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August 31, 2020

City of Volga
226 Kasan Avenue
PO Box 217
Volga, South Dakota 57071

Attn: Jameson Berreth

Subj: Geotechnical Exploration
Proposed Water Tower
City of Volga
E. 6th Street & Caspian Avenue
Volga, South Dakota
GeoTek #20-432

This correspondence presents our written report of the geotechnical exploration program for the referenced project. Our work was performed in accordance with your authorization. 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: Banner Associates, Inc., Attn: Joe Munson, PE

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APPENDIX A

GEOTECHNICAL EXPLORATION
PROPOSED WATER TOWER
CITY OF VOLGA
E. 6TH STREET & CASPIAN AVENUE
VOLGA, SOUTH DAKOTA
GEOTEK #20-432

INTRODUCTION

Project Information

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

Scope of Services

Our work was performed in accordance with the authorization of Jameson Berreth with the City of Volga. 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 southwest of the intersection of E. 6th Street and Caspian Avenue in Volga, South Dakota. A project location map (Figure 1) is attached showing the location of the site. The site is generally flat. The site was previously used for agricultural purposes.

Ground Surface Elevations & Test Boring Locations

The ground surface elevations at the test boring locations were provided by Banner Associates, Inc. and were 1,623.0 feet at test boring 1, 1,623.1 feet at test boring 2, 1,623.0 feet at test boring 3 and 1,622.7 feet at test boring 4. A site map (Figure 2) is attached showing the relative location of the test borings.

Subsurface Conditions

Four (4) test borings were performed at the site on April 15, 2020. The subsurface conditions encountered at the test boring locations are illustrated by means of the boring logs included in Appendix A.

The subsurface profile at the test boring locations consisted of the following soil types: topsoil materials, fine alluvium soils, coarse alluvium soils, glacial fluvial soils and glacial till soils. The thickness of the topsoil materials was ½ foot (test boring 3) and 1 foot (test borings 1, 2 and 4). The fine alluvium soils were encountered at test borings 1, 2 and 3 and extended to depths varying from 3 feet to 4 ½ feet. The coarse alluvium soils were encountered beneath the topsoil materials and fine alluvium soils. The coarse alluvium soils extended to depths of 14 feet and 14 ½ feet (elevation 1,609.0 feet to 1,608.2 feet). The glacial till soils were encountered beneath the coarse alluvium soils. The glacial fluvial soils were only encountered at test boring 1.

The topsoil materials consisted of lean clay soils. The fine alluvium soils consisted of lean clay soils. The coarse alluvium soils consisted of clayey sand soils and sand with silt soils. The glacial fluvial soils consisted of lean clay soils. The glacial till soils consisted of lean clay with sand soils and 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.

Water Levels

Measurements to record the groundwater levels were made at test borings 2, 3 and 4. A groundwater measurement was not made at test boring 1 due to the presence of drilling fluid that was used to advance the deep test boring. The time and level of the groundwater readings are recorded on the boring logs. Also, a summary of the groundwater levels is shown in Table 1.

Table 1. Groundwater Levels

Test Boring	Ground Surface Elevation, ft	Groundwater Level, ft	Elevation of Groundwater, ft
1	1,623.0	N/A	N/A
2	1,623.1	7	1,616.1
3	1,623.0	7	1,616.0
4	1,622.7	6 ½	1,616.2

The water levels may or may not be an accurate indication of the depth or lack of subsurface groundwater. The limited length of observation restricts the accuracy of the measurements. Long term groundwater monitoring was not included in our scope of work.

ENGINEERING REVIEW & RECOMMENDATIONS

Project Design Data

We understand that the project will consist of constructing a new water tower for the City of Volga in Volga, South Dakota. The water tower will have a capacity of approximately 750,000 gallons. The finished grade around the base of the water tower is expected to be near elevation 1,626.0 feet (grade raise of about 3 feet). No specific foundation loading information was provided, but we expect heavy foundation loads. We anticipate that the water tower will be supported by a spread/ring footing foundation (shallow foundation system) that will rest 8 feet to

10 feet below the finished grade. We assume that the width of the ring footing will be approximately 15 feet (based on 5,000 pounds per square foot (psf) bearing). We assume that the allowable total settlement is 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 a spread/ring footing foundation can be used for support of the proposed water tower after the recommended site preparation has been performed. In our opinion, the coarse alluvium soils and glacial till soils are suitable for support of the water tower.

