stiff Brown SILTY CLAY w/Sand (CL-ML)	SS 3	22	4-9-13 (22)	NI		18
	10	@8.5': w/Trace Gravel — 12.0'	SS 4	100	5-9-11 (20)	4.50		15
600	15	Moist Stiff Gray SANDY SILT w/Trace Gravel (ML) — 17.0'	SS 5	100	4-6-7 (13)	4.25		14
595	20	Moist Stiff Gray SILTY CLAY w/Sand and Trace Gravel (CL-ML) — 20.0'	SS 6	100	2-4-5 (9)	3.50		15

Bottom of hole at 20.0 feet.

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BORING NUMBER B-2

CLIENT City of Willoughby
PROJECT NAME Lake Shore East Equilization Basin
PROJECT NUMBER 230264
PROJECT LOCATION Eastlake, OH
DRILLING CONTRACTOR CT Consultants Inc. TB JP
RIG NO. D70
GROUND ELEVATION 612 ft
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 4/17/23 **COMPLETED** 4/17/23
AT TIME OF DRILLING None
LOGGED BY KKC **CHECKED BY** IEH
AT END OF DRILLING None
NOTES
0hrs AFTER DRILLING Backfilled w/Cuttings and Bentonite Chips

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	MC (PL/LL)
	0	TOPSOIL - 5 Inches (0.4')						
610		Moist Medium Stiff Brown LEAN CLAY w/Sand, Trace Gravel, and Organics (CL) (3.0')	SS 1	44	3-2-3 (5)	2.00		25
	5	Moist Stiff Brown SILTY CLAY w/Sand and Trace Gravel (CL-ML) (6.0')	SS 2	100	3-5-6 (11)	4.50		18
605		Moist Stiff Brown LEAN CLAY w/Sand, Trace Gravel, and Organics (CL)	ST 1	100			111	18
	10	@8.5': Gray	SS 3	100	4-5-7 (12)	4.25	108	17
600	15		SS 4	100	5-5-6 (11)	4.00		15
595	20		SS 5	100	3-4-5 (9)	1.79	118	16
590		(23.5')						
	25	Moist Medium Stiff Gray LEAN CLAY w/Sand and Trace Gravel (CL)	SS 6	100	3-3-4 (7)	1.23	115	16
585		(28.5')						
	30	Moist Stiff Gray LEAN CLAY w/Sand and Trace Gravel (CL) (30.0')	SS 7	100	5-5-6 (11)	3.75		16

Bottom of hole at 30.0 feet.

BORING NUMBER B-3

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CLIENT City of Willoughby
PROJECT NAME Lake Shore East Equilization Basin
PROJECT NUMBER 230264
PROJECT LOCATION Eastlake, OH
DRILLING CONTRACTOR CT Consultants Inc. TB JP
RIG NO. D70
GROUND ELEVATION 611 ft
DRILLING METHOD 3-1/4 in. HSA
GROUND WATER LEVELS:
DATE STARTED 4/17/23 **COMPLETED** 4/17/23
AT TIME OF DRILLING None
LOGGED BY KKC **CHECKED BY** IEH
AT END OF DRILLING None
NOTES
0hrs AFTER DRILLING Backfilled w/Cuttings and Bentonite Chips

ELEVATION (ft)	DEPTH (ft)	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	SPT N VALUE / MC
611	0	TOPSOIL - 6 Inches (0.5')						
610		Moist Stiff Brown SILTY CLAY w/Sand and Trace Organics (CL-ML) (3.5')	SS 1	83	4-4-5 (9)	3.25		19
605	5	Moist Very Stiff Brown SANDY SILT w/Trace Gravel (ML) (6.0')	SS 2	89	5-7-10 (17)	4.50		16
		Moist Stiff Brown SILTY CLAY w/Sand and Trace Gravel (CL-ML)	SS 3	100	6-7-8 (15)	3.12	110	17
600	10	(12.0')	SS 4	100	5-5-8 (13)	4.50		17
595	15	Moist Stiff Gray LEAN CLAY w/Sand and Trace Gravel (CL)	SS 5	100	4-4-6 (10)	2.67	121	15
	20	(20.0')	SS 6	100	4-5-6 (11)	3.00		14

Bottom of hole at 20.0 feet.

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BORING NUMBER B-4

CLIENT City of Willoughby
PROJECT NAME Lake Shore East Equilization Basin
PROJECT NUMBER 230264
PROJECT LOCATION Eastlake, OH
DRILLING CONTRACTOR Ridgeway Drilling, Inc. Pete Kevin
RIG NO. 328
GROUND ELEVATION 612 ft
DRILLING METHOD HSA
GROUND WATER LEVELS:
DATE STARTED 10/8/24 **COMPLETED** 10/8/24
AT TIME OF DRILLING None
LOGGED BY KKC **CHECKED BY** IEH
AT END OF DRILLING None
NOTES
0hrs AFTER DRILLING Backfilled w/Cuttings and Bentonite Chips

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL / MC / LL (20 40 60 80); ▲ SPT N VALUE ▲ (20 40 60 80)
	0		TOPSOIL - 12 Inches						
			1.0'						
610			Moist Stiff to Very Stiff Brown/Gray LEAN CLAY w/Sand and Trace Gravel (CL) (Possible Fill)	SS 1	58	2-3-6-8 (9)	>4.5		18
	5		@3.5': Brown	SS 2	78	3-4-6 (10)	>4.5		16
605			@6': Very Stiff to Hard	SS 3	100	4-8-9 (17)	>4.5		16
			8.5'						
	10		Moist Stiff to Very Stiff Brown/Gray LEAN CLAY w/Sand and Trace Gravel (CL)	SS 4	67	4-6-8 (14)	>4.5		17
600									
	15		@13.5': Gray	SS 5	89	4-4-6 (10)	4.00		15
595									
	20			SS 6	100	3-4-5 (9)	2.50		16
590									
	25			SS 7	100	3-4-7 (11)	3.25		16
585									
	30			SS 8	100	4-5-6 (11)	3.50		15

