UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2025
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DIVISION 31 - EARTHWORK

SECTION 31 33 30

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11/24

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USACE / NAVFAC / AFCEC **UFGS-31 33 30 (November 2024)**

Preparing Activity: USACE **New**

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SECTION 31 33 30

LIMITED MOBILITY GROUTING IN SOIL
11/24

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NOTE: This guide specification has been prepared as a construction guide specification to address limited mobility grouting (LMG) with cementitious grout. This specification includes requirements for drilling, grouting, furnishing, handling, transporting, storing, mixing and injecting the grouting materials; care and disposal of wastewater and waste grout; and clean-up of areas as necessary to complete the work.

This specification is appropriate for subsurface strength improvements and void filling. This specification is not appropriate for use to address seepage control issues--see specifications 31 33 20 Void and Permeation Grouting in Soil, 31 33 10 Foundation Grouting in Rock, and 31 73 19 Tunnel and Shaft Grouting for those grouting applications.

Do not use high pressures for grouting near dams. Methods for grouting in embankment dams or levees are not included in this specification. Grouting must not result in harm to the structure.

For USACE and Army: Soil grouting must never be used in any dam or levee embankment without approval from the appropriate Major Subordinate Command (MSC) Dam Safety Officer (DSO) and an approved Dam/Levee Safety Modification Study. If grouting in or within 61 meters 200 feet of a dam or levee embankment, or close enough for the proposed pressures to result in harm the foundation, adherence to Engineering Regulation 1110-2-1807 is required.

For Air Force and Navy: Soil grouting must never be used in any dam or levee embankment without approval of a qualified Subject Matter Expert (SME) and approval from the DSO.

This specification may be reworded for adaptation for various specialty forms of LMG to include compaction grouting, cap grouting, compensation grouting, etc. Edit this guide specification for project-specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information. Remove nonessential information whether or not brackets are present.

****

PART 1 GENERAL

****

NOTE: Caution must be exercised to not prohibit the use of a material or technique that may otherwise satisfy the scope. Proprietary products or manufacturers must not be specified within this specification without a Justification and Approval document from the Office of Counsel. Consideration must be given to conducting laboratory and field tests and evaluations of the system or systems being considered for a given application (including Standard Penetration Test (SPT) and Cone Penetratometer Test (CPT) data, soil gradation, unit weight, and shear strength tests).

If grouting is anticipated during extreme temperatures, alteration of certain field procedures may be necessary and must be included in the specifications. Generally, for cold weather cementitious grouting, the grout must be maintained at temperatures above 50 degrees F until injected, and storage of the grouting materials must be at temperatures above freezing. Insulation, heated enclosures, water heaters or other equipment or procedures may be required. Grouting in extremely hot weather may also require extra precautions.

Methods for listing subdivided items are described in Paragraph "Variations in Estimated Quantities-Subdivided Items" of Army Federal Acquisition Regulation Supplement (AFARS) 5152.211-9001. Subdivided items are recommended for all jobs unless there are extenuating circumstances for small jobs.

****

1.1 SYSTEM DESCRIPTION

****

NOTE: Provide a brief summary of the project scope and any prudent references applicable to the layout, depths, and orientation required for the grouting. Do not write the spec in such a manner that the entire program must be directed by the Government. Include relevant bracketed types of foundation features that may be encountered and specify where

they are found in the blank brackets. Include any special restrictions or coordination required.

****

The purpose of the work is to utilize limited mobility grouting (LMG) to [densify compressible soils] [fill voids in the subsurface soils][raise and level foundations (compensation grouting)]. Perform LMG according to the plans and as outlined in these specifications. Provide all labor, materials, tools, equipment, personnel, monitoring equipment, and quality control as necessary to accomplish the proposed work. Conditions encountered during the work may call for changes in the exact layout and number of grout holes as required herein.

1.2 PRICE AND PAYMENT

1.2.1 Mobilization and Demobilization

****

NOTE: The following unit prices can be adapted to the grouting techniques specified. If Section 01 20 00 PRICE AND PAYMENT PROCEDURES is included in the project specifications, this paragraph title (UNIT PRICES) must be deleted from this section and the remaining appropriately edited subparagraphs below must be inserted into Section 01 20 00.

****

****

NOTE: This provision applies for inclusion in instances where grouting is the primary feature of work.

****

1.2.1.1 Payment

Payment is made for costs associated with assembling all plant and equipment at the site, preparatory activities prior to initiating the work, and for removal and clean-up of the site once the drilling and grouting program has been completed. Sixty (60) percent of the contract lump-sum price for mobilization and demobilization will be paid following on-site assembly of all equipment to working order, and the delivery of materials necessary to perform the required drilling and grouting operations to the site. The remaining forty (40) percent of the contract lump-sum mobilization and demobilization price will be paid when all equipment has been removed from the site and all site restoration requirements have been fulfilled.

1.2.1.2 Unit of Measure

Unit of measure: Job.

1.2.2 Casing Installation

****

NOTE: This specification anticipates holes will be upstage grouted and not downstage grouted. If holes must be downstage grouted, adjust measurement, payment, and procedures accordingly.

****

1.2.2.1 Payment

All incidental costs associated with the performance of work in this section are included in the contract price for this item. Payment will be made for costs associated with advancing[vertical][10][20][30][_____] degree boreholes with casing installation, as specified herein. The casing item includes but is not limited to: equipment set up on the proposed borehole location; [advancement][drilling] of the hole; installing permanent casing or installing and then removing temporary casing; care and disposal of drilling wastes; clean-up of the site; and furnishing all equipment, labor, material, and supplies necessary and incidental to the work, including all records. Grout will be paid for under the appropriate grouting pay item. The Government will make no additional separate payment for items included herein or by reference.

1.2.2.2 Measurement

Measurement for payment is by length of properly placed casing as measured from the ground surface to the bottom of the pipe. Any length of casing projecting above the ground surface is considered incidental to the work and will not be measured or given credit for payment. Grout pipe and casing can be the same material. Subdivide the total linear footage of properly installed casing into "initial quantity" and "over initial quantity".

1.2.2.3 Unit of Measure

Unit of measure: Linear meter foot.

1.2.3 Grout and Grout Placement

****

NOTE: If the designer requires a restrictive flow rate less than 1.5 cubic feet per minute then the specification writer should create a separate line item for paying grouting by time.

****

1.2.3.1 Payment

Payment will only be made for grout installed and accepted by the Government in accordance with the plans and specifications. All incidental costs associated with the performance of work for this section are included in the contract price. Incidental work includes, but is not limited to, the following: (1) costs for all equipment, labor, materials, and supplies necessary to complete the grouting including grout hole setups; (2) grout hole connections; and (3) furnishing, batching, handling, transporting, and grout placement at various grout mixes and materials specified [proposed] at the required stages, pressures, rates, and volumes. This also includes storage and transportation of grout materials and samples; Quality Control testing and records; and associated cleanup and disposal of excess grout. No payment is made for wasted grout from excessive batching, from improper batching, or by the Contractor for any reason, including failed quality control tests. No payment will be made for time lost due to fault or negligence of the Contractor or due to defective equipment furnished by the Contractor. The Government will make no additional separate payment for items included herein or by reference.

1.2.3.2 Measurement

Measure injection of grout for payment by the volume of LMG properly mixed and injected. The volume is measured for payment based on the volume of grout satisfactorily placed in grout holes. Subdivide grouting and grout placement into "initial quantity" and "over initial quantity".

1.2.3.3 Unit of Measure

Unit of measure: cubic meter (CM)cubic foot (cf).

[1.2.4 Grout Containment

****
NOTE: Consider this optional line item item if working below water or in an otherwise sensitive area where additional controls may need to be placed on grouting for environmental compliance. Delete this section if the Contract addresses these concerns through stormwater protection or other means as part of the general site work. This section must be tailored to the meet requirements of local, state, federal, and other jurisdictions, including downstream considerations, which may be impacted by the project.
****

1.2.4.1 Payment

All incidental costs associated with fugitive grout containment, including but not limited to containment barriers, the placement of cover materials, and general environmental compliance are included in the contract price for this item. Payment will be made for costs associated with furnishing all equipment, labor, and supplies necessary for this item.

****
NOTE: Containment barriers can consist of washed aggregate fill to be placed on the surface immediately prior to grouting to aid in the containment of grout exiting from breakwaters. Limit the placement area to areas being grouted within 24 hours to avoid wave wash erosion of the containment barrier prior to grouting.

Materials used for grout containment should be inert, biodegradable, or temporary in nature. These systems must be removed by the Contractor unless their continued presence is considered inconsequential and allowed to remain by the designer/local jurisdiction.

Where crushed stone, sand or similar materials are specifically called out, these materials may be paid for on a quantity basis - i.e. measured by either surface area covered or tons of aggregate or sand placed. This may be beneifical when quantities are uncertain due to variations in available materials.
****

1.2.4.2 Measurement

Measurement is based on successful installation of required systems and compliance to appropriate regulations and restrictions as required in the Contract.

1.2.4.3 Unit of Measure

Unit of measure:[Job][Each]

][1.2.5 Drilling and Grouting Closeout Records

****

NOTE: Include this subpart only if Specification 01 78 00 Closeout Submittals is not included as part of the project specification list. Consider adding this requirement if grouting is part of a larger project and closeout submittals for grouting are required before the official closeout for the project.

****

1.2.5.1 Payment

Payment is made for material and labor cost associated with completion of all closeout records under the section entitled DRILLING AND GROUTING CLOSEOUT RECORDS.