Our groundwater measurements indicate that the groundwater level is near elevation 1,616.0 feet. In addition, waterbearing sand soils were encountered within the upper portion of the subsurface profile. Due to the groundwater level and the presence of waterbearing sand soils, it is our opinion that an extensive dewatering system will likely be needed if an excavation for the foundation of the water tower extends below elevation 1,616.0 feet. Therefore, it would be beneficial to have the foundation rest above elevation 1,616.0 feet. This may require raising the finished grade around the base of the water tower.

As an alternative to the spread/ring footing foundation, a deep foundation system of auger-cast piles could be used for support of the water tower. An intermediate foundation system of rammed aggregate piers or aggregate piers could also be an option; however, casing and extensive dewatering may be needed during installation. We have only provided specific recommendations for the auger-cast piles.

Site Preparation – Spread/Ring Footing Foundation

We recommend that the site preparation for the spread/ring footing foundation of the water tower consist of removing the topsoil materials and fine alluvium soils in order to expose the coarse alluvium soils. If an excavation required to expose the coarse alluvium soils extends below the design elevation, then we recommend placing and compacting granular structural fill up to the design elevation. Depending on the groundwater level during construction, we recommend compacting the exposed coarse alluvium soils prior to the placement of the granular structural fill or foundation. Please refer to Table 2 for a summary of the anticipated minimum excavation depths to remove the unsuitable soils encountered at the test boring locations. The depth of the excavation will likely vary within the footprint of the spread/ring footing foundation of the water tower.

Table 2. Estimated Excavation Depths – Spread/Ring Footing Foundation

Test Boring Number	Ground Surface Elevation, ft	Anticipated Excavation Depth, ft	Approximate Excavation Elevation, ft
1	1,623.0	4 ½	1,618.5
2	1,623.1	3	1,620.1
3	1,623.0	3 ½	1,619.5
4	1,622.7	1	1,621.7

If groundwater or saturated soils are encountered at the bottom of the excavation, then we recommend placing a layer (6 inches to 12 inches) of drainage rock at the bottom of the excavation prior to the placement of the granular structural fill or the foundation.

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 spread/ring footing 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 spread/ring footing foundation resting 8 feet to 10 feet below the finished grade, 5,000 psf bearing and a ring footing width of 15 feet), we estimate that the total settlement of the water tower will be on the order of 2 inches to 2 ½ inches. We also estimate that the differential tilting of the foundation will be on the order of 1 inch or less. 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 assume that the allowable total settlement for a shallow foundation system is 3 inches.

It is our opinion that a friction factor of 0.45 can be used between the natural sand soils, granular structural fill or drainage rock and the bottom of the concrete. The friction value is considered an ultimate value. We recommend applying a theoretical safety factor of at least 2.0.

Alternative Foundation Support Option – 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 3 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 3. 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	1,563	60	50
16	1,548	80	70
18	1,563	70	60
18	1,553	80	70
18	1,548	90	80

Notes: Alternative pile diameters and capacities could also be considered. The estimated pile tip elevations are based on a finished grade of approximately 1,626.0 feet with calculations starting around elevation 1,615.0 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:D1143). 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.

Depending on groundwater conditions at the bottom of the excavation (with the auger-cast piles), a layer of drainage rock (12 inches) may be needed 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.

Heavy Construction Equipment

The subgrade within and around the excavation for the water tower should be able to support the auger-cast pile rig (if used as a foundation system) and other construction equipment. In unstable areas, additional corrections may be needed to provide a stable condition.