(Continued Next Page)

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BORING NUMBER B-4

CLIENT City of Willoughby
PROJECT NAME Lake Shore East Equilization Basin
PROJECT NUMBER 230264
PROJECT LOCATION Eastlake, OH

ELEVATION (ft)	DEPTH (ft)	GRAPHIC LOG	MATERIAL DESCRIPTION	SAMPLE TYPE NUMBER	RECOVERY % (RQD)	BLOW COUNTS (N VALUE)	UNCONF. COMP. STR. (tsf)	DRY UNIT WT. (pcf)	PL / MC / LL (20 40 60 80); ▲ SPT N VALUE ▲ (20 40 60 80)
580									
	35		@33.5': Very Stiff to Hard	SS 9	100	5-7-10 (17)	4.25	118	15
575									
	40		@38.5': Stiff to Very Stiff	SS 10	100	5-5-7 (12)	>4.5		16
570									
	45		@43.5': Very Stiff to Hard	SS 11	100	6-7-10 (17)	4.25		16
565									
	50			SS 12	100	5-10-12 (22)	>4.5		14
560									
	55			SS 13	89	6-7-11 (18)	>4.5		16
555									
	60			SS 14	100	5-6-12 (18)	>4.5		15
550									
			63.5'						
	65		Moist Hard Gray LEAN CLAY w/Sand and Trace Gravel (CL) 65.0'	SS 15	56	7-12-20 (32)	>4.5	118	18
			Bottom of hole at 65.0 feet.						

APPENDIX B

Legend Key

LEGEND KEY

Unified Soil Classification System Soil Symbols

GW - WELL GRADED GRAVEL Includes Gravel-Sand mixtures, little or no fines.

GP - POORLY GRADED GRAVEL Includes Gravel-Sand mixtures, little or no fines.

GM - SILTY GRAVEL Includes Gravel-Sand-Silt mixtures.

GC - CLAYEY GRAVEL Includes Gravel-Sand-Clay mixtures.

SW - WELL GRADED SAND Includes Gravelly Sands, little or no fines.

SP - POORLY GRADED SAND Includes Gravelly Sands, little or no fines.

SM - SILTY SAND Includes Sand-Silt mixtures.

SC - CLAYEY SAND Includes Sand-Clay mixtures.

ML - SILT Includes Silt with Sand and Sandy Silt.

CL - LEAN CLAY Includes Sandy Lean Clay and Lean Clay with Sand and Gravel.

MH - ELASTIC SILT Includes Sandy Elastic Silt and Elastic Silt with Sand.

CH - FAT CLAY Includes Sandy Fat Clay and Fat Clay with Sand.

CL-ML - SILTY CLAY Includes Clayey Silt of low plasticity.

OL - ORGANIC SILT and ORGANIC CLAY of low plasticity.

OH - ORGANIC SILT and ORGANIC CLAY of medium to high plasticity.

Pt - PEAT Includes humus, swamp and other soils with high organic content.

FILL MATERIAL - Includes controlled and non-controlled soil and non-soil materials.

TOPSOIL

ASPHALT - Bituminous Asphalt

CONCRETE - Includes broken concrete rubble.

Sample Symbols

SS - Split Spoon

ST - Shelby Tube

RC - Rock Core

GS - Geoprobe Sleeve

AU - Auger Cuttings

GB - Grab

Notes:

1. Exploratory borings were drilled on April 17, 2023. The borings were advanced utilizing 3¼ -inch inside diameter hollow-stem augers.

2. These logs are subject to the limitations, conclusions, and recommendations in the report and should not be interpreted separate from the report.

3. The borings were located in the field by CT in accordance with a proposed Boring location plan, attached to the proposal.

4. Ground Surface Elevations were depicted from Google Earth and reported to the nearest foot.

5. Unconfined Compressive Strength (tsf):
   NI = Not Intact

APPENDIX C

Tabulation of Laboratory Test Data

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SUMMARY OF LABORATORY RESULTS

CLIENT City of Willoughby

PROJECT NAME Lake Shore East Equilization Basin

PROJECT NUMBER 230264

PROJECT LOCATION Eastlake, OH

Borehole	Depth	Liquid Limit	Plastic Limit	Plasticity Index	Maximum Size (mm)	%<#200 Sieve	Class-ification	Water Content (%)	Dry Density (pcf)	Satur-ation (%)	Void Ratio
B-1	1.0							17.5			
B-1	3.5							15.8	111.9		
B-1	6.0							17.7			
B-1	8.5							15.3			
B-1	13.5							14.3			
B-1	18.5							15.0			
B-2	1.0							24.9			
B-2	3.5							17.9			
B-2	6.0	32	21	11	19	78	CL	17.7	110.6		
B-2	8.5							17.3	107.8		
B-2	13.5							15.3			
B-2	18.5							15.8	118.2		
B-2	23.5							16.4	114.5		
B-2	28.5							15.6			
B-3	1.0							18.9			
B-3	3.5							15.9			
B-3	6.0							17.3	109.8		
B-3	8.5							17.2			
B-3	13.5	28	19	9	19	78	CL	14.7	120.7		
B-3	18.5							14.3			
B-4	0.0							17.8			
B-4	3.5							16.2			
B-4	6.0							15.8			
B-4	8.5							17.0			
B-4	13.5							15.2			
B-4	18.5							16.4			
B-4	23.5							15.9			
B-4	28.5							15.4			
B-4	33.5							14.8	118.3		
B-4	38.5							15.8			
B-4	43.5							16.3			
B-4	48.5							14.4			
B-4	53.5							16.4			
B-4	58.5							15.0			
B-4	63.5							18.0	117.7		

