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USACE / NAVFAC / AFCEC **UFGS-31 33 20 (November 2024)**

Preparing Activity: USACE **New**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated April 2026
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VOID AND PERMEATION GROUTING

11/24

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SECTION 31 33 20

VOID AND PERMEATION GROUTING
11/24

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NOTE: This guide specification has been prepared as a construction guide specification to address permeation grouting, void grouting, and grouting in unconsolidated deposits, such as breakwaters, alluvial/colluvial deposits, and soil/fill using both cementitious and solution grouts with high to moderate mobility. This specification is intended for minimally disruptive grouting techniques specific to cases where soil grouting may be needed for seepage control or structural support at lower grouting pressures. Large voids and cavities in cohesive soils are more appropriately treated through Limited Mobility Grouting using techniques not covered within this specification. Soil grouting must never be used in any USACE dam or levee without approval from the appropriate Major Subordinate Command (MSC) and the Dam Safety Modification Mandatory Center of Expertise.

This guide specification covers the requirements for advancing cased and uncased boreholes in soil for the purpose of grouting. This specification includes requirements for drilling, grouting, furnishing, handling, transporting, storing, mixing and injecting the grouting materials; care and disposal of drill cuttings, wastewater and waste grout; and clean-up of areas as necessary to complete the work.

This specification may be reworded for adaptation to various applications, such as foundation treatments, cutoff trenches, breakwater protection, 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. Seepage requirements must be removed if the grouting

is intended for structural support.

****

PART 1 GENERAL

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This guide specification may be included in combination with other UFGS grouting specifications for a complete soil and rock grouting program. Limited - mobility grouting and compaction grouting in soil is addressed in Specification 31 33 30. Foundation grouting in rock is addressed under Specification 31 33 10. Foundation grouting advanced within galleries or through concrete structures is addressed in Specification 31 43 13.13. Tunnel and shaft grouting is addressed in Specification 31 73 19.

This specification may be used as a general outline for cement grouting, chemical grouting (here after referred to as "solution grouting", or other specialty grouting applications by insertion of the proper equipment, materials, and procedures in the appropriate paragraphs and by modification and deletion of other paragraphs. Engineer Manuals 1110-2-3504, "Chemical Grouting", and 1110-2-3506, "Grouting Technology", should be consulted as guidance documents as appropriate for the grouting techniques under consideration. There may be occasions when the engagement of a consultant would be appropriate and advantageous to assist in the planning, selecting, and evaluating of a system under consideration.

Caution must be exercised to not prohibit the use of a material or technique that may otherwise satisfy the project scope. Specific products or manufacturers must not be specified within this specification. The use of performance criteria defining the problem, soil conditions, desired strength and/or permeability must be specified to allow manufacturers and Contractors to submit a suitable material that both meets this specification and the intended purpose of the grouting. Consideration must be given to conducting laboratory and field tests and evaluations of the system or systems being considered for a given application, including sieve analyses, unit weight, strength, and permeability tests. Manufacturer of systems and products must be contacted during design efforts to verify a suite of products exist which can meet the performance requirements established as part of the project. Specific products or manufacturers should not be sole sourced within this specification without a Justification and Approval document from the Office of Counsel.

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 having less than 10 holes.

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1.1 SYSTEM DESCRIPTION

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NOTE: Provide a brief summary of the project scope and any prudent references applicable to the layout, depths, and orientation required for the grouting. Include any special restrictions or coordination required. Include relevant bracketed types of foundation features that may be encountered and specify where they are found in the blank brackets.

****

[Historic seepage,] [sand boils and piped sand,] [depressions,] [settlement,] [open voids] have been encountered at [_____] project at the [_____] location. [Loose unconsolidated deposits,] [open work [sands][gravels] with large void capacity,] [engineered structures having open graded materials with large void capacity,] [_____] are known to exist at [_____] project at the [_____] location.

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NOTE: Choose the type of grouting to be performed, reference the proper plan sheets in the empty brackets. Specify the number of boreholes, and/or the length of grouting in the desired units. Fill in the additional quantities as needed in the last blank bracket.

****

Perform [Void] [Permeation] grouting as described in these specifications[and where indicated in the [plans on sheet [_____]]]. A total of [_____ boreholes,] [[_____] meters [_____] feet of grouting] are required in the base contract with additional [_____] quantities to be assigned based on the initial grouting results. Estimated grout quantities are detailed in the Bid Schedule. Perform installation, monitoring, and testing of grout, and provide all planning, labor, materials, tools, equipment, supervisory personnel, monitoring equipment, and quality control personnel and processes required to install grout in accordance with this specification. Verify closure through [verification cores] [falling head permeability tests] for [[_____] number full depth holes] [[_____] meters feet total to

be assigned by the Contracting Officer]. Install ground movement monitoring equipment and system to monitor and record [structure] [structure and] ground movement during grouting operations at [location 1,] [location 2,] [location 3].

1.2 UNIT PRICES

****
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.
****

1.2.1 Mobilization and Demobilization

****
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 percent of the contract lump-sum price for mobilization and demobilization will be paid following on-site assembly to working order of all equipment, and the materials necessary to perform the required drilling and grouting operations. The remaining forty percent of the contract lump-sum 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

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 degree] [20 degree] [30 degree] [____ degree] boreholes with casing, including multiple port sleeve pipe (MPSP) (Tube-A-Manchette (TAM)), as specified. Casing length projecting above the top of ground is not measured for payment and is incidental to the work. The payment 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, and supplies necessary and incidental to the work, including all records associated with this item. [Payment will be made for installation

of the required number of MPSPs.] Grout will be paid for under the appropriate grouting pay item. The Government will make no additional separate payment for items included herein. [Overburden and embankment drilling that is intended to limit the potential for hydrofracture must be performed per ER 1110-1-1807.]

1.2.2.2 Measurement

Measurement for payment is by linear 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 for payment. Grout pipe and casing can be the same material. The total linear footage of properly installed casing must be subdivided 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

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NOTE: If the designer requires a restrictive flow rate less than 2 gallons per minute, grouting time must be considered as a separate measurement and payment item due to the prolonged duration required to complete a single hole.

****

1.2.3.1 Payment

All incidental costs associated with the performance of work in this section are included in the contract price. Payment will be made for costs associated with furnishing all equipment, labor, and supplies necessary for grout hole setups, grout hole connections, and satisfactorily placing grout in grout holes. This includes injecting the grout at the required stages, pressures, rates, and volumes. Incidental work includes, but is not limited to, costs for all equipment, labor, and supplies associated with furnishing the various grout mixes specified herein; including but not limited to furnishing, handling, transporting and storing of grout materials; proportioning the mixes; mixing; quality control of grout; and storage, transportation of grout cubes, testing of grout cubes, and reporting of laboratory test results. Records and data required are incidental to this item. Payment for grout must only be made for grout installed and accepted by the Government in accordance with the plans and specifications. 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. Required quality Control testing is incidental to this item.

1.2.3.2 Measurement

Injection of grout must be measured for payment by the volume in [liter (L)] [gallon (gal)] of liquid grout properly mixed and injected. The grout mixes will be measured for payment on the basis of the volume of each grout mix satisfactorily placed in grout holes. Grouting and grout placement must be subdivided into "initial quantity" and "over initial quantity".

1.2.3.3 Unit of Measure

Unit of measure: [liter (L)][gallon (gal)].

[1.2.4 Grout Containment

****
NOTE: Consider this item if working below water or in an otherwise sensitive area where additional controls may be needed 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 edited 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 grout containment, including but not limited to containment barriers, the placement of cover materials, checking water quality for the presence of grout outside of the approved working area, 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.