Dewatering

As previously stated, our groundwater measurements indicate that the groundwater level is near elevation 1,616.0 feet. In addition, waterbearing sand soils were encountered within the upper portion of the subsurface profile. Due to the groundwater level and the presence of waterbearing sand soils, it is our opinion that an extensive dewatering system will likely be needed if an excavation for the foundation of the water tower extends below elevation 1,616.0 feet. The contractor should provide appropriate dewatering methods and equipment.

Lateral Loads & Foundation Backfill

We assume that a mixture of on-site clay soils and granular materials will be used as foundation backfill. All backfill placed next to and above the foundation should be compacted. If granular materials are used, then we recommend capping the granular materials with approximately 2 foot of clay soils to minimize infiltration of surface water. We recommend neglecting the soils within 5 feet of the ground surface 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 150 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 125 pcf above the groundwater level and a submerged unit weight of 63 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 gravel surfaced areas will be constructed as part of the project. Fine alluvium soils are expected to be encountered as subgrade soils. In our opinion, the fine alluvium soils will provide average subgrade support. In addition, some filling is expected in the gravel surfaced areas.

We recommend that the subgrade preparation in the gravel surfaced areas consist of removing the vegetation and highly organic materials. A removal depth of approximately 6 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 be needed if unstable areas are encountered. The additional corrections may include the following: moisture conditioning the soils (e.g. drying the soils by scarification), an overexcavation to remove and replace the unstable subgrade soils 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.

For the thickness of the gravel section, we recommend at least 4 inches of gravel surfacing over 6 inches of aggregate base course. It would be beneficial to provide a geotextile fabric beneath the gravel section. 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 could be expected.

Material Types & Compaction Levels

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.

Drainage Rock – The drainage rock should be crushed, washed and meet the gradation specifications shown in Table 4.

Table 4. 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

Foundation Backfill – We recommend that non-organic clay soils or granular materials 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. If granular materials are used, then we recommend capping the granular materials with approximately 2 foot of clay soils to minimize infiltration of surface water. Drying should be expected with the on-site clay 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. Some drying may be needed with the on-site clay soils. Organic materials should not be used as subgrade fill.

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.

Granular Subbase – If needed, the granular subbase should consist of crushed quartzite, recycled concrete or a crushed pit-run material meeting the gradation specifications shown in Table 5.

Table 5. 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

Recommended Compaction Levels – The recommended compaction levels listed in Table 6 are based on a material's maximum dry density value, as determined by a standard Proctor (ASTM: D698) test.

Table 6. 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: $S_S = 0.091$ g, $S_1 = 0.026$ g, $S_{MS} = 0.145$ g, $S_{M1} = 0.064$ g, $S_{DS} = 0.097$ g, $S_{D1} = 0.042$ 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 1 and 2 and were submitted for resistivity, pH, chloride content and sulfate content testing. The results of the laboratory tests are shown in Table 7.

Table 7. 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)
1	1 to 4 ½	Lean Clay (FA)	730	---	7.9	11	3
2	7 to 8 ½	Sand with Silt (CA)	5,150	---	8.7	3	6

Notes: The fine alluvium soils and coarse alluvium soils were received in a saturated condition. FA – fine alluvium soils and CA – coarse alluvium soils.

Generally, soils are considered mildly corrosive if the chloride content and sulfate content levels are below 100 mg/kg and 200 mg/kg, respectively, for soils with pH levels between 5 and 10. Soils are generally considered corrosive if the chloride content and sulfate content levels are higher than the levels discussed above. Based on the chloride content and sulfate content levels, the fine alluvium soils and coarse alluvium soils are considered mildly corrosive. Regarding the resistivity test results, the fine alluvium soils are considered extremely corrosive and the coarse alluvium soils are considered moderately 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 auger-cast piles. Detailed records should be kept for the auger-cast piles.

