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May 12, 2021

Banner Associates
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Sioux Falls, South Dakota 57108

Attn: Joe Munson, PE

Subj: Geotechnical Exploration
Proposed Water Tower
City of Lake Norden
Lake Norden, South Dakota
GeoTek #21-558

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.

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

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GEOTECHNICAL EXPLORATION
PROPOSED WATER TOWER
CITY OF LAKE NORDEN
LAKE NORDEN, SOUTH DAKOTA
GEOTEK #21-558

INTRODUCTION

Project Information

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

Scope of Services

Our work was performed in accordance with the authorization of Joe Munson with Banner Associates. The authorized scope of services included the following:

1. To perform 4 standard penetration test (SPT) borings to gather data on the subsurface conditions at the site.

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, pH, sulfate content, chloride content, resistivity, redox potential and sulfide 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 along the south side of Jay Headley Avenue (about 350 feet west of Park Street) in Lake Norden, South Dakota. A site location map (Figure 1) is attached showing the location of the site. The site is covered with vegetation. A large slough is located south of the site and an existing water tower is located just east of the site.

Ground Surface Elevations & Test Boring Locations

The ground surface elevations at the test boring locations were based on a temporary benchmark provided by Banner Associates and were 1,685.4 feet at test boring 1, 1,684.9 feet at test boring 2, 1,685.5 feet at test boring 3 and 1,685.7 feet at test boring 4. A test boring location map (Figure 2) is attached at the conclusion of this report showing the relative location of the test borings.

Subsurface Conditions

Four (4) test borings were performed at the site on April 26, 2021. 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: existing fill materials, fine alluvium soils, coarse alluvium soils and glacial till soils. The existing fill materials were only encountered at test borings 1 and 2 and extended to depths of 1 foot and 2 ½ feet. The fine alluvium soils were encountered at test borings 1, 3 and 4 and extended to depths varying from 2 feet to 3 feet. The coarse alluvium soils were encountered beneath the existing fill materials and fine alluvium soils and extended to depths varying from 7 feet to 9 ½ feet. The glacial till soils were encountered beneath the coarse alluvium soils and extended to the termination depth of the test borings. A subsurface diagram (Figure 3) is attached showing a cross-sectional view of the subsurface conditions encountered at the test boring locations.

The existing fill materials consisted of lean clay (CL). The fine alluvium soils consisted of lean clay (CL). The coarse alluvium soils consisted of clayey sand (SC) and sand with silt (SP-SM). The glacial till soils consisted of lean clay (CL), lean clay with sand (CL) and sandy lean clay (CL).

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 because drilling fluid was used to advance that 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	1,685.4	N/A (Rotary Mudding)	N/A
2	1,684.9	3	1,681.9
3	1,685.5	4	1,681.5
4	1,685.7	12	1,673.7

Note: If a delayed groundwater reading was made at test boring 4, then the groundwater level at test boring 4 would likely be similar to the groundwater levels at test borings 2 and 3.

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 Lake Norden in Lake Norden, South Dakota. The water tower will have a capacity of approximately 500,000 gallons. The finished grade around the base of the water tower is expected to be near elevation 1,687 feet (1 foot to 2 feet above existing grades). No specific foundation loading information was provided, but we expect heavy foundation loads. For a shallow foundation system, we assume that the allowable total settlement is 3 inches. For a deep foundation system, we assume that the allowable total settlement is ¾ inch.

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 a shallow foundation system (spread/ring footing foundation). The second option consists of an intermediate foundation system of rammed aggregate piers or aggregate piers. However, casing will likely be needed during the installation of the 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, if needed.

Our groundwater measurements generally indicate that the groundwater level is near elevation 1,682 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 be needed with the 3 options discussed above.

Dewatering

As indicated on the previous page, the presence of groundwater and waterbearing sand will require an extensive dewatering system. We recommend lowering the water levels to at least 2 feet below the deepest portion of the excavation prior to the actual excavation. Due to the sand soils encountered, the volume of dewatering will be high. The contractor should provide appropriate dewatering methods and equipment. Once the dewatering procedures have successfully lowered the water levels to at least 2 feet below the anticipated bottom of excavation, then the excavation can occur. The dewatering efforts will need to be maintained during construction.