Coordinate water quality requirements, including any monitoring while placement of grout or water used for grout production, with stormwater pollution requirements established for the site.
****

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]

]1.3 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 PETROLEUM INSTITUTE (API)

API RP 13B-1	(2026) Testing Water-Based Drilling Fluids
API Spec 13A	(2010; Errata 1 2014; Errata 2-3 2015) Specification for Drilling-Fluid Materials

ASTM INTERNATIONAL (ASTM)

ASTM C40/C40M	(2020) Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
ASTM C70	(2026) Standard Test Method for Surface Moisture in Fine Aggregate
ASTM C87/C87M	(2023) Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
ASTM C127	(2025) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
ASTM C128	(2025) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
ASTM C136/C136M	(2025) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C142/C142M	(2017; R 2023) Standard Test Method for Clay Lumps and Friable Particles in Aggregates
ASTM C150/C150M	(2024) Standard Specification for Portland Cement

ASTM C191	(2026) Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
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 C566	(2025) Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
ASTM C595/C595M	(2025) 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 C937	(2023) Grout Fluidifier for Preplaced-Aggregate Concrete
ASTM C939/C939M	(2022) Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
ASTM C940	(2022) Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory
ASTM C989/C989M	(2025) 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 D4219	(2022) Standard Test Method for Short-Term Unconfined Compressive Strength Index of Chemically Grouted Soils
ASTM D4380	(2020) Standard Test Method for Determining Density of Construction Slurries
ASTM D4832/D4832M	(2023) Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders

ASTM D6910/D6910M	(2019) Standard Test Method for Marsh Funnel Viscosity of Construction Slurries

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 100	(1975) Method of Sampling Concrete Aggregate and Aggregate Sources, and Selection of Material for Testing
COE CRD-C 112	(1969) Method of Test for Surface Moisture in Aggregate by Water Displacement
COE CRD-C 120	(1994) Test Method for Flat and Elongated Particles in Fine Aggregate
COE CRD-C 661	(2006) Specification for Antiwashout Admixtures for Concrete
EM 1110-1-1804	(2001) Engineering and Design -- Geotechnical Investigations
EM 1110-2-3506	(2017) Engineering and Design -- Grouting Technology
ER 1110-1-1807	(2023) Drilling and Invasive Activities at Dams and Levees
ER 1110-1-8100	(1997) Laboratory Investigations and Testing

1.4 DEFINITIONS

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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.
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[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 grouted. The system can also produce graphic and numerical outputs for grouting data in real-time with digital transmittable files, including but not limited to, PDF, excel, spreadsheets, and raw data files.

]1.4.2 Cement Grout

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NOTE: Chemical or cement grouts can be used for permeation or void grouting. Solution grouting may have advantages in soils with higher fines percentages or in locations where seepage may be present. The designer may select cementitious or solution grout, or allow both, per the project

scope. Most seepage related projects should require at least 2 grout mixes.

****

A fluid cementitious material used to reduce the permeability and improve the stability or modulus of coarse-grained materials. Grout can be composed of portland cement, slag cement, (or micro fine cement) and water, and may contain additives such as clay, bentonite, dispersant, retarders, silica fume, fly ash, pozzolan, anti-washout agents, and/or accelerators as appropriate.

1.4.3 Centipoise (cP)

For solution grouts, a common unit of measurement for viscosity allowing for a direct comparison to the viscosity of water. Water has a viscosity of 1 cP at 20 degrees Celsius 68 degrees Fahrenheit.

1.4.4 Closure

The completion of all grouting within a section such that refusal criteria is met, and no additional split spaced holes are required to achieve the objective of the grouting. For permeation grouting, the residual permeabilities following grouting are measured in verification holes for each completed section. For void filling, closure is assessed by verification holes verifying strength for each completed section.

1.4.5 Communication

The passage of water or grout from one hole to another or to any opening/observation point during drilling and/or grouting.

1.4.6 Downstage Grouting

A protocol involving drilling a zone and grouting of that zone before proceeding to the next deeper zone within the same borehole. It involves the placement of a grout by repeated drilling and grouting in successive stages in the downward direction in each hole.[In USACE's Engineering Manual EM 1110-2-3506, this is defined as "Stage Grouting".]

1.4.7 Effective Pressure

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

1.4.8 Exploratory Hole

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

1.4.9 Final Set

A degree of stiffening of a cementitious grout mixture indicating the time in hours and minutes required to stiffen sufficiently to resist the penetration of a weighted test needle (Vicat needle). Also called 'Final Set Time' or 'Time of Final Set'.

1.4.10 Gel Time

The time or period after mixing for a liquid solution grout to exhibit

measurable shear strength, or the onset of change from the liquid to plastic state.

1.4.11 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.

1.4.12 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.

1.4.13 Hydrofracture / Hydrofracturing

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

1.4.14 Initial Set

The time required for freshly mixed cementitious grout to achieve initial set.

1.4.15 Permeation Grouting

A grouting technique that injects the appropriate grout to reduce the effective porosity in the soil/material matrix in the area specified without causing excessive movement or fracturing of the formation, accomplished by solution (chemical) or cementitious grout.

1.4.16 Primary Hole

The first series of holes to be drilled and grouted, usually at the maximum allowable spacing. Grouting of primary holes is completed prior to secondary holes being drilled.

1.4.17 Refusal

The point during grout injection where little or no grout is accepted per the refusal criteria

1.4.18 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.

1.4.19 Restoration

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

1.4.20 Secondary Hole

The second series of holes to be drilled and grouted, spaced midway

between previously grouted primary holes. Secondary holes must be completed prior to drilling tertiary holes.

1.4.21 Section

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.

1.4.22 Solution Grout

A grout that is typically composed of chemical materials combined to form a liquid solution that hardens into a solid material composed of (1) matrix forming base materials, (2) reactants, and (3) accelerators or retarders.

1.4.23 Split Spacing

The procedure of locating an additional grout hole midway between two previously drilled and grouted holes that failed to reach refusal.

1.4.24 Split Space Criteria

The criteria by which split spacing is performed, based on whether a hole or stage meet refusal criteria. The split space criteria also includes occurrences of grout communication between holes, hole collapse, equipment failure, premature termination, or any interruption of grouting activities. The split space criteria may vary depending on the stage, zone, series, or grout line under consideration.

1.4.25 Stage

One complete operational cycle of pressure grouting, over a predefined length and within a pre-defined depth interval of the grout hole.

1.4.26 Stop

A pre-determined depth or elevation at which the expanding plug or packer is positioned.

1.4.27 Succeeding Series

Each of the succeeding series of holes is located based on the split space criteria. Succeeding series holes may be located as directed by the Contracting Officer based upon conditions and prior grouting results.

1.4.28 Tertiary Hole

The third series of holes to be drilled and grouted, spaced midway between previously grouted primary and secondary holes.

1.4.29 Upstage Grouting

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

1.4.30 Void Grouting

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NOTE: Many products for void grouting are available with variations in viscosity, reaction time, reaction with water, expansion characteristic and flexibility of the reacted grout. Products can be single or multi-component grouts and can react when coming in contact with water or require a reactant. The use of low mobility grouts requires special equipment and procedures and is covered under the low mobility grouting specification.

****

A grouting technique performed by injection of appropriate solution or cementitious grout to fill specific voids in the subsurface or structure. A casing pipe is advanced and the grout is injected at specified flow rates and depths to fill the void, and not damage the structure. Casing can be a permanent multiple port sleeve pipe or temporary casing that is withdrawn as the grouting proceeds. The process primarily fills most voids for structural support.

1.4.31 Zone

A pre-determined 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

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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.