SUBSURFACE EXPLORATION PROCEDURES

Test Borings

We performed 4 SPT borings on April 15, 2020 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

REGISTERED PROFESSIONAL ENGINEER
REG. NO 10971
JARED E. HASKINS
SOUTH DAKOTA
8-31-20

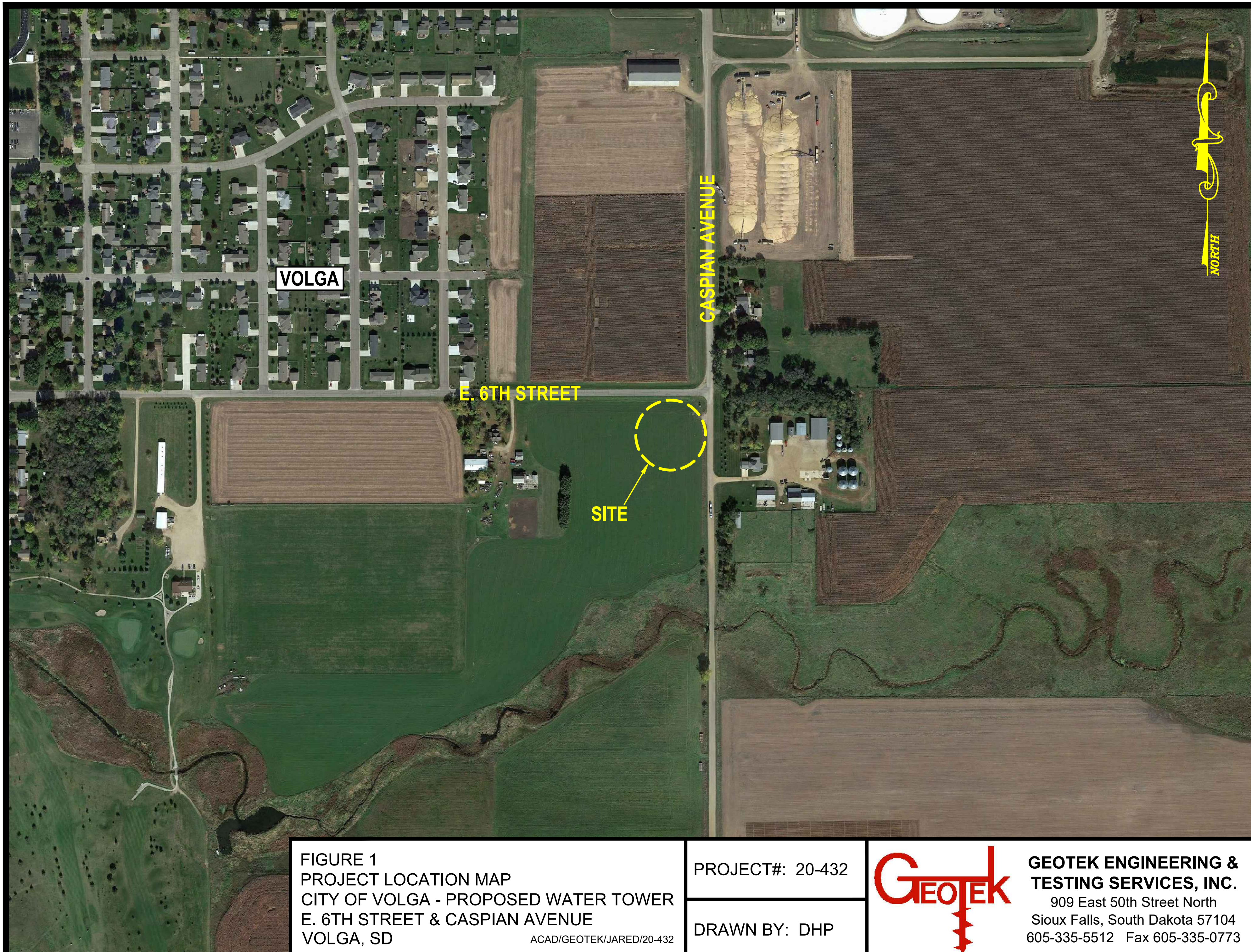

FIGURE 1
PROJECT LOCATION MAP
CITY OF VOLGA - PROPOSED WATER TOWER
E. 6TH STREET & CASPIAN AVENUE
VOLGA, SD

ACAD/GEOTEK/JARED/20-432

PROJECT#: 20-432

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FIGURE 2
TEST BORING LOCATION MAP
CITY OF VOLGA - PROPOSED WATER TOWER
E. 6TH STREET & CASPIAN AVENUE
VOLGA, SD