APPENDIX D

Laboratory Test Results

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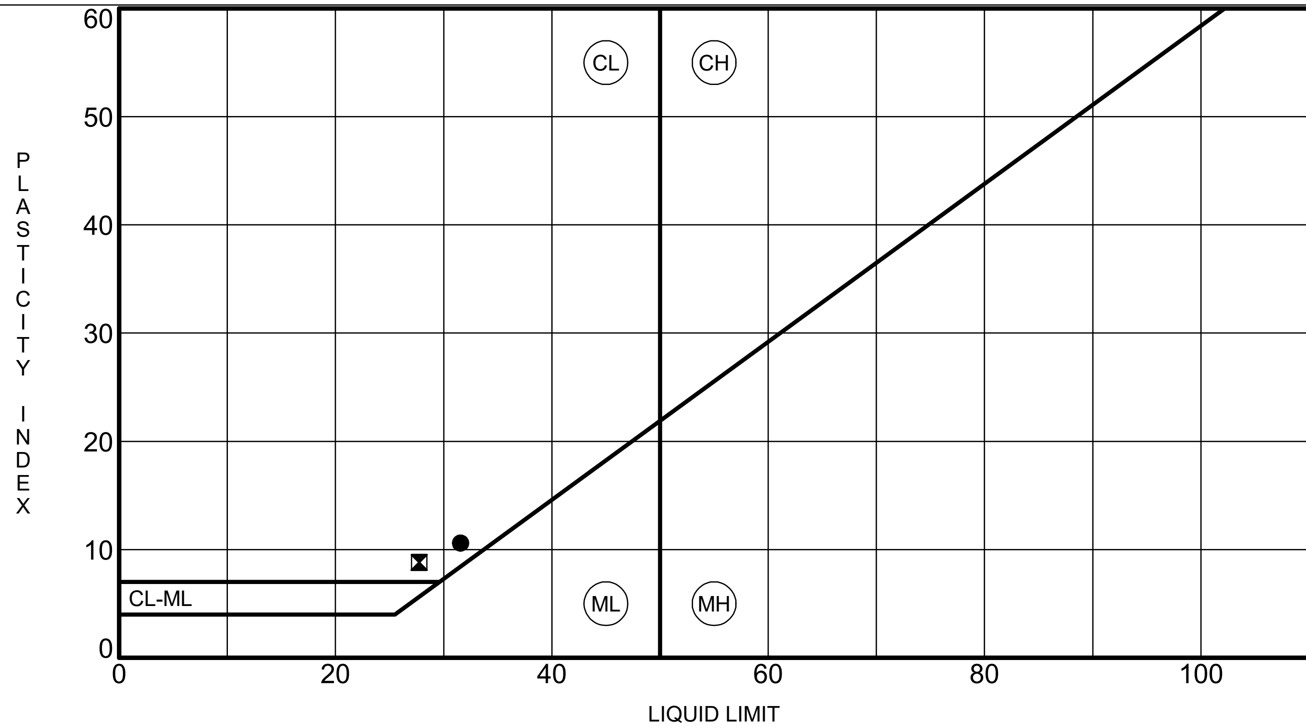
ATTERBERG LIMITS' RESULTS

CLIENT City of Willoughby
PROJECT NAME Lake Shore East Equilization Basin
PROJECT NUMBER 230264
PROJECT LOCATION Eastlake, OH



	Specimen Identification		LL	PL	PI	Fines	Classification
●	**B-2**	**6.0**	**32**	**21**	**11**	**78**	**LEAN CLAY with SAND (CL)**
⊠	**B-3**	**13.5**	**28**	**19**	**9**	**78**	**LEAN CLAY with SAND (CL)**

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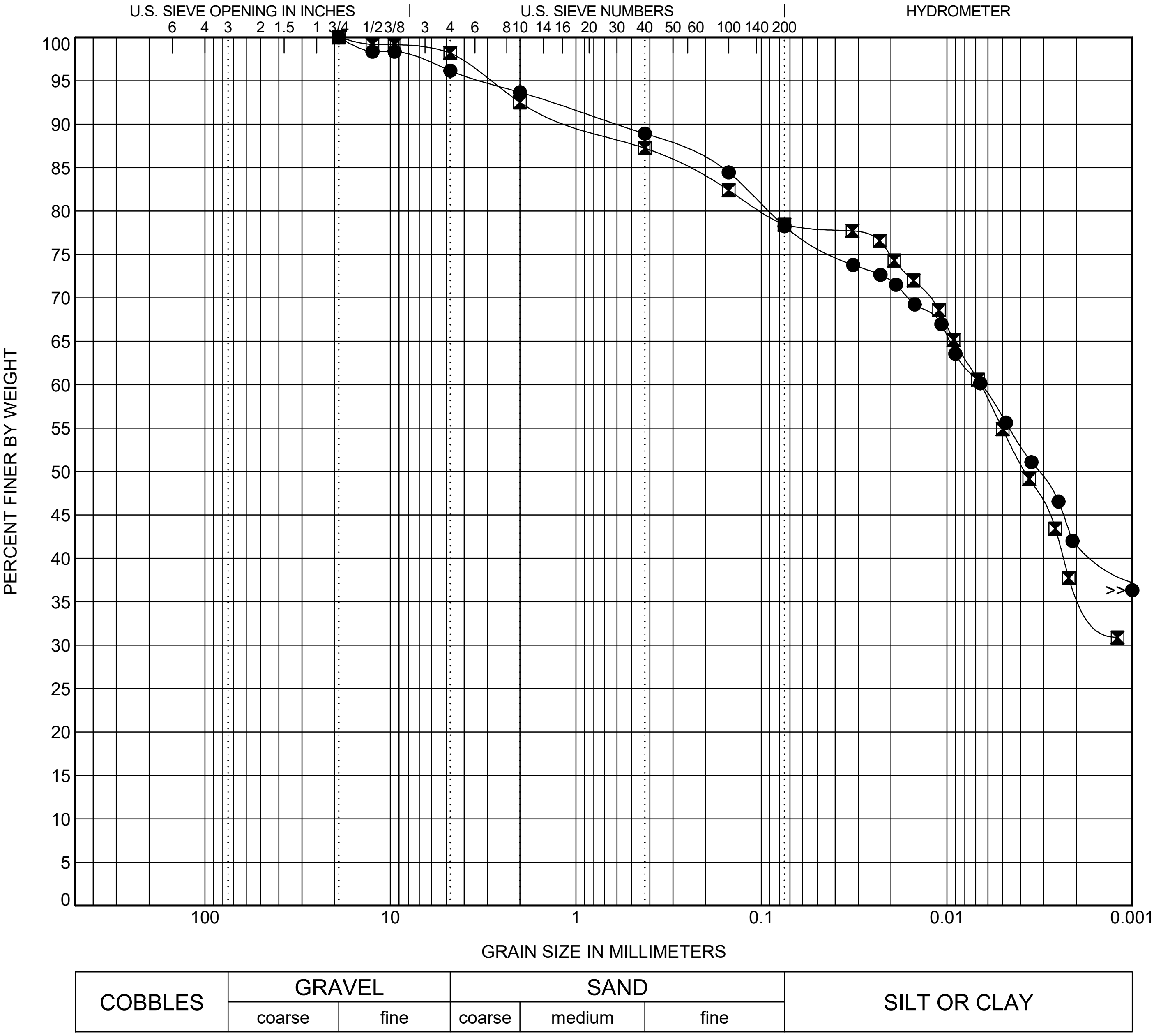
GRAIN SIZE DISTRIBUTION