1.2.5.2 Measurement

Measurement will be made when closeout records have been submitted and given final approval by the Government.

1.2.5.3 Unit of Measure

Unit of Measure: Job

]1.3 REFERENCES

****

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN CONCRETE INSTITUTE (ACI)

ACI 304R	(2000; R 2009) Guide for Measuring, Mixing, Transporting, and Placing Concrete

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

ASCE 53-19	(2019) Compaction Grouting Consensus Guide

ASTM INTERNATIONAL (ASTM)

ASTM C143/C143M	(2020) Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM C150/C150M	(2024) Standard Specification for Portland Cement
ASTM C403/C403M	(2023) Standard Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance
ASTM C494/C494M	(2024) Standard Specification for Chemical Admixtures for Concrete
ASTM C595/C595M	(2024) Standard Specification for Blended Hydraulic Cements
ASTM C618	(2025a) Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
ASTM C685/C685M	(2024) Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing
ASTM C989/C989M	(2024) Standard Specification for Slag Cement for Use in Concrete and Mortars
ASTM C1240	(2020) Standard Specification for Silica Fume Used in Cementitious Mixtures
ASTM C1602/C1602M	(2022) Standard Specification for Mixing Water Used in Production of Hydraulic Cement Concrete
ASTM C1797	(2023) Standard Specification for Ground Calcium Carbonate and Aggregate Mineral Fillers for use in Hydraulic Cement Concrete
ASTM D4318	(2017; E 2018) Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

ASTM D4832/D4832M	(2023) Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders

U.S. ARMY CORPS OF ENGINEERS (USACE)

EM 1110-1-1804	(2001) Engineering and Design -- Geotechnical Investigations
ER 1110-1-8100	(1997) Laboratory Investigations and Testing

1.4 DEFINITIONS

****
NOTE: Definitions may be included by reference to engineering manuals if the exact definition in the reference is to be used in the Contract. If definitions are edited for the project, then they must be included in this section.
****

1.4.1 Automated Grouting Data Collection System (AGDCS)

A computerized system for receiving, translating, recording, storing, and displaying pressure grouting data. The system is capable of viewing results in real-time or at any time after the stage is tested or grouted. The system can also produce graphic and numerical outputs for grouting and water pressure test data in real-time with digital transmittable files, including but not limited to, PDF, MS Excel spreadsheets or workbooks, and raw data files such as delimited text, XML, and DIGGS XML grout data formats.

1.4.2 Blended Hydraulic Cement

Blended Hydraulic Cement is a combination of Portland Cement, and one or more pozzolans or limestone.

[1.4.3 Cap Grouting

Cap grouting is a process used to prevent further soil loss over sinkhole voids. It involves injecting a cement-based grout to create a protective cap above the bedrock, effectively sealing the sinkhole and stabilizing the surrounding soil. It is typically the lowest zone to be grouted generally occurring 0.6 Meters 2 feet above the top of bedrock or otherwise located at the bottom of the borehole.

]1.4.4 Cement Grout

****
NOTE: Verify the type of cement locally available and tailor the specification based on locally available materials.
****

A fluid cementitious material used to improve the strength and stability of soil and coarse-grained materials. Grout is composed of a cement (Portland Cement, micro fine Portland Cement, Blended Hydraulic Cement, or

slag cement) and water, and may contain additives such as limestone, silica fume, fly ash, pozzolan, and/or admixtures as appropriate.

1.4.5 Closure

Closure is defined as the completion of all grouting within a section in a manner that refusal criteria are met and no additional split-spaced holes are required to achieve the objective of the grouting.

1.4.6 Communication

Communication is the passage of water, air, or grout from one hole to another or to any opening, observation point, or the ground surface during drilling and/or grouting.

1.4.7 Compaction Grouting

Compaction grouting is a ground improvement technique that improves ground strength and/or stiffness by slow and controlled injection of a low-mobility grout. Expansion of the grout mass displaces and compacts the soil. Provided that the injection process progresses in a controlled fashion, the grout material remains as a growing mass within the ground and does not permeate or fracture the soil. This behavior enables consistent densification around the expanding grout mass, resulting in stiff inclusions of grout surrounded by soil of increased density. This technique is typically applied to loose fills and loose native soils with sufficient drainage to prevent buildup of excess pore pressures.

1.4.8 Compensation Grouting

Compensation Grouting is the introduction of fluid or semi-fluid grout into the ground, increasing the local volume at the point of injection. This in turn causes movement by expansion of ground away from the area of injection, either compensating for movement in the opposite sense or causing movement to accumulate in the direction of expansion. Two processes have traditionally been used in conjunction with excavation for underground structures: soil fracture grouting and compaction grouting. For this specification, only the compaction grouting and LMG method is addressed.

1.4.9 Effective Pressure

The sum of all head losses and head gains in the injection system and the ground.

1.4.10 Exploratory Hole

Exploratory holes are drilled, grouted, and backfilled to investigate subsurface conditions.

1.4.11 Final Set

****

NOTE: Use ASTM C807 to determine the time of setting for hydraulic cement mortar using the modified vicat needle test. Use ASTM C403 to determine the time of setting by measuring the penetration resistance on mortar sieved from the

concrete mixture.
****

A degree of stiffening of a grout mixture indicating the time in hours and minutes required to stiffen sufficiently to resist the penetration of a weighted test needle ASTM C403/C403M. Also called 'Final Set Time' or 'Time of Final Set'.

1.4.12 Grout Take

The volume of grout placed. This can be for a specific grout stage, specific grout hole, a grout line, or treatment interval for the entire job.

1.4.13 Grout Verification Hole

A grout verification hole is drilled to verify the grouting results at the conclusion of grouting. All holes in a section must have reached refusal before a verification hole is initiated.

1.4.14 Hydrofracture / Hydrofracturing

The fracturing of an underground stratum by pumping water, drilling fluid, air, or grout under a pressure in excess of the tensile strength and minor principal stress, rupturing or heaving the soil fabric.

1.4.15 Karst Topography

A type of landscape, typically underlain by limestone, dolomite or gypsum, that has been eroded by dissolution, generally characterized by underground drainage, closed depressions, sinkholes, ridges, towers, fissures, or other characteristic landforms.

1.4.16 Limited Mobility Grouting (LMG)

Injection of a relatively stiff grout designed to displace the surrounding soils. The grout does not travel far from the point of injection and is intended to become immobile when injection pressure ceases, forming a compact mass or inclusion in the ground. The grout mass may improve the surrounding soil during pressure-displacement, although may also serve other functions such as settlement mitigation of overlying structures or grades, mitigation of soil loss to underlying sinkholes or solution features, compensation of settlement due to underground construction, or consolidation of open-graded rubble.

1.4.17 Primary Hole

The first series of holes to be drilled and grouted, usually at the maximum allowable spacing. Grouting of primary holes in one section or other defined work area, is completed prior to secondary holes being drilled. Primary holes can sometimes be the initial perimeter and grided rows of grout holes used for confinement to aid in the grouting.

1.4.18 Refusal

The point during grout injection where little or no grout is accepted into a particular stage per the refusal criteria

1.4.19 Refusal Criteria

When conditions are met to stop grouting within a stage, hole, or other established treatment zone that may include parameters such as pressure, flow, volume, grout communication, ground movement, or a prescribed combination of criteria.

1.4.20 Restoration

The correction by repair or replacement of any structure or area damaged, removed, or altered by construction activities under this section.

1.4.21 Secondary Hole

The second series of holes to be drilled and grouted, spaced midway between previously grouted primary holes. Secondary holes must be completed in a section or other defined work area prior to drilling tertiary holes.

1.4.22 Section

For linear or perimeter grouting, A section is a reach along the grout lines, not more than [_____] meters [_____] feet in length in which grouting operations are not to be permitted at the same time that drilling is in progress. For pattern grouting, a section is a subordinate component of the pattern grouting job, typically rectangular or square in shape.

1.4.23 Split Space Criteria

The split space criteria applies whenever a hole or stage does not meet refusal criteria.[The split space criteria may be applied for occurrence of hole communication, fugitive grout, hole collapse, equipment failure, premature termination, or any other interruption of grouting activities.] The split space criteria may vary depending on the stage, zone, series, or grout line under consideration.

1.4.24 Split Spacing

****
NOTE: See note under Succeeding Series
****

Split spacing is the procedure of locating an additional grout hole midway between two previously drilled and grouted holes that failed to reach refusal pressure limits or otherwise meet split space critieria. For this specification, split-spaced holes are unplanned succeeding series holes necessary to achieve desired engineering outcome(s), such as filling voids or stabilizing soils.

1.4.25 Stage

A stage is one complete operational cycle of pressure grouting, within a pre-defined depth of the grout hole.

1.4.26 Succeeding Series

****
NOTE: The designer must define the grouting

sequence in terms of succeeding series (primary, secondary, or tertiary holes) or some other prescribed sequence. Some grouting plans may have a grid of primary holes on a spacing of 10-20 feet and will then evaluate grout takes, pressures, and flow rates to determine where additional split spaced holes will be placed. In these instances, clarify that additional holes will be directed by the Government rather than based on pre-determined split space criteria. It is suggested that that the scope of the grouting campaign be bounded to prevent cost over runs due to unnecessary split spacing of grout holes.

****

Each of the succeeding series of holes must be located based on the split space criteria beyond the tertiary holes, or as assigned by the Government. Succeeding series holes are located as needed to achieve the desired engineering outcome, such as filling voids or stabilizing soils.

