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January 8, 2020

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Attn: Kristin Bisgard, PE

Subj: Geotechnical Exploration
Proposed Water Tower
City of Madison
Madison, South Dakota
GeoTek #19-K15

This correspondence presents our written report of the geotechnical exploration program for the referenced project. Our work was performed in accordance with the authorization of Dennis Rebelein with Banner Associates, Inc. We are transmitting an electronic copy of our report for your use. An additional copy of our report is also being sent as noted below.

We thank you for the opportunity of providing our services on this project and look forward to continued participation during the design and construction phases. If you have any questions regarding this report, please contact our office at (605) 335-5512.

Respectfully Submitted,
GeoTek Engineering & Testing Services, Inc.

Jared Haskins

Jared Haskins, PE
Geotechnical Manager

Cc: City of Madison, Attn: Chad Comes, PE

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GEOTECHNICAL EXPLORATION
PROPOSED WATER TOWER
CITY OF MADISON
MADISON, SOUTH DAKOTA
GEOTEK #19-K15

INTRODUCTION

Project Information

This report presents the results of the recent geotechnical exploration program for the proposed water tower for the City of Madison in Madison, South Dakota.

Scope of Services

Our work was performed in accordance with the authorization of Dennis Rebelein with Banner Associates, Inc. The authorized scope of services included the following:

1. To perform 4 standard penetration test (SPT) borings to gather data on the subsurface conditions within the footprint of the proposed water tower.

2. To perform laboratory tests that include moisture content, dry density, Atterberg limits (liquid and plastic limits), sieve analysis (#200 sieve wash), unconfined compressive strength, consolidation, resistivity, pH, sulfate content and chloride content.

3. To prepare an engineering report that includes the results of the field and laboratory tests as well as our earthwork and foundation recommendations for design and construction.

The scope of our work was intended for geotechnical purposes only. This scope of work did not include determining the presence or extent of environmental contamination at the site or to characterize the site relative to wetlands status.

SITE & SUBSURFACE CONDITIONS

Site Location & Description

The site for the new water tower is located approximately 1,500 feet southeast of the intersection of 12th Street SE and Washington Avenue S in Madison, South Dakota. A project location map

(Figure 1) is attached showing the location of the site. The site was previously used for agricultural purposes.

<u>Ground Surface Elevations & Test Boring Locations</u>

The ground surface elevations at the test boring locations were provided by Banner Associates, Inc. and were 1,703.3 feet at test boring 1, 1,703.1 feet at test boring 2, 1,702.5 feet at test boring 3 and 1,703.0 feet at test boring 4. A site map (Figure 2) is attached showing the relative location of the test borings.

<u>Subsurface Conditions</u>

Four (4) test borings were performed at the site on November 14 and November 15, 2019. The subsurface conditions encountered at the test boring locations are illustrated by means of the boring logs included in Appendix A.

The test borings encountered 2 feet of topsoil materials overlying glacial till soils. The glacial till soils extended to the termination depth of the test borings. The topsoil materials consisted of lean clay soils. The glacial till soils consisted of sandy lean clay soils.

The consistency or relative density of the soils is indicated by the standard penetration resistance (“N”) values as shown on the boring logs. A description of the soil consistency or relative density based on the “N” values can be found on the attached Soil Boring Symbols and Descriptive Terminology data sheet.

We wish to point out that the subsurface conditions at other times and locations at the site may differ from those found at our test boring locations. If different conditions are encountered during construction, then it is important that you contact us so that our recommendations can be reviewed.

<u>Water Levels</u>

Measurements to record the groundwater levels were made at the test boring locations, with the exception of test boring 4. A groundwater measurement was not made at test boring 4 due to the presence of drilling fluid that was used to advance the deepest test boring. The time and level of the groundwater readings are recorded on the boring logs. Groundwater was measured at a depth of 47 feet (elevation 1,656.3 feet) at test boring 1. Groundwater did not enter the boreholes at test borings 2 or 3 at the time of our measurements.

The water levels indicated on the boring logs may or may not be an accurate indication of the depth or lack of subsurface groundwater. A long period of time is generally required for subsurface water to stabilize in the impervious soils encountered at the test boring locations. Long term groundwater monitoring was not included in our work scope.

ENGINEERING REVIEW & RECOMMENDATIONS

Project Design Data

We understand that the project will consist of constructing a new water tower for the City of Madison in Madison, South Dakota. The tower style has not been determined yet. The water tower will have a capacity of approximately 750,000 gallons. The loads for the water tower were not provided, but we expect heavy loads. We anticipate that the water tower will be supported by a circular raft foundation (shallow foundation system) that will rest approximately 9 feet below the finished grade (near elevation 1,694.0 feet). We assume that the circular raft foundation will have a diameter of approximately 50 feet (based on 5,000 pounds per square foot (psf) bearing). We understand that the allowable total settlement is either 2 inches or 3 inches for a shallow foundation system and ¾ inch for a deep foundation system.

The information/assumptions detailed in this section of the report are important factors in our review and recommendations. If there are any corrections or additions to the information detailed in this section, then it is important that you contact us so that we can review our recommendations with regards to the revised plans.

Discussion

It is our opinion that 3 options could be considered for foundation support of the proposed water tower. The first option consists of an excavate/refill system. With the excavate/refill system, a layer of granular material (granular structural fill and/or drainage rock) will be provided below the foundation in order to provide uniform support. The second option consists of an intermediate foundation system of rammed aggregate piers or aggregate piers. The third option consists of a deep foundation system of auger-cast piles. We have provided specific recommendations for the 3 options. Recommendations for driven piles could also be provided.

Foundation Support Option 1 – Excavate/Refill System

For this option, we recommend that the site preparation for the circular raft foundation of the water tower consist of excavating to elevation 1,691.0 feet or deeper. At elevation 1,691.0 feet, we anticipate that suitable glacial till soils will be encountered. If suitable glacial till soils are not encountered at the bottom of the excavation (elevation 1,691.0 feet), then additional removals will be needed. Also, if the bottom of the excavation is not a minimum of 3 feet below the bottom-of-foundation elevation, then we recommend further excavating to a minimum depth of 3 feet below the bottom-of-foundation elevation. Therefore, a minimum of 3 feet of granular material will be provided beneath the foundation. We recommend that observations and hand auger borings be performed at the bottom of the excavation to determine if further excavation is needed.