CLIENT City of Willoughby **PROJECT NAME** Lake Shore East Equilization Basin

PROJECT NUMBER 230264 **PROJECT LOCATION** Eastlake, OH



Specimen Identification			USCS Classification	LL	PL	PI	Cc	Cu
●	**B-2**	**6.0**	**LEAN CLAY with SAND (CL)**	**32**	**21**	**11**		
⊠	**B-3**	**13.5**	**LEAN CLAY with SAND (CL)**	**28**	**19**	**9**		

Specimen Identification			D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
●	**B-2**	**6.0**	**19**	**0.007**			**3.8**	**17.9**	**22.0**	**56.2**
⊠	**B-3**	**13.5**	**19**	**0.007**			**1.8**	**19.8**	**23.6**	**54.9**

UNCONFINED COMPRESSION TEST

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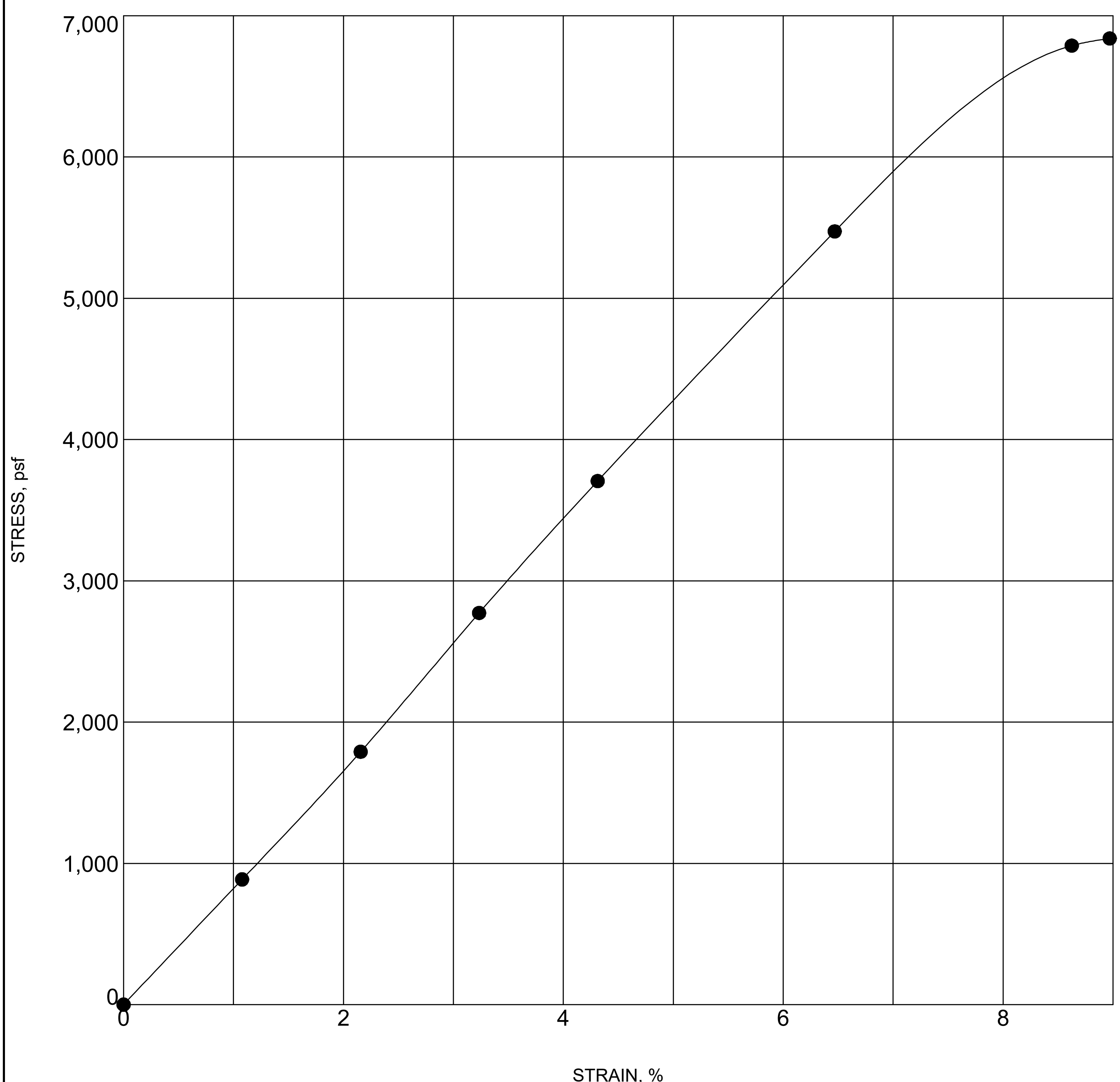
CLIENT City of Willoughby