1.4.27 Tertiary Hole

The third series of holes to be drilled and grouted, spaced midway between previously grouted primary and secondary holes. Grouting must be complete in a section or other defined work area before any succeeding series of holes are drilled.

1.4.28 Upstage Grouting

Upstage grouting involves drilling a grout hole to its final depth and grouting successive stages from the bottom upward.

1.4.29 Void Grouting

Void grouting is a grouting technique to fill specific voids in the subsurface [or below a structure]. A casing pipe is advanced to the bottom of the void and the grout is injected at specified flow rates and depths to fill the void and not damage the structure. The process primarily fills voids for the purpose of increasing structural support.

1.4.30 Zone

A pre-determined vertical subdivision of the overall depth of grout treatment defined in the Contract. A single zone may make up the full depth of treatment, or the depth of treatment may be divided into several zones.

1.5 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's

Quality Control System. Only add a “G” to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

LMG Work Plan; G, [_____]

Grout Mix Design; G, [_____]

Field QC Procedures; G, [_____]

Ground Movement Monitoring Plan; G, [_____]

Laboratory Accreditation; G, [_____]

Qualifications; G, [_____]

SD-03 Product Data

Drilling/Casing Installation Equipment

Grouting Equipment; G, [_____]

Automated Grouting Data Collection System (AGDCS); G, [_____]

SD-06 Test Reports

Daily Records; G, [_____]

Drilling Logs; G, [_____]

Grouting Records; G, [_____]

SD-11 Closeout Submittals

As-Built Drawings And Grouting Profiles; G, [_____]

LMG Grouting Final Report; G, [_____]

1.6 DELIVERY, STORAGE, AND HANDLING

****

NOTE: There are two methods of LMG grout production, from a commercial (supplier not non-subcontractor) ready-mix plant, or for a specialty plant onsite. Commercial plants utilzed for LMG will be a case by case basis and must be coordianted for each project. The sections below apply to a dedicated batch plant. If a commercial plant is utilized, coordinate those requirements and add them to the bracketted area below.

Grouting constituent components may pose health hazards. Verify grout products meet local, state, and federal laws and regulation and that appropriate health and safety precautions are considered during design and implemented during construction

****

A sufficient quantity of [cement][cementitious material] and fine aggregate is to be stored at or near the site of the work to ensure that grouting operations are not delayed by shortage of LMG grout components. Provide a storage capacity for each constituent component sufficient to supply at least [1 week's][1 month's] volume of grouting materials so as not to interrupt the work in the event of delivery delays.

Store material in accordance with the manufacturer's recommendation. Protect all materials from inclement weather, including rain, snow, and freezing conditions. The use of suitable enclosures to prevent the degradation of the various materials prior to use is required. The cement can be delivered to the jobsite in bags or by bulk delivery. Store delivered bulk cement in appropriate silos or other containers specially designed for cement storage. Cement storage facilities are subject to the Contracting Officer's approval. Otherwise, only use cement furnished in fabric or paper bags.[In the event the cement is found to contain deleterious lumps, as determined by the Contracting Officer, either screening through a standard 1.18 mm No. 16 mesh screen, or replacement is required. No payment will be made for such screening or replacement of material.] The use of bulk cement is permitted if methods of handling, transporting, and storage are approved by the Contracting Officer in writing.

[

Ready-mix batching plants are available at [_____]. Hours of operation are limited and must be coordianted direclty with the supplier. Any deviations proposed from the specification requirements for delivery, storage, and handling must be included in the LMG Work Plan for approval.]

1.7 PROJECT AND SITE CONDITIONS

The grouting program detailed in the plans and specifications is based on

currently available information. Examine the site conditions and available surface and subsurface data, including the boring logs, foundation plans, utility plans, and site plans to successfully prepare a suitable work plan to complete the work. Review site conditions and the objectives for the proposed work and propose any necessary changes as part of the work plan. Once the work plan is approved, field changes to grout mixes, injection pressures, injection rates, and the sequence in which the holes are drilled and grouted will require approval from the Contracting Officer.

The grout hole locations and depths are based on available geotechnical and structural exploration data. Conditions encountered during construction may require adjustments to the grouting program. As the work progresses, re-evaluate the precise limits of the area to be grouted and the exact location and required depth of the individual grout holes to confirm the objectives for the proposed work are met. The Contracting Officer may move locations of proposed grout holes, change the proposed depths to be grouted, add new holes, or eliminate some of the proposed holes shown on the plans.

****
NOTE: Select the following paragraph as required based on the status of previous or planned investigations. Choose the bracket as appropriate.
****

[Previous investigations and soils information obtained from the project are provided in the following document appended to the plans and specifications [_____].]

[Perform any necessary site investigations required in the plans and specifications in accordance with EM 1110-1-1804.]

1.7.1 Permits and Approvals

****
NOTE: Coordinate with property owners, utility providers, facilities, and other stakeholders as necessary to understand potential risks to personal property underground utilities and infrastructure from grouting operations. NPDES and Water Quality Permitting are the responsibility of the Contractor.
****

Obtain necessary permits and approvals based on application, site conditions, and project scope in a manner that is in compliance with all local, state, and federal laws and regulations.

The following permits are [obtained by the Contractor] [provided by the Government]: National Pollutant Discharge Elimination System (NPDES), [401 Water Quality], [_____].

1.7.2 Underground Utilities

Prior to the submission of the Drilling and Grouting Work Plan, verify the location, type, diameter, and depth of all underground utility lines in the work area. Mark utility information on the ground surface prior to

the onset of drilling. Determine and comply with any additional underground utility location, marking and/or potholing requirements by local jurisdictional agencies. Notify the Contracting Officer of any conflicts between the underground utility lines and the approved LMG Work Plan.

1.8 QUALIFICATIONS

****

NOTE: The minimum acceptable level of experience is typically considered to be 5 years or 3 projects.

If grouting is scheduled for 2 shifts or allowed to run 2 shifts, there should be a requirement for one of these persons for each shift.

This guide spec has a PE/PG requirement, but experienced EITs and GITs may provide adequate oversight, with enough experience, on lower-risk jobs.

The qualifications for a grouting lead is a risk decision. For sensitive structures, more experience may be needed than on a simple job with no structure (yet) or a shallow structure. This requirement may be deleted for smaller grout jobs.

The 'Grouting Specialist' is sufficient on small jobs (1-2 drills), but on larger jobs, a 'grouting foreman' may be required.

****

Meet the following criteria.

a. The grouting program, including installation of grout pipes, must be performed by a specialty grouting contractor with at least [five years] [3 projects] of documented successful experience. Provide a project list that includees a description of the project, relative size, and customer point of contact for the work.

b. Include resumes for the [Lead Grouting Professional Engineer/Professional Geologist,] Grouting Manager, Licensed Surveyor, and Grouting Foreman meeting the following requirements:

[(1) A Lead Grouting Professional Engineer/Geologist currently licensed in the State of [_____]. Required experience includes work on at least three projects where they successfully supervised similar grouting applications, and performed responsible supervision of ground treatment execution. The professional must have [3] years of experience over the past [10] years.[The Professional must have equivalent engineering and construction experience specific to drilling and grouting, including a minimum of 6 months of full-time field experience.] Provide complete documentation of applicable experience. This professional will be responsible for signing and stamping drawings, computations, and reports.

] (2) A Grouting Manager is full-time, on-site, and whose duties are limited to responsibility for LMG operations. Required experience

includes at least [3] years of experience in the successful design and/or construction of LMG grouting technology similar to the requirements specified for this project, including a minimum of 6 months of full-time field experience. Provide complete documentation of applicable experience.

(3) A surveyor licensed in the state of [_____]. The surveyor must establish temporary benchmarks, establish the ground monitoring system, provide input on the ground monitoring plan submittal, and check ground monitoring stations at least once a week, or when ground movement exceeds the limits established in the paragraph GROUND MOVEMENT MONITORING PLAN.[No prior experience with LMG is required.]

(4) A grouting foreman with at least [6][3] months of full-time, onsite experience with LMG grouting. When LMG grouting is in progress, the foreman is a full-time duty limited to grouting operations.[Provide documentation of applicable experience.]

1.9 LMG WORK PLAN

****

NOTE: Provide the subsurface information to the Contractor and allow flexibility for variations in the submitted work plan based on the Contractor's experience and site-specific conditions. Remain flexible during construction to balance contract administration with the need to adjust the grouting operations to effectively achieve the project goals.

****

At least [30][45][60] days prior to the commencement of drilling grout holes, submit the LMG Work Plan that includes but is not limited to details of the following:

a. Statement of proposed sequence of operations to include the type of LMG grout proposed, schematics of the site layout, hole sequence, hole naming convention in narrative form, and pertinent shop drawings. Detail step-by-step procedures for drilling methods, equipment, hole spacing, hole location, hole depth and grout injection operations. Include a synopsis for all proposed stage termination criteria.

1. Include work schedules and production hours.

2. Include theoretic quantities for a typical grout stage and a typical grout hole based on proposed pressure, flow, and volume criteria.