Due to potential groundwater, the initial 12 inches of material used to backfill the overexcavated area should consist of drainage rock. The remainder of the overexcavated area could be backfilled with drainage rock or granular structural fill.

The bottom of the excavation should be laterally oversized 1 foot beyond the edges of the foundation for each vertical foot of granular structural fill or drainage rock required below the foundation (1 horizontal : 1 vertical).

If our recommendations are followed during site preparations, then it is our opinion that the circular raft foundation of the water tower can be designed for a net allowable soil bearing pressure of up to 5,000 psf. It is our opinion that the recommended bearing pressure should provide a minimum safety factor of 3.0 against shear or base failure. The net allowable soil bearing pressure may be increased by 1/3 for transient wind or seismic loads.

Based on our assumptions (a circular raft foundation (5,000 psf bearing) with a diameter of approximately 50 feet resting near elevation 1,694.0 feet), we estimate that the total settlement of the water tower will be on the order of 2 ½ inches and differential settlement will be approximately half of the total settlement. Again, the estimated settlement is based on our assumptions. We recommend that we be contacted to perform another settlement analysis when the foundation loads, dimensions of the foundation and bottom-of-foundation elevation are known. As previously stated, we understand that the allowable total settlement for a shallow foundation system is either 2 inches or 3 inches. Based on our settlement analysis, the estimated total settlement exceeds the lower value of the allowable total settlement.

It is our opinion that a friction factor of 0.45 can be used between the granular structural fill or drainage rock and the bottom of the foundation.

Foundation Support Option 2 – Rammed Aggregate Piers & Aggregate Piers

We recommend that the rammed aggregate piers or aggregate piers be designed by a licensed professional engineer specializing in the design of rammed aggregate piers or aggregate piers. The designer will typically provide a net allowable soil bearing pressure and estimated settlements. The rammed aggregate piers or aggregate piers should be installed by an experienced licensed rammed aggregate pier or aggregate pier contractor. Testing of the rammed aggregate piers and aggregate piers should be performed at the beginning of the work and during production to confirm the design parameters. We can provide contact information of rammed aggregate pier and aggregate pier designers.

Protection of the rammed aggregate piers and aggregate piers will need to be considered before, during and after installation. The tops of the rammed aggregate piers and aggregate piers should be protected from construction traffic. Excavations performed within close proximity of a rammed aggregate pier or aggregate pier can affect the integrity of the rammed aggregate pier or aggregate pier. With that said, excavation work for underground utility installation, maintenance or future repair should be considered prior to the installation of the rammed aggregate piers or aggregate piers. Excavation work for future construction, maintenance or repairs should also take into account any risks that may affect the integrity of any rammed aggregate piers and aggregate piers.

If rammed aggregate piers or aggregate piers are used, then the designer of the rammed aggregate piers or aggregate piers should be able to provide a friction value.

Foundation Support Option 3 – Auger-Cast Piles

The auger-cast piles will develop their capacity from a combination of side friction and end-bearing, but mostly side friction. Please refer to Table 1 that summarizes the estimated pile tip elevations and allowable capacities using a safety factor of 2.5. We recommend that the final design of the auger-cast piles be confirmed by the pile installer. It should be noted that there is some risk involved with the auger-cast pile system due to the potential presence of cobbles/boulders within the glacial till soils.

Table 1. Pile Tip Elevations & Estimated Allowable Capacities for Auger-Cast Piles

Pile Diameter, in	Estimated Pile Tip Elevation, ft	Estimated Allowable Capacity, tons (Compression)	Estimated Allowable Capacity, tons (Uplift)
16	1,625	60	50
16	1,605	80	70
18	1,625	70	60
18	1,615	80	70
18	1,605	90	80

Notes: Alternative pile diameters and capacities could also be considered. The estimated pile tip elevations are based on a ground surface elevation of approximately 1,703 feet with calculations starting around elevation 1,690 feet.

The estimated allowable capacities and pile lengths are only estimates and must be confirmed by an appropriate test pile program. The actual pile capacity and length should be determined in the field by a testing program prior to the installation of the production piles. In order to verify the design capacity, we recommend that test piles be tested in accordance with the Standard Test Method for Deep Foundations Under Static Axial Compressive Load (ASTM:D1443). The number of test piles will depend on how many pile diameters are used for the project. If only 1 pile diameter is used for the project, then we recommend that 1 test pile be tested. If 2 different pile diameters are used, then we recommend that 1 test pile be tested per pile diameter. The design length for the production piles can be adjusted prior to installation based on the results of the test pile(s). Additional test piles may be needed if variable subsurface conditions are encountered during the installation of the piles.

With the auger-cast piles, we estimate that total settlement of the water tower will be on the order of ½ inch. Unknown soil conditions at the site that are different from those depicted at the test boring locations could increase the amount of expected settlement.

In our opinion, the compression and uplift capacities of piles spaced at least 3 pile diameters (center-to-center pile spacing) apart will not be reduced due to group effects. If a closer spacing is used, then we recommend evaluating the magnitude of the group effect to determine the extent to which the capacities should be reduced.

Drainage Rock with Foundation Support Options 2 & 3

In our opinion, a layer of drainage rock (6 inches to 12 inches) should be placed at the bottom of the excavation in order to provide a working surface for foundation construction.

Excavation

All excavations should be performed with a track backhoe with a smooth edge bucket. The subgrade should not be exposed to heavy construction traffic from rubber tire vehicles. The soils are susceptible to disturbance and can experience strength loss caused by construction traffic and/or additional moisture.

Dewatering

Dewatering may be needed during construction. If so, then it will likely be possible to remove and control water entering the excavation using normal sump pumping techniques due to the low permeable characteristics of the predominant clayey soils encountered at the test boring locations. More extensive dewatering techniques will be needed if waterbearing sand soils are encountered.