PROJECT NAME Lake Shore East Equilization Basin

PROJECT NUMBER 230264

PROJECT LOCATION Eastlake, OH



	Specimen Identification		Classification	γ_d	MC%
●	**B-1**	**3.5**		**112**	**16**

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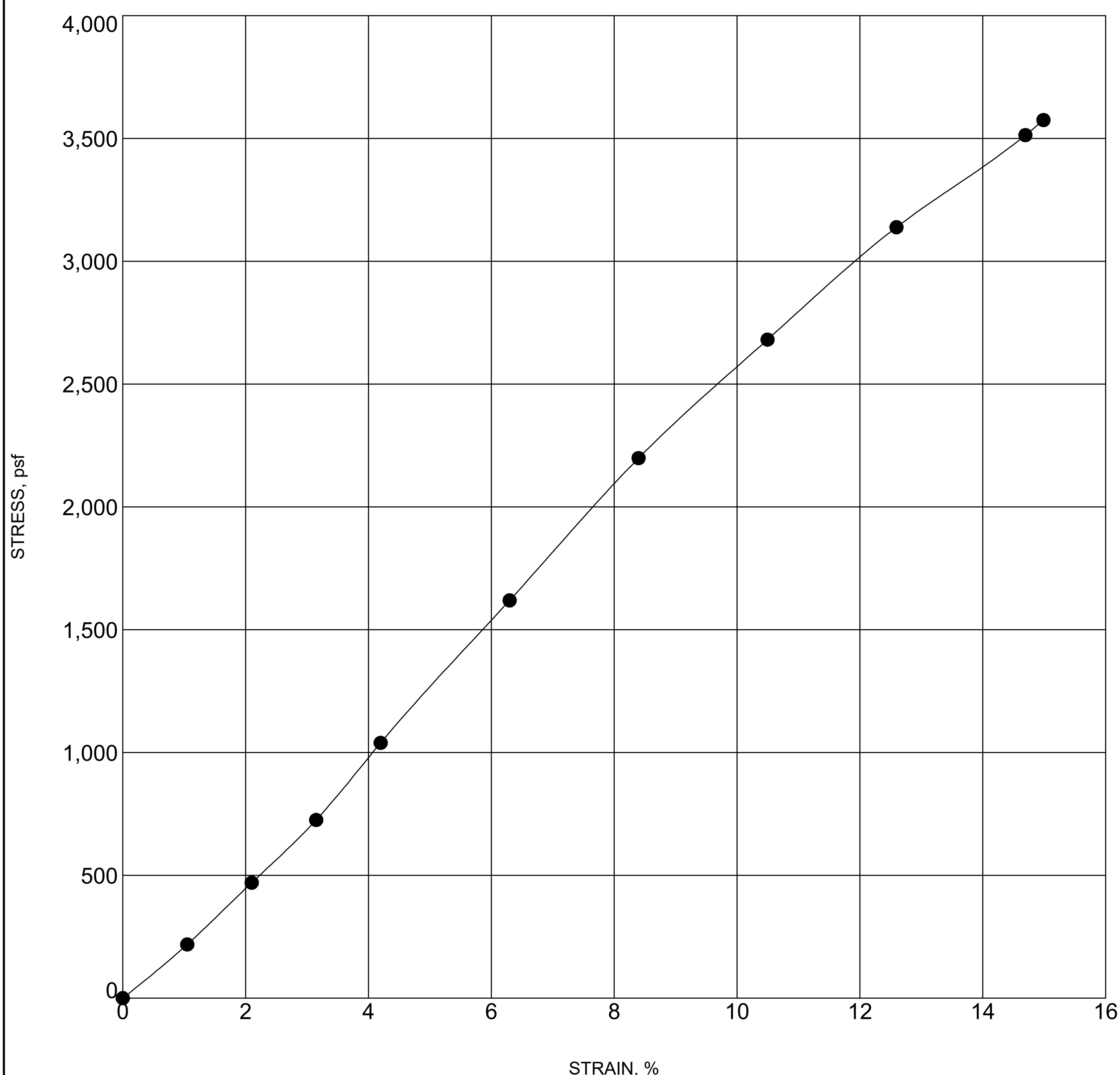
UNCONFINED COMPRESSION TEST

CLIENT City of Willoughby

PROJECT NAME Lake Shore East Equilization Basin

PROJECT NUMBER 230264

PROJECT LOCATION Eastlake, OH



	Specimen Identification		Classification	γ_d	MC%
●	**B-2**	**18.5**		**118**	**16**