ACAD/GEOTEK/JARED/20-432

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909 E 50th St N
Sioux Falls, South Dakota, 57104
605-335-5512 Fax
jhaskins@geotekeng.com

GEOTECHNICAL TEST BORING LOG

GEOTEK # **20-432**

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

PROJECT **Proposed Water Tower, City of Volga, E. 6th Street & Caspian Avenue, Volga, SD**

SURFACE ELEVATION 1623.0 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
1	**LEAN CLAY**: very dark brown to black, moist	TOPSOIL			1	FA					
	LEAN CLAY: brown, moist, soft, (CL)	FINE ALLUVIUM	4		2	SPT	25				
4½	**SAND WITH SILT**: a trace of gravel, fine to medium grained, brown, dry, dense, (SP-SM)	COARSE ALLUVIUM	23		3	SPT					
7	**SAND WITH SILT**: a little gravel, medium grained, brown, waterbearing, medium dense to dense, percent passing the #200 sieve = 7% (at 8') (SP-SM)	COARSE ALLUVIUM	22		4	SPT					
			10		5	SPT					
14	**LEAN CLAY WITH SAND**: a trace of gravel gravel, brown and gray, moist, firm to stiff, (CL)	GLACIAL TILL	8		6	SPT	24	105	44	18	2000
			9		7	SPT	26	103			2000
24	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, very stiff, (CL)	GLACIAL TILL	21		8	SPT	21	108	46	18	4300
			23		9	SPT					
			21		10	SPT					
39	**LEAN CLAY WITH SAND**: a little gravel, dark grayish brown and dark gray, moist, very stiff, (CL)	GLACIAL TILL	22		11	SPT					

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
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START 4-15-20 COMPLETE 4-15-20 1:20 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Roy Hanson

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **20-432** BORING NO. **1 (2 of 2)**

PROJECT **Proposed Water Tower, City of Volga, E. 6th Street & Caspian Avenue, Volga, SD**

SURFACE ELEVATION 1623.0 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	LEAN CLAY WITH SAND: a little gravel, dark grayish brown and dark gray, moist, very stiff, (CL) *(Continued from previous page)*	GLACIAL TILL									
			21		12	SPT					
			23		13	SPT					
			22		14	SPT	21	108			4800
59	**LEAN CLAY**: brown and dark brown, moist, very stiff, (CL)	GLACIAL FLUVIAL	19		15	SPT					
64	**LEAN CLAY WITH SAND**: a little gravel, dark grayish brown and dark gray, moist, very stiff, (CL)	GLACIAL TILL	20		16	SPT					
			24		17	SPT					
			24		18	SPT					
			26		19	SPT					
81	Bottom of borehole at 81 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
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START 4-15-20 COMPLETE 4-15-20 1:20 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Roy Hanson

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **20-432** BORING NO. **2 (1 of 1)**

PROJECT **Proposed Water Tower, City of Volga, E. 6th Street & Caspian Avenue, Volga, SD**

SURFACE ELEVATION 1623.1 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
1	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
3	**LEAN CLAY**: brown, moist, stiff, (CL)	FINE ALLUVIUM	14		2	SPT					
	SAND WITH SILT: a little gravel, fine to medium grained, brown, moist to waterbearing, medium dense to dense, percent passing the #200 sieve = 6% (at 10') (SP-SM)	COARSE ALLUVIUM	25		3	SPT					
				▼							
			17		4	SPT					
			12		5	SPT					
			10		6	SPT					
14½					11	SH					
	LEAN CLAY WITH SAND: a trace of gravel, brown, moist, firm, a few lenses of sand (CL)	GLACIAL TILL	5		7	SPT	23	111			1500
					12	SH					
19½	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, very stiff, (CL)	GLACIAL TILL	25		8	SPT	20	110			8400
			18		9	SPT					
31			21		10	SPT					
	Bottom of borehole at 31 feet.										

