Stabilization and Foundation Assessment Report
St. Vrain Mill
Mora, New Mexico

Prepared for:

St. Vrain Mill Preservation and Historical Foundation
P.O. Box 1282
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Project No. 140571

September 28, 2015

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1.0 INTRODUCTION

This report presents Engineering Analytics, Inc. (EA) recommendations for the stabilization and structural assessment of the St. Vrain Mill in Mora, New Mexico. The proposed repair of the St. Vrain Mill will include the stabilization of the mill foundation and repointing of masonry cracks in the walls. The work was conducted based on our proposal to the Historic Foundation dated April 15, 2015.

The purpose of this report is to provide a summary of our field investigation, geotechnical engineering recommendations, and design for:

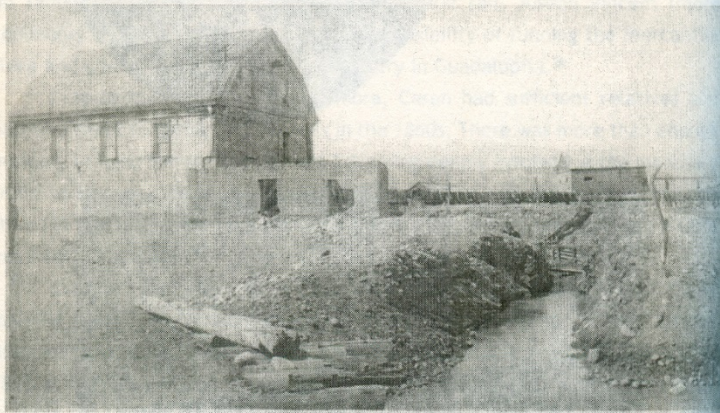
- Subsurface conditions;
- Groundwater conditions at the time of investigation;
- Foundation repair recommendations; and
- Other design and construction recommendations pertaining to the geotechnical aspects of the proposed repair.

The conclusions and recommendations contained in this report are based on the data collected during the field exploration and laboratory testing for this project and our experience with similar geotechnical and geological conditions. This work was funded by the St Vrain Mill Preservation and Historical Foundation through grants from the New Mexico Economic Development Department and the New Mexico Intervention Fund of the National Trust for Historic Preservation.

2.0 EXISTING CONDITIONS

The existing mill structure is a 3 story masonry block structure constructed in 1864. The structure has a footprint of 50 feet by 41 feet and the masonry wall is approximately 30 inches thick. . The north 1/3 of the structure has significant structural distress. Based on our site visit, review of photographs, review of the 2003 ATR institute report, and review of drawings provided by Spears Horn Architects the foundation system is composed of a stone foundation placed in “a shallow trench” (ATR, 2003).

It is not known for certain when the cracks in the east and west foundation walls developed. However, the timing of the distress is generally understood. The photograph in Figure 1 shows the mill with an intact east wall in the 1880-1890’s. Photographs from the 1930’s, 1976 and 1987 show the significant extent of the crack and wall separation. The maximum horizontal separation of 8 inches and geometry of the separation on the east wall is consistent from 1976 through 2015. The current large cracks on the east and west walls extend from the exterior face of wall to the interior face of the wall. The crack on the east wall was measured to be about 12 feet from the north wall and about 6 inches wide at the second floor of the building. The crack on the west wall was measured to be about 14 feet from the north wall and about 4 inches wide at the second story.



19. Early photograph of Ceran's stone mill. New Mexico Department of Tourism Collection (courtesy New Mexico State Records Center and Archives, Collection 1987-066, Photo #001934)

Figure 1 Mora Mill Circa 1880-1890

3.0 SITE GEOLOGY

The geology of the site was evaluated by reviewing current aerial photographs of the site and vicinity, geologic maps of the area, and information obtained from the boring at the site. The geologic map by the New Mexico Bureau of Geology and Mineral Resources (2003) indicates that the site is underlain by alluvium overlying Paleoproteroterozoic granitic plutonic rocks. A review of aerial photos indicates the potential of an infilled creek oxbow in the area of the mill

4.0 FIELD INVESTIGATION

Engineering Analytics conducted a field investigation June 25, 2015 that included drilling of one exploratory borehole (EA-B1) to a depth of 20.5 feet below the ground surface (bgs) and visual observation of the crack in the east and west walls of the building. . In addition, three grout samples were collected from the walls. The overall site map, which includes the borehole and grout sample locations, is presented on Sheet 1 of the attached drawings.

Drilling was performed by Elite Drilling Services, LLC. of Denver, Colorado, using a CME 75 drill rig equipped with 7-inch outside diameter hollow stem augers. Personnel from EA supervised the drilling and logged the materials encountered in the boreholes. California and Split spoon samples were collected at approximately 5-foot intervals in the boring. Auger refusal was encountered at a depth of 20.5. The boring log and site visit photographs are provided in Appendix B of this report.

5.0 LABORATORY TESTING

Laboratory testing was conducted on selected samples obtained from boring EA-B1 to measure geotechnical engineering properties of the underlying soils. Laboratory testing included measurements of water content, dry density, grain size analyses, and completion of a direct shear test. The laboratory testing was performed by Smith Geotechnical Engineering Consultants in

Fort Collins, Colorado. The laboratory test results are included as Appendix C and are summarized as follows:

Water Content and Dry Density: Measurements of water content and dry density were conducted on two samples in accordance with ASTM D2216 and D2937, respectively. The values of water content were 6.4 and 16.3 percent. The values of dry density were 108.0 and 94.2 pcf.

Grain Size Analyses: Grain size analyses were completed on three samples collected from boring EA-B1 in accordance with ASTM D422. The percent passing the #200 sieve ranged from 4.1 and 5.4 percent.

Direct Shear Test: A direct shear test was performed on a selected sample from EA-B1 in accordance with ASTM D3080. The direct shear test resulted in a friction angle of 35 degrees and a measured cohesion value of 122.4 psf.

6.0 STRUCTURAL ASSESSMENT

The existing cracks and wall separation are now considered part of the historic fabric of the structure and are acceptable in their current condition as long as the structure is habitable for the general public. A visual evaluation of the masonry walls and foundations was performed by EA to develop recommendations and design for stabilization of the walls and foundations. The walls were evaluated for repair of the cracks. The evaluation did not include the structural capacity of the walls or compliance with building codes.

The current extent of the cracking and wall separation does not allow the building to be used for its intended purposes without some amount of long term monitoring and wall and/ or foundation stabilization. The walls are approximately 30 inches thick and 23 feet tall with a weight of about 8.6 kips per liner foot.

The 2012 International Building Code requirements and our recommendations for floor and roof live loads are:

First floor: 125psf
Second floor: 60 psf
Third floor: 40 psf
Roof: 20 psf
Roof snow load: 15 psf

Adding the floor dead and live loads to the dead load of the walls results in a lineal foot load of 11.0 kips/LF and a required allowable footing bearing pressure of 4,410 psf. The results of our field investigation indicate the existing soils are capable of supporting an allowable soil bearing pressure of 3,500 psf. This indicates the soils would be overstressed by the total dead and live loads of the structure.

7.0 RECOMMENDATIONS

7.1 Foundation and Wall Stabilization

Several foundation stabilization options were evaluated for stabilizing the existing foundation system while maintaining the historic nature of the building. These options included:

- Installing a long term monitoring instruments to monitor the north wall for movement as the mill is renovated
- Underpinning and stabilizing the walls with helical piers
- Underpinning and stabilizing the walls with micropiles
- Reconnecting the north 1/3 of the structure walls to the remaining part of building by tensioned rods on the interior of the structure
- Reconnecting the north 1/3 of the structure walls to the remaining part of building by tensioned cables around the perimeter of the structure
- Grouting of the existing gravel foundation under the walls and underlying soils to increase support of the walls and stabilizing the walls

The first option of long term monitoring is recommended as a long term evaluation of the north wall once the wall is stabilized. The monitoring can be performed using visual crack gauges such as Avonguard crack monitors that can be attached across existing cracks.

The second and third options consist of helical piers or micropiles to support the north half of the structure by transferring the structure loads to the relatively dense soils at 20 feet below the base of the walls. However these foundation systems have several limitations for this project. The existing stone masonry wall has a dead load of approximately 8 kips/ LF. This dead load in addition to building live loads would require helical piers on 3-foot spacings and micropiles on 4 to 5-foot spacings. The underlying soils are relatively dense sands and gravels that will be difficult for helical piers to penetrate to develop their design load capacity. The use of helical piers or micropiles would require the additional cost of a reinforced concrete grade beam under the existing stone masonry walls to attach the piers or piles to. While possible to use micropiles to stabilize the foundation, it was determined that the existing stone foundation system would make it very difficult and costly to attach and support a helical pier or micropile foundation system.

The fourth and fifth options use tensioned cables or tie rods to connect the north wall to the rest of the structure. The 1976 plans from W.F. Turney and Associates identified the use of interior tensioned rods to connect the north wall to the south wall of the structure. This method would stabilize the wall but would not provide long term stabilization of the north wall foundation. The use of exterior tensioning cables is typically used on cylindrical structures such as concrete grain elevators to increase allowable hoop stress in the walls. This method is not considered practical on structures with 90 degree corners where stress concentrations can create cracking of the walls.

The existing stone masonry walls are unreinforced and not designed for lateral stressing that tensioning cables would apply. For these reasons these methods are not considered feasible for the project.

The sixth option consisting of stabilizing the north wall by grouting is the most feasible. The results of the grain size analyses, presented in Section 4.0, indicate that the underlying soils would be amenable to permeation grouting and compaction grouting to stabilize north 1/3 of the structure. Permeation grouting and compaction grouting allow the foundation and building to be stabilized with minimal excavation at the base of the stone masonry walls. This method does not require a mechanical connection between the stone masonry and the underlying foundation grouting. Therefore permeation grouting and compaction grouting were selected as the most appropriate system to stabilize the foundation and wall and partially relevel the north 1/3 of the building. The grouting will need to extend beyond the north 1/3 of the structure to develop a transition zone with the southern 2/3 of the structure. This transition zone will reduce the potential for differential settlement between the north and south portions of the structure in the future.