UNCONFINED COMPRESSION TEST

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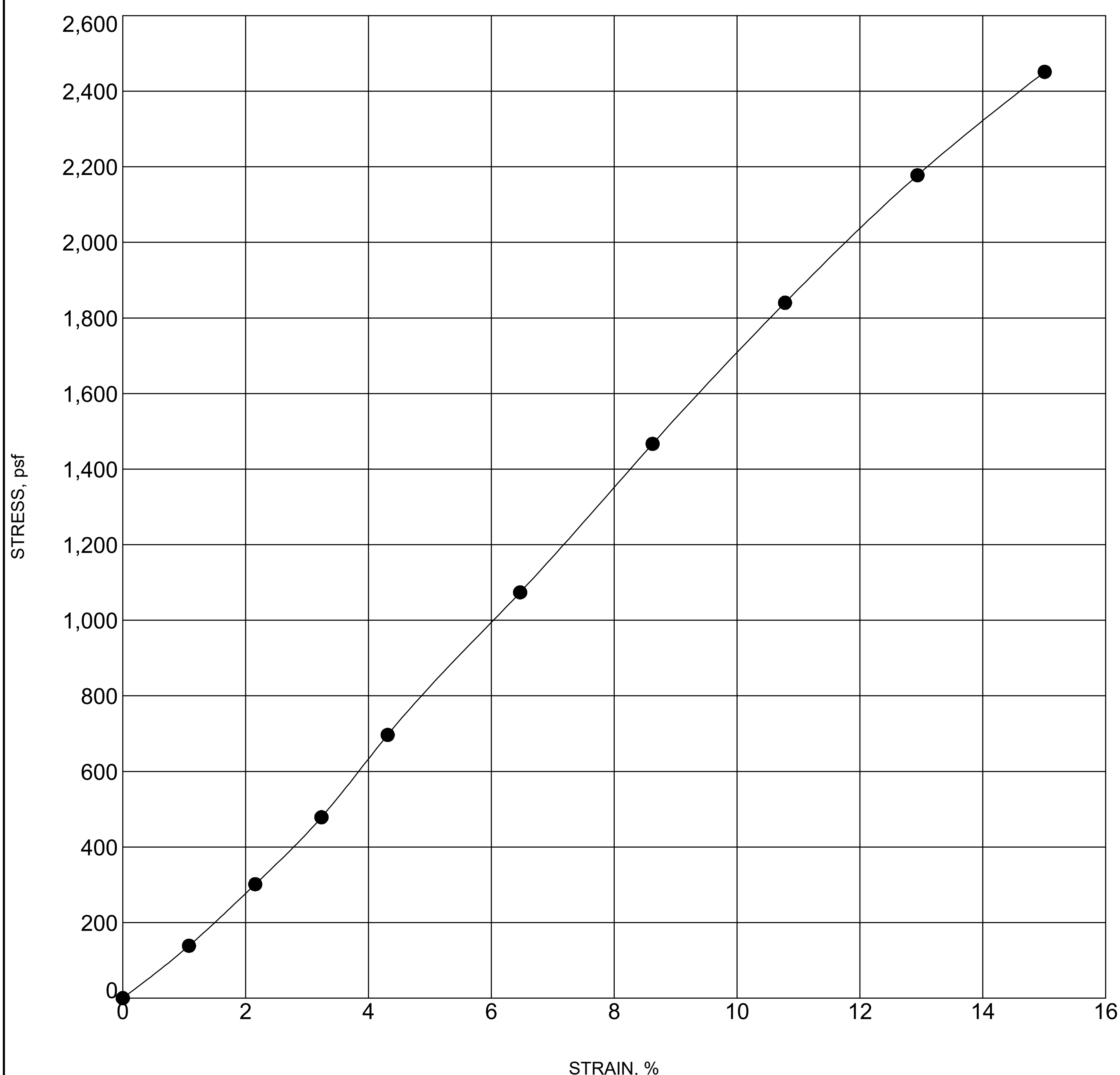
Telephone: (419)324-2222

CLIENT City of Willoughby
PROJECT NAME Lake Shore East Equilization Basin
PROJECT NUMBER 230264
PROJECT LOCATION Eastlake, OH



	Specimen Identification		Classification	γ_d	MC%
●	**B-2**	**23.5**		**115**	**16**