WATER LEVEL MEASUREMENTS					
DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-15-20	4:47 pm	31	--	7	▼ 7
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START 4-15-20 COMPLETE 4-15-20 4:46 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **20-432**

BORING NO. **3 (1 of 1)**

PROJECT **Proposed Water Tower, City of Volga, E. 6th Street & Caspian Avenue, Volga, SD**

SURFACE ELEVATION 1623.0 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
0½	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
3½	**LEAN CLAY**: brown, moist, firm, (CL)	FINE ALLUVIUM	7		2	SPT					
	SAND WITH SILT: a little gravel, fine to medium grained, brown, moist to waterbearing, medium dense to dense, (SP-SM)	COARSE ALLUVIUM	18		3	SPT					
				▼							
			15		4	SPT					
			12		5	SPT					
14½			21		6	SPT					
19½	**LEAN CLAY WITH SAND**: a trace of gravel, brown, moist, firm, a few lenses of sand (CL)	GLACIAL TILL	7		7	SPT	22	109			2400
	LEAN CLAY WITH SAND: a little gravel, brown and gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	13		8	SPT					
			23		9	SPT					
31			20		10	SPT					
	Bottom of borehole at 31 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-15-20	4:41 pm	31	--	7	▼ 7
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START 4-15-20 COMPLETE 4-15-20 4:41 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **20-432** BORING NO. **4 (1 of 1)**

PROJECT **Proposed Water Tower, City of Volga, E. 6th Street & Caspian Avenue, Volga, SD**

SURFACE ELEVATION 1622.7 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
1	**LEAN CLAY**: very dark brown, moist, (CL)	TOPSOIL			1	HSA					
	SAND WITH SILT: a little gravel, fine to medium grained, brown, moist to waterbearing, loose to dense, percent passing the #200 sieve = 7% (at 10') (SP-SM)	COARSE ALLUVIUM	13		2	SPT					
			6	▼	3	SPT					
			18		4	SPT					
			10		5	SPT					
12	**CLAYEY SAND**: a trace of gravel, fine to medium grained, dark brown, wet, dense, percent passing the #200 sieve = 17% (at 13') (SC)	COARSE ALLUVIUM	16		6	SPT					
14½	**SANDY LEAN CLAY**: a trace of gravel, brown, moist, stiff, percent passing the #200 sieve = 52% (at 17') (CL)	GLACIAL TILL			11	SH					
			10		7	SPT	13	121			
19½	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, very stiff, (CL)	GLACIAL TILL	17		8	SPT	22	109			4400
			21		9	SPT					
31			18		10	SPT					
	Bottom of borehole at 31 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-15-20	4:34 pm	31	--	6.5	▼ 6.5
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START 4-15-20 COMPLETE 4-15-20 4:34 pm