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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

Qualifications; G, [_____]

Ground Movement Monitoring Plan; G, [_____]

Drilling and Grouting Work Plan; G, [_____]

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

Laboratory Accreditation; G, [_____]

SD-02 Shop Drawings

Detail Drawings; G, [_____]

SD-03 Product Data

Daily Records; G, [_____]

Drilling Logs; G, [_____]

Grouting Equipment

Equipment Calibration and Certifications; G, [_____]

SD-05 Design Data

Grout Mix Design; G, [_____]

Demonstration Section; G, [_____]

SD-06 Test Reports

Field QA/QC Procedures; G, [_____]

SD-11 Closeout Submittals

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

Completion Report; G, [_____]

1.6 DELIVERY, STORAGE, AND HANDLING

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NOTE: Grouting constituent components may pose health hazards. Some components of solution grouts may require special health/environmental considerations. 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.

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Material must be stored in accordance with the manufacturer's recommendation. Store a sufficient quantity of grout material at or near the work site to ensure grouting operations are not delayed by a shortage of materials. 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. [Store chemicals and materials in metal tanks, and suitably protect from accidental discharge by valving and other necessary means.]

The use of bulk cement is permitted if methods of handling, transporting, and storage are approved by the Contracting Officer in writing. Submit methods in the Drilling and Grouting Work Plan submittal for 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.]

Storage capacity for each constituent component must be sufficient to supply at least 1 week [1 month's] volume of grouting materials so as not to interrupt the work in the event of delivery delays.

1.7 PROJECT/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. Conditions encountered during construction may require adjustments to the grouting program. 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.

[Previous investigations and work completed at the project include [_____].] [Perform any necessary site investigations in accordance with EM 1110-1-1804.]

****

NOTE: Coordinate with property owners, utility providers, facilities, and other stakeholders as necessary to understand potential risks to personal property and infrastructure from grouting operations. The Government must assist with Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) and Water Quality Permitting.

****

1.7.1 Permits and Approvals

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, and mark 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 proposed Drilling and Grouting Work Plan.

1.8 CONTRACTOR QUALIFICATIONS

Meet the following criteria.

a. The grouting program, including installation of grout pipes, must be performed by a specialist Grouting Contractor with at least [five years] [3 projects] of documented successful experience in permeation grouting. The project list must include a description of the project, relative size, and customer point of contact for the work.

b. Include resumes for the [Professional Engineer] [Professional Geologist], Grouting Manager, Project Superintendent, and Project Foreman meeting the following requirements:

[(1) A Professional Engineer or Professional Geologist currently licensed in the State of [_____]. Required experience includes work on at least two projects where they successfully designed and supervised similar grouting applications, and performed responsible supervision of ground treatment design and execution. This engineer will be responsible for signing and sealing drawings, computations, and reports.

] (2) A Grouting Manager who is full-time, on-site, and whose duties are limited to responsibility for grouting operations. Required experience includes at least [5] [10] years of experience in the successful design and field application of grouting technology similar to the requirements specified for this project. Provide complete documentation of applicable experience.

(3) The superintendent must have at least [5] [10] years of successful experience in permeation grouting. Provide complete documentation of applicable experience.

1.9 DRILLING AND GROUTING 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 tweak the grouting

operations to most effectively achieve the project goals.

****

Design the program to meet all applicable criteria and ensure grouting objectives are fulfilled. Submit the following items for approval at least [60] days prior to the start of grouting (except where specific time requirements are stated with the item):

a. Produce a detailed layout drawing of the working area, including the batch plant layout[, and grout hole layout. Show the presence of all utilities as described in the paragraph "UNDERGROUND UTILITIES" within [_____] meters [_____] feet of any planned drilling location].

b. Submit a detailed description of grouting work procedures, including methodology and equipment to be used, and installation of a [structure and] ground movement monitoring system in accordance with paragraph "GROUND MOVEMENT AND MONITORING PLAN". Detail the installation/removal of casing, [installation of MPSP], sequence of grouting operations for each hole, sequences for multiple holes, and field monitoring activities to successfully accomplish the work. [Include the procedure and equipment used to contain grout, and prevent grout from exiting the working area.] Discuss how work will be coordinated to ensure it is in compliance with all work restrictions and requirements.

c. For the submittal, assume at least [_____] meters feet of casing, [MPSP] [and] [_____] cubic meters yards of grouting. Address variations in these quantities in accordance with the applicable FAR Clauses for variations in standard quantities, or as otherwise directed by the Contracting Officer.

d. An explanation of the suitability of the grout materials and procedures proposed, and why they are ideal for successful grouting in the subsurface conditions of the site (see paragraph "DEMONSTRATION SECTION"). Provide applicable supporting data.

e. Describe delivery, storage, and handling procedures for all constituent components of the grout mix design. [Use of bulk cement must be approved.]

f. If grouting operations may be impacted by the presence of underground or other utilities, discuss where, how, and the planned procedure for mitigating these impacts. Detail all applicable local jurisdictional agency requirements and resulting work. Indicate which agency verified the utilities present, and the date verified.

g. A list of personnel and details for each titled role including responsibilities.

h. Discuss closure verification methods and frequency.

i. Produce Detail Drawings and submit [15][_____] days prior to beginning work. For each borehole, include the anticipated volume, pressure, and flow rate for each grout stage, per depth.

[1.10 RESTRICTIONS

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

****

[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 drawings.][Special restrictions exist at the project which limit the use of[diesel equipment,][gasoline equipment,][electrical equipment][_____].]

]1.11 LABORATORY ACCREDITATION

All laboratories submitting testing results for this contract must be accredited by Engineering Regulation ER 1110-1-8100. Submit written proof of accreditation for each laboratory utilized within [30][_____] days prior to the start of work. If the accreditation expires during the contract period, submit the accreditation renewal at least 5 business days prior to the expiration. Submit each laboratory accreditation 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.

NOTE: In general, for permeation grouting, cementitious grouts, cementitious/bentonite grouts, and polyurethane grouts are only appropriate to grout open-graded gravels and poorly-graded coarse sands with a minimum particle size of 1.0 mm. Microfine and ultrafine cement grout is appropriate for treating gravels, coarse, and medium to fine sand having less than 15 percent non-plastic fines. Acrylates and Acrylamide grouts can be used in fine sands and silts with particle sizes less than 0.01 mm.

****

Submit a mix design for the project at least [15] [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. The grout mixes must be approved by the Contracting Officer prior to use. After approved, future changes must be recommended by the [Professional Engineer] [Professional Geologist] and approved by the Contracting Officer. Any modification must be based on an evaluation of grout takes and site conditions.

Deliver, store and handle bulk and bagged cement and pozzolans in accordance with paragraph "DELIVERY, STORAGE, AND HANDLING". Grout mix designs must meet the requirements for cementitious or solution grouts as

required in paragraph CEMENTITIOUS GROUT MIX DESIGN and paragraph SOLUTION GROUT MIX DESIGN. Grout pressures must be adjusted to consider effective pressure acting on the grout stage.