3. Provide a general plan and description of proposed grout monitoring operations.

4. Dimensionally reference grout hole locations to features on the Contract Drawings.

5. Provide copies of proposed drilling and grouting record forms.

6. Include work schedules and production hours.

b. A list, description, specifications, and technical data for all grouting equipment proposed for use, including but not limited to: mixers, grout pumps, delivery lines, gauges, instruments, and appurtenances. Include the make, model, year manufactured, and general condition of each item. If items are to be rented, submit written verification that the unit is available from the renter.

c. A list, description, specifications, and technical data for all drilling & casing equipment proposed for use, including the drilling mechanism (top-hammer, downhole-hammer, non-hammer rotary, sonic, etc.) and the type of drilling fluids proposed [including air]. If separate casing oscillators are proposed, include details. Include information on the type of casing proposed including inner or outer diameter, thickness, material composition, and the connection type between casing segments. Include the make, model, year manufactured, and general condition for drills, casing installers or removers, and casing. Note whether the Contractor has prior successful experience with this specific equipment or not.

d. Proposed methods to obtain and record grout monitoring data and copies of proposed monitoring data forms.[Details, technical specifications, and capabilities for the Automated Grouting Data Collection System (AGDCS).]

****

NOTE: AGDCS should only be required for large, complex jobs and may be deleted for low budget and smaller jobs.

****

e. A completed example for a daily report to be used for this LMG project.

f. A description of the casing and casing withdrawal system to be used, including a review of previous experience in the use of such casing in similar soils and to similar depths as the contemplated project.

g. Methods and equipment for calibrating the proportioning of the grout constituents, grout quantity pumped, and pumping rate.

h. Grout material sources, including grain-size distributions of the course & fine aggregate, Plasticity Index (PI) values [and hydrometer test results] of the fine aggregates to be used in the proposed mix design.

i. A description of all survey equipment and survey monitoring instruments to be used for the Ground Movement Monitoring Plan.

j. Names and qualification statements for all personnel who will be working on the drilling, grouting, and monitoring operations. Include all drillers, mixer and pump operators, grout header technicians, and monitoring personnel. List the previous LMG work experience (if any) of each employee. Meet the requirements for Paragraph QUALIFICATIONS for quality control personnel.

1.10 GROUND MOVEMENT MONITORING PLAN

****

NOTE: Utilities and allowable displacements must be determined as part of the design through coordination with local utility providers, owners, and regulatory agencies.

Change survey requirements based on the sensitivity of the job. In some cases detection of movement may not be necessary, and in others it may be paramount. Requirements such as frequency and magnitude should be considered for addition here. Ensure the allowed equipment is capable of measuring the ground movement required by the specification.

This guide specification has limits of 1.6mm, 1/16 inch for vertical movement. Detecting the same horizontal limits are possible, but require a total station. Survey points can be used to detect horizontal movement more economically, and can be checked periodically as needed. The author must determine the resolution needed for the ground survey. Add these requirements if horizontal movement detection is necessary for your work.

****

Provide instrumentation to detect any movement of the ground surface in accordance with the project threshold and action limits. Provide monitoring devices capable of detecting movements of [1.6][_____] mm [1/16][_____] inch for any structure identified within [9 meters][30 feet].

The vertical instrumentation may include, but is not limited to, string lines, telltales, manometers, lasers, tiltmeters, and optical devices. Provide surveyor's instruments in such quantity as to allow evaluation of all structures' movements and ground heave. Provide backup surveyor instruments in such quantity as to allow evaluation of movement without needing to move the instruments during injection. Establish all structures' original positions before grout injection by placing suitable markings or targets thereon.

The licensed professional surveyor for the project must provide input and sign the Ground Movement Monitoring Plan. Assign experienced and fully qualified personnel to monitor the instrumentation to prevent any damage to the site or structures. Repair or replace any damage that occurs because of insufficient instrumentation or monitoring effort at no cost to the Government.

1.11 RESTRICTIONS

****

NOTE: List any restrictions to the working area, means and methods, or other site constraints. Delete any unneeded examples or brackets. Tailor to the project.

****

Notify the Contracting Officer each day prior to commencement of any grouting operations.[Perform all work in the presence of the Contracting Officer.][No LMG hole may be pressure grouted within [6 meters 20 feet] or 24 hours of another LMG hole being pressure grouted.][No grouting

work may commence[between the following][dates,][times,][weather conditions] without written approval from the Contracting Officer.][Access the site from [street][access point][pier][dock][_____] as shown on the plans.][Special restrictions exist at the project which limit the use of [diesel equipment,] [gasoline equipment,] [electrical equipment] [_____].]

1.12 LABORATORY ACCREDITATION

Provide laboratories submitting testing results for this contract accredited by Engineering Regulation ER 1110-1-8100. Submit written proof of accreditation for each laboratory utilized. Submit accreditation renewal prior to the expiration if the accreditation expires during the contract period. Each laboratory will be submitted separately.

PART 2 PRODUCTS

2.1 GROUT MIX DESIGN

****

NOTE: Section GROUT MIX DESIGN applies to the general grouting submittal. Additional requirements that are part of this submittal are in brackets in the proceeding sections based on whether solution or cementitious grout is preferred.

There could be situations where the same supplies are used as a previous job, so that previous testing could be directly applied to the new job. The bracketed paragraph addresses this.

While this guide spec had a maximum slump of 50mm/2 inches, there may be special circumstances where higher slumps could be utilized. These include cap grouting and Karst grouting.

****

Submit mix design(s) for the project at least [30][60] days prior to the start of work. Detail the types of grout materials and source suppliers. Include mix proportions, and material test data[from previous projects] including compressive strength. Contracting Officer to approve the grout mixes prior to use. After initial approval, obtain the Contracting Officer's approval for any future changes recommended by the Contractor based on an evaluation of grout takes, site conditions, pumpability, or grout mix component availability.

[

When the Contractor is proposing the same mix design(s), using the same suppliers and gradations of coarse aggregate, fine aggregate, cement, and additives, as a job within the last 2 years, the Contractor may propose the same mix without re-testing that mix. Provide mix design testing mix QC test data collected from the prior job.]

a. Design a grout mixture consisting of cement, water, aggregate, and any necessary additive(s). Slump not to exceed [50] mm [2] inches when measured by the ASTM C143/C143M slump test cone. Either Portland Cement or Blended Hydraulic Cement is an acceptable source of cement.

****

NOTE: Typical LMG jobs may utilize a minimum of 10-percent cement. As little as 5-percent portland cement may work when sufficient silt aggregate is present in the mix and LMG strength is not a major concern.

****

b. Use a minimum of [10][5][_____]% cement by weight of the aggregate. Include the dry weight for each solid component and the weight of water used on a per cubic metercubic yard basis.

****

NOTE: The ASCE Consensus Guide to LMG states: "Grout strength is usually not a factor where compaction is the objective, although the grout usually provides some additional support because its strength is typically greater than that of the surrounding soil. Structural applications of this kind of grouting fall into the larger classification of limited-mobility displacement grouting, which is beyond the scope of this document. For compaction grouting the grout's strength at the completion of injection need only match that of the improved soil. Strength beyond that of the surrounding soil is neglected in evaluating compaction grouting effectiveness." The ASCE Consensus guide also states; "A common requirement for compressive strength is 700 kN/m2 (100 lb/in.2)." Therefore, the LMG strength should be tied to the soil strength, unless higher strengths are desired. Tests. Strengths should generally not exceed 500 psi.

****

c. Provide a minimum grout unconfined compressive strength of [_____][700]kPa [_____][100] psi when tested in accordance with the requirements of ASTM D4832/D4832M.

d. Do not use additives such as concrete pumping aids, gums, gelling agents, organic matter, or similar materials. Bentonite may be used in specific circumstances, but only with prior approval from the Contracting Officer's.

2.1.1 Portland Cement

Meet the requirements of ASTM C150/C150M. Include the source(s) of cement, [3 months][6 months] of mill tests, and an ASTM C150/C150M compliance certificate in the Grout Mix Design Submittal. Provide monthly after approval.

2.1.2 Blended Hydraulic Cement

****

NOTE: Blended hydraulic cements are becoming more common, and in some areas, the only cement products that are available. The industry will continue to grow and develop new cement products to limit the carbon footprint by the industry. Alternate mix designs may be acceptable if field demonstrated to meet the intent of the design.

****

Conform to ASTM C595/C595M which recognizes four types of blended cements: Type IS (X), Type IP (X), Type IL (X), and Type IT. The "X" in the name refers to the percentage of secondary ingredient in the blend. Type IS (X) has slag as the secondary component, Type IP (X) has pozzolan, typically fly ash, as the secondary component. Type IL cement has limestone as the secondary component, and Type IT(PX)(PY) has two types of pozzolans. For example, Type IP (15) would contain 15-percent pozzolan. All four types of blended cements are permissible for use in grout.[Verify fresh and hardened grout properties through trial batching and field demonstrations.] Test blended cement with limestone to determine the chemical composition of the lime using ASTM C1797. Include the source(s) of cement, [3 months][6 months] of mill tests, and an ASTM C595/C595M compliance certificate in the Grout Mix Design submittal. Provide monthly after approval.

2.1.3 Mixing Water

Provide water free of excessive salts and other impurities that adversely affect the set or hydration of the cement in the grout mixture, as specified by ASTM C1602/C1602M.

2.1.4 Pozzolans

Transport, handle, and store all pozzolans so as to avoid damage, waste, or absorption of moisture.

a. Provide fly ash [or other raw or calcined natural pozzolans], if used, conforming to ASTM C618. Fly ash may be furnished in paper sacks or in bulk.

b. Provide ground-Granulated Blast Furnace Slag (GGBFS), if used, conforming to ASTM C989/C989M, [Grade 100][Grade 120].

c. Provide Silica Fume, if used, conforming to ASTM C1240. Pelletized silica fume is not permitted for use.

2.1.5 Admixtures

****

NOTE: For USACE projects the bracketed text in subpart b should be included.