Foundation Support Option 1 – Spread/Ring Footing Foundation

After the dewatering system is in place, we recommend that the site preparation for the spread/ring footing foundation of the water tower consist of removing any existing fill materials and fine alluvium soils in order to expose the coarse alluvium soils or glacial till soils. Following the initial removals, we recommend that an overexcavation be performed to a minimum depth of 1 foot below the bottom-of-foundation elevation. We recommend that observations and hand auger borings be performed at the bottom of the excavation to determine if further excavation is needed. The overexcavated area should be backfilled with a minimum of 1 foot of drainage rock. The thickness of the drainage rock beneath the foundation will exceed 1 foot in areas where the coarse alluvium soils or glacial till soils are exposed more than 1 foot below the bottom-of-foundation elevation.

The bottom of the excavation should be laterally oversized 1 foot beyond the edges of the foundation for each vertical foot of 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 4,000 pounds per square foot (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.

We performed a settlement analysis based on the following assumptions: a spread/ring footing foundation with an outside radius of 36 feet and an inside radius of 18 feet (ring width of 18 feet), bottom-of-foundation elevation near 1,677 feet and a bearing pressure of 4,000 psf. Based on our analysis, 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 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, estimated settlements and a coefficient of friction. 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. As previously stated, casing will likely be needed during the installation of the rammed aggregate piers or aggregate piers. Extensive dewatering will also be needed. The rammed aggregate pier or aggregate pier contractor may experience difficulties due to the casing and extensive dewatering needed during installation.

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.

We would like to point out that not all applications/systems are equivalent and each submitted design should be reviewed. In addition, the designer and installation contractor should have appropriate experience (e.g., at least 5 years of experience and at least 15 or more successfully completed projects).

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 2 that summarizes the estimated pile tip elevations and allowable capacities using a safety factor of 2.0. 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 2. 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	1,615	60	50
16	1,600	80	70
18	1,615	70	60
18	1,605	80	70
18	1,600	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 1,687 feet with calculations starting around elevation 1,675 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.

Drainage Rock with Foundation Support Options 2 & 3

In our opinion, a layer of drainage rock (minimum of 1 foot) should be placed at the bottom of the excavation prior to the installation of the rammed aggregate piers, aggregate piers or auger-cast piles. The drainage rock will also 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.

Lateral Loads & Foundation Backfill

We assume that a mixture of 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 feet 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 155 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 should be based on a high groundwater level. Groundwater was measured at depths of 3 feet (elevation 1,681.9 feet) and 4 feet (elevation 1,681.5 feet) at test borings 2 and 3.

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 understand that gravel surfaced areas will be constructed as part of the project. Based on the test borings, existing fill materials and fine alluvium soils are expected to be encountered as subgrade soils. In our opinion, the existing fill materials and fine alluvium soils will provide below average to average subgrade support.

We recommend that the subgrade preparation in the gravel surfaced areas consist of removing any vegetation and highly organic materials. A removal depth of 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 8 inches of gravel base. We also recommend placing 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 would be expected.

Material Types & Compaction Levels

Drainage Rock – The drainage rock should be crushed, washed and meet the gradation specifications shown in Table 3.

Table 3. 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 – If needed, 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 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. Some drying should be expected with the on-site clay soils.

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	98%
Foundation Backfill	95%
Non-Structural Areas	90%

Notes: Compaction specifications are not applicable with the drainage rock.

Recommended Moisture Levels – The moisture content of the clay backfill materials, when used as backfill around a foundation should be maintained within a range of plus or minus 2 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 = 0.093 g, S_1 = 0.027 g, S_{MS} = 0.149 g, S_{M1} = 0.064 g, S_{DS} = 0.099 g, S_{D1} = 0.043 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/III. 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 of the Soils

Soil samples were collected from test borings 2 and 4 and were submitted for pH, sulfate content, chloride content, resistivity, redox potential and sulfide content testing. The results of the pH, resistivity, redox potential and sulfide content testing are shown in Table 5 and the results of the chloride content and sulfate content testing are shown in Table 7.