Lateral Loads & Foundation Backfill

We recommend neglecting the soils within the upper 5 feet from the lateral load resistance due to frost softening. The soils below a depth of 5 feet can be assigned a submerged passive equivalent fluid unit weight of 175 pounds per cubic foot (pcf). This value will give ultimate resistance to lateral loads. We recommend using a theoretical safety factor of at least 2.0 to resist the lateral loads.

It is our opinion that the compacted backfill over the foundation can be assigned a total unit weight of 130 pcf above the groundwater level and a submerged unit weight of 68 pcf below the groundwater level. These values provide the ultimate resistance to uplift and moment loads. We recommend using a theoretical safety factor of at least 1.5 to resist the uplift and moment loads.

The design parameters discussed in this section are based on a groundwater level of approximately 5 feet. We would like to point out that this does not mean that groundwater was encountered at a depth of 5 feet; it is to account for future fluctuations in the groundwater level. We can revisit the design parameters once the design elevations for the project are determined.

Frost Protection

We recommend that the foundation be placed at a sufficient depth for frost protection. Foundations for unheated areas and canopies, or foundations that are not protected from frost during freezing temperatures, should be placed such that the bottom of the foundation is a minimum of 5 feet below the finished exterior grade.

Gravel Surfaced Areas

We assume that some gravel surfaced areas will be constructed as part of the project. We recommend that the subgrade preparation in the gravel surfaced areas consist of removing the vegetation and highly organic materials. A removal depth of 12 inches to 18 inches should be expected. Following the removals, the subgrade should be prepared by cutting or placing subgrade fill to the design elevations. Once the design elevations have been achieved, we recommend that the exposed subgrade be scarified (with a disc harrow) to a minimum depth of 8 inches and adjusted to a moisture level that is 1 percent to 4 percent below the optimum moisture content as determined by standard Proctor (ASTM:D698). The moisture-conditioned soils should then be compacted.

Additional corrections will likely be needed if unstable areas are encountered during construction. The additional corrections may include the following: moisture conditioning the soils (e.g. drying the soils by scarification), mixing cement with the subgrade soils, an overexcavation to remove and replace the unstable subgrade soils, the placement of a woven geotextile fabric at the subgrade surface, and/or the placement of granular subbase at the subgrade surface. The type of correction performed should be determined after observing the condition of the subgrade. We expect that stable conditions will be encountered during drier periods of the year, while some unstable conditions could be encountered during wetter periods of the year.

For the thickness of the gravel section, we recommend at least 4 inches of gravel surfacing over 6 inches of aggregate base course. In our opinion, it would be beneficial to place a geotextile fabric below the aggregate base course. Regarding the geotextile fabric, we recommend using Mirafi HP 370, Propex Geotex 3x3 HF, Huesker Comtrac P 45/45 or approved alternative. Without the geotextile fabric, aggregate loss and additional maintenance should be expected.

Material Types & Compaction Levels

Drainage Rock – The drainage rock should be crushed, washed and meet the gradation specifications shown in Table 2.

Table 2. Drainage Rock Gradation Specifications

Sieve Size	Percent Passing
1 ½-inch	100
1-inch	70 – 90
3/4-inch	25 – 50
3/8-inch	0 – 5

Granular Structural Fill – The granular structural fill should consist of a pit-run or processed sand or gravel having a maximum particle size of 3 inches with less than 15 percent by weight passing the #200 sieve. The granular structural fill should be placed in lifts of up to 1 foot in thickness.

Foundation Backfill – We recommend that non-organic clay soils be used as foundation backfill. It is our opinion that the on-site soils could be used as foundation backfill. The topsoil materials should not be used as foundation backfill. The foundation backfill should be placed in lifts of up to 6 inches in thickness. Some drying should be expected with the on-site soils.

Subgrade Fill – The subgrade fill should consist of either a granular or clay material. Debris, organic material, or over-sized material should not be used as subgrade fill. If a granular material is used, then it should consist of a pit-run or processed sand or gravel having a maximum particle size of 3 inches. The granular material can be placed in lifts of up to 1 foot in thickness. If a clay material is selected, then it should consist of a non-organic clay soil. Scrutiny on the clay material's moisture content should be made prior to the acceptance and use. The clay fill should be placed in lifts of up to 6 inches in thickness. The majority of the on-site soils can be used as subgrade fill. Organic materials should not be used as subgrade fill.

Granular Subbase – The granular subbase should consist of crushed quartzite, recycled concrete or a crushed pit-run material meeting the gradation specifications shown in Table 3.

Table 3. Granular Subbase Gradation Specifications

Sieve Size	Percent Passing
4-inch	100
3-inch	70 – 90
2-inch	60 – 80
1-inch	40 – 70
#4	10 – 50
#40	5 – 20
#200	0 – 8

Gravel Surfacing Material – We recommend that the gravel surfacing meet the requirements of Sections 260 and 882 of the SDDOT Standard Specifications. In our opinion, it is important to provide a gravel surfacing material that meets the plasticity index requirement that ranges from 4 to 12.

Aggregate Base Course Material – We recommend that the aggregate base course materials meet the requirements of Sections 260 and 882 of the SDDOT Standard Specifications.

Recommended Compaction Levels – The recommended compaction levels listed in Table 4 are based on a material's maximum dry density value, as determined by a standard Proctor (ASTM: D698) test.

Table 4. Recommended Compaction Levels

Placement Location	Minimum Compaction Specifications
Below the Foundation	100%
Foundation Backfill	95%
Subgrade Fill	95%
Aggregate Base Course	97%
Gravel Surfacing	97%
Granular Subbase	97%
Non-Structural Areas	90%

Notes: Compaction specifications are not applicable with the drainage rock. Compaction testing may not be practical for the granular subbase due to the large aggregate.