[2.1.1 Cementitious Grout Mix Design

Furnish balanced and stable cementitious grout. The use of a site-batched grout is required and must conform to the following:

a. Dry weight of each solid component and weight of water on a per cubic meter yard basis in accordance with ASTM C128. Show conversion to litersgallons.

b. [7][28]-day unconfined compressive strength test results exceed [690][1034][2068] kPa [100][150][300] psi in accordance with ASTM D4832/D4832M.

c. Batch volume is as proposed by the Contractor in the Work Plan.

d. Required mixing time as proposed by the Contractor in the Work Plan.

e. Reduce the permeability to below the target permeability, based on the soil stratum selected for treatment [_____] cm/s [_____] in/s.

f. Temperature is between 10-32 degrees C 50-90 degrees F.

g. Bleed tests must be in accordance with ASTM C940. Grout bleed must not exceed [1][2] percent after 2 hours.

h. Conduct pressure filtration test in accordance with API Method API RP 13B-1, low-pressure/low-temperature or [ASTM D4380].

i. Set Time is between 8-24 hours in accordance with ASTM C191, method 'A'.

j. Measure viscosity using a Marsh funnel. Determine which viscosity is appropriate for your project and perform Marsh Funnel testing in accordance with ASTM D6910/D6910M:
Mix A between 27-40 seconds [Mix B between 40-55 seconds][Mix C between 55-70 seconds].
[
Due to flowing water conditions, prepare a thicker grout mix based on the flow cone test per ASTM C939/C939M: Mix D between 20-40 seconds.]

k. Test results establishing the working time and set time of the mix design at [30-60 minutes][45-90 minutes][60-120 minutes] in accordance with [ASTM C191, Method A][ASTM C403/C403M].

2.1.1.1 Portland Cement

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

Cement used in grout must conform to the requirements of ASTM C150/C150M Type [I][II][III][,and][V]. The Grout Mix Design submittal must include the source(s) of cement, [6 month][1 year][2 years] of mill tests, and an

ASTM C150/C150M compliance certificate.

2.1.1.2 Blended Hydraulic Cement

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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.

****

Blended hydraulic cement is a combination of portland cement, and one or more pozzolans or limestone. Blended hydraulic cements must conform to ASTM C595/C595M. ASTM C595/C595M 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].

When using blended hydraulic cement, the grout mixes must contain at least 30-percent portland cement by dry weight of the mixture. Test blended cement with limestone to determine the chemical composition of the lime using ASTM C1797. The Grout Mix Design Submittal must include the source(s) of cement, [6 month][1 year][2 years] of mill tests, and an ASTM C595/C595M compliance certificate.

2.1.1.3 Mixing Water

Furnish the water used in grout. The water must be fresh, clean and free from deleterious amounts of sewage, oil, acid, alkali, salts, or organic matter. [Non-potable water is available on site and testing is required to confirm the acceptability of the water. Perform water testing quarterly to ensure that the water does not cause a deleterious effect on the grout.] Perform tests in accordance with ASTM C1602/C1602M, and submit to the Contracting Officer within 24 hours of completion. Withdrawing water from the [lake] [river] requires a permit from the [_____].[Potable water suitable for use in the work is furnished by the Government.][Provide any necessary connections and extensions to the provided supply line.]

2.1.1.4 Pozzolans

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

a. Fly ash [or other raw or calcined natural pozzolans], if used, must conform to ASTM C618. Fly ash may be furnished in paper sacks or in bulk. Reclaimed ash and alternatives to Class F and Class C ash are not permitted for use.

b. Ground-Granulated Blast Furnace Slag (GGBFS), if used, must conform to

ASTM C989/C989M, [grade 100][grade 120].

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

2.1.1.5 Admixtures

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

Ship, handle, and store materials a way that prevents 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, and use an appropriate combination of one or more of the following: water reducers, superplasticizers, fluidifiers, anti-washout additives[, as approved in the Grout Mix Design submittal]. All admixtures must be compatible with other components of the grout. Alternatives may be proposed as part of the work plan. Deviations from the work plan must be approved by the Contracting Officer. No time extension will be given by the Government for review time required due to submitted alternative materials.

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

b. A Superplasticizer is a high-range water reducer possessing characteristics that reduce the water demand by at least 12 percent. Superplasticizer, if used, must meet the requirements of ASTM C494/C494M, type F.[Use Naphthalene sulphonate or polycarboxylate with the ability to coat grout particles in the suspension with a film having a negative charge.]

c. Fluidifier is a compound possessing characteristics which increase the flowability of the mixture, assist in dispersal of the cement grains, and neutralize the setting shrinkage of the grout. If used, fluidifier must meet the material quality requirements specified in ASTM C937.

d. Viscosity Modifier is a natural, soluble, copolymer having a high molecular weight which enhances the stability of the suspension grouts. If used, the material quality must meet the requirements of API Spec 13A (such as welan gum or diutan gum). Viscosity Modifier may also be classified as conforming to ASTM C494/C494M Type S.

e. Anti-Washout Admixtures, if used, must meet the requirements of ASTM C494/C494M Type S and COE CRD-C 661. Consult with the anti-washout admixture manufacturer to ensure compatibility with other grout mix ingredients.

f. Retarders, if used, must meet the requirements of ASTM C494/C494M, Type B.

[2.1.1.6 Sand

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NOTE: Modern grout mixes may be able to produce low viscosity mixes for plugging holes without the use

of sand. Be flexible during construction if a submitted mix design can meet the requirements of a sanded mix without the use of sand.

****

a. Sand for grout must be clean and consist of hard, tough, durable, uncoated particles with no more than [5] percent passing the [0.075] mm [No. 200] sieve. The shape of the particles must be generally rounded or cubical [and must not contain more than [_____] percent of flat or elongated pieces having a maximum dimension in excess of five times the minimum dimension]. When coarse sand is used, the sand must be well graded from fine to coarse per ASTM C136/C136M with 100 percent passing the [2.36] mm [No. 8] sieve.

b. Test the sand to determine its acceptability. Perform these tests at no additional expense to the Government. Sample sand in accordance with the applicable sampling provisions contained in COE CRD-C 100, or as directed by the Contracting Officer. Perform the following tests:

(1) Table 1: Sand Properties

Property	Standard	Criteria
Specific Gravity	ASTM C128	[greater or equal to 2.55]
Absorption	ASTM C128	[less than or equal to 2.0]
Flat and Elongated	COE CRD-C 120	[less than 25 percent]
Clay Lumps and Friable Particles	ASTM C142/C142M	[less than 1%]
Organic Impurities	ASTM C40/C40M and if fails then ASTM C87/C87M	[3 maximum or minimum, 95 percent strength retention]

c. The percentage of surface moisture of the saturated surface-dried sand must be determined in accordance with ASTM C70, ASTM C566, COE CRD-C 112, or other approved method giving comparable results.

d. Store sand a manner that prevents the inclusion of any foreign materials in the grout. All sand must remain in free draining storage bins for at least 72 hours prior to use.

e. The Grout Mix Design submittal must include the source(s) of sand and all required test results.

]]2.1.2 Solution Grout Mix Design

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NOTE: Acrylic grouts will not substantially strengthen/densify soils. They are primarily used for seepage control.

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NOTE: Polyurethane grout can be used for seepage control in boulders, cobbles,and open graded stone. These grouts can strengthen these soils.

NOTE: Sodium silicates are only recommended for short term applications.

NOTE: Remove any sections that are not applicable to the scope to be executed.

****

Furnish solution grout composed of reactant, hardener, accelerator, resin, and water. Structural solution grouts must provide a permanent and irreversible gel with a controlled gel time. The volume change of the grout must not exceed [10][20][50][100] percent of the initial volume.

Provide solution grout with the following properties:

a. Batch weight of each solid component and weight of water on a per [liter][cubic meter] [gallon][cubic yard] basis in accordance with ASTM C127. If using cubic yards, also show conversion to gallons.

b. Select viscosity for compatibility with the material to be grouted. The materials to be be grouted consist of [strata of] [Silt,] [Sand,] [Gravel]. The anticipated hydraulic conductivity of the layer to be grouted is [_____].

****

NOTE: Reduce strength requirements if permeability reduction is the intended goal for the project. For voids or for structural support, the strength should be equivalent to the in-situ soil conditions, or slightly stronger.