Table 5. pH, Resistivity, Redox Potential and Sulfide Content Results

Test Boring	Depth (ft)	Soil Classification	pH	Resistivity (ohm-cm)	Redox Potential (mV)	Sulfide (mg/kg)
2	4 ½ to 9 ½	SC (Coarse Alluvium)	8.5	2546	134	<0.01
4	7 to 12	CL (Glacial Till)	8.1	1139	137	<0.01

Note: The resistivity values are minimum values (saturated condition).

Using the Ductile Iron Pipe Research Association's (DIPRA) 10-point system and the lab results shown in Table 5, we evaluated the corrosive potential of the tested soils. The 10-point system is based on resistivity, pH, redox potential, sulfides and moisture. An explanation of the point system is shown on Figure 4. The results of the evaluation are shown in Table 6. According to DIPRA, a value of 10 or more indicates that the soil is corrosive to underground piping and metals, while a value below 10 indicates that the soil is not corrosive to underground piping and metals. Based on Table 6, the coarse alluvium soils tested are not corrosive and the glacial till soils tested are corrosive. With that said, protective measures should be taken.

Table 6. Results of DIPRA 10-Point System Evaluation

Test Boring	Depth (ft)	Soil Classification	Total Value	Result
2	4 ½ to 9 ½	SC (Coarse Alluvium)	3	Not Corrosive
4	7 to 12	CL (Glacial Till)	12	Corrosive

Notes: A "poor drainage, generally wet" was used for the moisture condition (2 points).

Table 7. Sulfate & Chloride Content Test Results

Test Boring	Depth (ft)	Soil Classification	Sulfate (mg/kg)	Chloride (mg/kg)
2	4 ½ to 9 ½	SC (Coarse Alluvium)	147	20
4	7 to 12	CL (Glacial Till)	192	19

As shown in Table 7, the sulfate contents were 147 mg/kg and 192 mg/kg. Generally, the sulfate attack on concrete is considered mild if the sulfate content is below 150 mg/kg, moderate if the sulfate content is between 150 mg/kg and 1,500 mg/kg and severe if the sulfate content is above 1,500 mg/kg. Based on the test results, the potential sulfate attack on the concrete will be mild for the coarse alluvium soils and moderate for the glacial till soils. Type II cement could be considered for the potential moderate sulfate attack. Regarding the chloride content levels, levels below 250 mg/kg are considered mildly corrosive.

CONSTRUCTION CONSIDERATIONS

Groundwater & Surface Water

Water will 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 April 26, 2021 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), pH, sulfate content, chloride content, resistivity, redox potential and sulfide content. The strength tests consisted of unconfined compressive strength. 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

