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USACE / NAVFAC / AFCEC / NASA **UFGS-02 35 27 (May 2010)**

Preparing Activity: USACE **Superseding**
UFGS-02 35 27 (April 2006)

GUIDE SPECIFICATION FOR CONSTRUCTION

References are in agreement with UMRL dated January 2017
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05/10

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SECTION 02 35 27

SOIL-BENTONITE (S-B) SLURRY TRENCH
05/10

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NOTE: This guide specification covers the requirements for constructing a soil-bentonite slurry trench at both conventional and hazardous waste projects.

Adhere to UFC 1-300-02 **Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. 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 information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR)**.**

****

PART 1 GENERAL

****

NOTE: In using this guide specification, the designer should realize that the requirements for the bentonite, backfill, and construction procedure are highly dependent on the intended purpose of the slurry trench and the environment in which it is to be used.

The primary considerations for S-B slurry trenches are blowout requirements, permeability, strength, and compressibility.

The S-B backfill should be designed to prevent possible blowout or piping of the S-B backfill into the surrounding foundation material due to the

hydraulic gradient acting across the slurry trench. Design criteria are presented in Chapter 9, Corps of Engineers (COE) EM 1110-2-1901.

The permeability for S-B slurry trenches is usually in the order of 10-6 to 10-8 cm/sec. The actual permeability of the slurry trench is dependent on both the filter cake, which forms on the sides of the trench and the S-B backfill. The contributions of both are dependent on the relative permeability and thickness of the two materials. For design purposes, however, it is recommended that the permeability of the slurry trench be based only on the S-B backfill. For permanent or critical temporary projects, laboratory permeability tests should be utilized in establishing the mix design.

When design requirements dictate, both shear strength and compressibility of the S-B backfill should be analyzed by conducting laboratory testing.

Since chemical contaminants commonly associated with hazardous waste sites may increase the permeability of S-B backfill, a compatibility testing program must be undertaken prior to constructing a slurry trench. If the trench is to be excavated through contaminated material, consider performing compatibility testing using two potential backfill materials; soils to be excavated from the trench and an uncontaminated borrow source. It should be noted that compatibility testing can take from 2 to 6 months to complete. For this reason, it is generally recommended that compatibility testing be completed during the design phase of the project.

A recommended compatibility testing program consists of:

1. Free swell (ASTM D5890) and filter cake permeability tests of several bentonites using contaminated site ground water and site mixing water that will be used during construction to determine acceptable bentonites for use on the project.

2. Mix design optimization tests to determine the most economical mix of soils, dry bentonite, and bentonite slurry to produce the required permeability. This consists of short-duration (48-72 hours) permeability tests varying the amount of dry bentonite added (0, 2, and 4 percent) and if necessary the amount of additional fines added (0, 10, 20 percent) using site mixing water as the permeant.

3. Long-term flexible wall permeameter testing of at least 3 S-B backfill samples: the optimum mix design with site mixing water only as the permeant (control); the optimum mix design with contaminated site ground water as the permeant (after 1 pore

volume of site mixing water permeant to ensure a good test setup); and a bentonite content 2 percent greater than the optimum determined in step 2 with contaminated site ground water as the permeant (after 1 pore volume of site mixing water permeant). It is recommended that 3 pore volumes of ground water permeant pass through the S-B backfill samples. This typically takes at least 2 months.

To approximate field conditions in the lab, it is important to obtain contaminated ground water and mixing water from the site. The site mixing water used during compatibility testing shall be the water used to make the bentonite slurry during construction.

For laboratory testing, consider requiring a permeability of one-half an order of magnitude less than the required field permeability (for example, 5x10-8 cm/sec in the lab for 1x10-7 cm/sec in the field).

****

1.1 MEASUREMENT AND PAYMENT

****

NOTE: Delete this paragraph when work is covered by lump sum contract price.

****

1.1.1 Measurement

Measurement for S-B Slurry Trench shall be based on the area in square meters feet of completed slurry trench measured in a vertical plane through the centerline of the slurry trench, from the top of the working surface to the bottom of the excavated trench, and vertical lines at each corner of the full depth of the excavated trench. Measurement shall be based on surveys and soundings taken at the site as directed and approved.