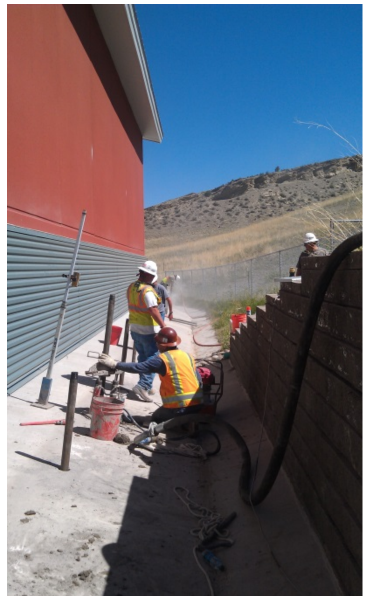
<u>Permeation Grouting</u>

Permeation grouting solidifies granular soils into sandstone-like masses by permeation with a low viscosity grout consisting of micro-fine cement. Permeation grouting offers the advantages of being easily performed where access and space is limited. Sandy soils with low fines content are best suited for this technique. Typically, a pipe is grouted into a predrilled hole under the foundation. The grout is then injected under pressure through the ports located along the length of the pipe. As the grout permeates the soil it solidifies it into a sandstone-like mass. The grouted soil has increased strength and stiffness, and reduced permeability. This stiffer soil mass will act as a grade beam and will allow some releveling of the structure using compaction grouting below the permeation grouted soil mass.

The proposed grouting locations are shown on Sheet 2. The permeation grouting locations are to be located at approximately 4 feet on center around the exterior of the building. The grouting depth should extend 4 feet below the bottom of the stone foundation. Due to the high groundwater table we recommend that the permeation grout consist of micro fine cement. The contractor should provide their mix design for approval by the engineer prior to grouting.

<u>Compaction Grouting</u>

Compaction grouting displaces and densifies loose granular soils and reinforces fine grained soils by the staged injection of aggregate grout. The compaction grouting increases the surrounding soils density, friction angle and stiffness, and the grout columns reinforce the soils within the treatment zone. An injection pipe will be advanced through the permeation grouted layer to the maximum treatment depth. The grout is then injected as the pipe is slowly extracted in lifts, creating a column of grout bulbs. As the pipe is extracted and elevation of the solidified permeation grouted soil mass is reached the compaction grout can be used to lift the building in an effort to relevel the structure.



Grout Pipe Placement

The compaction grouting locations are shown on Sheet 2 and are to be located at approximately 8 feet on center on both the interior and exterior of the building. Compaction grouting should be commenced after the permeation grout has had time to cure. The compaction grouting should be implemented in the bottom up method starting at a depth of 20 feet below the ground surface until the depth of the permeation grouting is intersected or until ground or building heave is observed. The contractor should provide their mix design for approval by the engineering prior to grouting.

The grout hole spacing will need to be adjusted in the field based on grout quantities, grout pressures, and building movement.

7.2 Wall Repair

The masonry cracks range from less than 1/4-inch to up to 8-inches in width. Stabilization and releveling of the walls will possibly close some of the wider cracks. Once the walls are stabilized the cracks will require partial repointing. Repointing, also known simply as "pointing", is the process of removing deteriorated mortar from the joints of a masonry wall and replacing it with new mortar. Properly done, repointing will restore the visual and physical integrity of the masonry. The mortar found in masonry structures built between 1873 and 1930 can range from pure lime and sand mixes to a wide variety of lime, portland cement, and sand combinations.

The cracks will need to be properly cleaned and prepared prior to infilling and repointing. Old mortar should be removed to a minimum depth of 2 to 2-1/2 times the width of the joint to ensure an adequate bond and to prevent mortar "popouts."

For repointing, lime should conform to ASTM C 207, Type S, or Type SA, Hydrated Lime for Masonry Purposes. This machine-slaked lime is designed to assure high plasticity and water retention. The following criteria should be evaluated for designing the mortar mix:

- The new mortar must match the historic mortar in color, texture and tooling. This will require preparation of sample mortar mixes for approval by the Owner and Architect.
- The sand must match the sand in the historic mortar. (The color and texture of the new mortar will usually fall into place if the sand is matched successfully.)
- The new mortar must have greater vapor permeability and be softer (based on compressive strength) than the masonry units.
- The new mortar must be as vapor permeable and as soft or softer than the historic mortar. (Softness or hardness is not necessarily an indication of permeability; old, hard lime mortars can still retain high permeability.)

We recommend the use of either Type O or Type N mortar with the mix proportions shown in Table 1 below.

Table 1- Mortar Types (Measured by volume)

Designation	Cement	Hydrated Lime or Lime Putty	Sand
N	1	1	5–6
O	1	2	8–9

7.3 Water Wheel Foundation

The existing foundation walls of the water wheel are in relatively good condition. The foundation of the structure does not require stabilization at this time. Minor repointing can be performed at the same time as repointing of the structure walls.

8.0 CONSTRUCTION METHODOLOGY

The foundation stabilization proposed for the project will require contracting with a specialty geotechnical construction contractor. This report including the technical specifications in Appendix D will form the basis of a project manual. Procurement documents including an agreement and contract terms and conditions will need to be added to the document to create a complete project manual. There are several contractors in Colorado that can perform the work and should be included on a potential bidder's list. Once a contractor is selected a preconstruction meeting will be necessary to review the contractor's methodology and site constraints. The actual construction work will require approximately 3 weeks.

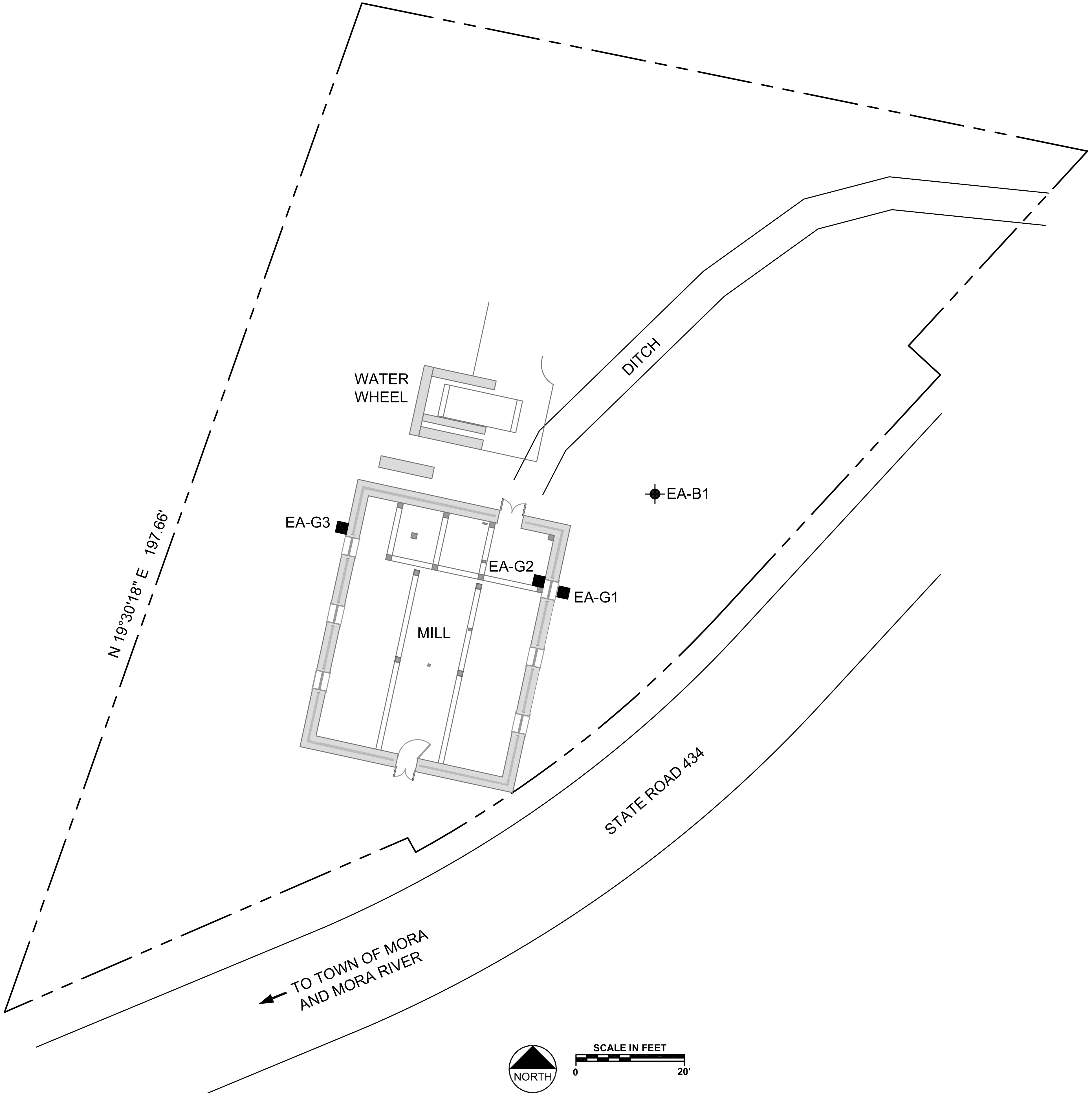
9.0 INSPECTION AND TESTING

Since a project of this nature requires many soil-related judgments and decisions, we recommend that Engineering Analytics be retained as part of the construction team. The work should include a geotechnical engineer or a trained technician to visually observe the placement of the grout and stabilization efforts.

10.0 LIMITATIONS

This report has been prepared based upon review of the reference documents, the field investigation, laboratory testing, geotechnical analyses, and our experience with similar geotechnical and geological conditions. This study has been conducted in accordance with generally accepted geotechnical engineering practices at this time and location. The conclusions and recommendations submitted in this report represent our best judgment based on the information available. If additional information becomes available, we should be allowed to review that information and modify our conclusions accordingly. This report has been prepared exclusively for our client and we are not responsible for technical interpretations by others.

DRAWINGS



LEGEND:

EA-B1 BORING LOCATION

EA-G1 GROUT SAMPLE LOCATION

REVISIONS

Revision	Date	Description
0	9/22/2015	SUBMITTAL

Designed by: Engineering Analytics, Inc.