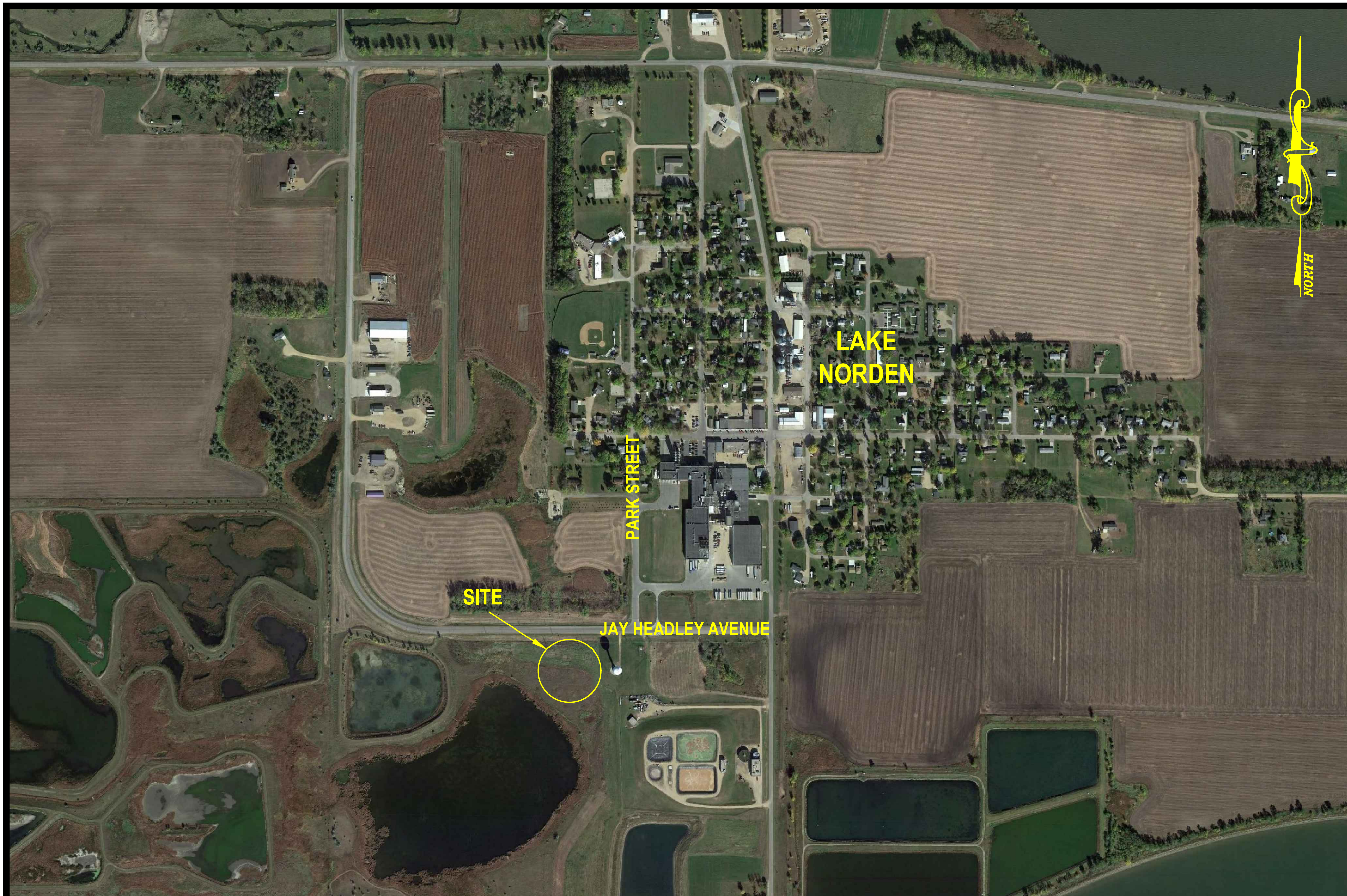

FIGURE 1
SITE LOCATION MAP
PROPOSED WATER TOWER
CITY OF LAKE NORDEN
LAKE NORDEN, SD

ACAD/GEOTEK/JARED/21-558

PROJECT#: 21-558

DRAWN BY: MAB

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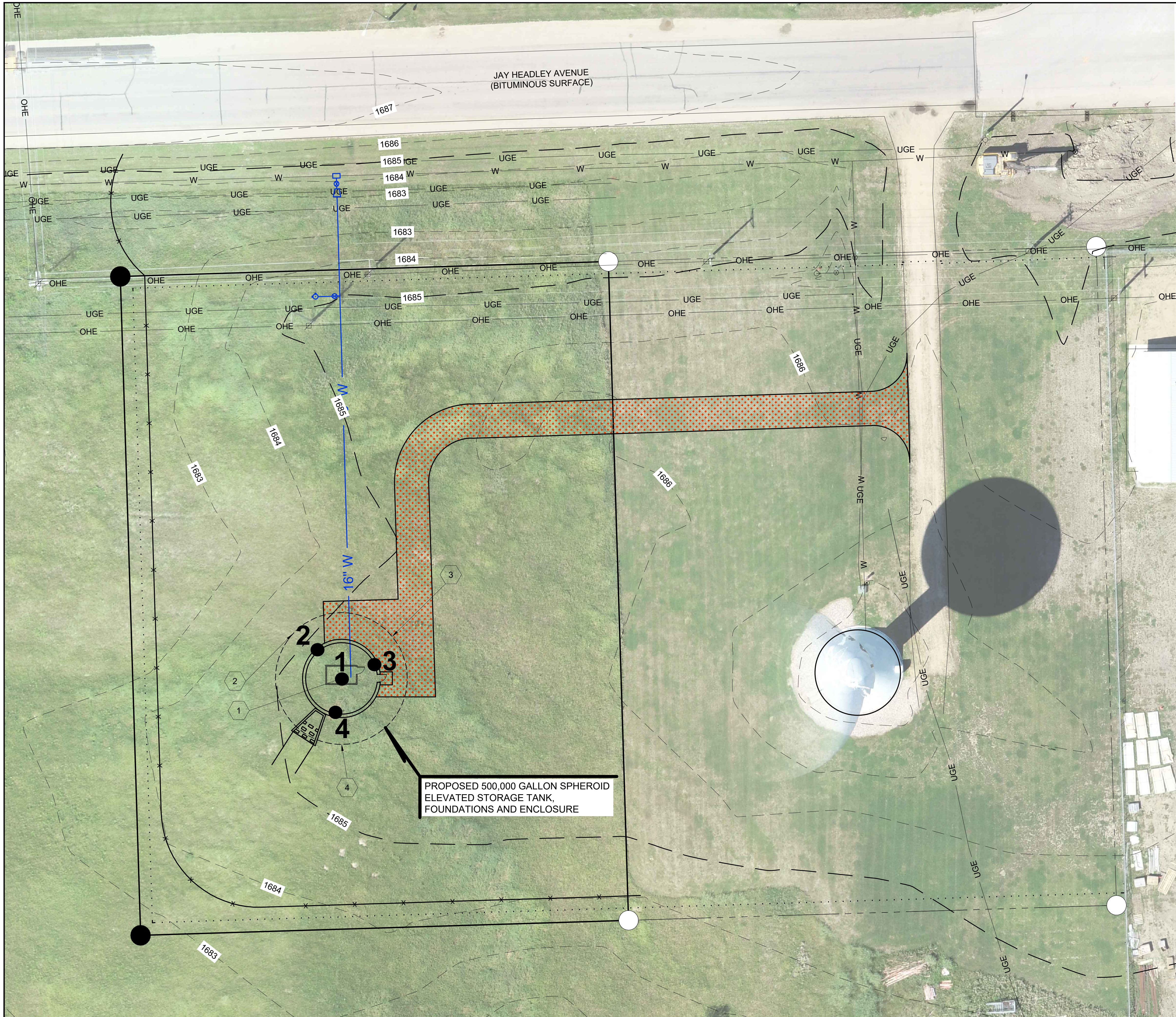
Figure 2



SOIL BORING LOCATIONS			
POINT #	DESCRIPTION	NORTHING	EASTING
1000	SB-1	283480.61	2694411.18
1001	SB-2	283498.67	2694390.93
1002	SB-3	283497.96	2694432.06
1003	SB-4	283453.46	2694411.18

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PROJECT / SHEET TITLE :
LAKE NORDEN WATER TOWER - 2021
OVERALL LAYOUT
LAKE NORDEN, SOUTH DAKOTA

REV.	DATE	DESCRIPTION

JOB No.:	23417.00.01
DATE:	MAY 2021
DESIGNED BY:	JDB
CHECKED BY:	BEN
DRAWN BY:	AME

0 1/2" 1"
SCALE REDUCTION BAR

SHEET No. :