1.1.2 Payment

Payment for S-B Slurry Trench will be made at the contract unit price per square meter foot. Such price will include costs incurred for the construction and completion of the slurry trench. No separate payment will be made for material, equipment, handling and cleaning the slurry, quality control testing, record keeping, and site preparation including construction of the working surface.

1.2 DEFINITIONS

****

NOTE: Remove items not required in the project.

****

The terms used in this Section are defined as follows:

1.2.1 Slurry Trench

The slurry trench is a [_____] [900] mm [3] feet minimum width trench

excavated through the existing ground or prepared working surface using the slurry method of excavation and backfilled with S-B backfill material, to form a low permeability cutoff wall.

1.2.2 Slurry Method of Excavation

The slurry method of excavation consists of excavating a vertical walled trench and at the same time keeping the trench filled with a bentonite slurry mixture. The purpose of the slurry is to support the walls of the trench and prevent movement of ground water.

1.2.3 Bentonite

Bentonite is an ultrafine natural clay whose principal mineral constituent is sodium cation montmorillonite.

1.2.4 Slurry

Slurry is a colloidal mixture of bentonite and water.

1.2.5 Soil Bentonite (S-B) Backfill

S-B backfill is a homogeneous mixture of material produced by mixing soil with bentonite slurry [and additional dry bentonite], which is placed into the excavated trench to complete the soil-bentonite slurry trench.

1.2.6 Ground Water Level

The ground water level is the piezometric level of the ground water as determined from piezometers and wells.

1.2.7 Working Surface

The working surface is the top of the [stripped and/or prepared natural ground] [or] [the surface of previously compacted fill] from which the slurry trench shall be constructed.

1.2.8 Confining Stratum

The confining stratum is the soil stratum or rock unit to or into which the bottom of the slurry trench is excavated.

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 Reference Identifier (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.
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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	(2009; R 2016) Recommended Practice for Field 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 C143/C143M	(2015) Standard Test Method for Slump of Hydraulic-Cement Concrete
ASTM D1140	(2014) Amount of Material in Soils Finer than the No. 200 (75-micrometer) Sieve
ASTM D2216	(2010) Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D422	(1963; R 2007; E 2014; E 2014) Particle-Size Analysis of Soils
ASTM D4318	(2010; E 2014) Liquid Limit, Plastic Limit, and Plasticity Index of Soils
ASTM D5084	(2016a) Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
ASTM D698	(2012; E 2014; E 2015) Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/cu. ft. (600 kN-m/cu. m.))

U.S. ENVIRONMENTAL PROTECTION AGENCY (EPA)

EPA 600/4-79/020	(1983) Methods for Chemical Analysis of Water and Wastes

1.4 SUBMITTALS

****
NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have

designated 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 submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation 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, Air Force, and NASA projects.

Use the "S" classification only in SD-11 Closeout Submittals. The "S" following a submittal item indicates that the submittal is required for the Sustainability Notebook to fulfill federally mandated sustainable requirements in accordance with Section 01 33 29 SUSTAINABILITY REPORTING.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

****

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.][information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submittals with an "S" are for inclusion in the Sustainability Notebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Preconstruction Testing Plan; G[, [_____]]
Slurry Trench Implementation Plan; G[, [_____]]
Blasting Plan; G[, [_____]]

SD-02 Shop Drawings

As-Built Profile

SD-04 Samples

Bentonite; G[, [_____]]
Backfill Material; G[, [_____]]

SD-06 Test Reports

S-B Backfill Test Report
Quality Control Testing
Soundings
Water
Bentonite Slurry Mixes
Slurry Properties

SD-07 Certificates

Bentonite

1.5 OTHER SUBMITTAL REQUIREMENTS

Submit the following:

a. Plan describing the general work sequence and layout of operations. The layout of operations shall include scale drawings, which depict slurry and S-B backfill preparation and storage areas. The plan shall describe Contractor qualifications, equipment, method of trench excavation, [blasting,] use or disposal of excavated material, bottom cleaning, slurry preparation and maintenance, S-B backfill preparation and placement, and site clean-up.

b. Plan describing quality control equipment and test procedures, sample test forms for reporting test results, and the offsite laboratory proposed for use.

c. Data on the equipment to be used in the construction of the slurry trench; equipment to be used to obtain [bedrock] [impervious stratum] samples; [equipment to be used to obtain record control samples of the completed slurry trench;] and equipment to be used in the Contractor's quality control testing.

d. A copy of the test results from the bentonite manufacturer for each lot shipped to the site and a certificate of compliance stating that the bentonite complies with applicable standards.