Recommended Moisture Levels – The moisture content of the clay backfill materials, when used as backfill around the exterior of a foundation should be maintained within a range of plus 1 percent to minus 4 percent of the materials' optimum moisture content. When the clay backfill materials are used below a vehicle area, or as site grading, the materials' moisture content should be maintained within a range of minus 1 percent to minus 4 percent of the materials' optimum moisture content. The optimum moisture content should be determined using a standard Proctor (ASTM: D698) test.

The moisture content of the granular backfill materials should be maintained at a level that will be conducive for vibratory compaction.

Seismic Site Classification

Based on the 2018 International Building Code (IBC), it is our opinion that the site, as a whole, corresponds to a Site Class D (stiff soil). Also, the ground acceleration values are as follows: S_S = 0.101 g, S_1 = 0.028 g, S_{MS} = 0.162 g, S_{M1} = 0.068 g, S_{DS} = 0.108 g, S_{D1} = 0.045 g. Therefore, the seismic design category is "A". The ground acceleration values are based on the ASCE 7-16 (referenced standard for 2018 IBC) with Risk Category II. If needed, we can provide ground acceleration values for a different design code.

Site Drainage

Proper drainage should be maintained during and after construction. The general site grading should direct surface run-off waters away from the excavation. Water which accumulates in the excavation should be removed in a timely manner.

Corrosive Potential

Soil samples were collected from test borings 2 and 3 and submitted for pH, chloride content, sulfate content and resistivity testing. The results of the laboratory tests are shown in Table 5.

Table 5. Laboratory Test Results

Test Boring	Depth (ft)	Soil Type	Resistivity (ohm-cm) (as-received)	Resistivity (ohm-cm) (saturated)	pH	Chloride (mg/kg)	Sulfate (mg/kg)
2	9 ½ to 11	Sandy Lean Clay (GT)	1,130	1,000	7.7	2	1,746
3	4 ½ to 6	Sandy Lean Clay (GT)	1,140	1,080	7.8	3	117

Based on the soil resistivity test results, the glacial till soils are considered highly corrosive. Based on the chloride content test results, the results generally indicate that the glacial till soils are mildly corrosive. Based on the sulfate content test results, the results indicate that the glacial till soils from test boring 2 (9 ½ feet to 11 feet) are corrosive, while the glacial till soils from test boring 3 (4 ½ feet to 6 feet) are mildly corrosive.

CONSTRUCTION CONSIDERATIONS

Groundwater & Surface Water

Water may enter the excavation due to subsurface water, precipitation or surface run off. Any water that accumulates in the bottom of the excavation should be immediately removed and surface drainage away from the excavation should be provided during construction.

Disturbance of Soils

The soils encountered at the test boring locations are susceptible to disturbance and can experience strength loss caused by construction traffic and/or additional moisture. Precautions will be required during earthwork activities in order to reduce the risk of soil disturbance.

Cold Weather Precautions

If site preparation and construction is anticipated during cold weather, then we recommend all foundations, slabs and other improvements that may be affected by frost movements be insulated from frost penetration during freezing temperatures. If filling is performed during freezing temperatures, then all frozen soils, snow and ice should be removed from the areas to be filled prior to placing the new fill. The new fill should not be allowed to freeze during transit, placement and compaction. Concrete should not be placed on frozen subgrades. Frost should not be allowed to penetrate below the foundations. The subgrade soils will likely require reworking and recompacting due to the loss of density caused by the freeze/thaw process.

Excavation Sideslopes

The excavations must comply with the requirements of OSHA 29 CFR, Part 1926, Subpart P, “Excavations and Trenches”. This document states that the excavation safety is the responsibility of the contractor. Reference to this OSHA requirement should be included in the project specifications.

Observations & Testing

This report was prepared using a limited amount of information for the project and a number of assumptions were necessary to help us develop our conclusions and recommendations. It is recommended that our firm be retained to review the geotechnical aspects of the final design plans and specifications to check that our recommendations have been properly incorporated into the design documents.

The recommendations submitted in this report have been made based on the subsurface conditions encountered at the test boring locations. It is possible that there are subsurface conditions at the site that are different from those represented by the test borings. As a result, on-site observation during construction is considered integral to the successful implementation of the recommendations. We believe that qualified field personnel need to be on-site at the following times to observe the site conditions and effectiveness of the construction.

Excavation

We recommend that a geotechnical engineer or geotechnical engineering technician working under the direct supervision of a geotechnical engineer observe all excavations for foundations, slabs and pavements. These observations are recommended to determine if the exposed soils are similar to those encountered at the test boring locations, if unsuitable soils have been adequately removed and if the exposed soils are suitable for support of the proposed construction. These observations should be performed prior to placement of fill or foundations.

Testing

After the subgrade is observed by a geotechnical engineer/technician and approved, we recommend a representative number of compaction tests be taken during the placement of the structural fill and backfill placed below foundations, slabs and pavements, beside foundation walls and behind retaining walls. The tests should be performed to determine if the required compaction has been achieved. As a general guideline, we recommend at least 1 test be taken for every 2,000 square feet of structural fill placed in building and pavement areas, at least 1 test for every 75 feet to 100 feet in trench fill, and for every 2-foot thickness of fill or backfill placed. The actual number of tests should be left to the discretion of the geotechnical engineer. Samples of proposed fill and backfill materials should be submitted to our laboratory for testing to determine their compliance with our recommendations and project specifications.

We recommend that a geotechnical engineer or a geotechnical engineering technician working under the direct supervision of a geotechnical engineer monitor the installation of the rammed aggregate piers, aggregate piers or auger-cast piles. Detailed records should be kept for the rammed aggregate piers, aggregate piers or auger-cast piles.

SUBSURFACE EXPLORATION PROCEDURES

Test Borings

We performed 4 SPT borings on November 14 and November 15, 2019 with a truck rig equipped with hollow-stem auger. Soil sampling was performed in accordance with the procedures described in ASTM:D1586. Using this procedure, a 2-inch O.D. split barrel sampler is driven into the soil by a 140-pound weight falling 30 inches. After an initial set of 6 inches, the number of blows required to drive the sampler an additional 12 inches is known as the penetration resistance, or “N” value. The “N” value is an index of the relative density of cohesionless soils and the consistency of cohesive soils. In addition, thin walled tube samples were obtained according to ASTM:D1587, where indicated by the appropriate symbol on the boring logs.