Avoid specifying the use of air entrainment, except on rare occasions when grout may be exposed to severe freezing and thawing conditions.

Many admixtures and viscosity modifiers may be detrimental to LMG performance based on the application (compaction grouting). These products should generally not be used.

****

Ship, handle, and store materials to prevent deterioration, contamination, damage, or waste. Reject and replace any admixtures allowed to freeze without cost to the Government. Add admixtures to the grout immediately before or during mixing. Provide admixtures compatible with other components of the grout and that do not inhibit the grout's intended

rheological properties, which are designed to limit the grout's mobility. Alternatives may be proposed as part of the work plan. Obtain approval from the Contracting Officer for any deviations from the work plan. No time extension will be given by the Government for review time required due to submitted alternative materials.

a. Provide Water Reducing Admixtures, if used, meeting the requirements of ASTM C494/C494M, type A.

b. Provide Retarders, if used, meeting the requirements of ASTM C494/C494M, Type B.

2.1.6 Fine Aggregate

Provide grout aggregate consisting of naturally occurring, round-grained materials conforming to the grain-size distribution shown in the envelope in Figure A-1 of ASCE 53-19 from the Compaction Grouting Consensus Guide. Limit the inclusion of clay-size particles in the aggregate to 5% by mass (see Figure A-1 from the Compaction Grouting Consensus Guide). Ensure the portion of the aggregate passing a No. 40 sieve has a plasticity index (PI) of 15 or less when tested in accordance with ASTM D4318. Where gradations that meet Figure A-1 of ASCE 53-19 from the Compaction Grouting Consensus Guide are not available in a geographic area, the Contractor may propose by submittal an alternate fine aggregate gradation that will be subject to satisfactory performance. The gradation will be as close to Figure A-1 as economically possible with satisfactory performance in at least two Contractor-provided test LMG holes that are either cored or exposed by excavation.

[2.2 CONTAINMENT BARRIERS

****

NOTE: If containment barriers are required to prevent unwanted grout loss, either include this requirement in the Drilling and Grouting Work Plan to be submitted by the Contractor or add site specific provisions in this paragraph.

****

Provide grout-containment barriers of a material and design such that they will restrict the escape of grout[into the body of water].[Provide forms, if used, of sufficient strength and design to contain the grout materials. Barriers may be constructed of wood, steel, impermeable geotextile, or other material accepted by the Contracting Officer, and may be single-use or reusable.] Remove barriers upon completion of the work, unless otherwise approved by the Contracting Officer. Do not perform grouting within 8 meters 25 feet of the leading edge of barriers.

]PART 3 EXECUTION

3.1 DRILLING/CASING INSTALLATION EQUIPMENT

****

NOTE: Hole spacing will depend on grouting technique, grout materials, and the properties of the soils being grouted. In general primary hole spacing will vary from; 2.5-3.5 meters 7-10 feet.

Holes can be drilled with temporary casing or holes can be advanced with probes and lances that are vibrated or driven into the ground. Both methods result in a cased hole that is sufficient for grout injection.

****

The grout holes are produced either by drilling, driving a temporarily plugged casing, or by a probe/lance. Advance grouting lances and probes, both of which are considered casing, using driven/vibratory methods that allow for drilling and grouting to occur. The term drilling herein includes driving methods for casing placement. Provide a method capable of penetrating rocks and other obstructions. Regardless of the method used, provide casing in tight, intimate contact with the resulting hole's surrounding soil so that it is held firmly in place and resists ejection from the grout pressure and/or leakage of grout around the perimeter.

Provide casing with a minimum of 45 mm 1 3/4 inch and a maximum of 150 mm 6 inch internal diameter that possess sufficient strength to withstand the drilling and driving, grout injection, and withdrawal forces required for the work. Provide casing with flush joints on both the interior and exterior surfaces that are threaded or welded. Install all casing as approved in the LMG Work Plan. Casing is considered temporary unless otherwise approved by the Contracting Officer in writing. Provide a casing withdrawal system capable of withdrawing the casing in the required stages under both normal and extraordinary conditions during grouting. Replace any hole lost because of the Contractor's inability to pull the casing with a new hole at the Contractor's expense. Report all lost drilling steel, drill rods, or casing to the Contracting Officer and document in the final reports and as-built drawings.

****

NOTE: Remnants of many drilling fluids, especially mud, can result in hydraulic fracturing of the soil and loss of control of the grout injection when pressurized by the grout. Compressed air has often caused fracturing and raised the ground surface for about a 3 m (10 ft) radius around the hole.

****

The Contracting Officer may require or prohibit injection of water into the drilled holes in addition to any remnant water from the drill circulation, depending on the exact soil conditions encountered. Accomplish circulation flush with [air] water or air-water foam.[The use of other drilling fluids is subject to the Contracting Officer's approval.] Capture and direct water or other circulation media to an approved disposal location. Ponding of uncontrolled drilling flush or wastewater in the work area is not permitted.[Use settling tanks or other devices to separate drill cuttings and other solids from the water.]

3.1.1 Hole Location and Alignment

Indicate hole locations, alignments, orientations, and tolerances in the LMG Work Plan. The exact location, depth, and spacing of the grout holes are subject to change, as directed by the Government during execution of the grouting program. Provide the proper devices to horizontally and vertically align the drilling rigs and injection pipes within the specified tolerances. Provide grout holes within [_____][2] degrees of

vertical. Contact the Contracting Officer prior to drilling if adjustments in location are required to avoid utilities or due to accessibility.

3.2 GROUTING EQUIPMENT

Provide grouting equipment of a type, capacity, and mechanical condition suitable for performing the work, as determined by the Contracting Officer. Provide equipment capable of advancing the grout pipe through overburden soils and other obstructions to the specified depth or as required to meet the project objectives.

3.2.1 Grout Plant

Provide a grout mixing system capable of precisely proportioning, mixing, and blending the mix constituents into a homogeneous grout of uniform consistency and in sufficient quantity, without interruption. Any grout hole that is lost or damaged due to mechanical failure of equipment or inadequacy of grout supply is required to be replaced by another hole drilled and grouted at the Contractor's expense. Provide equipment capable of allowing for changes to slump between batches and real-time changes to grout pressure during grouting, as needed in the field.

3.2.2 Grout Mixing

Mix grout in accordance with the approved LMG Work Plan and the approved mix design. Automatic volumetric proportioning and mixing systems that comply with the requirements of ASTM C685/C685M and/or ACI 304R are acceptable. Where used, calibrate automatic metering systems in the presence of the Contracting Officer before grout injection begins, and as directed. Provide properly calibrated volumetric containers and scales. Batch-type mixers may be used subject to provision of an accurate means of proportioning the individual grout constituents.[The use of ready mix grout is permitted.]

3.2.3 Grout Pump

Provide a positive displacement piston type grout pump with a stroke volume not to exceed 0.38 cubic meters 0.5 cy. Provide a grout pump capable of pumping low to zero slump grout at variable rates of 5 to 55 lit/min 0.2 to 2 cfm and at continuous pressures as high as 7,000 kPa 1,000 psi. Operate the pump in accordance with the specification and approved work plan. Provide a remote off-on control for the pump at the grout injection point.

Provide an accurate system to measure the quantity of grout pumped at any time interval. Perform a pump calibration in the presence of the Contracting Officer [daily][weekly] and when a new pump is brought to the site. Additionally, calibrate the grout volume-measuring system if short-stroking, if there is a change in the grout pumping rate, upon replacement of wear parts, or at any time by the direction of the Contracting Officer. Short stroking of the pump is not allowed, and any grout pumped during such malfunctions is at the Contractor's expense.

3.2.4 Grout Delivery Lines

Provide a grout delivery line consisting of high-pressure flexible hose or a combination of hose and rigid pipeline that is watertight under pressure and a maximum of 100 mm4 inches in diameter. Provide components of the

delivery line, including coupling clamps, in good condition and capable of handling the pumping pressures to be used with a minimum safety factor of 2. Perform a pressure test of the delivery line to confirm its conformance herewith as required by the Contracting Officer. Secure connections with high pressure hoses with a safety lashing/whip.

3.2.5 Grout Gauges and Instruments

Install pressure gauges at the grout pump and at the grout header (top of the hole casing) to monitor the maximum pressure in the grout line. Provide gauges that are accurate and in good working order. Protect gauges from grout intrusion by suitable gauge protectors. Provide gauges with a minimum dial diameter of 75 mm 3 in, and a maximum pressure range be not greater than 150 percent of the anticipated maximum grout pressure. Provide [2][_____] spare pressure gauges at the jobsite. Replace any gauge of questionable accuracy promptly.[Install an appropriate flow measuring device in the grout line to measure grout volume pumped within accuracy of plus or minus 2 percent.]

3.3 GROUT PLACEMENT

****

NOTE: USACE Requirement: Do not use high pressures for grouting near dams. If grouting in or within 61 meters 200 feet of a dam, or close enough for the proposed pressures to result in harm to a dam, adherence to Engineering Regulation 1110-2-1807 is required. Increase the minimum offset as prudent to protect the structure.

Upstage grouting is typically (but not always) the preferred method. Downstaging is sometimes used to enhance confinement or to allow better control of uplift (such as in the case of compensation grouting)or to control fugitive grout. However, down-stage grout techniques are time-intensive and typically involve removal and re-installation of grout casing, often after previous stages have achieved initial set. A combination of methods may be necessary to meet the designer's purpose. Inexperienced designers should consult with industry experts or an experienced A/E before methods are specified to avoid recommending unnecessarily complicated procedures.