METHOD
3.25" ID Hollow Stem Auger

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

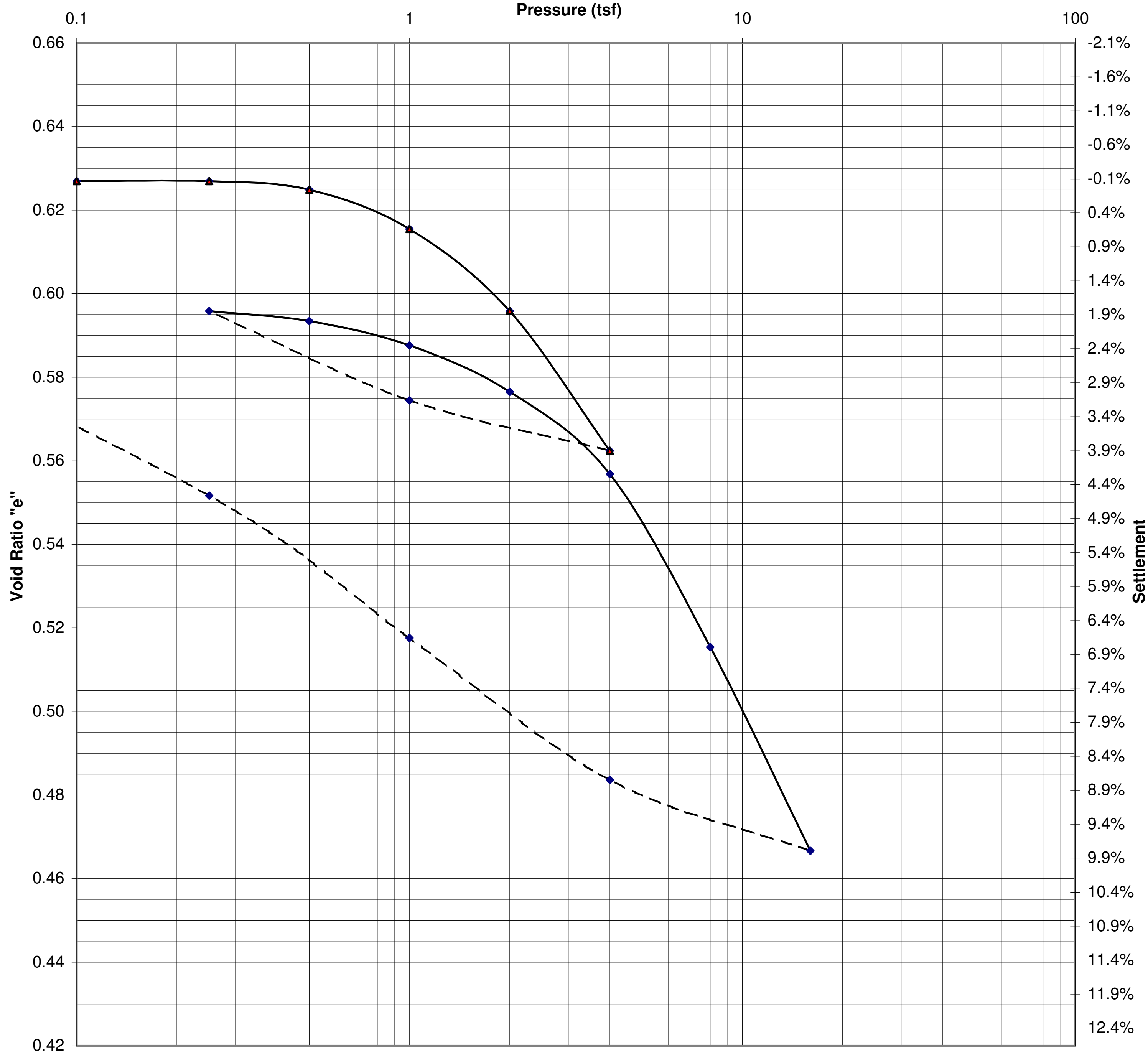
PARTICLE SIZES

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 - City of Volga - E. 6th Street & Caspian Avenue - Volga, SD - #20-432 / Geotek			Date: 5/5/20
Sample #:	Boring #: SB-2	Depth ft: 14.5-16.5	Job #: 12508
Soil Type: Sandy Lean Clay w/a little gravel (CL)			
Initial W/C (%): 22.7	Dry Density (pcf): 104.8	LL: PL: PI:	Gs: 2.73 (Assumed)
Organic Content (%):	Initial Height (in.): 0.760	Diameter (in.): 2.500	e_o= 0.626
Preconsolidation Pressure (Pc): 2.4 tsf	Compression Index (Cc): 0.16	Recompression Index (Cr): 0.04	