The test borings were backfilled with on-site materials and some settlement of these materials can be expected to occur. Final closure of the holes is the responsibility of the client or property owner.

The soil samples collected from the test boring locations will be retained in our office for a period of 1 month after the date of this report and will then be discarded unless we are notified otherwise.

Soil Classification

As the samples were obtained in the field, they were visually and manually classified by the crew chief according to ASTM:D2488. Representative portions of all samples were then sealed and returned to the laboratory for further examination and for verification of the field classification. In addition, select samples were then submitted to a program of laboratory tests. Where laboratory classification tests (sieve analysis and Atterberg limits) have been performed, classifications according to ASTM:D2487 are possible. Logs of the test borings indicating the depth and identification of the various strata, the “N” value, the laboratory test data, water level information and pertinent information regarding the method of maintaining and advancing the drill holes are also attached in Appendix A. Charts illustrating the soil classification procedures, the descriptive terminology and the symbols used on the boring logs are also attached in Appendix A.

Water Level Measurements

Subsurface groundwater levels should be expected to fluctuate seasonally and yearly from the groundwater readings recorded at the test boring locations. Fluctuations occur due to varying seasonal and yearly rainfall amounts and snowmelt, as well as other factors. It is possible that the subsurface groundwater levels during or after construction could be significantly different than the time the test borings were performed.

Laboratory Tests

Laboratory tests were performed on select samples to aid in determining the index and strength properties of the soils. The index tests consisted of moisture content, dry density, Atterberg limits (liquid and plastic limits), sieve analysis (#200 sieve wash), resistivity, pH, sulfate content and chloride content. The strength tests consisted of unconfined compressive strength and consolidation. The laboratory tests were performed in accordance with the appropriate ASTM procedures. The results of the laboratory tests are shown on the boring logs opposite the samples upon which the tests were performed or on the data sheets included in the Appendix.

LIMITATIONS

The recommendations and professional opinions submitted in this report were based upon the data obtained through the sampling and testing program at the test boring locations. We wish to point out that because no exploration program can totally reveal the exact subsurface conditions for the entire site, conditions between test borings and between samples and at other times may differ from those described in our report. Our exploration program identified subsurface conditions only at those points where samples were retrieved or where water was observed. It is not standard engineering practice to continuously retrieve samples for the full depth of the borings. Therefore, strata boundaries and thicknesses must be inferred to some extent. Additionally, some soils layers present in the ground may not be observed between sampling intervals. If the subsurface conditions encountered at the time of construction differ from those represented by our test borings, it is necessary to contact us so that our recommendations can be reviewed. The variations may result in altering our conclusions or recommendations regarding site preparation or construction procedures, thus, potentially affecting construction costs.

This report is for the exclusive use of the addressee and its representatives for use in design of the proposed project described herein and preparation of construction documents. Without written approval, we assume no responsibility to other parties regarding this report. Our conclusions, opinions and recommendations may not be appropriate for other parties or projects.

STANDARD OF CARE

The recommendations submitted in this report represent our professional opinions. Our services for your project were performed in a manner consistent with that level of care and skill ordinarily exercised by members of the engineering profession currently practicing at this time and area.

This report was prepared by:
GeoTek Engineering & Testing Services, Inc.

Jared Haskins, PE
Geotechnical Manager

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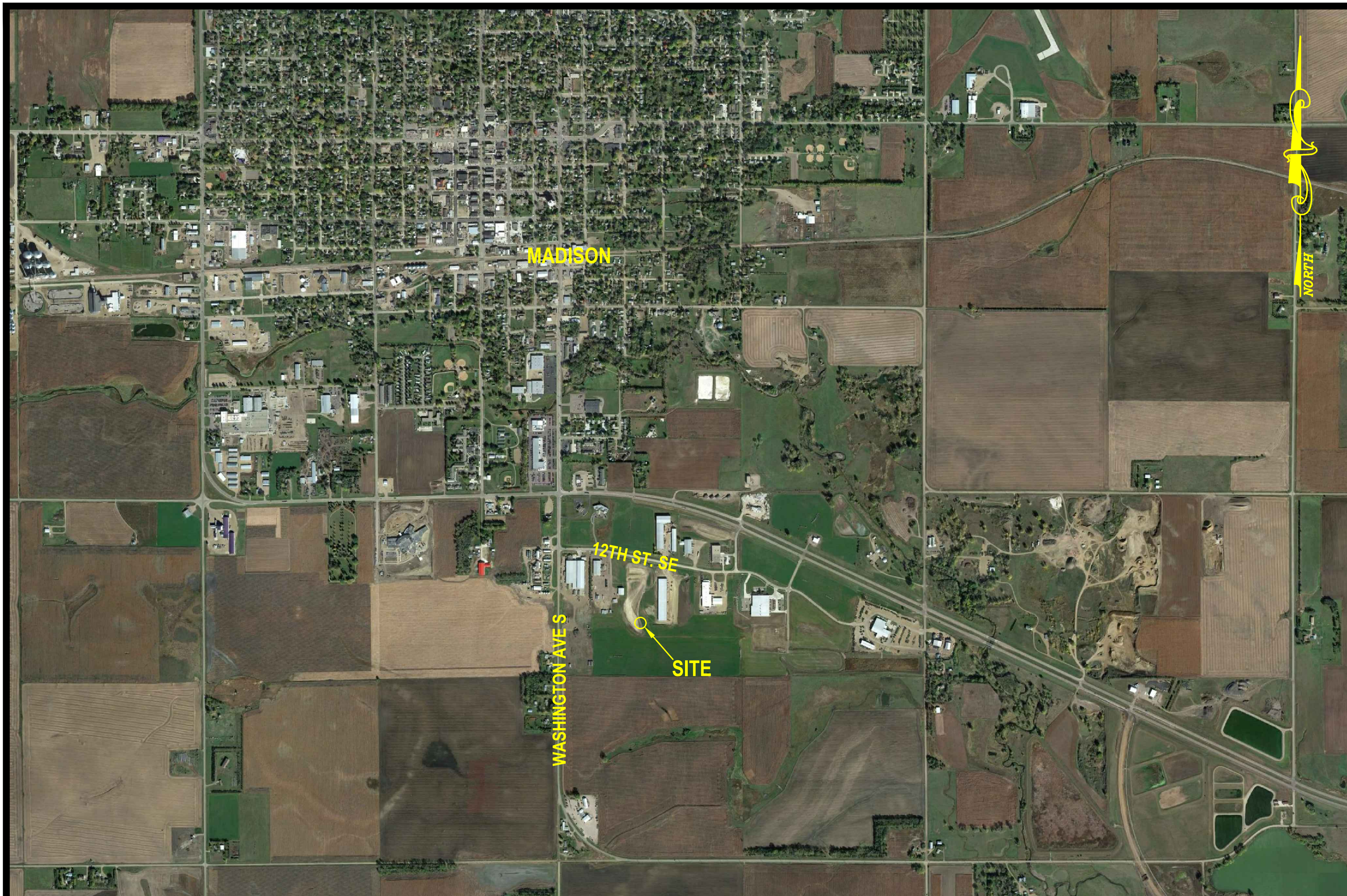