Designed by: JSA

Approved by: RJT

FOUNDATION STABILIZATION OF ST. VRAIN MILL

SITE PLAN

Project Number: 140571

Date: September 21, 2015

Sheet: 1 of 2

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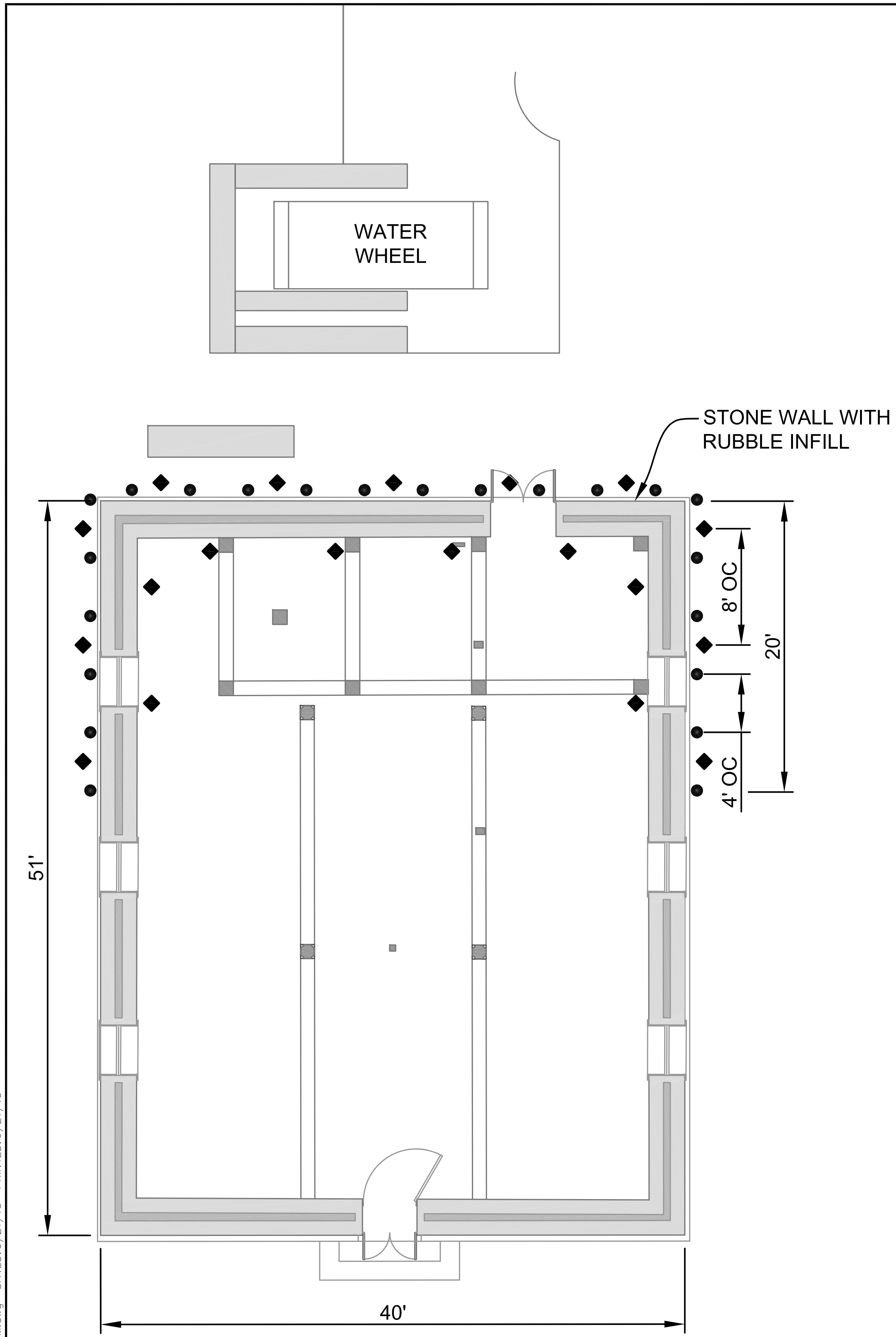
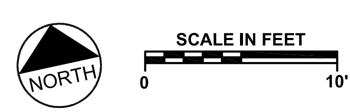
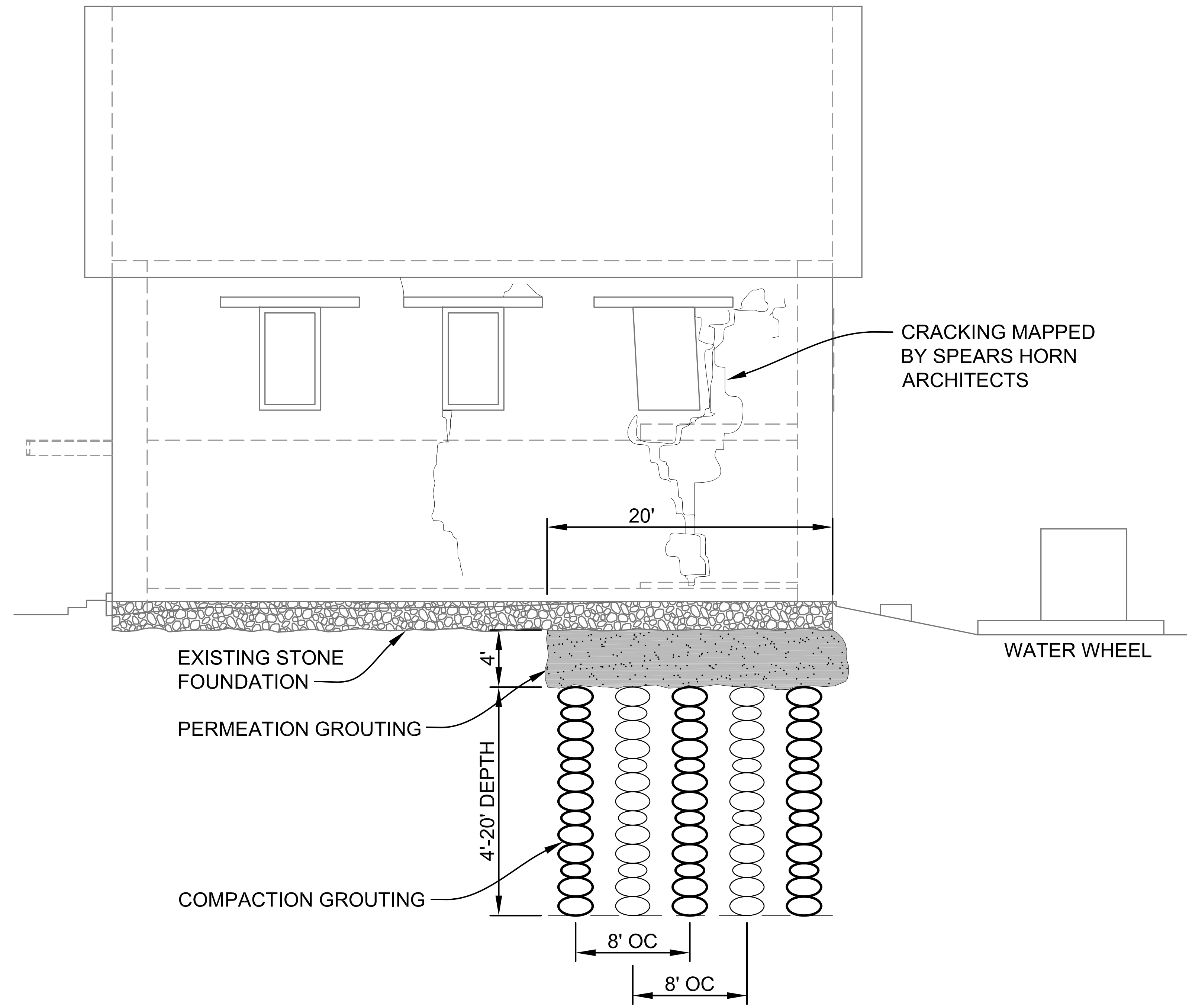


LEGEND:

- ● PERMEATION GROUTING - 0-4' BELOW LINE WALL
- ◆ COMPACTION GROUTING - 4'-20' BELOW LINE WALL (ALTERNATING INTERIOR AND EXTERIOR LOCATIONS AS SHOWN)





NOTES:

1. CONTRACTOR SHALL NOT ATTEMPT TO RELEVEL THE BUILDING USING COMPACTION GROUTING. BUILDING PERFORMANCE SHOULD BE MONITORED DURING GROUTING. GROUTING SHOULD BE STOPPED IF UNACCEPTABLE MOVEMENT IS OBSERVED.
2. EXISTING TONGUE AND GROOVE FLOOR BOARDS TO BE REMOVED AT INJECTION LOCATIONS. REINSTALL AFTER COMPLETION OF GROUTING.
3. BASE MAP AND MILL PLANS PROVIDED BY SPEARS HORN ARCHITECTS.

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REVISIONS

Revision	Date	Description
0	9/22/2015	SUBMITTAL

Designed by: Engineering Analytics, Inc.

Designed by: JSA

Approved by: RJT

FOUNDATION STABILIZATION OF ST. VRAIN MILL

GROUTING PLAN

Project Number: 140571

Date: September 21, 2015

Sheet: 2 of 2

APPENDIX A
REFERENCES

REFERENCES

ATR Institute, The University of New Mexico. (2003) Letter Report – *Ken Earle, Historic Preservation Division Re: St. Vrain Mill, Mora, New Mexico.* October 15.

Crocker LTD. (2014) *Proposal for Structural Underpinning, St. Vrain Mill,* August 14.

New Mexico Bureau of Geology and Mineral Resources. (2003) *Geologic Map of New Mexico,* scale 1:500,000.

W.F. Turney and Associates Consulting Engineers. (1976) *Saint Vrain Mill Stabilization North Wall Stabilization Sheet 4 and Major and Minor Crack Repair Sheet 7,* prepared for New Mexico State Planning Office.

APPENDIX B
BORING LOG AND PHOTOGRAPHS

Engineering Analytics, Inc.

BOREHOLE LOG

PAGE: 1 OF 2

DATE: 6/25/2015

BOREHOLE NO.: **EA-B1**

PROJECT INFORMATION

PROJECT: ST VRAIN MILL

PROJECT NO.: 140571

CLIENT: ST VRAIN MILL PRESERVATION & HISTORIC FOUNDATION

OWNER:

LOCATION: MORA, NEW MEXICO

FIELD INFORMATION

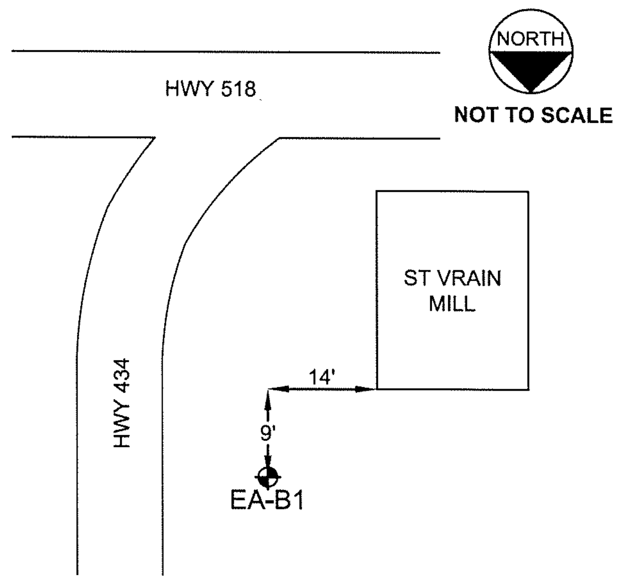
DATE & TIME ARRIVED: 6/25/2015

BOREHOLE LOGGED BY: JSA

VISITORS: MERLE

WEATHER: RAINY AT TIME OF ARRIVAL, SUNNY, 70°

BOREHOLE LOCATION



DRILLING INFORMATION

DRILLING COMPANY: ELITE DRILLING

START TIME: 4:10 PM

BORING DEPTH: 20.5' - COBBLES BOUND UP AUGER

BORING DIA.: 7"

DRILLING METHOD: 7" HOLLOW STEM AUGER

SAMPLING METHOD: CA, BULK

TIME DRILLING COMPLETE: 5:12 PM

BOREHOLE COMPLETION / ABANDONMENT INFORMATION

START TIME: N/A

COMPLETE TIME: N/A

INSTRUMENTATION: N/A

BACKFILL: NO CUTTINGS CAME UP HOLE

ELEVATION - TOP OF BORING: ---

NORTHING / EASTING: ---

GROUNDWATER CONDITIONS

GROUNDWATER ENCOUNTERED AT APPROX. 4.5' DURING DRILLING

FOLLOWING FIELD WORK

TIME OF CLEAN-UP COMPLETE:

TIME LEFT SITE: 6:20 PM

NOTES: COVERED HOLE WITH TELEPHONE POLE. MERLE WILL COME BACK AND BACKFILL.