****

Confirm the actual depth of the open grout hole with a properly weighted measuring tape immediately before connection of the grout delivery line. Record the measured depth. Redrill the grout hole to the proper depth before grouting if the measured hole depth is not sufficient to allow grouting at the target depth. The Government may modify the sequence in which the holes are drilled and grouted. Inject holes located on or near a downslope of the treatment area, or near a retaining wall or structure foundation element, before holes that are farther from the outer edge of the treatment area. Provide access to the mixing, pumping, and injection locations to the Contractor Officer at all times. Inject holes in ascending stages, starting at the bottom and working upward. No stage can be injected until the immediate underlying stage has been completed. Provide individual stage lengths a minimum of 0.3 m 1 foot and a maximum of

0.6 m 2 feet. Stage lengths may be changed with prior approval from the Contracting Officer.

Backfill and replace at no cost to the Government any grout hole that:

1. Is lost or damaged;

2. Does not reach the design depth; or

3. Is not continuously grouted as a result of equipment deficiencies or mechanical failure; inadequate control of the grout pipe (including allowing the grout pipe to be expelled from the hole because of insufficient restraint); inadequacy of the grout mix; or improper drilling, mixing, or injection procedures.

The termination criteria is as identified in the following sections, or as directed by the Government. Injection rates are subject to change based on in-situ conditions.

3.3.1 LMG Termination Criteria In Cohesionless Soil

****

NOTE: Adjust the LMG termination criteria below to best suit the grouting application and project objectives. That is, adjust any or all numbers to best suit the engineering application this specification is trying to address. If there are concerns for hydrofracture, establish safe methods for drilling and grout placement, and calculate safe grouting pressures.

****

Discontinue grout injection into any stage of any grout hole if so directed by the Contracting Officer. Measure refusal pressures when injecting grout at the approved injection rates. General refusal criteria include any one of the following:

a. Pumping at a header pressure of [_____][1.0][1.8][3.5] MPa [_____][150][250][500] psi, except for the initial pressure that may be required to initiate grout flow when starting a new hole.

b. Sustained pumping at a header pressure of [_____][1.0][1.8][3.5] MPa [_____][150][250][500] psi or greater for a period of more than [30][60] seconds.

c. Maximum flow rate exceeding 0.0566 cubic meters per minute 2 cubic feet per minute (cfm). Consistent flow rate required through each hole.

d. A grout volume of [0.566][_____] cubic meters [20][_____] cubic feet has been injected in a stage.

e. Unwanted displacement of an adjacent structure of greater than 3 mm 1/8 in occurs.

f. Unwanted displacement of the ground surface of more than 1.6 mm 1/16 in occurs during a grout stage.

g. Grout communication to the ground surface.

All refusal criteria may be field adjusted with written approval by the Contracting Officer.

[3.3.2 LMG Termination Criteria in Clay Soils and Karst

****

NOTE: Cap grouting is a variation of compaction grouting where a special first stage, typically 2 feet thick, is placed above the top of rock. The interface is grouted at high pressures and with higher theoretical volumes and flow rates than typical LMG. This method is most prevalent for the treatment of karst. Delete the bracketed text for projects where cap grouting is not required. If there are concerns for hydrofracture, establish safe methods for drilling and grout placement, and calculate safe grouting pressures.

****

All refusal criteria may be field adjusted with written approval by the Contracting Officer. Upstage grout LMG grout holes. Do not inject a stage until the immediate underlying stage has been completed. Individual stage lengths will be a minimum of 30 cm 1 foot and maximum of 1.5 meters 5 feet. Discontinue grout injection into any stage of any grout hole if so directed by the Contracting Officer. Measure refusal pressures when injecting grout at the approved injection rates.

a. Refusal Pressure:

1. Deep Grouting: (10 meters 30 feet): Terminate when the sustained pumping pressure at the header reaches [_____][2.8] MPa [_____][400] psi.[Field adjust termination max pressure based on test holes.]

2. Shallow Grouting: (5-10 meters 15-30 feet): Terminate when the sustained pumping pressure at the header reaches [_____] [2.1] MPa [_____] [300] psi. [Field adjust refusal pressure based on test holes.]

3. Near Surface Grouting: (0-5 meters 0-15 feet): Terminate when the sustained pumping pressure at the header reaches [1.4 MPa][_____] [200][_____]psi.[Field adjust refusal pressure based on test holes.]

b. Flow Rate:

1. Deep Grouting: Limit maximum flow rate to [.05][.1][_____] cubic meter per minute [2][4][_____] cubic feet per minute (cfm). Provide consistent flow rate through each hole.

2. Shallow Grouting: Limit maximum flow rate to [.05][_____] cubic meter per minute [2][_____] cubic feet per minute (cfm). Provide consistent flow rate through each hole.

c. A grout volume of [0.566][_____] cubic meters [20][_____] cubic feet has been injected in a stage.

d. Unwanted displacement of an adjacent structure of greater than 3

mm 1/8 inch occurs.

e. Unwanted displacement of the ground surface of more than 1.6 mm 1/16 inch occurs during a grout stage.

f. Grout communication to the ground surface.

All refusal criteria may be field adjusted with written approval by the Contracting Officer.

][3.3.3 Cap Grouting

****

NOTE: Cap grouting is a variation of limited-mobility grouting in clay soils where a special first stage, typically 2 feet thick, is placed above the top of rock. The interface is grouted at high pressures and with higher theoretical volumes and flow rates than typical LMG. This method is most prevalent for the treatment of karst. In some instances, cap grouting holes may drill deeper below the soft interface zone to make sure they are penetrating boulder and weathered rock and may not be the lowest zone. Delete the bracketed text for projects where cap grouting is not required.

****

General refusal criteria is met when any one of the following occur:

a. Refusal Pressure:

[1. If bedrock is encountered at depths less than 4.5 meters 15 feet, terminate when the sustained pumping pressure at the header reaches [1][_____] MPa [150][_____] psi.]

2. If bedrock is encountered at depths greater than 4.5 meters 15 feet, terminate when the sustained pumping pressure at the header reaches [2.8][_____] MPa [400][_____] psi.[Field adjust refusal pressure based on test holes.]

b. Flow Rate: Limit maximum flow rate to [0.0566][0.1] cubic meters per minute [2][4] cubic feet per minute (cfm). Provide consistent flow rate through each hole.

c. A grout volume of [0.76][_____] cubic meters [27][_____] cubic feet has been injected in a stage.

d. A grout volume of [0.566][_____] cubic meters [20][_____] cubic feet has been injected in a stage.

e. Unwanted displacement of an adjacent structure of greater than 3 mm 1/8 in. occurs.

f. Unwanted displacement of the ground surface of more than1.6 mm 1/16 in occurs during a grout stage.

g. Grout communication to the ground surface.

All refusal criteria may be field adjusted with written approval by the Contracting Officer.

]3.3.4 Ground Movement Monitoring

Comply with paragraph GROUND MOVEMENT MONITORING PLAN, as approved. Assign experienced and fully qualified personnel to monitor the instrumentation to prevent any damage to the site or structures. Repair or replace at no cost to the Government any damage that occurs because of insufficient instrumentation or monitoring effort.

[3.4 DEMONSTRATION SECTION

****

NOTE: A demonstration section (test section) is not always required, but is usually recommended, except for the very smallest jobs. The designer needs to determine a nearby analog for the site that is suitable for demonstration. LMG columns can be: a) dug up, b) drilled through, or c) drilled nearby with a CPT rig, to determine grouting effectiveness.

****

After the LMG Work Plan is submitted, and at least [7][14][30] days prior to initiating work, complete a demonstration section meeting the following requirements:

a. Verify the subsurface material characteristics and determine the suitability of the proposed mix designs. Advance [Standard Penetration Testing (SPT)][Cone Penetrometer Testing (CPT)][geophysical testing] for the full depth of the hole.

b. Demonstrate capabilities of proposed personnel, equipment, and materials.

c. Refine methodology and equipment; technical approach; and grout mix designs based on performance.

d. Demonstrate methods are effective at accomplishing the scope to [fill voids][densify][strengthen][stabilize][_____] .

e. Demonstrate the compatibility of the proposed materials, including water source, equipment, and personnel to complete the work.

[

f. Demonstrate protocols to protect the integrity of the structure against construction induced damage. Demonstrate emergency procedures if damage occurs.]

]3.5 GROUT MONITORING

Obtain approval by the Contracting Officer for the type and location of gauges in the LMG Work Plan. Provide certified pressure gauges submitted under the Grouting Equipment submittal with accuracy to within plus or minus 5 percent. Where used, locate the primary pressure transducer at the grout header immediately above the top of the casing. Provide a communication system that allows immediate voice contact among the people at the grout hole, the pump operator, and monitoring personnel. Repair or replace at no cost to the Government any damage that occurs as a result of

lack of immediate communication. Monitor the following items:

a. The rate of grout take during grout injection. Determine the cause of sudden drops in grout injection pressures following initial start-up pressure adjustments.

b. Grout flow rate during all grout injection. If using a flowmeter, use one compatible with the LMG rheology. Provide pressure gauges at the pump and at the grout pipe head to measure pressure.

[

c. Periodically monitor paved areas and the ground surface adjacent to the grouting site for grout leakage. In the event that grout leaks are observed, temporarily terminate injection, and plug leaks before resuming pumping.]