****

c. [7] [28]-day unconfined compressive strength exceeding [34] [172] [345] kPa [5] [25] [50] psi in accordance with ASTM D4219.

d. Test results establishing the working time/gel time of the mix design at [5/30 minutes] [30/50 minutes] [in accordance with manufacturer's recommendations and field demonstrated] [Verify gel time in the field with "cup tilting test" where product is poured from one cup to another until it gels.] Cure time for all grouts must be [0.5-10] hours.

e. All solution grouts must be non-toxic and non-flammable during and after grouting, and non-toxic in the set form.

f. Batch volume as proposed by the Contractor in the Work Plan..

****

NOTE: Note for viscosity requirements in Part g, below. These requirements are site specific and should be informed by a site investigation to fully capture the conditions anticipated on site. In general viscosity requirements should generally be:

Less than 2 cP for hydraulic conductivities less than 1E-4 cm/s 4E-5 in/s.

Between 2-5 cP for hydraulic conductivities between 1E-4 cm/s 4E-5 in/s and 1E-3 cm/s 4E-4 in/s.

Between 5-12 cP for for hydraulic conductivities between 1E-3 cm/s 4E-4 in/s and 1E-2 cm/s 4E-3 in/s.

If an acrylamide/acrylate grout is used, the grout must have a specific gravity between 1 and 1.5.

****

g. For seepage control applications the grout must be less permeable than 1x10-6 cm/s 3.9x10-7 in/s and viscosity requirements must be submitted as part of the work plan.
[
Viscosity requirements must be less than [_____ cP] for hydraulic conductivities less than [_____].]
[
Viscosity requirements must be [between] [_____ cP and _____ cP] for hydraulic conductivities between [_____ and _____].]

h. If a polyurethane grout is used for void filling, the grout must have a specific gravity between 1 and 1.4. The viscosity requirements must be submitted as part of the work plan [must be less than [40 cP][100 cP][500 cP][1,000 cP].]

[i. Sodium Silicate Grouts (Chemical Grout for temporary strengthening and seepage control) must not be used for permanent applications as the only grouting product). The minimum sodium silicate concentration must be forty percent of the mix by volume. The sodium silicate must be delivered in sealed containers or certified tank truck, and must be accompanied by the supplier's certificate of origin. Provide the supplier's certificate of origin to the Contracting Officer. Sodium silicate in non-gelled liquid form, while not considered toxic, is strongly alkaline and must be handled by authorized personnel only. Injected or pluviated sand-grout samples must exhibit less than [1][2] percent shrinkage. Grout gel and/or grouted material must not exhibit objectionable odors such as ammonia. Sodium bicarbonate, sodium aluminate and other reactants that produce a temporary grout will not be allowed. The accelerator, if required, must be technical grade, water soluble calcium chloride or other approved metal salt.]

[2.1.3 Containment Barriers

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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.

Place an approved turbidity curtain as minimum containment barrier. The grout-containment barriers must be of a material and design such that they will restrict the escape of grout [into the body of water].[If used, forms must be 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.] Barriers must be removed 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 EQUIPMENT

Supply equipment capable of advancing the grout pipe to the greatest specified depth, or as required to meet the project objectives. Equipment must be capable of drilling required hole depths at required diameters, inclinations, and tolerances required to install grout pipes at the locations and in the condition indicated. Any grout hole that is lost or damaged due to mechanical failure of drilling equipment or inadequacy of grout supply must be replaced by another hole, and drilled at no cost to the Government.

3.2 GROUTING EQUIPMENT

****

NOTE: SECTION GROUTING EQUIPMENT, and associated subsections, will apply to cementitious or solution grouts as edited by the designer. Select cementitious or solution grouting brackets in the following subsections.

****

All grouting equipment used must be of a type, capacity, and mechanical condition suitable for performing the work as approved by the Contracting Officer. Provide all necessary equipment and materials, including but not limited to; electric generators, compressors, heaters, hoses, containers, valves, clamps, connections, and gauges to safely and efficiently conduct and control the work [and minimize the impact to the existing structure]. Equip each main pump with recording instruments and gauges to document continuous pressure, flow, and injection rate. Supply pressure gauges at the pump, and at the grout pipe head. Grout injection is not permitted without fully operational recording instrumentation and gauges in place.

The pumping unit must be equipped with piping and/or hoses of adequate capacity to carry the [cementitious grout] [solution grout and reactant solution components separately] from the point of mixing or batching to the point of placement. The pumping unit must be capable of varying the flowrate without changing the mixture proportions of the materials. Distribution of proportioned grout, under pressure, to the grouting locations must be monitored and controlled by separate, automatic recording, flow rate meters and gauges. Any grout hole that is lost or damaged due to mechanical failure of grouting equipment or inadequacy of grout supply must be replaced by another grout hole at no cost to the Government. Install all structural monitoring equipment required, including ground movement monitoring devices.

3.2.1 Solution Grouting Equipment

Advance solution grouting using MPSP or installed temporary casing. Inject solution grouts in accordance with paragraph GROUT PLACEMENT.

a. Provide solution grouting equipment having the capacity and mechanical capability to perform the specified work. Maintain equipment in operating condition at all times. Monitor and record constituent components and final mix volumes and pressures. Injection pumps must meet the grout manufacturer's recommendations per the selected grouting products.

b. Solution Grout Plant - The grout plant must be a continuous mixing type capable of proportioning and mixing to provide a continuous supply of pumped grout with a gel time established in paragraph SOLUTION GROUT MIX DESIGN. Batch-type systems are not permitted. Equip main pumps with positive displacement meters, capable of recording data, constructed of materials that are non-corrodible for the intended products, and that operate independently of the viscosity of the fluid. Provide a pumping unit with the capability to vary the rate of pumping while maintaining the component ratios constant.

c. Pumping Unit - Equip with piping and hoses of adequate capacity to carry the base grout and reactant solutions separately to the point of mixing. The hoses must contain check valves to prevent backflow. Place a water flushing connection or valve in the line to facilitate flushing the grout between grouting sessions. Distribute proportioned grout under pressure, to the grouting locations monitored by separate, automatic real-time display, flow rate indicators and gauges. Provide a sampling valve beyond the point of mixing and the baffling chamber, easily accessible for sampling mixed grout.

d. Provide, at the site, the required quality control testing apparatus including hydrometers, balance scales, graduates, viscometers, and other devices required to conduct acceptance tests, proportioning tests, and grout quality tests.

e. Provide redundant equipment to include, but not be limited to, hoses, headers, fittings, pumps, gauges, sensors, and instrumentation systems to ensure work can commence without interruption.

f. Grout delivery system must be via MPSP, through injection rams, lances, and probes, or open ended casing pipe.

3.2.2 Cement Grout Equipment

Select the appropriate storage vessels, proportioning equipment, hoses, measurement and control systems, mixing plant, transfer pumps, agitator, circulation systems, valves, injection pumps, and all other required equipment for grouting. The pumping unit must be capable of controlling the rate of flow of material as required to deliver the grout in a controlled manner. The unit must be equipped with a manufacturer's certified flow meter to measure the amount of grout injected at each location. All equipment must be maintained in a condition that allows safe operation and must be inspected before and after each shift. Any hoses, fittings, pipes, gauges or other equipment exhibiting significant wear or degradation must be promptly removed from service, tagged and replaced with safe and appropriate components. In addition, equipment must meet the following requirements:

a. Equipment for mixing and injecting cement grout - Designed for grouting service; maintained throughout duration of work to be capable of mixing, agitating, and forcing grout into grout holes, in a continuous flow, at required pressures in accordance with this specification.

b. Mixer Type: Must utilize a high speed colloidal mixer, sized to adequately supply a single grout pump at its full rated capacity.

c. Mixer Capacity: The mixer capacity must be as submitted and approved in the Drilling and Grouting Work Plan, but not be less than 400[750]