FIGURE 1
PROJECT LOCATION MAP
PROPOSED WATER TOWER
CITY OF MADISON
MADISON, SD

ACAD/GEOTEK/JARED/19-K15

PROJECT#: 19-K15

DRAWN BY: DHP

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **19-K15** BORING NO. **1 (1 of 1)**

PROJECT **Proposed Water Tower, City of Madison, Madison, SD**

DEPTH in FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 1703.3 ft)	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
	SANDY LEAN CLAY: a little gravel, mottled brown and gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	12		2	SPT					
			12		3	SPT					
			12		4	SPT	20	106	43	19	5100
			16		5	SPT					
			18		6	SPT	19	113			8400
19½			23		7	SPT					
	SANDY LEAN CLAY: a little gravel, gray, moist, stiff to very stiff, percent passing the #200 sieve = 64% (at 35') (CL)	GLACIAL TILL	13		8	SPT	17	112	34	16	2500
			12		9	SPT					
			13		10	SPT					
			14		11	SPT	17	116			4200
			14		12	SPT					
			15	▼	13	SPT					
51			16		14	SPT					
	Bottom of borehole at 51 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
11-15-19	11:51 am	11	--	47	▼ 47
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START 11-14-19 COMPLETE 11-14-19 5:30 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

GEOTEK ENGINEERING
& TESTING SERVICES, INC.
909 E 50th St N
Sioux Falls, South Dakota, 57104
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GEOTECHNICAL TEST BORING LOG

GEOTEK # **19-K15**

BORING NO. **2 (1 of 1)**

PROJECT **Proposed Water Tower, City of Madison, Madison, SD**

SURFACE ELEVATION 1703.1 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
	SANDY LEAN CLAY: a little gravel, mottled brown and gray, moist, stiff to very stiff, percent passing the #200 sieve = 61% (at 15') (CL)	GLACIAL TILL	10		2	SPT					
			11		3	SPT					
			16		4	SPT					
			16		5	SPT	19	110			4100
					15	SH					
			15		6	SPT					
			15		7	SPT	20	110			
19½	**SANDY LEAN CLAY**: a little gravel, gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	12		8	SPT	18	115			3300
					16	SH					
			14		9	SPT					
					17	SH					
			16		10	SPT					
			15		11	SPT					
			15		12	SPT					
			15		13	SPT					
51			16		14	SPT					
	Bottom of borehole at 51 feet.										

START 11-15-19 COMPLETE 11-15-19 9:57 am

METHOD 3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
11-15-19	11:51 am	51	--	48	none
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GEOTECHNICAL TEST BORING LOG

GEOTEK # **19-K15** BORING NO. **3 (1 of 1)**

PROJECT **Proposed Water Tower, City of Madison, Madison, SD**

SURFACE ELEVATION 1702.5 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
	SANDY LEAN CLAY: a little gravel, mottled brown and gray, moist, stiff, percent passing the #200 sieve = 57% (at 13') (CL)	GLACIAL TILL	9		2	SPT					
			11		3	SPT					
			15		4	SPT					
			15		5	SPT	20	105			3300
			14		6	SPT	21	105			
19½			14		7	SPT					
	SANDY LEAN CLAY: a little gravel, gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	13		8	SPT					
			11		9	SPT	18	113			3700
			13		10	SPT					
			14		11	SPT					
			16		12	SPT					
			18		13	SPT	17	116			3900
51			18		14	SPT					
	Bottom of borehole at 51 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
11-15-19	11:51 am	51	--	46	none
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START 11-15-19 COMPLETE 11-15-19 11:48 am

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **19-K15** BORING NO. **4 (1 of 2)**

PROJECT **Proposed Water Tower, City of Madison, Madison, SD**

SURFACE ELEVATION 1703.0 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
	SANDY LEAN CLAY: a little gravel, mottled brown and gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	7		2	SPT					
			12		3	SPT					
			19		4	SPT					
			12		5	SPT	23	103			
19½			17		6	SPT	22	109	39	17	
	SANDY LEAN CLAY: a little gravel, gray, moist, stiff to very stiff, percent passing the #200 sieve = 69% (at 55') (CL)	GLACIAL TILL	15		7	SPT					
			13		8	SPT					
			14		9	SPT					
			15		10	SPT					
			15		11	SPT					
			15		12	SPT					
			15		13	SPT					

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
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START 11-14-19 COMPLETE 11-14-19 3:42 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Mike Wagner

GEOTEK ENGINEERING
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909 E 50th St N
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GEOTECHNICAL TEST BORING LOG