1.6 QUALITY ASSURANCE

The Government may perform quality assurance testing on representative samples obtained by the [Contractor] [Government] of the bentonite slurry and S-B backfill using the laboratory and equipment furnished by the Contractor. The Government testing will in no way relieve the Contractor of the responsibility of performing tests necessary to meet the Construction Quality Control (CQC) requirements. Provide the equipment and laboratory space to government personnel on demand and these services will be considered a subsidiary obligation of the soil bentonite slurry trench construction. Make all routine testing procedures available for inspection by the Contracting Officer at any time.

1.6.1 Qualifications

****
NOTE: Remove subparagraphs not required in the project.
****

1.6.1.1 Contractor

Successfully installed a minimum area of [_____] 100,000 square meters 1,000,000 square feet. The qualifications and experience of personnel who shall be responsible for conducting the operations shall include references (name and telephone number) of the owners of the Contractor's previous slurry trench construction projects.

1.6.1.2 Slurry Trench Specialist

The slurry trench specialist shall be an individual who has had experience with at least [_____] [5] projects in all aspects of slurry trench construction which includes, but is not limited to:

a. The use, testing, and control of bentonite slurries,

b. The mixing methods required to properly mix the slurry and backfill materials as required,

c. Trench excavation and backfilling procedures, and

d. A thorough knowledge of construction equipment and material testing required for slurry trench construction.

1.6.1.3 Slurry Trench Excavation Equipment Operator

The slurry trench excavation equipment operator shall have experience using similar slurry trench excavation equipment to be used for this contract in a minimum of [_____] [2] projects of similar or greater magnitude (depth).

1.7 DELIVERY, STORAGE, AND HANDLING

Protect materials delivered and placed in storage from the weather, dirt, dust or other contaminants.

1.8 GEOTECHNICAL SITE CONDITIONS

1.8.1 Exploratory Borings

****

NOTE: In most cases, the exploratory borings along the alignment should be obtained during design. However, in some cases, it may be necessary to have the Contractor obtain exploratory borings to determine or verify the depth or characteristics of the key stratum. This should be performed well in advance of slurry trench installation to prevent delays. If additional drilling is required, it is recommended that a separate specification be prepared for that work.

****

Subsurface exploratory borings have been obtained by the Government to determine the character of materials to be excavated. Locations of the borings are shown on the drawings and the logs of those borings, which fall within the area of this contract, are included in [_____] for the convenience of the Contractor. The Government assumes no responsibility for interpretation or deductions made from the logs and borings. Local minor variations may exist in the subsurface materials between boring

locations and, if encountered, will not be considered as being materially different within the purview of this contract [_____]. Soils classifications shown on the logs are the result of [field visual classifications] [laboratory classifications] in accordance with the Unified Soil Classifications System. [The results of all laboratory testing, including rock and soil, are available for review by the Contractor in the [_____].] [Attention is invited to paragraph SUBSURFACE INVESTIGATIONS in the Special Clauses for availability of core borings and soil samples for inspection.]

1.8.2 Subsurface Conditions

****

NOTE: A general description of the conditions to be encountered during the excavation should be provided. Also, provide a description of the stratum or formation into which the slurry trench will be keyed.

****

[_____].

1.8.3 Ground Water

****

NOTE: Provide a discussion of the ground water that could affect the slurry trench construction.

****

[_____].

1.8.4 [Embankment Conditions]

****

NOTE: When a slurry trench is installed through an existing embankment, a description of the embankment materials to be excavated should be provided.

****

[_____].