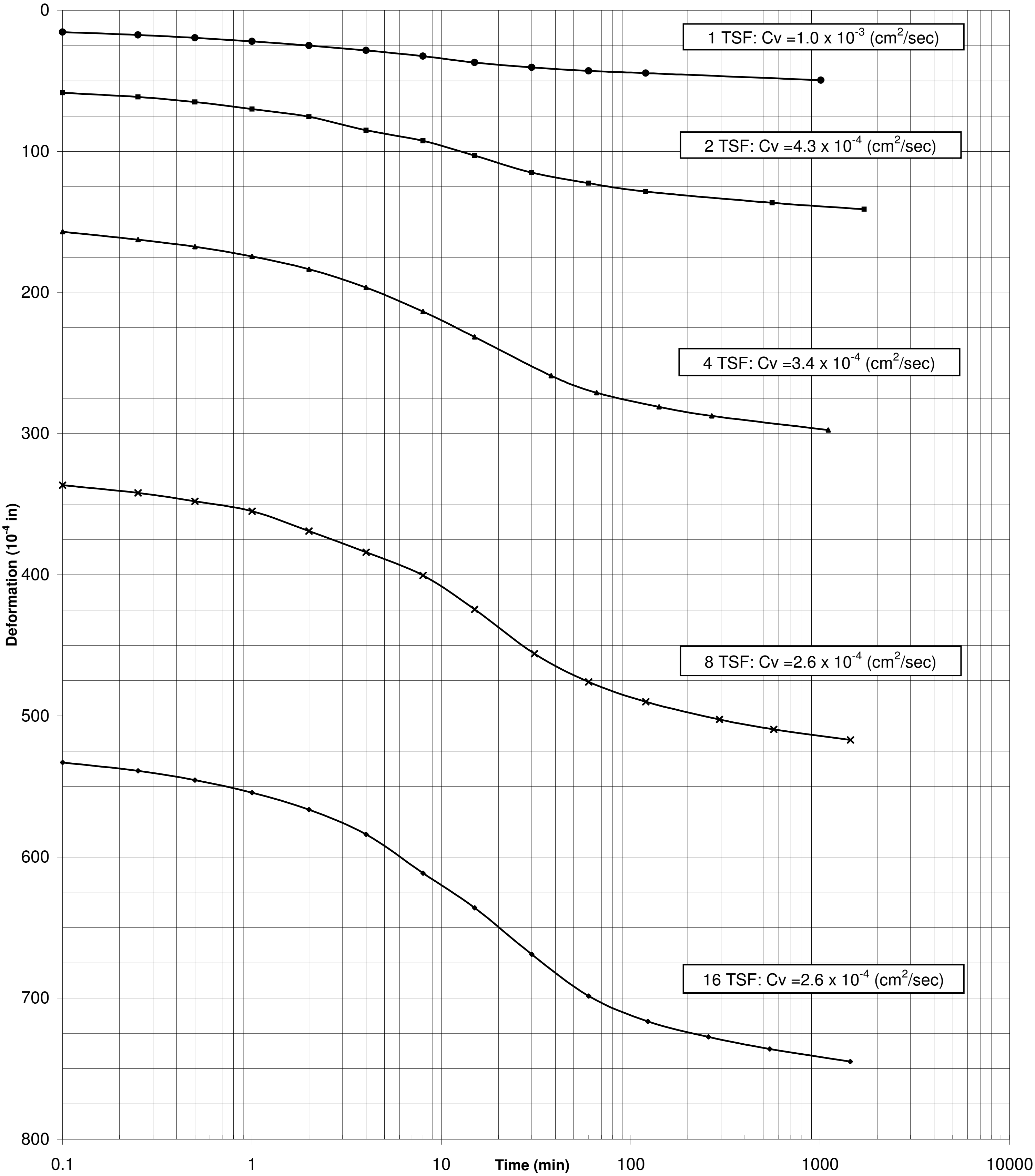
Remarks: Testing performed in general accordance with ASTM:D2435

9530 James Avenue South

SOIL ENGINEERING TESTING, INC.

Bloomington, Minnesota 55431

Consolidation Log of Time Curves



Project: Proposed Water Tower - City of Volga - E. 6th Street & Caspian Avenue - Volga, SD - #20-432 / Geotek			Date: 5/5/20
Sample #:	Boring #: SB-2	Depth ft: 14.5-16.5	Job #: 12508

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