Liters 100[200] gallons. The mixer must have an accurate water meter reading to within 0.5 percent, for measuring the amount of mixing water added to dry ingredients for the grout.

d. Provide grout pump capable of developing pressure in a continuous, uniform manner, without pulsation, at grout hole connections up to the maximum pressure required.

e. Hose for pressure grouting: Inside diameters must be sufficient for the expected flow rate identified in the Drilling and Grouting Work Plan with a rated burst pressure of at least 4 times the maximum working pressure.

f. Arrange grouting equipment to permit accurate pressure control at grout hole connection. Keep equipment and lines clean by circulation of grout and by periodic flushing with water.

g. Configure equipment so flushing can be accomplished with grout intake valves closed, with water supply valve open, and with grout pump running at full speed. Suitable check-valves must be placed in the grout lines at the proper locations to prevent backflow.

h. In addition to grout mixer, provide mechanical agitator tanks equipped with suitable screens.

i. Provide one pressure gauge on manifold hookup at collar of hole being grouted. Use pressure gauge, with range that includes maximum required injection pressure, and that can be read to an accuracy of at least 35 kPa 5 psi. Furnish accurately calibrated, high-precision gauge; use for weekly [daily] checks of accuracy of gauges used in grouting. Submit initial and periodic gauge calibration records in the Equipment Calibration and Certifications submittal.

j. Provide suitable stop valves at collar of hole for use in maintaining pressure, as required, until grout has set. When MPSPs are proposed by the Contractor, valves on the hole collar are not required.

k. Provide a totalizing type meter meeting the requirements of Paragraph INSTRUMENTATION to accurately determine amount of grout injected.

l. Equip pump with by-pass valve to prevent sudden excessive grout pressure from developing at the grout hole connection.

m. Sanded grout mixes can have sand added by batching and pumping grout to an intermediate mixing unit where the sand can be dosed and added to the mix outside of adding the material at the pump. Submit the method to be used in the Drilling and Grouting Work Plan.

3.2.3 Instrumentation

a. Install a flow measuring device with an accuracy of plus or minus 5 percent in the grout line to measure and record the cumulative grout volume pumped and flow rate.

b. Use a grout pressure sensor to measure, monitor, and record maximum and minimum grout pressure in the grout line on a time domain.

c. Monitor for ground heave or movement on a time domain.

3.3 GROUT HOLE DRILLING

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NOTE: Hole spacing will depend on grouting technique, grout materials, and the properties of the soils being grouted. In general, for permeation grouting, the primary hole spacing will vary from; [2.5-3.5 meters] 7-10 feet for cobbles/boulders/armor stone; [1.5-1.7] meters4.5-6 feet for sands and gravels; [1.2-1.5] meters3.5-5 feet for medium sand; [1-1.2] meters3-4 feet for fine sand; [0.8-1] meters2-3 feet for silty sand;

****

Perform the general sequence of drilling as approved in the Drilling and Grouting Work Plan.

3.3.1 Drill Advancement

Advance grout holes at the diameter specified to support [installation of temporary casing][and]installation of MPSPs for each hole location, unless otherwise directed by the Contracting Officer. Be prepared to advance the grout holes spaced every [_____] metersfeet through[concrete][gravels][sands and gravels][sands][silts and sands][silts and clays][cobbles][boulders].

Drill grout holes at the locations and to the depths as shown on the drawings, or as directed by the Contracting Officer. The locations must be within 0.2 meter 0.5 foot (location of center of borehole) at the ground surface of the directed location. Drilling or grouting of holes that have been overdrilled will not be paid unless performed at the direction of the Contracting Officer.

3.4 INSTALLATION OF GROUT PIPES

****

NOTE: Casing is required when a hole is not stable or an area is not intended to be treated by the grouting operation. Sleeve-port pipes can be used for both permeation and void grouting. Oversized casing is typically not required for void/permeation grouting.

****

Maintain an open hole from time of drilling to grouting. Utilize temporary/permanent casing, MPSPs, or other methods to safely install grout as approved in the Drilling and Grouting Work Plan. All casing, if used, must be installed tight against the adjacent ground to prevent grout travel to the surface. Either of the following methods are permitted:

Advance temporary casing before installing the MPSP. Provide re-groutable MPSP with grout ports at maximum in 0.3 or 0.6 meters 1 or 2 foot increments on center along the pipe, and covered by expandable rubber sleeves. Thermoplastic sleeves are not permitted. Use a centralizer while installing the MPSP. If the MPSP cannot be placed to the full depth drilled, restore the open hole at no additional cost to the Government. Installation of MPSP within a borehole requires a weak grout to fill the annular space between the MPSP and the borehole wall in order to prevent unwanted grout communication within the annulus. This annulus grout

material is integral to the installation of the MPSP and must be included in the agreed price for installation of grout pipes. This material will typically be an A-Mix Grout.

Steel pipes or lances that are vibrated or hammered into place are permissible to double as casing and the grout pipe, as long as the injection point is protected and can be opened and closed down hole to prevent clogging. The diameter of casing and grouting pipes may vary based on means and methods approved in the Drilling and Grouting Work Plan. The following requirements apply:

a. Provide the proper devices to horizontally and vertically align the drilling rigs and grout pipes as required to complete drilling and grouting. If adjustments in location are required to avoid obstructions or due to accessibility, contact the Contracting Officer for approval prior to drilling.

b. Place grout pipes in accordance with the approved work plan.

c. Grout pipes may be installed, inclined or vertically, to obtain the planned grout coverage between adjacent grout pipes. A continuous brittle sheath grout mix can be placed in the hole with the MPSP installed through the grout. Grouted MPSPs are not required if grouting is completed through open ended casing or with the use of a ram, lance, or probe.

d. Grout through the MPSP with an internal double packer to inject grout at each sleeve-port. Double packers are not required if grouting is completed through open ended casing or with the use of a ram, lance, or probe.

e. Fill and replace any grout holes that are lost or damaged due to mechanical failure of the equipment, inadequacy of grout supply, improper injection procedure, or inadequate coverage at no cost the Government.

f. Measure the cased depth with a weighted tape prior to grouting.

g. Adequately protect grout pipes from hazards.

h. Once the grout pipe is lowered to the full hole depth the grout pipe must not be withdrawn from the ground until grout injection for each stage is completed.

i. After completion of grouting in each area, fill all holes and leave the area clean of debris.

j. Provide grout pipe pulling jacks, or other mechanical withdrawal means, capable of safely withdrawing steel casing in specified increments during grouting.

3.5 GROUT PLACEMENT

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USACE Engineering Manual EM 1110-2-3506 GROUTING TECHNOLOGY recommends that grouting in soil not exceed an effective pressure of 1/2 psi per foot of depth. This requirement is conservative, and is based on experience grouting in embankment dams.

Typically, allowable grouting pressures will exceed this value based on the scope and intent of the grouting. For any application where structural harm to a facility or loss of life may result, it is recommended to restrict grouting pressures to less than 90% of the theoretical effective hydrofacture pressure and to demonstrate methods in the field to establish safe grouting pressures to complete the work.

Do not use high pressures for grouting near dams. If grouting in or within 61 meters 200 feet of 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 required if worried about isolation or confinement. A combination of methods may be necessary to meet the designers purpose. Complicated grout jobs and/or inexperienced designers should consult with industry or an A/E before methods are specified.

Inject grout on a continuous basis until grouting for any given stage is complete without damaging the structural integrity of existing or appurtenant structures. Conduct surface pressure test of each grout stage from the manifold to the injection point, or equivalent to the maximum hole depth, to ascertain system pressure differential. Use this measured pressure for estimating appropriate grouting pressures for production grouting.[Temporary high injection pressures are permitted to crack open sleeve-ports, but these pressures are not allowed for longer than [10][_____] seconds.] Stoppages in the grout injection must not be longer than the established working time for the last grout that has been injected. Perform all grouting operations in the presence of the Contracting Officer. Any deviations or changes must be approved by the Contracting Officer.