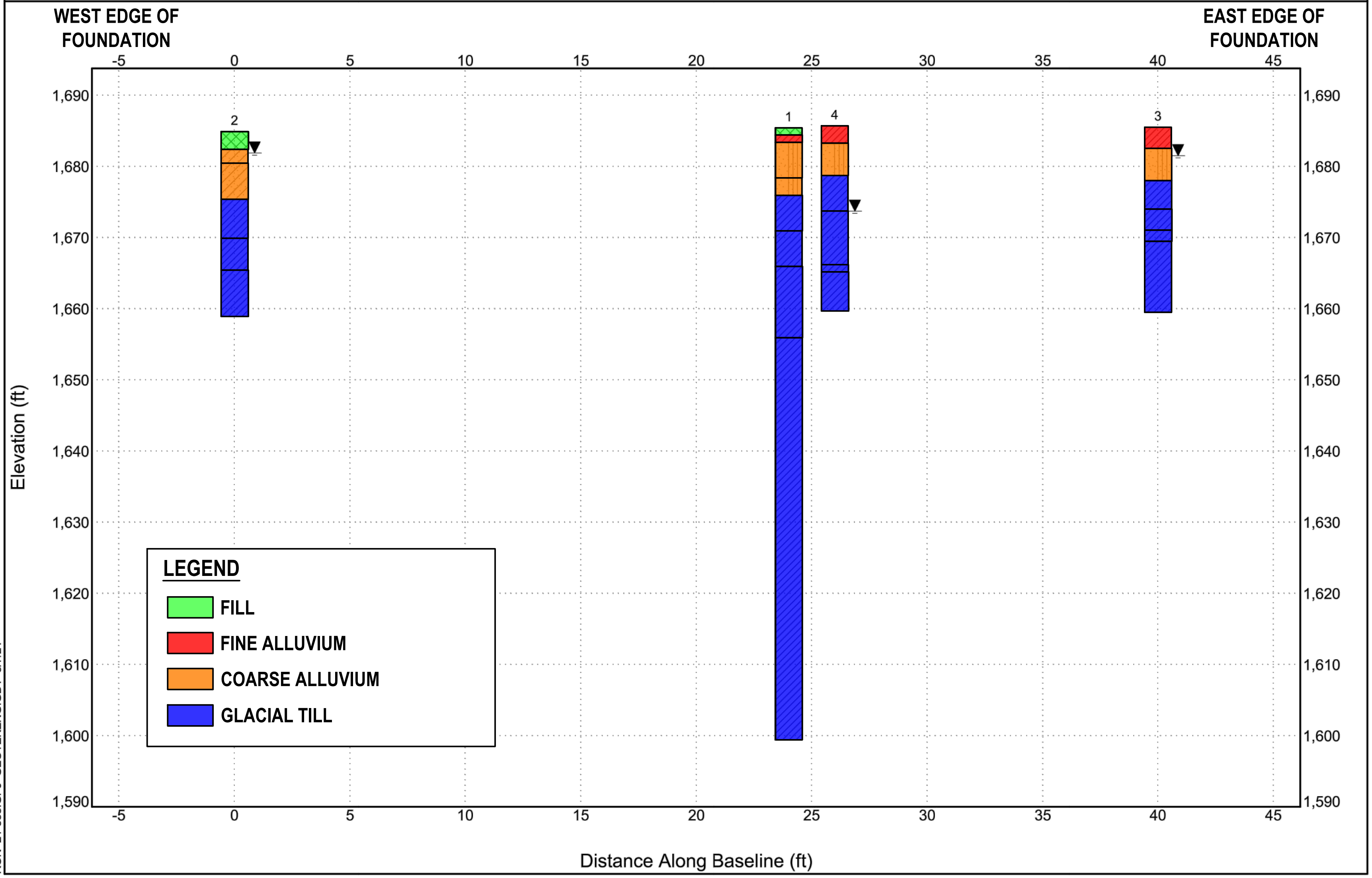
FIGURE 3 SUBSURFACE DIAGRAM

CLIENT

PROJECT NUMBER 21-558

PROJECT NAME Proposed Water Tower

PROJECT LOCATION



RON 21-558.GPJ GEOTEKENG.GDT 5/7/21

FIGURE 4

Table A.1 Soil-test evaluation

Soil Characteristics Based on Samples Taken Down to Pipe Depth		
Resistivity—ohm-cm (based on water-saturated soil box):		Points*
	<1,500	10
	≥1,500–1,800	8
	>1,800–2,100	5
	>2,100–2,500	2
	>2,500–3,000	1
	>3,000	0
pH:		
	0–2	5
	2–4	3
	4–6.5	0
	6.5–7.5	0†
	7.5–8.5	0
	>8.5	3
Redox potential:		
	> +100 mV	0
	+50 to +100 mV	3.5
	0 to +50 mV	4
	Negative	5
Sulfides:		
	Positive	3.5
	Trace	2
	Negative	0
Moisture:		
	Poor drainage, continuously wet	2
	Fair drainage, generally moist	1
	Good drainage, generally dry	0

*Ten points or greater indicates that soil is corrosive to ductile-iron pipe; protection is needed. Refer to paragrapl A.3 for a description of Uniquely Severe Environments and additional considerations.

†If sulfides are present and low (<100 mv) or negative redox-potential results are obtained, add three points for this range.

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **21-558**

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

PROJECT **Proposed Water Tower, City of Lake Norden, Lake Norden, SD**

SURFACE ELEVATION 1685.4 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
1	**FILL, MOSTLY LEAN CLAY**: brown and black, moist	FILL			1	FA					
2	**LEAN CLAY**: grayish brown, moist, (CL)	FINE ALLUVIUM	12		2	SPT	16				
	SAND WITH SILT: a little gravel, medium to coarse grained, brown, waterbearing, medium dense to dense, percent passing the #200 sieve = 9% (at 3') (SP-SM)	COARSE ALLUVIUM	26		3	SPT					