PART 2 PRODUCTS

2.1 MATERIALS

2.1.1 Bentonite

****

NOTE: Bentonites for use may conform to either Section 4 or Section 5 of API Spec 13A, provided the desired permeability is obtained during pre-construction mix design and compatibility testing. Bentonites, which conform to Section 4 of API Spec. 13A, have typically been treated with small amounts of polymers. Bentonites, which conform to Section 5 of API Spec 13A, have not been chemically treated. For this specification, the values shown in Table 1 for bentonite, reflect the requirements of API Spec 13A, Section 5. Values in

Table 1 should be modified accordingly for Section 4 bentonites.

In the event no bentonites conforming to either Section 4 or 5 of API Spec 13A can produce the desired permeability due to contaminants in ground water, bentonites or other materials with substantial chemical alterations or additives may be used. Use of these materials will depend upon the successful completion of a compatibility testing program and the concurrence of all appropriate State and Federal regulatory agencies. These materials should be used with caution due to the general lack of long-term performance data. These materials may be proprietary products. Modify appropriate sections of this guide specification according to manufacturer's recommendations.

****

The bentonite shall be sodium cation base montmorillonite powder that conforms to API Spec 13A, Section [4][5], and Table 1, located at the end of this section. [Chemically treated bentonite will not be allowed.] [Other chemically treated bentonites may be considered provided the required permeability values can not be obtained with bentonites conforming with Section 4 or Section 5 of API Spec 13A.] No bentonite from the bentonite manufacturer shall be used prior to acceptance by the Contracting Officer. Bentonite not meeting specifications shall be promptly removed from the site at the Contractor's expense. Bentonite shall be protected from moisture during transit and storage. Submit a minimum of 4.5 kg 10 pounds of the proposed bentonite at least [1] [_____] month prior to use.

2.1.2 Water

The [Contractor shall] [Government will] supply [and condition] water required for mixing with bentonite to produce slurry. The water shall be clean, fresh, and comply with the standards specified in Table 1. Submit water quality test results for water used for mixing the bentonite slurry to assure conformance to these standards. Submit a record of the water source and associated chemical analysis.

2.1.3 Backfill Material

****

NOTE: For backfill materials with a low percentage of fines (less than 20 percent), it may be necessary to add supplemental fines from an additional borrow area to achieve the desired permeability.

If offsite borrow material is selected for use as the backfill material, it should be tested to ensure that it is uncontaminated. Testing requirements should be addressed in Section 01 35 45.00 10 CHEMICAL DATA QUALITY CONTROL. It may be possible to use material excavated from the trench as backfill material, even if it is slightly contaminated. If contaminated material is being considered for use, it must be verified that the material can be safely handled in the field.

The gradation requirements below should be modified to fit the chosen backfill material. In general, no particles greater than 76 mm 3 inches should be in the mix, and a minimum fines content of 20 percent is always recommended.
****

The backfill material shall be obtained from [material excavated from the slurry trench] [a Government furnished borrow area] [an offsite borrow area]. Thirty days prior to utilization of any off-site borrow, the site shall be identified and a minimum of 22.5 kg 50 pounds of each type of proposed borrow soil, at least [1] [_____] month prior to use.of each type of material, shall be submitted to the Contracting Officer for QA testing. Backfill shall be free of [contamination] [_____], roots, debris, brush, sod, organic or frozen material. [Material passing the 75 micrometer No. 200 sieve shall have a liquid limit greater than [30] [_____] and a plasticity index greater than [10] [_____]]. Materials shall be thoroughly blended prior to mixing with bentonite slurry and shall conform to the following gradation requirements:

Screen Size or Number (U.S. Standard)	Percent Passing by Dry Weight
[75 mm 3 inch][_____]	[100][_____]
[4.76 mm No. 4][_____]	[40-80][_____]
[0.42 mm No. 40][_____]	[25-60][_____]
[75 micrometer No. 200][_____]	[20-40][_____]

2.2 EQUIPMENT

Furnish all necessary plant and equipment for use on this project.

2.2.1 Trench Excavation Equipment

Equipment for excavating the slurry trench shall be any type or combination of excavating equipment capable of performing the work as specified and shown on the drawings. [The equipment shall be capable of excavating the required minimum width of trench in a single pass of the excavating equipment.] The buckets utilized with such equipment may be perforated, tapered and equipped with bottom-side cutter teeth protruding no more than 150 mm 6 inches. The bucket shall be designed to maintain the width of the trench and to minimize raveling of the trench sides during use. The equipment shall be able to reach at least [_____] 1500 mm 5 feet deeper than the maximum depth shown on the drawings.