Engineering Analytics, Inc.

BOREHOLE LOG

PROJECT: ST VRAIN MILL

PAGE: 2 OF 2

PROJECT NO.: 140571

DATE: 6/25/2015

BOREHOLE NO.: **EA-B1**

DEPTH (FT)	CORE RECOV.	DRIVE SAMPLES: SAMPLE TYPE	DRIVE SAMPLES: BLOWS (PER 6")	DRIVE SAMPLES: RECOV.	ADD'L SAMPLES	LITHOLOGY GRAPHIC
4.5–5		CA B A	7 14 17	10"		
9.5–10		CA B A	10 7 8	18"		
14.5–15		CA B A	12 17 10	10"		
19.5–20		SPT	12 22 24	10"		

SOIL DESCRIPTION

TOPSOIL (0 - APPROX. 6")
MOIST, BLACK, TOPSOIL WITH ROOTS

GRAVEL WITH SAND (APPROX. 6"-APPROX. 9')
WET, OLIVE BROWN (2.5YR 4/3), MEDIUM DENSE GRAVEL WITH SAND, VERY FEW GRAVEL FINES, COARSE SAND WITH ¾" MINUS

(APPROX. 4.5') GROUND WATER ENCOUNTERED DURING DRILLING

- **(APPROX. 8')** COBBLES

SAND (APPROX. 9'-APPROX. 15')
WET, BROWN (7.5YR 4/2), MEDIUM DENSE SAND, MEDIUM-GRAINED

GRAVEL (APPROX. 15'-APPROX. 19.5')
WET, OLIVE BROWN (2.5YR 4/3), MEDIUM DENSE GRAVEL WITH SAND, VERY FEW GRAVEL FINES, COARSE SAND WITH ¾" MINUS

- **(APPROX. 19')** NOT ABLE TO GET CA SAMPLER DOWN HOLLOW STEM AUGER DUE TO COBBLES PUSHING AUGER SIDEWAYS WILL TRY SPT

SAND (APPROX. 19.5'-APPROX. 20')
WET, BROWN (7.5YR 4/2), DENSE SAND

GRAVEL (APPROX. 20'-E.O.B.)
WET, OLIVE BROWN (2.5YR 4/3), MEDIUM DENSE GRAVEL WITH SAND, VERY FEW GRAVEL FINES, COARSE SAND WITH ¾" MINUS

E.O.B. = 20.5'

Engineering Analytics, Inc.

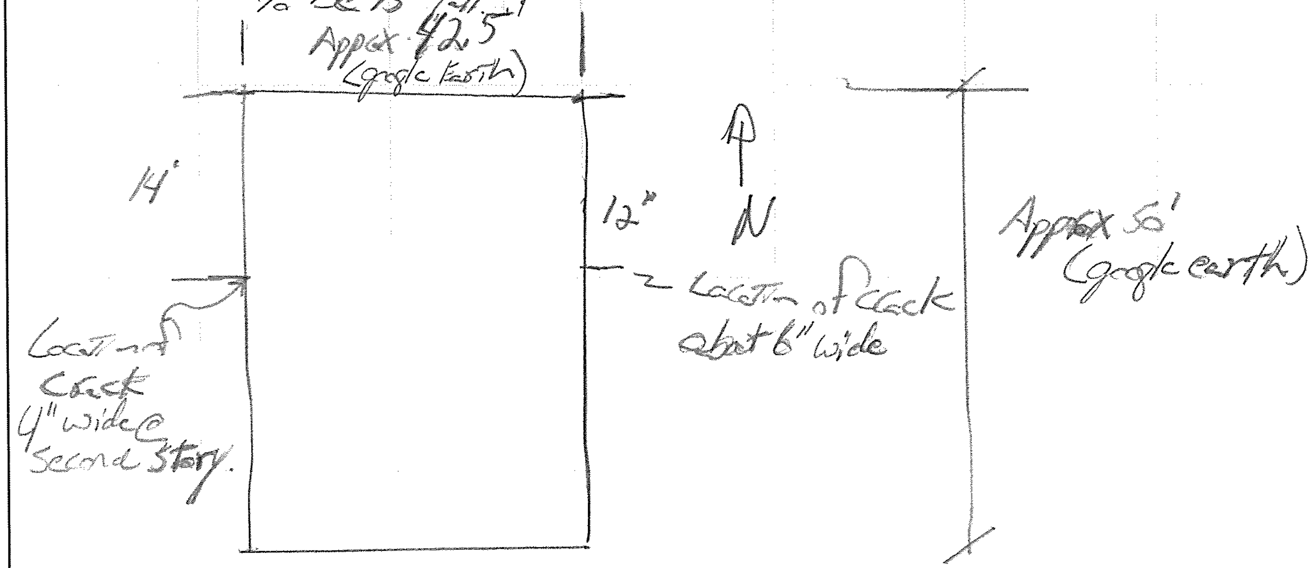
CLIENT ______ JOB NO. 140571 PAGE ______ OF ______

PROJECT ST VrainMill DATE 8/25/15 DATE CHECKED ______

DETAIL ______ COMPUTED BY JSA CHECKED BY ______

Field Notes:

Wall @ location of the crack on the east side of the Building Measure 30" Thick. The "Average" Block height was Measured To Be 15" Tall.



Crack width at the 1st floor on the east side of the building.

Crack on the east side of the mill.

First floor of the mill looking at the northwest corner

Second floor of the mill looking at the west wall crack.

APPENDIX C
LABORATORY TEST RESULTS

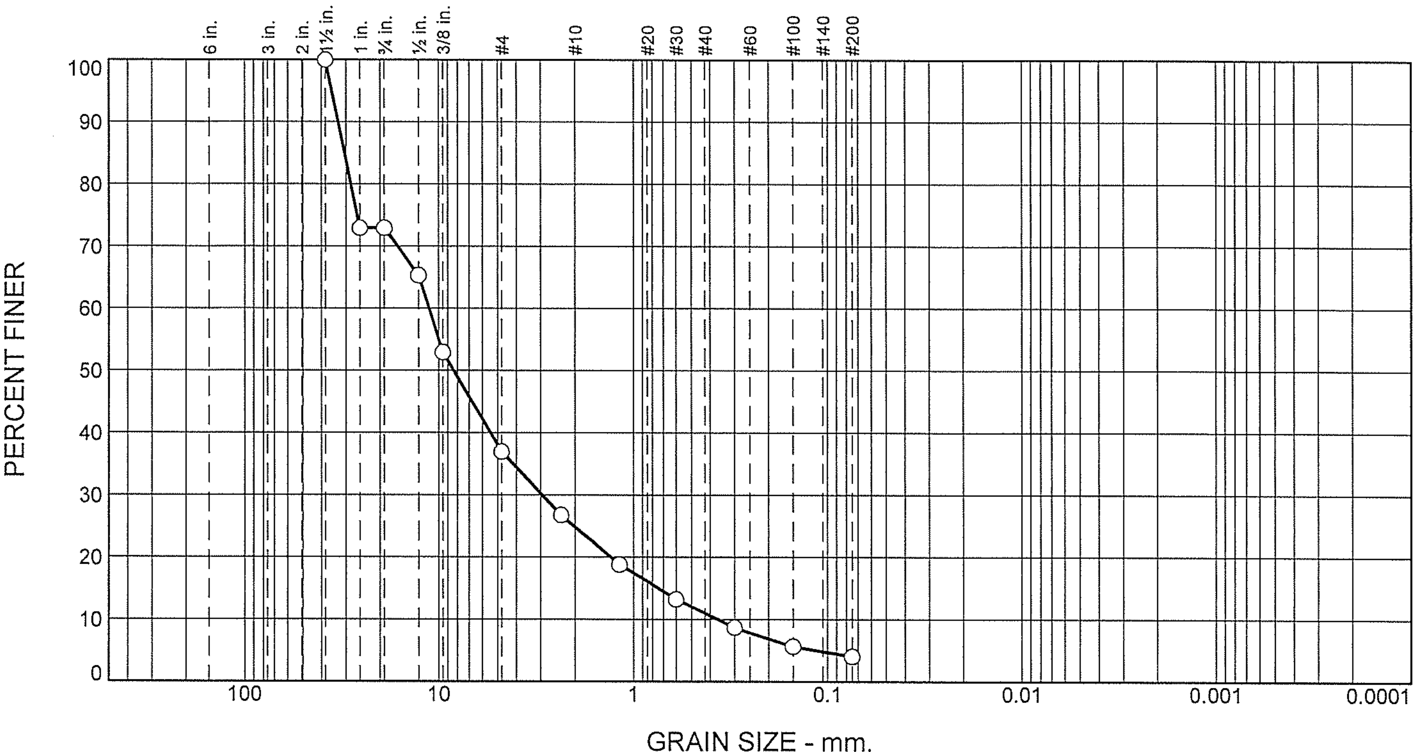
SUMMARY OF LABORATORY TEST RESULTS

JOB NAME: EA-140571 St. Vrain Mill   JOB NUMBER: 15.053T   Date: July-2015

Depth (ft)	Sample Type	Moisture (%)	Dry Density (pcf)	Atterberg Limits LL / PL / PI *	% Passing #200 Sieve	Grain Size Analysis	Direct Shear	Swell Pressure (psf)	% Swell	Inundation Pressure (psf)
EA-B1										
4	CA	6.4	108.0		4.1	(1)				
9	CA	16.3	94.2		4.6	(1)	(1)			
19	CA				5.4	(1)				

*LL = Liquid Limit PL = Plastic Limit PI = Plasticity Index N.P.= Non Plasticity   (1) See Attached   ** Insufficient Sample