[

d. [_____]]

3.5.1 Grout Data Logger

At a minimum, record continual plots of pressure and injection rate in a time domain. Record data in a format compatible with contemporary spreadsheet software, such as Microsoft Excel. Supply data to the Contracting Officer in digital, and when requested, printed form.

[3.5.2 Automated Grouting Data Collection System (AGDCS)

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NOTE: NOTE: Automated grouting data collection systems are becoming more prevalent and may be options for large jobs where a lot of data is generated in a short period of time. For small jobs or non-sensitive jobs, it may not represent a value-added. All provisions of this section apply to the submittal.

****

Provide, set up, maintain, and operate the AGDCS. Utilize the system during all grouting operations. Include in the AGDCS all necessary equipment, materials, computer hardware, and software to direct grouting operations in accordance with these specifications. Collect and display digital data [in real-time]. Ensure the system is capable of producing data in hard copy and digital formats. Perform manufacturer's recommended calibration of any AGDCS equipment utilized and provide initial and periodic records in the AGDCS submittal.

3.5.2.1 AGDCS Equipment Capabilities

Provide AGDCS capable of the following:

a. Monitoring and recording all grouting including but not limited to mix type, [line losses], pressure, volume, and flow rates.

b. Continuously monitoring the grouting operation without interference or interruption to the grout injection process while grouting a stage when a mix change is warranted.

c. Listing cumulative drilling and grouting issues including, but not limited, to lost tooling, hole communications, rod drops, etc.

d. Correcting and reducing the collected data to account for correction factors and field parameters (pressure head losses, pressure measurements, actual depth of the stage being grouted, etc.)

[

e. Exporting raw data files into a non-proprietary file format and producing tabular digital records as specified in Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION, paragraph DATA REQUIREMENTS.]

f. Producing graphs in Microsoft Excel format. Propose specific reporting graph design and the use of other file formats within the AGDCS submittal.

g. Graphically displaying in real-time, recording, and plotting, the following at a minimum:

(1) Plots of flow versus time and maximum pressure versus time in any stage;

(2) Start and stop times of grout injection;

(3) The time, type, and volume of a particular grout mix for the full duration of the grouting;

(4) The entire grouting record for the stage versus time, organized and combined by grout hole[;][.]

[

(5) A consistent time scale plotted on real-time plots.]

3.5.2.2 Automated Grouting Data Collection System (AGDCS Submittal

Include the following information about the automated grouting data collection system in the submittal:

a. System name and manufacturer.

b. The calculations for determining stage pressure for conversion into both total and effective pressures. Obtain groundwater measurements from boreholes prior to grouting.

c. Describe the process for data input to the system.

d. Describe the process for data storage for all generated data, including but not limited to grouting, testing, or other required processes.

e. Describe the data visualization (e.g., GIS mapping, CAD profiles, and plots) methodology, including any data transformations.

f. Describe methodology used for export of data to [Excel Spreadsheets] [Enterprise Database].

g. Data backup process used to ensure no data loss occurs.

h. Screenshots of raw data format and typical plots.

i. Example grout log showing change in mix type.

]3.6 FIELD QC PROCEDURES

****

NOTE: This guide spec contains only three types of testing, slump testing, and compressive strength testing and grout quantity verification (including unit weight determination). More testing could be required, but these are the only types of testing typically utilized in normal LMG jobs.

Often in soil improvement projects a pre and post CPT or SPT can be used to verify ground improvement. Consideration to whether this is necessary should be considered. If it is determined to be necessary, follow UFGS guide specification 02 32 13 Subsurface Drilling And Sampling.

In paragraph 1, select the most appropriate bracket for QA/QC required for your project.

****

Only conduct LMG operations in the presence of the Contractor's approved staff [and the Contracting Officer].[Notify the Contracting Officer prior to beginning LMG operations each work day.] Perform the following tests:

a. Modified Slump Testing: Perform slump testing in accordance with ASTM C143/C143M, except the Contractor is not required to rod the mix. Tapping the sides of the cylinder during filling instead of rodding is permitted. The slump test results must be within the requirements approved in Section "Grout Mix Design". Modified Slump tests are to be performed at least twice per dayshift, and at the request of the Contracting Officer. Additional slump tests are to be performed for any change in the mix design.

****

NOTE: Following the ASTM Method for slump testing utilizes rodding of the mix. This rodding will introduce air pockets into LMG mixes. This causes problems, as described at the beginning of the Chapter 3 of the ASCE Compaction Grouting Consensus Guide. Consideration should be given to directing that the slump testing should exclude the rodding during slump testing.

****

b. Strength Testing: Cast minimum size 7.5 cm by 15 cm 3 inch by 6 inch grout test cylinders or 15 cm by 30 cm 6 inch by 12 inch test cylinders for strength testing. One set of two cylinders or molds will be cast [during each slump test] [daily]. Both samples will be tested at [3][7] days in accordance with ASTM D4832/D4832M. Water can be added as long as the specified mix properties are met. If water is added to the mix after strength cylinders are cast, the Contractor will be required to cast 1 additional cylinder each time water is added to the mix.

c. Grout Set Time: Set Time is between 12-24 hours in accordance with ASTM C403/C403M, method 'A'. Test [1] time per week.

d. Fresh Grout Temperature: Must be between10-32 degrees C 50-90 degrees F tested 1 time per shift.

e. Grout Pump Volume Verification: Test the accuracy of the grout pump and measuring devices [Daily][Weekly] by filling a 208 Liters 55 gallon drum, or other object of known volume, to verify the accuracy of equipment.

[

f. The Contracting Officer reserves the right to require additional testing if determined necessary by the design engineer.]

3.7 GROUT VERIFICATION

3.7.1 Production Grouting Quantity Verification

Verify the reported grout volume by reconciling records of delivered grout constituents (cementitious material and fine aggregate) and water meter readings for water consumed in the grout batching process with its reported grout volume produced. Measure and record the grout unit weight at least [1][2] times every [shift][day][week]. Maintain daily records of all grout constituents delivered to the project including: certified weight tickets for grout fine aggregate; certified weight tickets or sack counts for all cementitious components; and water meter readings for all water used to batch the grout. Reported daily production grout volume must agree with records of grout constituents consumed during site batching (or with certified ready-mix delivery tickets) within a tolerance of 10 percent.

Collect samples for grout unit weight determination from the grout hose near the header connection (and not directly from the batch mixer or transit-mix truck prior to passing through the grout pump and primary delivery hoses). Collect grout into a container of known volume (typically 0.028 cubic meters 1 cubic foot) for unit weight testing and pump stroke count verification (or for comparison with flowmeter readings if so equipped). Following unit weight determination, the sampled material may also be used for slump determination and strength test samples

3.7.2 Post Grouting Verification

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NOTE: Post grouting verification must always be paired with a pre-grouting baseline condition. Succeeding series holes should show a reduction in flow, volume, and an increase in pressure. If the pre-grouting average SPT blow count is 4, one level of success for the project would be to increase the average blow count to 8 or 12. The same requirement can be applied to cone penetrometers for changes in shear wave velocity, tip resistance, or other parameters.

****

Complete all testing before the grouting equipment is demobilized from the site. Verify the subsurface material characteristics for [strength][void filling][other]. Verify subsurface improvement by evaluation of pressure and grout volumes injected in the split spaced holes/verification holes. Provide borings made to depths similar to the depths treated for grouting.

[Additional verification and testing is required. Locations of testing must be agreed upon between the Contractor and the Contracting Officer. All testing must be overseen by the Contractor's QC staff and include one of the following methods:

a. Post grouting standard penetration test N-values achieve an average of [_____] blows per foot or greater within the soil improvement zone.

b. Post grouting CPT results indicate a minimum improvement of [_____] percent of the[pre-treatment cone tip resistance][pre-treatment shear wave velocity] within the target soil improvement zone.

c. Geophysical methods to include[ground penetrating radar][electrical resistively tomography][_____].]

3.8 DAILY RECORDS

Make daily data and quality control records available to the Contracting Officer at all times. Submit paper records included herein daily. Submit digital records for each grout hole to the Contracting Officer within [7][_____] days of grout injection.[Use an automated grouting data collection system to record grouting injection operations. Provide all raw data outputs from the AGDCS within [12][_____] hours of generation.] Monitoring and logging of data for LMG operations to be completed by the Grouting Contractor's Quality Control Manager or Project Superintendent. Maintain accurate daily records of all grout pipe installation, drilling logs, grouting quantities including stage data, volume, ground monitoring, pressure, and depth for each grout pipe location in accordance with the following:

a. Date and weather conditions.

b. Drilling and Grouting Hole ID,[hole series,] hole[station and offset][latitude and longitude] for any hole that is drilled or grouted.

c. Depth and diameter of each drilled hole, include depth to bedrock if applicable. Include hole inclination (vertical = 90 degrees).

d. Stage geologic formation.

e. Grout stage ID, date, injection depth and elevation, grout mix ID.

f. Field QC Procedures and testing performed, include test number and test ID.

g. For each grout hole, include a per stage summary to include the grout injected per stage, the maximum injection pressure, and maximum flow rate, per stage.

h. For each grout hole: Summarize the grout stage information to include the total volume of grout injected, the maximum/minimum pressure, maximum flowrate, depth at which ground heave was detected, depth at which grout intrusion into subsurface structures or communication with another grout hole was detected.

i. Summary of grout used for each grouting effort with itemized

total quantities of grout injected vs quantity of grout wasted.

j. Materials received and time of delivery.

k. Copies of receipts or delivery tickets for all materials delivered to the jobsite and daily quantity reconciliation. Provide all receipts or delivery tickets to the Contracting Officer.

l. Names of Contractor's personnel on site. Include the names of any visitors and time at the jobsite.

m. Details of any accidents, injuries, or other unusual events, including time;

n. Presence of any of the following:

(1) Voids or changes in drill advancement rate in soil or other material with depths to the top and bottom of each void.