GEOTEK # **19-K15** BORING NO. **4 (2 of 2)**

PROJECT **Proposed Water Tower, City of Madison, Madison, SD**

DEPTH in FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 1703.0 ft)	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	SANDY LEAN CLAY: a little gravel, gray, moist, stiff to very stiff, percent passing the #200 sieve = 69% (at 55') (CL) *(Continued from previous page)*	GLACIAL TILL									
			15		14	SPT	21	112			
			16		15	SPT					
			17		16	SPT					
			17		17	SPT					
			18		18	SPT					
			18		19	SPT					
			19		20	SPT	20	112			
			20		21	SPT					
			21		22	SPT					
101			22		23	SPT					
	Bottom of borehole at 101 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
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--	--	--	--	--	--

START 11-14-19 COMPLETE 11-14-19 3:42 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Mike Wagner

SOIL CLASSIFICATION CHART

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

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS

BORING LOG SYMBOLS AND DESCRIPTIVE TERMINOLOGY

SYMBOLS FOR DRILLING AND SAMPLING

Symbol	Definition
Bag	Bag sample
CS	Continuous split-spoon sampling
DM	Drilling mud
FA	Flight auger; number indicates outside diameter in inches
HA	Hand auger; number indicates outside diameter in inches
HSA	Hollow stem auger; number indicates inside diameter in inches
LS	Liner sample; number indicates outside diameter of liner sample
N	Standard penetration resistance (N-value) in blows per foot
NMR	No water level measurement recorded, primarily due to presence of drilling fluid
NSR	No sample retrieved; classification is based on action of drilling equipment and/or material noted in drilling fluid or on sampling bit
SH	Shelby tube sample; 3-inch outside diameter
SPT	Standard penetration test (N-value) using standard split-spoon sampler
SS	Split-spoon sample; 2-inch outside diameter unless otherwise noted
WL	Water level directly measured in boring
▼	Water level symbol

SYMBOLS FOR LABORATORY TESTS

Symbol	Definition
WC	Water content, percent of dry weight; ASTM:D2216
D	Dry density, pounds per cubic foot
LL	Liquid limit; ASTM:D4318
PL	Plastic limit; ASTM:D4318
QU	Unconfined compressive strength, pounds per square foot; ASTM:D2166

DENSITY/CONSISTENCY TERMINOLOGY

Density Term	N-Value	Consistency Term
Very Loose	0-4	Soft
Loose	5-8	Firm
Medium Dense	9-15	Stiff
Dense	16-30	Very Stiff
Very Dense	Over 30	Hard

DESCRIPTIVE TERMINOLOGY

Term	Definition
Dry	Absence of moisture, powdery
Frozen	Frozen soil
Moist	Damp, below saturation
Waterbearing	Pervious soil below water
Wet	Saturated, above liquid limit
Lamination	Up to ½” thick stratum
Layer	½” to 6” thick stratum
Lens	½” to 6” discontinuous stratum

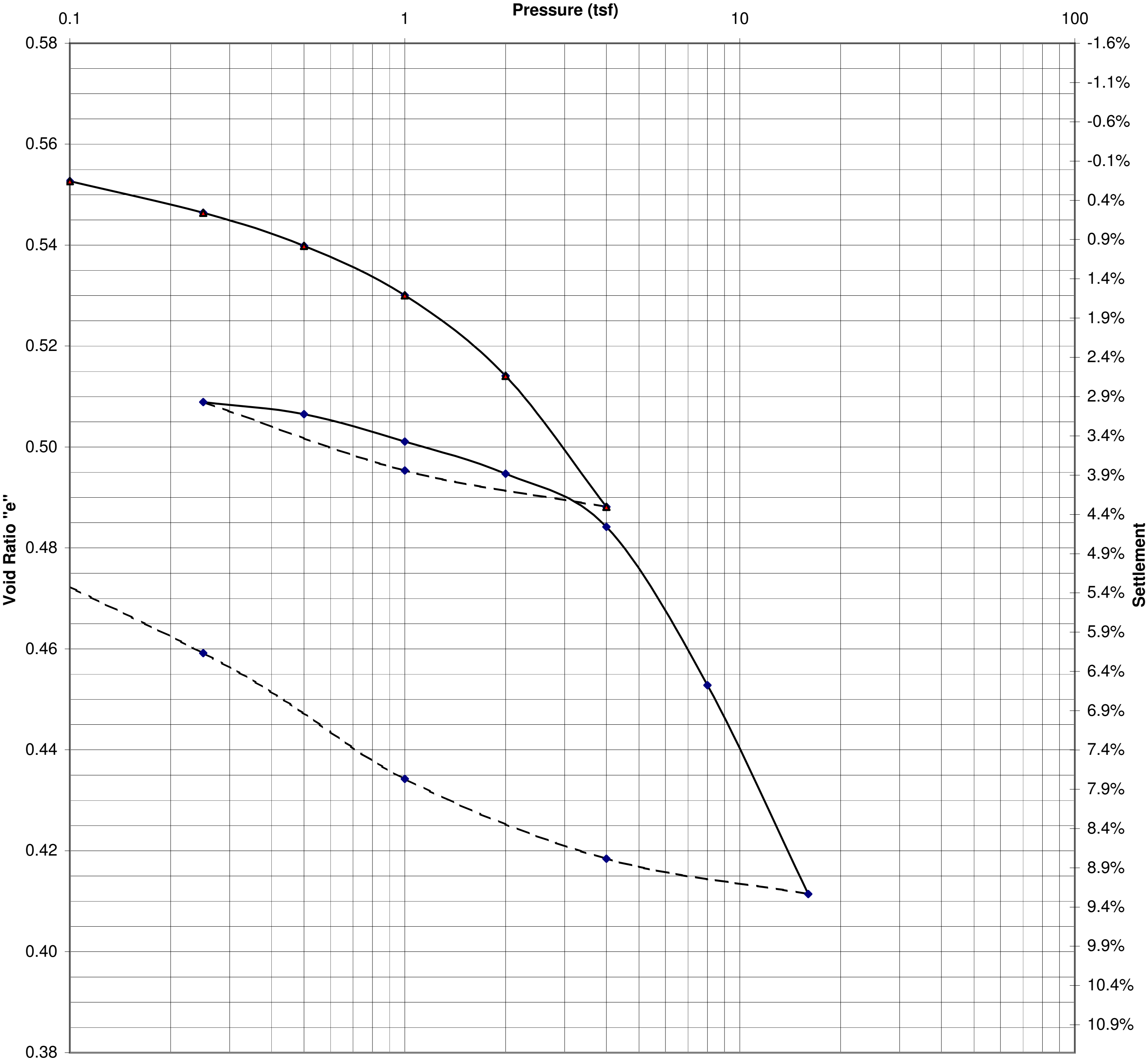
PARTICLE SIZES

Term	Particle Size
Boulder	Over 12”
Cobble	3” – 12”
Gravel	#4 – 3”
Coarse Sand	#10 – #4
Medium Sand	#40 – #10
Fine Sand	#200 – #40
Silt and Clay	passes #200 sieve