7	**SAND WITH SILT**: a little gravel, medium to coarse grained, gray, waterbearing, dense, percent passing the #200 sieve = 10% (at 8') (SP-SM)	COARSE ALLUVIUM	24		4	SPT	19				
9½	**LEAN CLAY WITH SAND**: a little gravel, brown and gray, moist, stiff, (CL)	GLACIAL TILL	14		5	SPT	22	104			5000
14½	**SANDY LEAN CLAY**: a little gravel, gray, moist, stiff, (CL)	GLACIAL TILL	14		6	SPT	20	113			2600
19½	**LEAN CLAY**: a trace of gravel, gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	15		7	SPT	23	105			4300
			17		8	SPT	22	105	38	16	4200
29½	**LEAN CLAY WITH SAND**: a little gravel, gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	15		9	SPT					
			15		10	SPT					
			15		11	SPT	22	107			3400
			15		12	SPT					

START 4-26-21 COMPLETE 4-26-21 12:27 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Mike Wagner

WATER LEVEL MEASUREMENTS

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

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **21-558**

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

PROJECT **Proposed Water Tower, City of Lake Norden, Lake Norden, SD**

SURFACE ELEVATION 1685.4 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, gray, moist, stiff to very stiff, (CL) *(Continued from previous page)*	GLACIAL TILL									
			16		13	SPT					
			17		14	SPT					
			22		15	SPT					
			22		16	SPT					
			21		17	SPT					
			22		18	SPT					
			20		19	SPT					
86			19		20	SPT					
	Bottom of borehole at 86 feet.										

WATER LEVEL MEASUREMENTS

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

START 4-26-21 COMPLETE 4-26-21 12:27 pm

METHOD
Rotary Mud Drilling

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **21-558** BORING NO. **2 (1 of 1)**