(2) Groundwater depth.

(3) Unusual or unexpected conditions including communication, bypass, etc.

Submit data electronically in a [.csv][.xls][, or other] ASCII-readable format. Submit clear, legible analog records in [PDF][_____] format. Make the Contractor's records available to the Contracting Officer at all times.

3.8.1 Drilling Logs

Prepare a log of each grout hole that delineates the nature of the geomaterial penetrated, including: the depths of hard or soft soil zones; any existing voids; reduction or loss of circulation flush; and any rocks, boulders, or other significant conditions encountered. Provide copies of the logs to the Contracting Officer on completion of drilling of each hole.

Maintain and provide the Contracting Officer a continuous log delineating the drilling and grout injection parameters for each hole. Provide the following minimum data on the log:

a. Date(s) and time the hole was drilled;

b. Any obstructions encountered or unusual events occurring during drilling;

c. Depth drilled or elevation of both the top and bottom of the hole;

d. Description of soil conditions encountered, including groundwater depths.

Provide the name of the person preparing the logs and the current date on all pages of the log and number the pages chronologically from the start of work. Note the time at each log entry. Submit typed copies of the logs for each LMG hole to the Contracting Officer within seven days of grout injection and include as part of the As-Built Drawings and the Final Report.

3.8.2 Grouting Records

Provide a daily report delineating grouting activities containing at a minimum the following:

a. Hole Id, location, elevation and depths - with datum.

b. For each grout stage, produce tabular data that summarizes the time, grout stage depth and depth interval, grout stage pressure, total stroke count for each grout stage (or flowmeter reading if so equipped), grout volume for each grout stage, and flowrate for each grout stage. At the completion of each hole, provide the total volume of grout injected. For the entire hole, provide the range of final grouting pressures obtained across all stages (absolute max/min). Include a comparison of theoretical vs actual grout takes. Note any grout communication to the ground surface and the approximate estimated quantity.

c. Provide plots of grout injection (flow) and grout pressure versus time for each completed stage in the project. Include in a graphical presentation a depiction of pressure versus time where the maximum and minimum pressures can be directly compared.

3.9 SITE CLEANING, MAINTENANCE, AND RESTORATION

Keep the site clean, organized, and safe at all times. Promptly clean up spilled materials and grout. Neatly store hoses, delivery lines, and other items that are not in immediate use where they will not impede the ongoing work. Upon completion of the work for each hole, remove grout pipes installed from surface. Promptly collect and dispose of water and waste grout. Do not allow water to pond in the work area. Collect trash and store in an approved manner until it is removed from the site. Remove all waste from the site. Restore the site to the original condition. Completely remove any remnants of drilling fluid or grout. Restore or replace any appurtenant structures damaged during production.

[3.10 DATA MANAGEMENT

Provide all generated data - no data source or format is subject to exemption. All data generated as part of this specification are subject to the requirements in Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION. This would include any GIS files, access files, and other programs/systems used to store raw and processed data. In case of a conflict in Contract language, whichever requirement is more detailed, rigorous, specific, precise, and complete as determined by the Contracting Officer will be used.

]3.11 AS-BUILT DRAWINGS AND GROUTING PROFILES

Submit progress drawings per the same format requirements for As-Built Drawings. Maintain progress drawings in the field and provide to the Government[weekly][monthly]. As-Built drawings are not limited to the sheets in the Contract drawings. Add as many sheets as necessary to show the work completed. Include two new views for the entire grouting work. The color and binning symbology for grout volume and drilling issues will be[provided by the Contracting Officer][chosen by the Contractor]. Make changes to symbology, binning, and color representations as directed by the Contracting Officer.

Produce drawings at scale of [1:250][1:150]. At minimum, include the following grouting drawings, along with raw data organized in tabular form:

a. Submit a plan view of the array of grouting holes to include hole-ID, station/offset, and hole coordinates.

b. Provide section and profile views of the drilling results, including interpretive geology. Include the grout holes on a series of lines, with the ground surface and top-of-rock noted for each hole. Display voids, an interpreted top-of-rock line, and interpreted connections between voids. Show any lost tooling at the presumed lost depth. Show all casing with top and bottom depth.

c. Provide section and profile views of the grouting results. Include the grout holes on a series of lines, with each grouting stage shown with a color-coded box indicating grout volume. Provide the maximum grout pressure and flow rate used for the corresponding stage for each box. For each grout hole on each line, include the absolute total volume for each grout hole with the max and min range of pressure and flowrate indicated below the total volume for the grout hole.

Submit records in [hard copy (2 copies),][electronic format on CD or DVD,] in native file formats, and in .pdf, on the project SFTP site.[Drawing views of progress drawings that are unchanged from the previous week do not need to be submitted in hard copy, but submit the electronic copy.]

3.12 LMG GROUTING FINAL REPORT

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NOTE: The Final Report should not be deleted. The final report provides critical information for permanent project record, some of which will be difficult for anyone but the contractor to know, including production rates. In addition, this information is critical for Government Cost Estimators for future jobs.

****

Prepare and submit a drilling and LMG grouting final report that covers all the activities throughout construction. Submit [three][five] hard copies of the complete report, and a digital copy of the report. Include all forms, sketches, drawings, tables, graphs, color photographs, and other supporting materials, as necessary to provide a full understanding of how the work was accomplished and any difficulties, problems, or unusual conditions which were encountered. The report must 'standalone' and not reference other material to the maximum extent possible, except for the As-Built drilling and grouting drawings.

Submit the final report no later than [30][60] days after grouting the final hole.[Submit an outline of the report for approval when 50 percent of the construction is completed.] The report must contain the following at a minimum:

a. The equipment used, final layout of the grout holes, grout takes by hole, problems encountered and solutions applied.

b. Drilling records including hole [easting and northing]

[latitude longitude], elevation and depths, [hole azimuth and inclination,] vertical and horizontal datums used to survey the holes, and any applicable reference coordinate systems. Include the same data for all survey control points.

c. Include grout quantity pumped versus time for each completed stage in the project. Provide plots of grout injection (flow) and grout pressure versus time for each completed stage in the project. Include in a graphical presentation a depiction of pressure versus time where the maximum and minimum pressures can be directly compared.

d. A minimum of [25][_____] annotated color photographs of each phase of construction and equipment.

e. A discussion of the grout mix(es) used and quality control procedures for maintaining the grout mix required properties during production.

f. A descriptive list of any lost tooling, including type of tooling, length, depth, batter, and location (station and offset plus longitude and latitude).

g. Discussion of any deviations from the Drilling and Grouting Work Plan submittal(s).

h. Instantaneous and Industrial Production rates for drilling and grouting. Compare production rates achieved with the production rates forecast in the baseline schedule; note any actual rate 25-percent different from that forecast in the baseline schedule, and an interpretation of why they were different.

i. Summary statistics of each test for each grout mix during the Contract. Include: Mean, Median, Mode, Standard Deviation, and 95-percent confidence limit.

j. For compressive strength data, include histogram of the [3][7]-day strength results. Additionally, include a time-series plot showing strength versus time, with specifications limits clearly delineated on the plot.

[3.13 LMG GROUTING RESULTS DATABASE

****

NOTE: On very small jobs, it could make sense to utilize a spreadsheet instead of a database. If utilized, change the wording "[Enterprise][Microsoft Access] database" to "Microsoft Excel Spreadsheet".

****

Develop an [Enterprise][Microsoft Access] database in accordance with Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION that contains all data generated over the course of the project - including but not limited to drilling, grouting, water pressure testing, and verification drilling and testing. Provide a database that includes all of the information required in paragraph DAILY RECORDS.[A data dictionary detailing the specific data tables, fields, and relationships of the database required for use [is provided as an addendum to the

Contract] [will be provided by the Government upon issuance of the notice to proceed].] See Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION for additional database requirements.[Provide a database that complies with Section 01 78 00 CLOSEOUT SUBMITTALS, paragraph GEO-DATA-BASE FILES.]

]3.14 RADIO SYSTEM

At minimum, provide a radio system that allows immediate voice contact between personnel and inspectors at the grout injection location, grout pump operator, batching location, and all other operations on site.[Furnish two devices per shift to the Contracting Officer that communicate on the Contractor's frequency or line for monitoring and coordination of grouting operations. These will be returned by the Contracting Officer at the end of grouting operations. Normal wear and tear must be considered.]

Repair or replace any damage that occurs because of lack of immediate communication from a faulty or under-utilized radio system personnel at no cost to the Government.

[3.15 GROUT CONTAINMENT

Contain grout by a combination of physical barriers suitable for the grouting program design. Place containment only in areas to be grouted within 24 hours of placement so as to limit the need to replace containment measures over time. Immediately stop grouting or adjust the grout mixes and pump rates if it is determined that the grout is too thin to be contained by the containment measures.[As a minimum, place [____] millimeters [_____] inches diameter, [_____] millimeters [_____] inches thick stone protection, to a depth of [_____] meters [_____] feet along the slope of the structure in the area to be grouted.][As a minimum, install a correspondingly sized approved turbidity silt fence on the interior side of the structure to at least the same depth.][Consult weather and water stage forecasts and adjust placement of containment measures that might be damaged or rendered ineffective before grouting operations in those areas.]

]

-- End of Section --