3.5.1 Permeation Grouting and Small Voids

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NOTE: Grouting increments must match sleeve port pipe openings. Note that items A-C must be specified for all jobs. Item D may be required for sensitive projects where the potential for overpumping grout may result in structural damage. The volume of voids in the soil stratum must be known, generally 0.2-0.4 for sands and gravels. This should be determined from soil gradations.

****

Perform permeation grouting using upstage grouting in [0.3][0.6] meters [1][2] foot increments. Limit grouting to the stage that is being treated. Complete holes according to the locations and sequences indicated on the plans. Inject grout until the specified volume or pressure thresholds are obtained, or a decision has been made to split space additional holes. Withdraw the grouting apparatus at suitable intervals to grout each grout stage. Sequence permeation grouting so that grouting does not take place within 1 meter 3 feet of recently grouted

holes that have not reached the gel time for solution grout or the set time for cement grout. The termination header pressure may be adjusted in the field with approval of the Contracting Officer. Adjust injection procedures as required to prevent excessive surface or structure heave. The following criteria apply:

a. Pressure thresholds: Do not exceed 90 percent of the theoretical hydrofracture pressures based on the material type.[The effective grouting pressure for any stage cannot exceed [_____] kPa [_____] psi per meter foot as determined at the mid-point for the stage.]

b. Rate threshold. In any event, the rate of injection into any port must not exceed [4][8][_____] liters [1][2][_____] gallons per minute. Adjust injection procedures, (injection rate, mix design, and pressure), as required to prevent excessive heave.

c. Heave threshold: Stop grouting if 3 millimeters 1/8 inch of surface deflection is observed in any grout stage, or if grout is observed at the ground surface.

[d. The volume threshold for each stage is determined by the equation: Pi*(Hole spacing/2)^2*Stage Length*Volume Voids Percentage. The volume of voids percentage will vary from [0.2 to 0.4] based on [sands and gravels] in Stratum [_____]. [Grouting requires installation of grout plugs, as necessary to control grout loss.][Grouting requires a thick mix in the first grouting line to control grout loss.]]

[e. If a volume threshold is met, the Contracting Officer may require that the hole rest at least 12 hours for [gelling] [setting] before additional grouting is permitted in the remaining stages.]

f. Repeat grouting operations until termination criteria is reached for each successive stage.

g. Completely fill grout holes to the ground surface.

3.5.2 Ground Movement Monitoring Plan

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

Monitor existing ground surface and structures within a radius of 8 meters 25 feet of each permeation grout column at all times during grout injection with laser levels, manometers, or other such equipment to immediately detect movement. Underground utilities that could be affected by grout intrusion and located within 15 meters 50 feet of the permeation grout holes must also be monitored at all times so that any intrusion of grout will be immediately detected. Provide a direct communication system linking the grout pump operator, the personnel at the grout pipe, and the personnel at the monitoring points/equipment. Damage to the existing underground utilities or surrounding buildings or other structures as a result of the failure to detect movements of the ground or intrusion of grout into the piping system must be repaired in kind at the Contractor's expense.[Maximum allowable displacement of underground utilities must not exceed a total of 6 millimeters 0.25 inches.] Perform manufacturers

recommended calibration of any ground movement monitoring equipment and provide initial and periodic records in the Equipment Calibration and Certifications submittal.

[3.5.3 Automated Grouting Data Collection System (AGDCS)

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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.

****

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 and 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 Equipment Calibration and Certifications submittal.

3.5.3.1 AGDCS Equipment Capabilities

The AGDCS must have the following capabilities:

a. Monitor and record all grouting including but not limited to mix type, [line losses], target pressure, gauge pressure, total volume, flow rates and apparent Lugeon values at the midpoint of each stage.

b. Calculated maximum total pressures from the specified gravity pressure criteria

c. Measure effective pressure in the ground. Calculate effective grouting pressure based on 1) pressure readings in the grouting zone, minus 2) the pressure provided by the local water table.

d. The automated system must have the ability to continuously monitor the grouting operation without interference or interruption to the grout injection process while grouting a stage when a mix change is warranted.

e. List of cumulative drilling and grouting issues including but not limited to broken PVC, lost tooling , hole communications, rod drops, fluid loss etc.

f. Correct and reduce the collected data to account for correction factors and field parameters (pressure head losses, pressure measurements, actual depth of the stage being grouted, groundwater influence, mix batching/cycling).

g. Export raw data files into a non-proprietary file format and produce tabular digital records as specified in Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION, paragraph "DATA REQUIREMENTS".

h. Capable of producing graphs in Microsoft Excel format. Propose specific reporting graph design and the use of other file formats

within this submittal.

i. Graphically display in real-time, record, and plot, the following at a minimum:

(1) Total volume of grout placed in the stage;

(2) Gauge pressure, [total pressure,] and [effective pressures,] [and measured effective pressure,] at active zone being grouted;

(3) Start and stop times of grout injection;

(4) A continuous dotted line showing the target pressure;

(5) Rate of injection (volume per time);

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

(7) Plots for Time History of flow and pressure;

(8) The entire grouting record for the stage versus time[;][.]

[(9) A consistent time scale must be plotted on real-time plots.]

3.5.3.2 Automated Grouting Data Collection System (AGDCS) Submittal

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

a. System name and manufacturer.

b. The calculations for producing effective pressure.

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 QA/QC PROCEDURES

Perform all grouting operations under the supervision of the Contracting Officer. In addition, the Quality Control Manager must be present during grouting operations.

3.6.1 Drilling Logs

Keep records of all drilling operations and all quantities associated with the drilling activities. Submit complete, legible records of the locations, depths and designations of all grout holes drilled [as an attachment to submitted DAILY RECORDS][as directed by the Contracting Officer]. The drilling logs must utilize the [USACE Form 1836 and 1836 Continuation][_____] Form for drilling logging, including the date, hole ID, hole northing and easting, top elevation, and station, drill rig ID, driller ID, logger ID, start and stop times for drilling, and ground surface description. Describe any unusual drilling conditions encountered including but not limited to discontinuities, voids, soft zones, hole collapse, hole communication, water loss, or other conditions. Survey all Primary and Verification holes.

3.6.2 Daily Records

Daily data and quality control records must be available to the Contracting Officer at all times. Submit field records upon completion of the hole. 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.] 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. Draft and final drilling logs.

b. Hole ID,[hole series,] hole[station and offset][latitude and longitude].

c. [Hole][Casing and MPSP] top and bottom elevation, depth, and diameter of hole.

d. Hole inclination (vertical = 90 degrees).

e. Stage geologic formation.

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

g. Stage target effective pressure and target gauge pressure.

h. Injection pressure, flow rate, and volume in liters gallons for each grout mix injected for each grout stage[and grout zone] summarized for each grout hole.[Include[w:c Ratio][Solution grout percentages][placed each hole.]]

i. Maximum pressure and flow rate reached in each zone.

j. Summary of grout mixes used for each grouting effort with itemized total quantities of grout materials placed vs quantity of grout wasted.

k. Location and number of grout holes completed.

l. Depth at which ground heave/displacement was detected.

m. Depth at which grout intrusion into an underground piping system or

communication with another grout hole is detected.

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.

3.7 GROUT MONITORING

****

NOTE: Requirements for water quality monitoring are site specific and must be coordinated with local, state, and federal agencies based on the scope and sensitivity of the project. It is the responsibility of the Government to determine what these requirements are and include them in the Contract.