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	27.1	35.9	12.1	13.9	6.9	4.1	

TEST RESULTS

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1.5	100.0		
1	72.9		
.75	72.9		
.5	65.3		
.375	52.9		
#4	37.0		
#8	26.8		
#16	18.8		
#30	13.3		
#50	8.7		
#100	5.7		
#200	4.1		

* (no specification provided)

Material Description

Gravel with sand, Dark Brown, Moist

Atterberg Limits (ASTM D 4318)

PL= LL= PI=

Classification

USCS (D 2487)= GW AASHTO (M 145)=

Coefficients

D_{90}= 32.8006 D_{85}= 30.4341 D_{60}= 11.2249
D_{50}= 8.3884 D_{30}= 2.9475 D_{15}= 0.7401
D_{10}= 0.3649 C_u= 30.76 C_c= 2.12

Remarks

Date Received: **Date Tested:** 7/17/2015
Tested By:
Checked By:
Title:

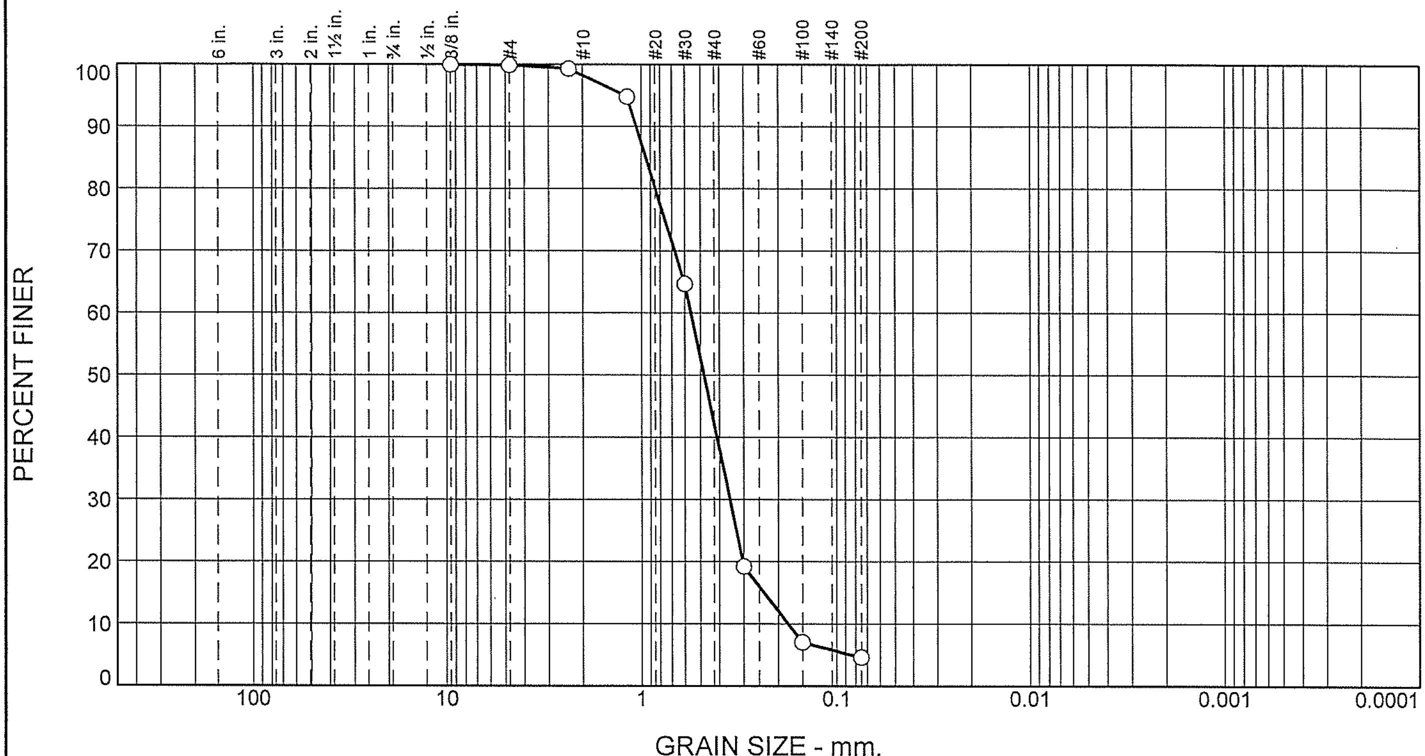
Source of Sample: EA-B-1 **Depth:** 4' **Date Sampled:** 7/15/2015
Sample Number: CA

SMITH GEOTECHNICAL

Client: Engineering Analytics, Inc.
Project: EA-140571 St. Vrain Mill

Project No: 15.053T **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	0.0	0.1	1.6	56.2	37.5	4.6	

TEST RESULTS			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
.375	100.0		
#4	99.9		
#8	99.4		
#16	94.8		
#30	64.7		
#50	19.3		
#100	7.1		
#200	4.6		

* (no specification provided)

Material Description

Sand, Dark Brown, Moist

Atterberg Limits (ASTM D 4318)

PL= LL= PI=

Classification

USCS (D 2487)= SP AASHTO (M 145)=

Coefficients

D_{90}= 1.0595 D_{85}= 0.9470 D_{60}= 0.5588
D_{50}= 0.4796 D_{30}= 0.3535 D_{15}= 0.2354
D_{10}= 0.1772 C_u= 3.15 C_c= 1.26

Remarks

Date Received: **Date Tested:** 7/17/2015

Tested By:

Checked By:

Title:

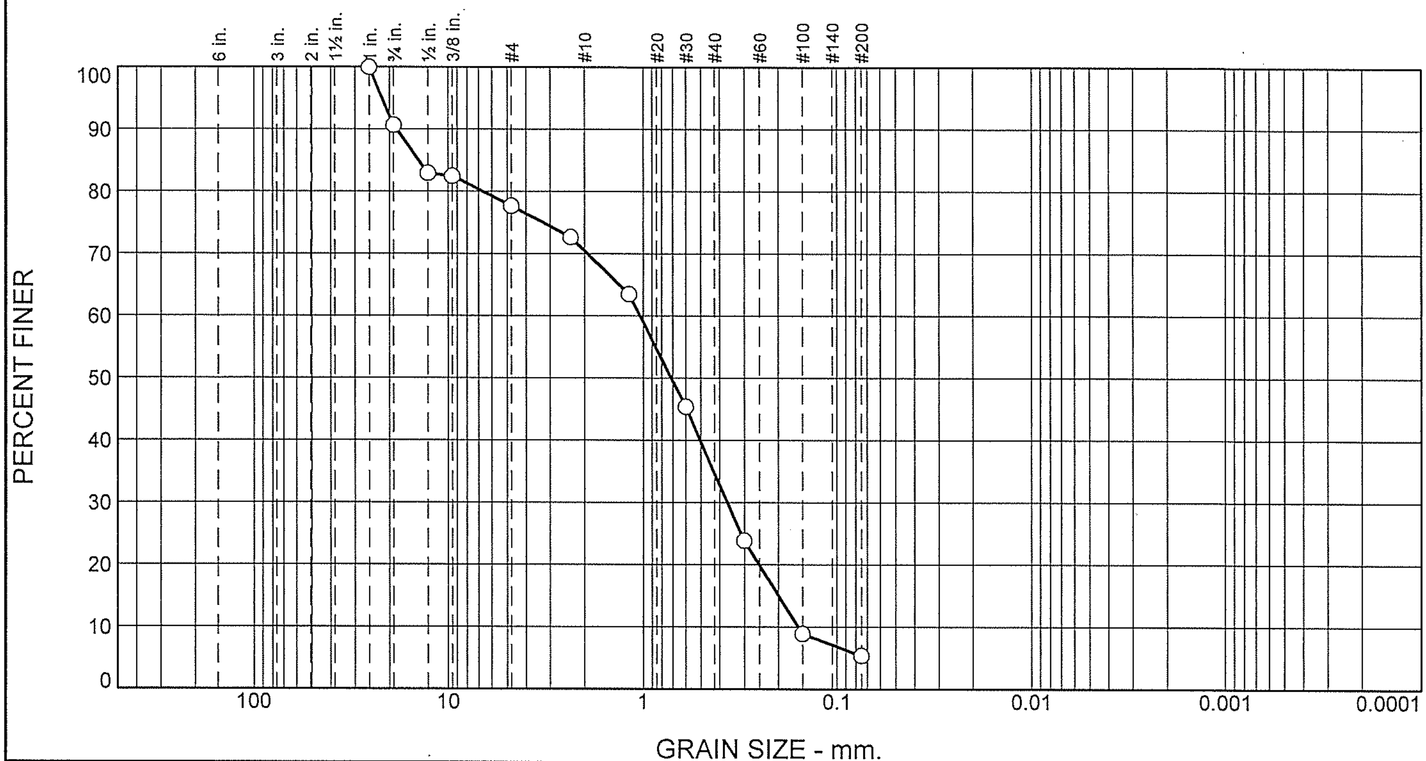
Source of Sample: EA-B-1 **Depth:** 9' **Date Sampled:** 7/15/2015
Sample Number: CA

SMITH GEOTECHNICAL

Client: Engineering Analytics, Inc.
Project: EA-140571 St. Vrain Mill

Project No: 15.053T **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0.0	9.3	13.0	7.2	35.8	29.3	5.4	

TEST RESULTS			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
1	100.0		
.75	90.7		
.5	82.9		
.375	82.5		
#4	77.7		
#8	72.7		
#16	63.5		
#30	45.4		
#50	23.9		
#100	8.9		
#200	5.4		

* (no specification provided)

Material Description

Gravel with sand, Dark Brown, Moist

Atterberg Limits (ASTM D 4318)

PL= LL= PI=

Classification

USCS (D 2487)= AASHTO (M 145)=

Coefficients

D_{90}= 18.4053 D_{85}= 14.1625 D_{60}= 1.0361
D_{50}= 0.7130 D_{30}= 0.3652 D_{15}= 0.1986
D_{10}= 0.1576 C_u= 6.57 C_c= 0.82

Remarks

Date Received: **Date Tested:** 7/17/2015

Tested By:

Checked By:

Title:

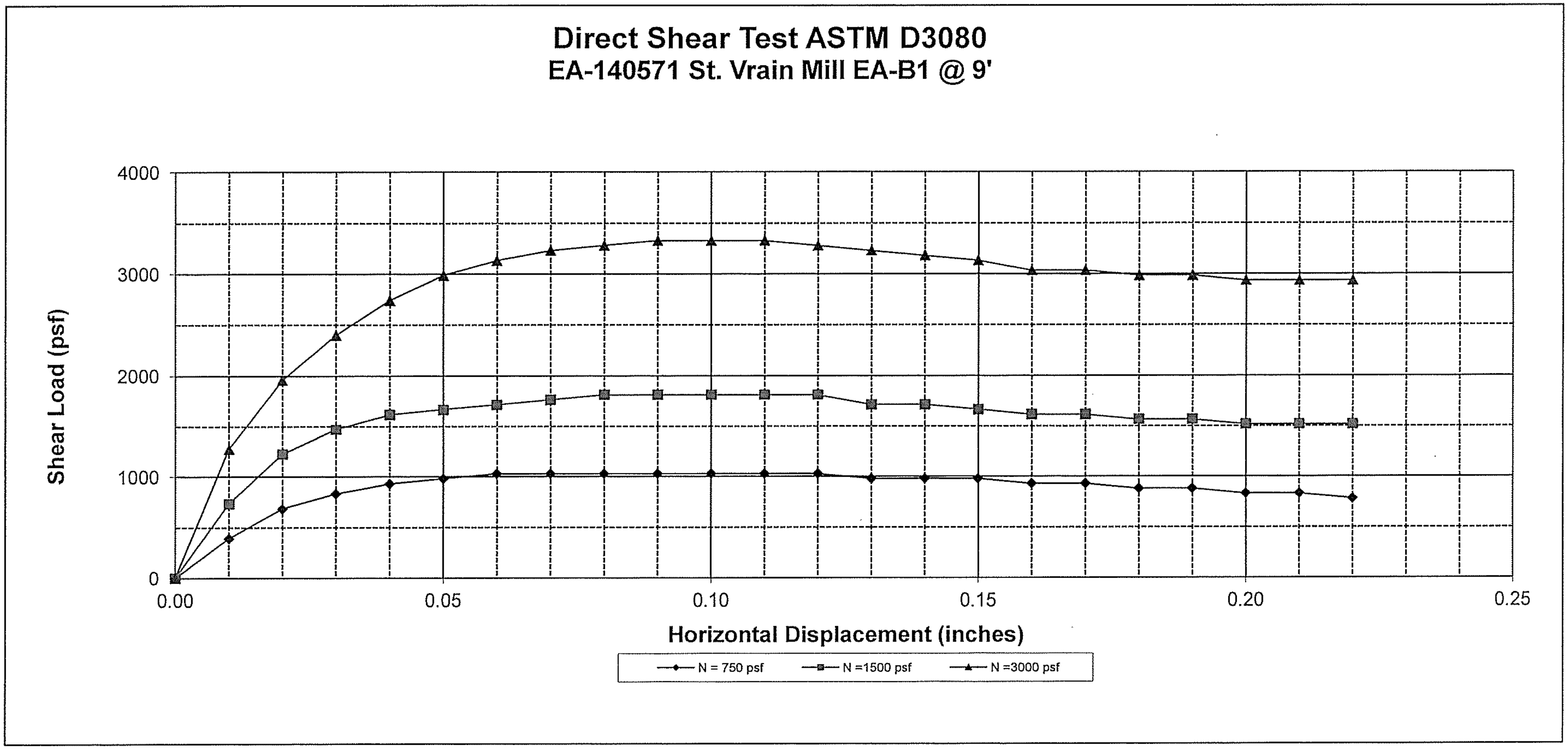
Source of Sample: EA-B-1 **Depth:** 19'
Sample Number: CA

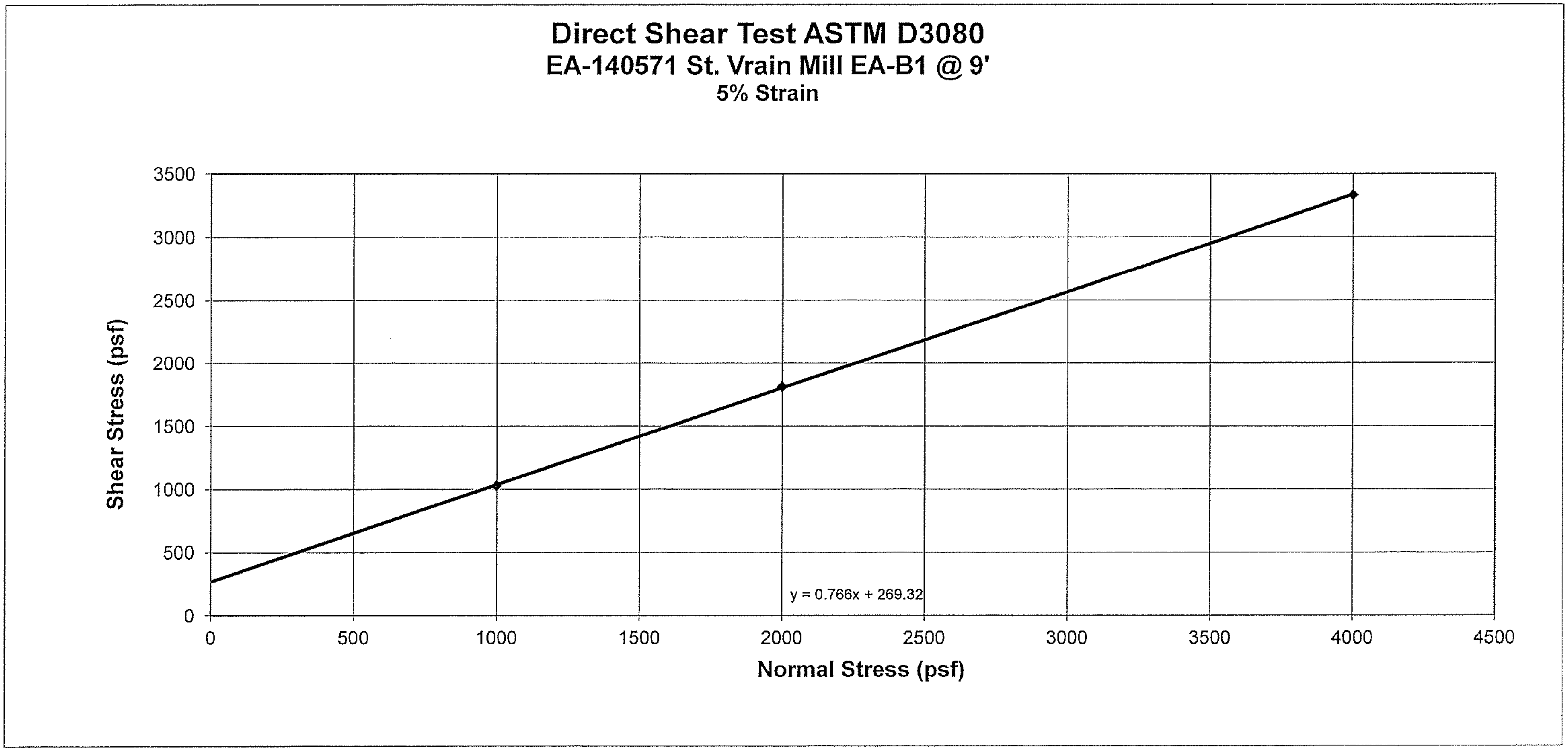
Date Sampled: 7/15/2015

SMITH GEOTECHNICAL

Client: Engineering Analytics, Inc.
Project: EA-140571 St. Vrain Mill

Project No: 15.053T **Figure**


Direct Shear Test ASTM D3080
EA-140571 St. Vrain Mill EA-B1 @ 9'
Shear Load (psf)
4000
3000
2000
1000
0
0.00
0.05
0.10
0.15
0.20
0.25
Horizontal Displacement (inches)
N = 750 psf
N =1500 psf
N =3000 psf

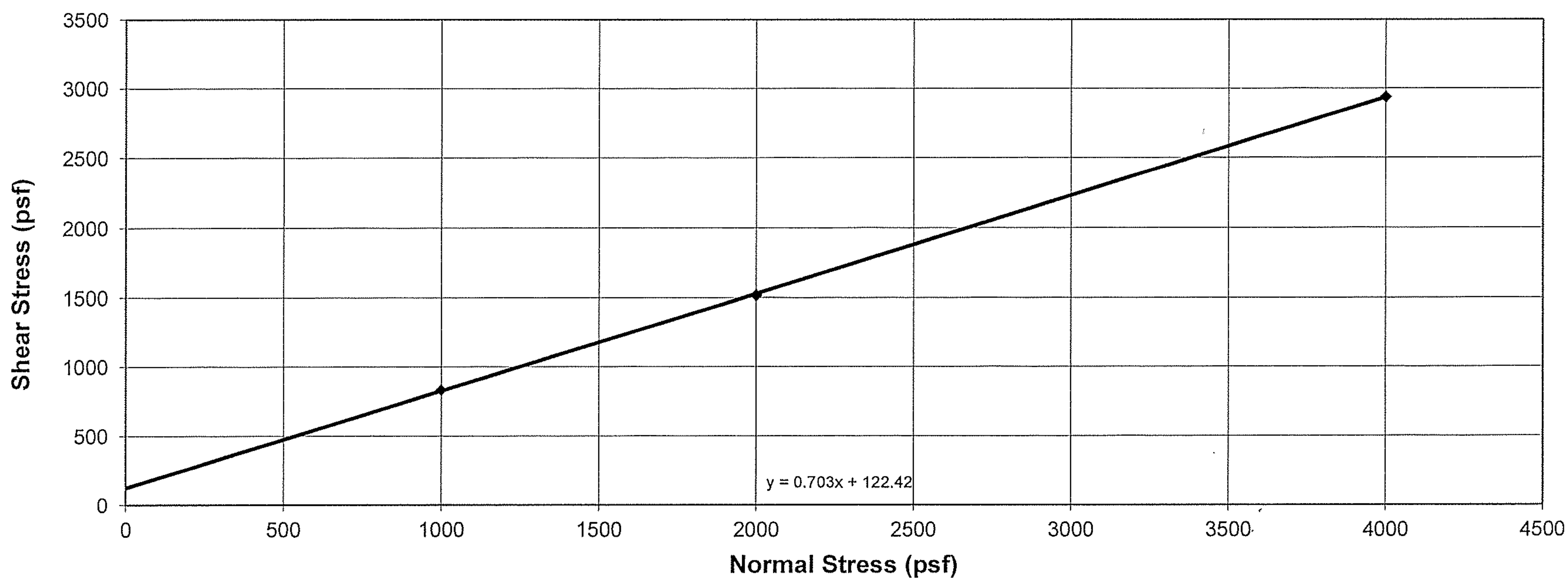


Direct Shear Test ASTM D3080
EA-140571 St. Vrain Mill EA-B1 @ 9'
5% Strain
Shear Stress (psf)
3500
3000
2500
2000
1500
1000
500
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Normal Stress (psf)
y = 0.766x + 269.32

Direct Shear Test ASTM D3080

EA-140571 St. Vrain Mill EA-B1 @ 9'

10% Strain



APPENDIX D
TECHNICAL SPECIFICATIONS

PERMEATION/CHEMICAL GROUTING

PART 1 – GENERAL

1.01 INTRODUCTION

A. Chemical Grouting for underpinning application involves the permeation of sands with fluid grouts to produce sandstone-like masses to carry loads.