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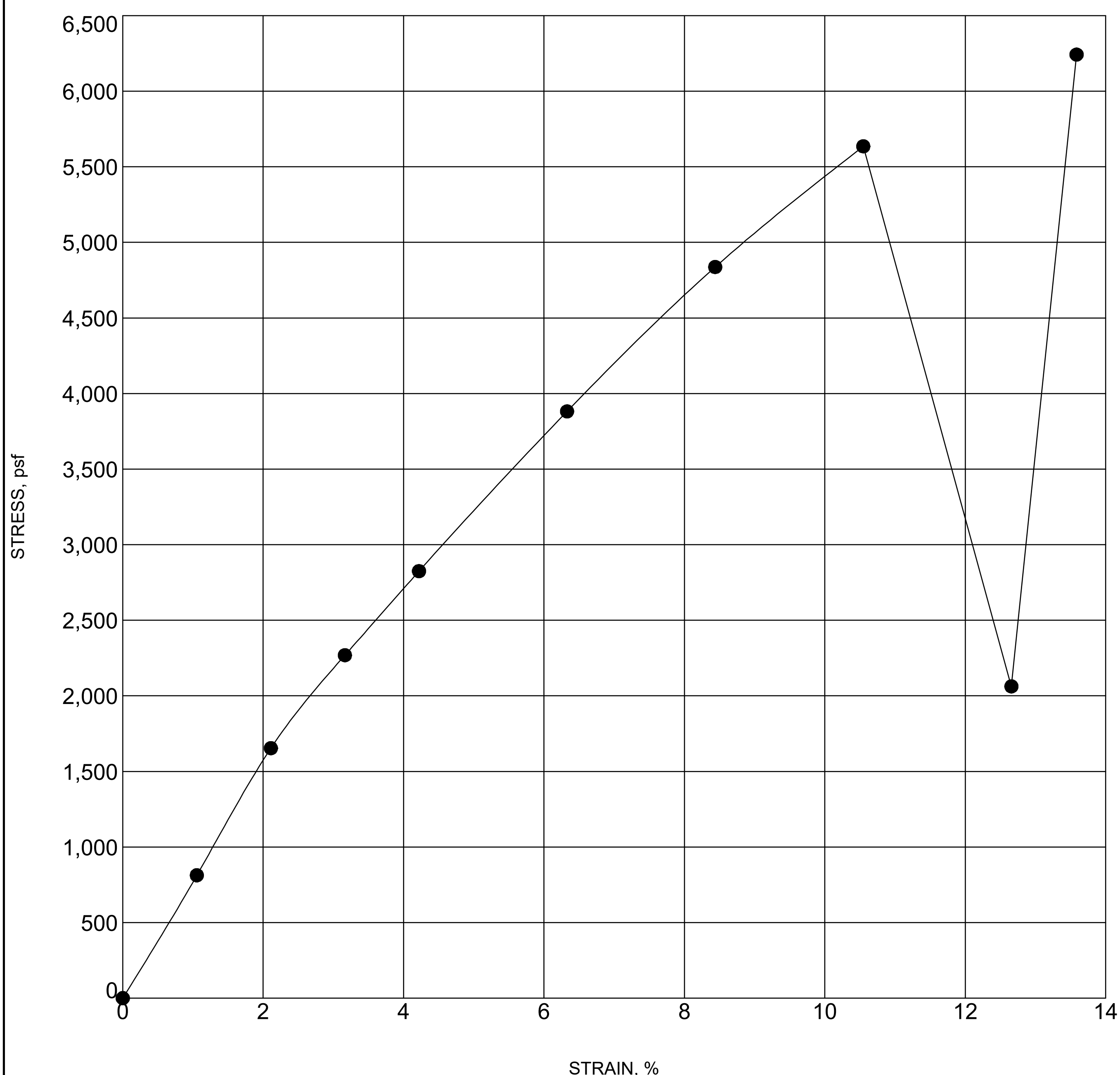
UNCONFINED COMPRESSION TEST

CLIENT City of Willoughby
PROJECT NAME Lake Shore East Equilization Basin
PROJECT NUMBER 230264
PROJECT LOCATION Eastlake, OH



	Specimen Identification		Classification	γ_d	MC%
●	**B-3**	**6.0**		**110**	**17**

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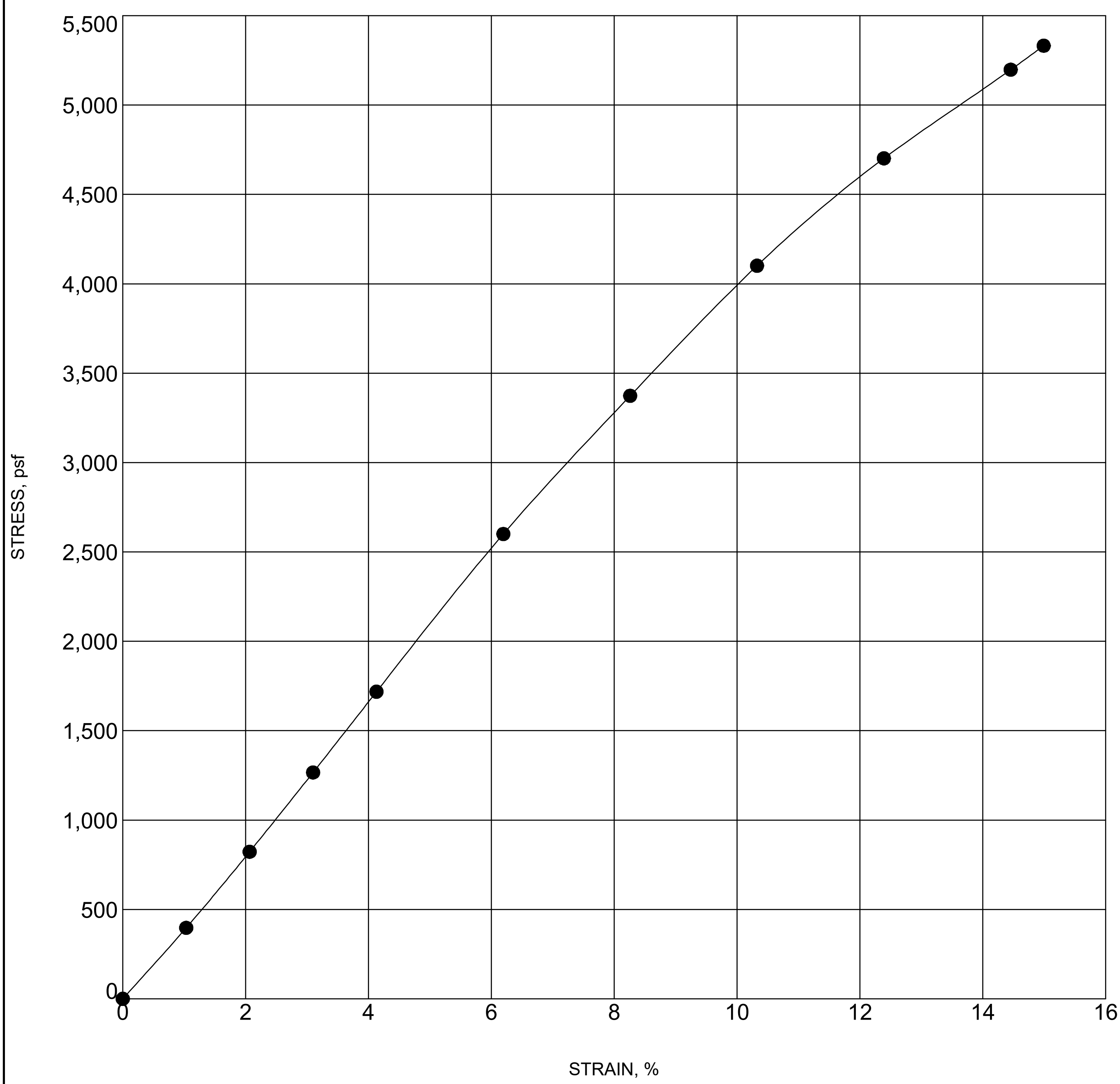
UNCONFINED COMPRESSION TEST