GRAVEL PERCENTAGES

Term	Range
A trace of gravel	2-4%
A little gravel	5-15%
With gravel	16-50%

Void Ratio and % Settlement vs. Log of Pressure



Project: Proposed Water Tower / Geotek Engineering & Testing Services, Inc.			Date: 12/3/19
Sample #:	Boring #: SB-2	Depth ft: 22.5-24.5	Job #: 12308
Soil Type: Sandy Lean Clay (CL)			
Initial W/C (%): 19.1	Dry Density (pcf): 109.9	LL: PL: PI:	Gs: 2.74 (Assumed)
Organic Content (%):	Initial Height (in.): 0.746	Diameter (in.): 2.505	e_o= 0.556
Preconsolidation Pressure (Pc): 2.7 tsf	Compression Index (Cc): 0.14	Recompression Index (Cr): 0.02	

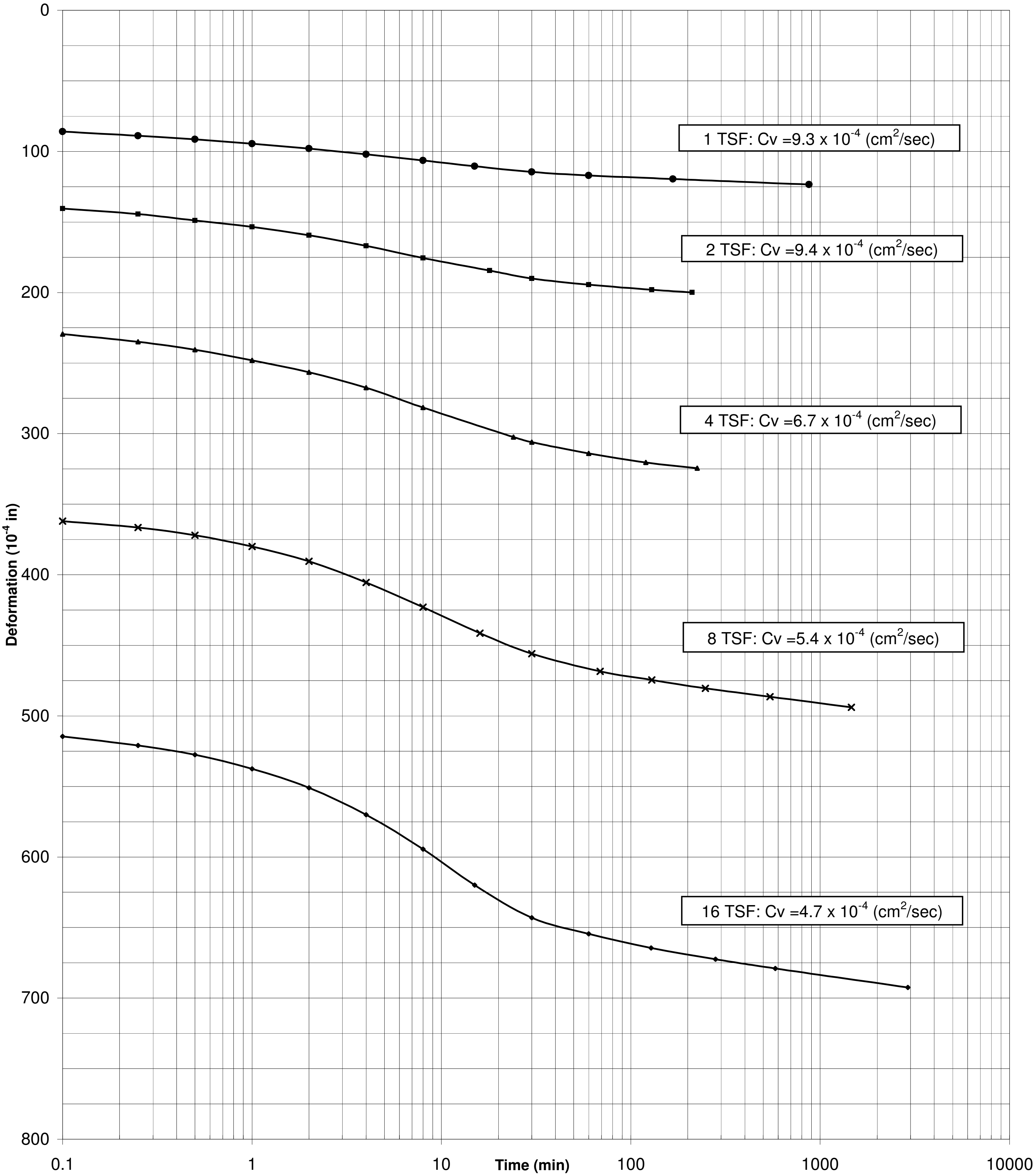
Remarks: Testing performed in general accordance with ASTM:D2435

9530 James Avenue South

SOIL ENGINEERING TESTING, INC.

Bloomington, Minnesota 55431

Consolidation Log of Time Curves



Project: Proposed Water Tower / Geotek Engineering & Testing Services, Inc.			Date: 12/3/19
Sample #:	Boring #: SB-2	Depth ft: 22.5-24.5	Job #: 12308

9530 James Avenue South

SOIL ENGINEERING TESTING, INC.

Bloomington, Minnesota 55431