B. Groutable Soils: Gravels, sands, and some silts.

C. Applications: This project requires chemical grouting for underpinning**.** Chemical grouting can also be used for lagging operations, support of footings, grouted tunnel support, and grouted pipeline support.

1.03 STANDARDS AND REFERENCES

A. All testing to determine specification compliance will be provided by an independent testing agency retained by the Owner. Regardless of the method selected, the same test method shall be utilized both before and after the soil improvement work in order to provide the most accurate assessment of the degree of improvement obtained.

B. Reference documents as provided to the grouting contractor shall include:

1. Project specifications.
2. Project drawings:
   a. Engineer's foundation plan
   b. Grout injection point layout, as detailed in the Submittals section of these specifications.
3. Project geotechnical report.
4. Contract documents.

1.04 SUBMITTALS

A. The following shall be submitted to the Owner's representative by the grouting contractor with the bid documents*:*

1. A list of at least five previously completed projects of similar scope and purpose for approval by the Owner's representative. The list shall include a description of the project, relative size, and contact person with phone number.

B. The following shall be submitted to the Owner's representative by the grouting contractor two weeks prior to the start of the work*:*

1. Resumes of the management, supervisory, and key personnel, for approval by the Owner's representative.
2. Mix design.
3. Work procedures and control criteria (including injection volumes and maximum pressure for each stage).
4. A detailed Work Plan for the area, specifying the locations and grout-pipe installation procedures. The Work Plan shall show the basis for establishing grout target volumes at each primary and secondary grout port.

C. The following shall be submitted to the Owner's representative by the grouting contractor *during the work:*

1. Accurate and timely records of all permeation grouting. These records shall include, but not be limited to:

   a. grout mix and gel time

   b. injection date and time

   c. injection pressure and flowrate

   d. injection volumes

   e. exact injection location.

   In addition, these data shall be displayed in an acceptable chart-type format that facilitates rapid visual evaluation of the results of the work. This display shall be updated daily.

2. Any change in the predetermined grouting program necessitated by a change in the subsurface conditions.

1.05 QUALITY ASSURANCE

A. The permeation grouting program, including installation of grout pipes, shall be performed by a specialist grouting contractor with at least ten continuous years of documented experience in permeation grouting.

B. The grouting contractor shall provide experienced management, supervisory and key personnel as required to implement the compaction grouting program, as follows:

1. The project manager shall have at least five years of continuous experience in permeation grouting, with at least the last two years in the full-time employ of the grouting contractor.
2. The superintendent shall have at least five years of experience in permeation grouting.

3. As detailed in Section 1.04 of these specifications, the grouting contractor shall provide:

   a. Evidence of previous permeation grouting project experience.

   b. Evidence of management, supervisory and key personnel experience.

C. The Owner's representative will ensure that procedures and documentation conform to these specifications.

PART 2 EQUIPMENT AND MATERIALS

2.01 GROUTING EQUIPMENT

A. All permeation grouting equipment shall be of a type, capacity and mechanical capability suitable for doing the work.

B. The grout plant shall be of the continuous mixing type and shall be capable of supplying, proportioning, mixing and pumping the grout with a set time between 5 minutes and 50 minutes. Batch-type systems will not be permitted.

C. Each main pump shall be equipped with recording, positive displacement meters. The meters shall be constructed of materials that are non-corrodible for the intended products and shall operate independently of the viscosity of the metered fluid. The pumping unit shall be capable of varying the flowrate while maintaining the component ratios constant.

D. The pumping unit shall be equipped with piping and/or hoses of adequate capacity to carry the base grout and reactant solutions components separately to the point of mixing. The component hoses shall come together in a 'Y' fitting containing check valves to prevent backflow. The 'Y' fitting shall be followed by a suitable baffling chamber for thorough mixing. A sampling valve shall be placed beyond the point of mixing and the baffling chamber, and shall be easily accessible for sampling mixed grout. A water flushing connection or valve shall be placed behind the 'Y' to facilitate flushing the grout from the mixing hose and baffle between grouting sessions. Distribution of proportioned grout, under pressure, to the grouting locations shall be monitored and controlled by separate, automatic recording, flow rate meters and gauges.

E. Chemicals shall be stored in metal tanks, suitably protected from accidental discharge by valving and other necessary means. Tank capacity shall be sufficient to supply at least one day's volume of grouting materials so as not to interrupt the work in the event of chemical delivery delays.

2.02 GROUT PIPES

A. Grout pipes may be installed horizontally, inclined, or vertically to obtain the specified minimum grout coverage. The grout pipes shall be either steel or PVC sleeve-port type. After being placed in a borehole, the sleeve-port grout pipes shall be encased in a continuous brittle mortar sheath. An internal double packer shall be used to inject grout at a specific sleeve port.

2.03 GROUT MATERIALS

A. Structural chemical grout will be composed of liquid sodium silicate, approved reactant, water and accelerator, if required. The design chemical grout mix shall be such that, when injected into medium dense Ottawa 20-30 sand, will provide an unconfined compressive strength of 75 psi or more.

1. The base material for the structural chemical grout shall be liquid sodium silicate, which shall have a specific gravity of 1.4 to 1.5 and a silicate to soda ratio in the range of 3.20 to 3.35. The minimum sodium silicate concentration shall be 40 percent of the mix by volume. The sodium silicate should be delivered in sealed containers or certified tank truck and shall be accompanied by the supplier's certificate of origin. Sodium silicate in non-gelled liquid form, while not considered toxic, is strongly alkaline and shall be handled by authorized personnel only.

2. The reactant shall be of organic base type and shall, when properly mixed with the other grout components, provide a permanent, irreversible gel with controllable gel times. Injected samples shall exhibit less than 2 percent syneresis within 30 days. Neither grout gel nor grouted soil shall exhibit objectionable odors such as ammonia.

3. The accelerator, if required, shall be technical grade, water soluble calcium chloride or other approved metal salt and shall contain a minimum amount of insoluble.

4. Water used with grout shall be free of impurities that will affect the grout.

B. All grouts shall have a gel time between 5 and 50 minutes, with most grout having gel times in the range of 20 to 40 minutes. Samples of grout shall be obtained for gel time checks at least once every hour of pumping or for every 1,000 gallons of grout, whichever is more frequent.

3.03 PERMEATION GROUTING

A. Grouting Mixing Method

1. The method of injection for permeation grouting shall be the *continuous mixing method*, with the proper amounts of sodium silicate base material, water, reactant, and accelerator automatically proportioned and continuously supplied at proper flow rates and pressures. The batch system of mixing grout shall not be permitted.

2. The base material and the water-accelerator-catalyst solution shall pass through parallel separate hoses to a suitable baffling chamber near the top of the hole. A sampling cock, to allow frequent gel time checks, shall be placed after the baffling chamber. Suitable check-valves shall be placed in the grout lines at the proper locations to prevent backflow.

B. Injection Procedures

1. Using double (straddle) packers, chemical grouts shall be injected through the grout ports of the sleeve pipes into the design zones. The grouting pressure for any one pipe shall not be more than 2 psi per foot of overburden.

2. Temporary very high injection pressures will be permitted to crack open sleeve-ports, but these pressures will not be permitted for longer than a one

minute duration. In any event, the rate of injection into any port shall not exceed three gallons per minute.

3.04 FIELD QUALITY CONTROL

A. All permeation grouting shall be performed under the inspection of the Owner's quality control representative.

B. Monitoring and logging of permeation grouting operations for both testing and production work.

C. Prior to the commencement of excavation or tunneling through or adjacent to the grouted zone, the grouting contractor shall demonstrate, using either soil sampling or probing methods or geophysical methods such as radar, acoustic velocity measurements, or other means satisfactory to the engineer, that the grouting zones have been thoroughly impregnated and stabilized with chemical grout. Excavation and/or tunneling through and/or adjacent to the grouted areas shall not commence until the chemical grouting work has been completed and accepted by the chemical grouting design engineer.

3.05 TESTING AND INSPECTION

A. The grouting contractor shall provide at the site all necessary chemical quality control testing apparatus, including but not limited to: hydrometers, pH paper, graduates, and all other devices that are required to conduct chemical material acceptance tests, chemical proportioning tests, and grout quality tests for proper quality control of the work.

B. The grouting subcontractor shall submit certified laboratory testing results documenting the required performance of the proposed chemical grouting at least 10 days prior to the commencement of injection operations, as detailed in section 1.06 of this specification.

C. The effectiveness of the proposed grouting program shall be verified as follows:

1. The Owner's engineer may design and/or perform in situ testing. Test sections will be performed as follows:

3.06 RESTRICTIONS

A. The Owner or General Contractor or Specialty Contractor shall be responsible for obtaining any State and municipal permits (if required) and conforming to all State and local regulations.

B. The Owner or General Contractor will be responsible for the precise delineation of all above and below ground utilities and obstructions.

C. The following shall also be listed within this section when applicable:

1. Environmental restrictions.
2. Work boundaries.
3. Hours for construction.

COMPACTION GROUTING

PART 1 – GENERAL

1.0 DESCRIPTION

A. This section covers compaction with Sand/Cement/Flyash grout including the installation of injection pipes.

B. The responsibilities of the Contractor include project control, supervision, labor, materials and equipment to accomplish the following items of work:

1. Review and approve the detailed grouting plan prepared by the Owner or Owners representative prior to beginning of work.
2. Remove interior wood floor for the installation of interior grout piping.
3. Install Grout Pipes
4. Monitor ground and existing structure movements during grouting operations.
5. Perform grouting program under the supervision of personnel experienced in grouting for settlement control.
6. Relevel building as possible.

2.0 MATERIALS

A. Sand: Sand shall conform to ASTM C-33

B. Cement: Cement (if used) shall be Type I or Type II Portland and free of contamination. Cement shall be either supplied in water resistant paper bags or in bulk. Cement containing lumps shall be rejected or screened to remove lumps.

C. Flyash: Flyash (if used) shall conform to ASTM C-618 and be either Class C or Class F. D. Lime: Lime (if used) shall be hydrated agricultural lime. Lime shall be supplied in water resistant paper bags or in bulk. Lime containing lumps shall be rejected or screened to remove lumps.

E. Water: Water shall be clean and free from contamination. Volume shall be as necessary to achieve the desired slump.

F. Admixtures: Admixtures such as a superplastizer or a pumping aid may be added to increase set time or improve pumpability.