CLIENT City of Willoughby **PROJECT NAME** Lake Shore East Equilization Basin

PROJECT NUMBER 230264 **PROJECT LOCATION** Eastlake, OH



	Specimen Identification		Classification	γ_d	MC%
●	**B-3**	**13.5**	**LEAN CLAY with SAND (CL)**	**121**	**15**

APPENDIX E

Groundwater Monitoring Well Readings and Hydrographs

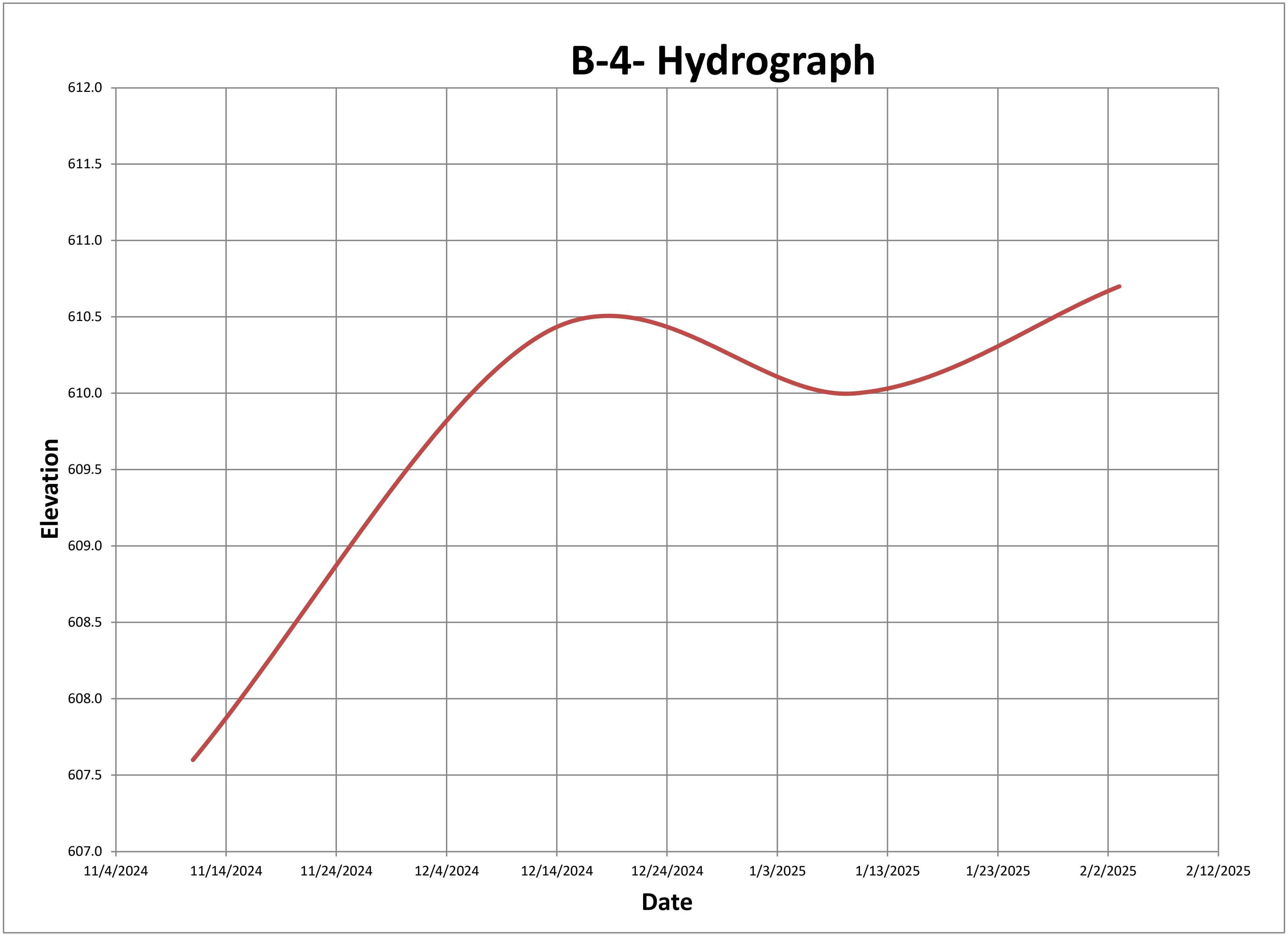
PROJECT: Lakeshore Equilization Basin

Project Number: 230264

1. Elevations assumed to reference North American Vertical Datum of 1988 (NAVD88).
2. NE = not encountered.

Summary of Measured Water Level Readings

Boring Number	Ground Surface Elevation (feet)[1]	Elevation Referenced From	Depth to Groundwater[2] (feet)	Elevation of Groundwater at Time of Measurement (feet)[1]	Date Measured
B-4	612	Survey	4.4	607.6	11/11/2024
			1.6	610.4	12/13/2024
			2.0	610.0	1/10/2025
			1.3	610.7	2/3/2025


B-4- Hydrograph
Elevation
612.0
611.5
611.0
610.5
610.0
609.5
609.0
608.5
608.0
607.5
607.0
11/4/2024
11/14/2024
11/24/2024
12/4/2024
12/14/2024
12/24/2024
1/3/2025
1/13/2025
1/23/2025
2/2/2025
2/12/2025
Date