PROJECT **Proposed Water Tower, City of Lake Norden, Lake Norden, SD**

SURFACE ELEVATION 1684.9 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
2½	**FILL, MOSTLY LEAN CLAY**: brown and black, moist	FILL			1	HSA					
4½	**CLAYEY SAND**: a trace of gravel, medium grained, dark brown, wet, medium dense, (SC)	COARSE ALLUVIUM	11	▼	2	SPT					
9½	**CLAYEY SAND**: a little gravel, medium to coarse grained, brown, waterbearing, dense, percent passing the #200 sieve = 13% (at 8') (SC)	COARSE ALLUVIUM	22		3	SPT					
			19		4	SPT	19				
15	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, very stiff, (CL)	GLACIAL TILL	18		5	SPT	25	103	36	17	2400
					10	SH					
			16		6	SPT	21	108			
19½	**LEAN CLAY WITH SAND**: a little gravel, gray, moist, stiff, (CL)	GLACIAL TILL	11		7	SPT					
					11	SH					
26	**LEAN CLAY**: a trace of gravel, gray, moist to wet, stiff, (CL)	GLACIAL TILL	13		8	SPT	26	101			1000
			13		9	SPT	23	107			
	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-26-21	2:21 pm	26	--	22	4
4-26-21	4:27 pm	26	--	11	▼ 3
--	--	--	--	--	--
--	--	--	--	--	--

START 4-26-21 COMPLETE 4-26-21 2:17 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **21-558** BORING NO. **3 (1 of 1)**

PROJECT **Proposed Water Tower, City of Lake Norden, Lake Norden, SD**

SURFACE ELEVATION 1685.5 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	LEAN CLAY: grayish brown, moist, (CL)	FINE ALLUVIUM			1	HSA					
3			8		2	SPT					
	SAND WITH SILT: a little gravel, medium to coarse grained, brown, moist to waterbearing, dense, percent passing the #200 sieve = 10% (at 5') (SP-SM)	COARSE ALLUVIUM	19	▼	3	SPT	16				
7½	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff, (CL)	GLACIAL TILL	12		4	SPT					
					10	SH					
11½	**SANDY LEAN CLAY**: a little gravel, gray, moist to wet, stiff, with lenses of sand (CL)	GLACIAL TILL	11		5	SPT	20	109			
			11		6	SPT	18	112			1000
14½	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff, (CL)	GLACIAL TILL	12		7	SPT	21	106			2200
16	**LEAN CLAY WITH SAND**: a little gravel, gray, moist, stiff, (CL)	GLACIAL TILL									
			12		8	SPT					
26			12		9	SPT					
	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-26-21	3:11 pm	26	--	23	6
4-26-21	4:27 pm	26	--	18	▼ 4
--	--	--	--	--	--
--	--	--	--	--	--

START 4-26-21 COMPLETE 4-26-21 3:10 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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GEOTECHNICAL TEST BORING LOG

GEOTEK # **21-558** BORING NO. **4 (1 of 1)**

PROJECT **Proposed Water Tower, City of Lake Norden, Lake Norden, SD**

SURFACE ELEVATION 1685.7 ft

DEPTH in FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO.	SAMPLE TYPE	WC	D	LL	PL	QU
	LEAN CLAY: brown, moist, (CL)	FINE ALLUVIUM			1	HSA					
2½	**SAND WITH SILT**: a little gravel, medium to coarse grained, brown, moist to waterbearing, dense, (SP-SM)	COARSE ALLUVIUM	16		2	SPT					
			18		3	SPT	12				
7	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff to very stiff, (CL)	GLACIAL TILL	14		4	SPT					
			17		5	SPT	19	113			
12	**LEAN CLAY WITH SAND**: a little gravel, gray, moist, stiff to very stiff, (CL)	GLACIAL TILL	17	▼	6	SPT					
					10	SH					
			14		7	SPT	18	116			
19½	**LEAN CLAY WITH SAND**: a little gravel, brown, moist, stiff, (CL)	GLACIAL TILL	13		8	SPT	20	108			2600
20½	**LEAN CLAY**: a trace of gravel, gray, moist, stiff, (CL)	GLACIAL TILL									
			14		9	SPT					
26	Bottom of borehole at 26 feet.										

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	WATER LEVEL
4-26-21	4:28 pm	26	--	16	▼ 12
--	--	--	--	--	--
--	--	--	--	--	--
--	--	--	--	--	--

START 4-26-21 COMPLETE 4-26-21 4:24 pm

METHOD
3.25" ID Hollow Stem Auger

CREW CHIEF Mike Wagner

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%

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