3.0 METHODS AND PROCEDURES

A. EQUIPMENT

1. The equipment used to mix and pump grout shall be specifically designed for this purposed. Because of the high pressure involved all equipment, including hoses, couplings, gauges and pipes, shall be able to operate to the maximum requirements stated in these specifications. The mixing and grout pump system shall be designed to provide continuous flow of the grout mixture without interruption during any single hookup for a specific stage due to inadequate batching or pump feed capacity.

2. Grout mixing system: The grout mixing system shall be capable of thoroughly mixing grout over the specified range. Grout shall either be supplied by transit mix or mixed on site. For each batch of transit mixed grout, a ticket shall be issued by the mix plant stating the amount of Sand, Cement, Flyash, Water any additives, the time mixed, amount of water added at the site, time the truck has fully discharged. Any grout over 3 hours old shall be wasted unless it can be demonstrated that extended hold time has no detrimental effect. On site mixing systems shall be capable of precisely measuring, recording, and mixing all materials.

3. Grout Pump System: The grout pump shall include a positive displacement type pump with variable speed capabilities. The grout pump shall have the capability of injecting grout at a pressure of 800 psi. The pump shall have a minimum capacity of 0.05 cfm and maximum of up to 5 cfm. Pumps shall be equipped with remote controls for operation in vicinity of the probe collar to control the injection process.

4. Grout Delivery System: The grout delivery system shall consist of hoses, couplings, and pipes compatible with the equipment used for this work and shall be capable of withstanding the pressures delivered by the pump. Pressure gauges shall be provided at the pump discharge and at the top of the injection pipe to monitor pressure.

5. Pressure Gauges: All pressure gauges shall be adequately protected from the grout with suitable gauge savers to provide accurate pressure reading on a continuous basis and shall be calibrated to a Master Gauge prior to use.

6. Grout Injection Volume measurement System: There shall be a reliable mechanical means of measuring the quantity of grout pumped in every stage to within 0.25 cf.

B. GROUT PIPE INSTALLATION

1. The grout pipes shall be installed utilizing the top down injection below the permeation grouted layer followed by a secondary sequence of bottom-up injection perimeter, primary and secondary sequence. The perimeter grout holes should be installed around the buildings first. The adjacent primary grout pipes shall be grouted prior to installing or injection into the secondary pipes. The Secondary pipes shall be used to verify the densification of the soil strata.

2. The pipes can be drilled or driven. The end of the pipe must be sealed to prevent strata from entering the pipe during installation. The injection pipes shall be installed to prevent grout leakage and/or premature upward movement of the

casing during injection of high-pressure compaction grout.

4. Pipes shall be steel of sufficient diameter and wall thickness to allow the grout to be placed over the range of slumps and to the pressures as specified.

C. GROUT INJECTION

1. Grout shall be mixed on site or provided from a transit mix grout truck. The slump of the mix shall not exceed 3 inches. Grout shall be injected at a rate not to exceed 4.0 cfm unless authorized by the Owner.
2. Grouting pressure shall be continuously monitored at the surface connection to the injection pipe with a suitable protected gauge. A grout injection plan has been provided on Sheet 2 of the drawings provided in the report. The grout shall be injected beginning with a top down approach at the lower depth of the grouting limits as shown on the plans.
3. Grout injection shall cease for any given stage when movement is detected or when maximum injection pressure is reached or when a sudden drop in pressure is noted. Pressure shall drop when the injection pipe is raised or the pipe will be considered plugged and shall be removed and reinstalled or cleaned out by a wash hose from the surface.
4. Grouting for primary grout holes will utilize a top-down, bottom-up method in order to minimize disturbance to the structures. The upper five two of soil (below the permeation grouting layer) will be grouted, in one foot increments and allowed to set up for 24 hours. Grout pipes will then be installed through this upper grouted area to the full depth and grout will be placed per the bottom-up method until the top section is reached. The bottom up method stages start at the bottom of the grouting pipe, 1 ft into the underlying dense material, progressing upward at 1 ft maximum intervals. The Owner shall be notified of the quantities placed in the secondary holes before further split spacing or an area is determined complete.
5. Grout pipes shall be installed to the depths of the underlying gravels at all locations across the site. Grouting shall proceed for a stage until one or more of the criteria listed below are attained:

   a. 5.0 cubic feet of grout is injected

   b. 500 psi is recorded at depths greater than 30’ or a pressure reading of 350 psi is recorded at depths less than 30 feet.

   c. When undesirable movement of the slabs, structure, or grading is detected.

   Grouting and cutoff criteria can be modified in the field as site conditions warrant or per Engineering Analytics. Pressures below 150 psi may warrant that additional grout be placed.
6. The compaction grout pumping rates and pressures shall be carefully controlled.
7. Any hole lost due to Contractor negligence or error shall be replaced at not charge to the Owner.

D. TESTING AND QUALITY CONTROL

1. The Contractor shall pay the cost of sampling and testing.
2. All daily drilling, grouting and testing reports shall be submitted to the Owner within 24 hours. A level control system will be installed and operated by the Contractor for use during grouting. Changes in elevation of the control points shall be tabulated and submitted to Owner at the completion of the project.
3. Drilling reports shall contain at least the following information: Name of driller, type of drill, method used, date, location of hole, hole ID number, tip depth or elevation of injection pipe.
4. Grouting reports shall contain at least the following information: Name of grouting technician, grout mix, quantity injected per stage, date, rate of pumping, beginning and final pressure obtained in each stage. The reason for refusal, such as refusal pressure, movement of the surface, movement of a structure.

E. PROTECTION OF WORK AREA AND CLEANUP

1. During the work operations the Contractor shall take such precautions as may be necessary to permit drill cuttings, equipment exhaust, oil, wash water and grout from defacing and/or damaging the surrounding area.
2. The Contractor shall furnish such pumps as may be necessary to care for wastewater and grout from his operations and shall clean up all waste resulting from his operations.

4.0 FIELD QUALITY CONTROL

A. Quality control shall be the responsibility of the grouting Contractor. Due to the specialized nature of the grouting operation required to perform the specified stabilization, proposals will only be accepted from pre-qualified grouting Contractors. To apply for pre-qualification, the grouting Contractor shall submit a list of compaction grouting projects undertaken in the past five years. At least three of the grouting projects specified shall be of equivalent difficulty and/or scope. No Contractor will be considered acceptable without a minimum of five years experience in compaction grouting.

B. Cylinders must be taken by the Contractor daily or when the mix design changes. Cylinders shall be 3" x 6". Three cylinders shall be taken and marked with the date and time of day taken. Cylinders shall be broken at 7 and 28 days with the remaining cylinder being held. A testing laboratory certified by the Owner shall test cylinders.

C. The work plan must be submitted to the Owner for review and comments a minimum of 5 calendar days prior to commencement of work in the field. The work plan shall contain the following:

- The proposed mix design.
- System used to monitor movement of surface or structures.
- Estimate of the duration of the work time in the field.
- Grout pump manufacturer, model number and pressure capacities.

- Refusal criteria.

D. The location of the compaction grouting is shown on the drawings.

E. The subsurface investigation report and soil samples obtained during the subsurface investigation may be examined by contacting the Owner, a minimum of two days in advance of the day of examination.

5.0 MEASUREMENT AND PAYMENT

A. Mobilization/Demobilization will be measured as lump sum. Eighty percent will be paid when all equipment is on site. The remaining twenty percent will be paid after all equipment is removed from site, the site is restored, and all reports, including drilling, grouting, and elevations, are received by the Owner.

B. Injection pipes shall be measured by each pipe installed to the depth indicated on the Plans. Payment will be made for each pipe successfully installed. Pipes that become plugged shall be removed and replaced at no charge to the Owner.

C. Grout shall be measured by the Cubic Yard successfully placed. Grout shall be paid for by the Cubic Yard successfully placed.

D. Grout wasted at the direction of the Owner as a result of grout hole refusal will be paid at the cost specified. Measurement and payment will be made by the cubic yard.

Item #	Item Unit
Mobilization	LS
Injection Pipes Installed	EA
Grout Placed	CY
Grout Wasted	CY

SITE CLEARING

PART 1 - GENERAL

1.1 DESCRIPTION

A. This section covers the requirements for removal of existing surface soil materials; clearing of vegetation and organic soils; and removal of surface debris and rubble as necessary in preparation for construction.

PART 2 – PRODUCTS

A. Not Used

PART 3 - EXECUTION

3.1 PREPARATION

A. Contractor shall verify the extent of clearing necessary for the conduct of the Work and shall ensure that existing plant life and features (if any) designated by the St. Vrain Historical Foundation are clearly tagged or otherwise identified.

B. Place surface debris cleared from the work area and any borrow areas outside of the work areas on the Site. Such surface debris shall be properly disposed off site.

3.2 PERMITS

A. Contractor shall obtain necessary permits and pay any applicable fees for removal and/or disposal of cleared materials.

3.4 CLEARING

A. Contractor shall clear only those areas required for access to the site and execution of Work, and shall minimize disturbance to adjacent land, subject to the approval of Engineer.

B. Existing root systems shall be removed to a minimum depth of 6 inches below final subgrade, as shown on the Drawings, or as otherwise directed.

C. Maintain cleared materials separate from other excavated materials.

D. Cover materials to protect against blowing as needed.

SURFACE WATER CONTROL

PART 1 – GENERAL

1.1 DESCRIPTION

A. This specification section covers the requirements for controlling surface water and sediment during construction.

1.2 QUALITY CONTROL

A. Surface water control shall be conducted in such a manner that does not result in the release of excessive sediments or other excavated materials into adjacent storm drainage systems and water courses.

B. Engineer may direct the Contractor to provide additional stormwater control measures as necessary.

PART 2 – PRODUCTS

2.1 EQUIPMENT

A. Contractor shall ensure that appropriate equipment and materials are available on site, prior to commencement of work, such that operation of the surface water control systems can be constructed and continuously maintained in a timely manner. All equipment and materials shall be of good quality and in good working order.

2.2 MATERIALS

A. Hay or straw bales, silt fences, or other materials used to control erosion and sediment transport from surface run off and other work areas shall be new and appropriately sized to serve the intended purpose.

B. Use 30- to 36-inch high silt fences including lath (posts) for stability.

PART 3 – EXECUTION

3.1 SEDIMENT CONTROL AND DIVERSIONS

A. Provide sedimentation control to prevent excessive sediment loading to drainages.

B. Provide silt fences with suitable posts and proper anchorage along the entire length of each silt fence, in accordance with the manufacturer's recommendations around the perimeter of the work area.

C. Provide hay bale check dams at areas where concentrated surface drainage may exit the work area.

D. Remove and dewater silt or sediment buildup behind silt fences, straw bales, and sedimentation control berms as necessary during construction and near the end of construction.