****

a. Closely monitor 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. Cementitious Grout flow rate must be monitored by magnetic flow meter or coriolis mass flow meter during all grout injection. Gauges must be provided at the pump, and at the grout pipe head, to measure pressure. Type and location of gauges must be approved by the Contracting Officer in the Drilling and Grouting Work Plan. All pressure gauges must be certified for accuracy to within plus or minus 5 percent and submitted under the Equipment Calibration and Certifications submittal.

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. If excessive grout take is experienced that is not attributable to leakage, change injection pressure, pumping rates, gel or setting times, or grout composition, subject to approval by the Contracting Officer, to reduce grout use to acceptable levels.

e. For storm drains located within the grout zone and in close proximity to the grout injection points, perform water quality monitoring continuously during grouting.

3.7.1 Grout Data Logger

Use a Grout Data Logger, at each individual grout header, capable of electronically storing and displaying the hole number, date and time of the start and stop of grout injection, continuous flow rates, injection

pressures, and total grout placed for each grout hole. Perform manufacturer's recommended calibration of any equipment utilized, and provide initial and periodic records in the Equipment Calibration and Certifications submittal.

3.8 TESTING

The Contracting Officer reserves the right to require additional field testing if the grout appears to be out of specification tolerances.

[3.8.1 Solution Grouting

****
NOTE: Only select the second strength verification paragraph if the verification program requires confirmation of the soil strength post grouting.
****

a. Production Strength Test: Prepare lab strength tests using the approved grout mix applied to three samples of [Ottawa sand] [material obtained on-site] for every 950 liters 2,500 gallons of grout injected in accordance with ASTM D4219. Verify strength requirements are met as approved in Paragraph "Solution Grout Mix Design".
[
Strength Verification Tests: During verification hole drilling, core a minimum of [three][_____] boreholes to obtain a total of [9][_____] recovered samples to verify the grouted zones have been thoroughly permeated and stabilized with grout. Perform compressive strength tests on the retrieved samples for each location per ASTM D4219. Verify the strength meets the requirements approved in Paragraph "Solution Grout Mix Design".]

b. Production Viscosity Test: Verify the viscosity of the grout mix 1 time per [shift] for each grout mix used in accordance with the manufacturer's recommendations. Ensure the viscosity meets the requirements approved in Paragraph "Solution Grout Mix Design".

c. Permeability Verification Test: Conduct falling head tests per the [Hvorslev Method,] [_____] in each open verification hole between two previously grouted holes. Conduct the test for a period of [4][8] [_____] hours to verify the design permeability of [_____] cm/s[_____] in/s was achieved. Pump the hole out upon completion, and grout the hole per the same methods as production holes. Verify of the grout hole refuses. Split spaced holes are required if the verification hole fails permeability and does not reach refusal.

[
d. Solution Grout Gel Times: Determine minimum and maximum gel times to ensure appropriate penetrations of grout into the grouted material. For gel time quality control, take at least one sample every [4] hours of pumping for each grout mix used. Verify gel time requirements are met as approved in paragraph SOLUTION GROUT MIX DESIGN. Properly label gel samples and store until completion of the work.]

][3.8.2 Cementitious Grouting

****
NOTE: Items A-F are specific to permeation and small void grouting. Item G applies to all.
****

a. Production Viscosity Test: Perform Marsh Funnel testing in accordance with ASTM D6910/D6910M 1 time per shift for each grout mix used. The Marsh time must meet the requirements approved in paragraph CEMENTITIOUS GROUT MIX DESIGN.[The Marsh time must be between [____] and [____] seconds for stratum [_____].]
[
Perform flow cone test, if used, in accordance with ASTM C939/C939M 1 time per [shift] for each grout mix used. The flow cone time must meet the requirements approved in paragraph CEMENTITIOUS GROUT MIX DESIGN.]

b. Production Strength Test: Perform [7] [28]-day unconfined compressive strength test per ASTM D4832/D4832M every 950 liters 2,500 gallons of grout batched to verify strength meets the requirements approved in paragraph CEMENTITIOUS GROUT MIX DESIGN.[Test each grout mix when used in production weekly].

c. Production Pressure Filtration Test: Conduct pressure filtration test in accordance with API RP 13B-1, low-pressure/low-temperature at least [1] time[s] per week for each grout mix used. Must meet requirements approved in paragraph CEMENTITIOUS GROUT MIX DESIGN.

d. Production Bleed Test: Conduct bleed tests in accordance with ASTM C940 at least [1] time[s] per week for each grout mix used. Must meet requirements approved in paragraph CEMENTITIOUS GROUT MIX DESIGN.

e. Cementitious Grout Set Time: Set Time is between 8-24 hours in accordance with ASTM C191, method 'A'. Test [1][_____] time per week.

f. Permeability Verification Test: Conduct falling head tests per the [Hvorslev Method,] [_____] in each open verification holes between two previously grouted holes. Conduct the test for a period of [4][8] [_____] hours to verify the design permeability of [_____] cm/s[_____] in/s was achieved. Pump the hole out upon completion, and grout the hole per the same methods as production holes. Verify of the grout hole refuses. Split spaced holes are required if the verification hole fails permeability and does not reach refusal.

g. Temperature must be between 50-90 degrees F tested 1 time per shift.

][3.9 DEMONSTRATION SECTION

****
NOTE: Tailor the section as needed based on the materials to be grouted.
****

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

a. Verify the grout mixes are appropriate and effective for the subsurface material characteristics.

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 verify permeability, advance [_____] verification borings to include falling head permeability tests per the requirements herein.
[
To verify strength and void filling, advance [_____] verification borings to obtain core for unconfined compressive strength testing per the requirements herein.]
[
To verify strength and void filling, conduct [Standard Penetration Testing (SPT)] [Cone Penetrometer Testing (CPT)] between two completed grout holes for the full depth of the hole.]
[
Excavate a test pit to expose a grouted hole for inspection.]

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.]

][3.10 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.]

]3.11 SITE RESTORATION

a. Remove grout pipes installed from surface. [Sleeve port pipes to be cut off flush with the ground surface].

b. Promptly clean up spilled materials and grout.

c. Restore street pavement and sidewalks in accordance with requirements of local jurisdiction.

d. Where grouting or grout operations are performed from the ground surface, restore grouting locations to their existing condition, including re-paving of the street right of way in areas where grout holes have been installed.

3.12 DATA MANAGEMENT

3.12.1 AS-BUILT DRAWINGS AND GROUTING PROFILES

Maintain progress drawings in the field and provide to the Government [weekly][monthly]. Include at least one updated plan view showing total grout volume for all grout holes. In profile, display stage pressure and volume for each grout hole. Use the progress drawings to develop the as-built drawings for submittal to the Government. Submit drawings of as-built grouting locations detailing grout volumes and pressures for each incremental grout injection upon completion of grouting activities[for each alignment].[Include separate profiles for drilling and grouting information.]

Produce drawings at scale of [1:250] or [1:150]. Provide separate sheets for 1) plan view, 2) [section] [profile] view(s) of drilling including lost tooling and interpretive geology, 3) [section] [profile] view(s) of grouting results. 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 the electronic copy must still be submitted.]

3.13 COMPLETION REPORT

Fourteen days prior to the Contract completion, prepare and submit a drilling and 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, and color photographs, or 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 15 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. Include statistical analyses.

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

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.

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 plots of the [7-day and] 28-day strength, for each mix, showing results versus time, with specifications limits clearly delineated on the plots.

3.14 COMMUNICATIONS

Install a communications system that links (at a minimum) the grout plants, grout injection stations, and all other operations on site as necessary.[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, and it should be expected they will be subject to normal wear and tear.]

-- End of Section --