2.2.2 Slurry Mixing and Cleaning Equipment

The slurry mixing plant shall be equipped with a high-speed/high-shear, colloidal mixer or a high-velocity/high pressure venturi jet mixer used in conjunction with a high-speed/high-shear centrifugal pump. The plant shall be equipped with a mechanically or hydraulically agitated sump and shall include pumps, valves, hoses, supply lines, tools, and other equipment and materials required to prepare the slurry and deliver it in a continuous supply from the hydration pond [or tanks] to the slurry trench. Mixers shall be capable of achieving complete dispersion of bentonite and

additives, and shall be capable of continually mixing the slurry to provide and maintain a uniform blended slurry. Provide sufficient ponds [or tanks] for storage of hydrated bentonite slurry. [Slurry cleaning equipment shall be available to reduce sand, sediment, or other solids as necessary to maintain the sand content or density requirements of the slurry in the trench. Slurry cleaning equipment may include but not be limited to vibratory shaker screens, centrifugal sand separators, or stilling ponds.]

2.2.3 Field Laboratory Equipment

The field laboratory shall contain as a minimum the following equipment:

1	Mold and rod for slump test
2	Marsh funnel sets
1	Standard filter press
2	Mud balances (direct reading of density)
1	Slurry sampler
2	0.075 mm Number 200 sieves
1	Set of standard sieves and sieve shaker
1	Oven for moisture content
1	Balance
1	pH [meter] [paper]
2	Sand content sets
1	101.6 mm 4 inch Cylindrical mold

2.3 BENTONITE SLURRY MIXES

2.3.1 Initial Bentonite Slurry Mixture

****

NOTE: For most bentonites, 4 to 6 percent by weight should produce a slurry that will meet all the specified requirements. Other mixtures may be determined to be acceptable during pre-construction tests. S-B backfill mix designs should be determined during pre-construction testing. Results from the tests should be used in Table 1.

****

The initial bentonite slurry mixture shall conform to the standards specified in Table 1.

2.3.2 Trench Bentonite Slurry Mixture

The trench bentonite slurry mixture shall conform to the standards

specified in Table 1.

2.3.3 Additional Bentonite

If directed by the Contracting Officer, thicken the slurry to a more viscous condition than the limits specified above. Use additional bentonite, as directed.

2.3.4 Additives

Peptizing agents and bulking agents shall not be mixed with the slurry. Approved thinners or dispersants and flocculants of the types used in the control of oil field drilling muds, may be used to control standard properties of the slurry such as apparent viscosity, pH and filtration characteristics.

2.3.5 S-B Backfill

The S-B backfill, consisting of [backfill material and bentonite slurry] [backfill material, bentonite slurry, and a minimum of [2] [_____] percent dry bentonite] shall be thoroughly mixed and shall conform to the standards specified in Table 1 just prior to placement in the trench.

PART 3 EXECUTION

3.1 GENERAL REQUIREMENTS

The slurry trench shall be constructed to the elevations, lines, grades, and cross-sections shown and in accordance with these specifications, unless otherwise directed. The Government may modify the dimensions and quantities of the work as determined necessary. Submit a Slurry Trench Implementation Plan for approval, a minimum of [_____] weeks prior to the start of construction.

3.2 WORKING SURFACE

****

NOTE: The maximum slurry trench surface slope along the slurry trench alignment during construction should be 1 percent. For sites with grades greater than 1 percent, the working surface should be designed to achieve the 1 percent slope. If contaminated, it is common practice to remove the top 300 mm 12 inches of the working surface after completion of the slurry trench. Most excavation equipment requires 6 meters 20 feet of clearance to swing around; therefore, a minimum working surface width of 12 meters 40 feet is recommended. Some equipment may require wider work platforms in order to negotiate trench corners. At sites where S-B backfill will be mixed beside the trench, instead of at a central mixing area, a wider working surface may be required. The slurry trench alignment is not required to be in the centerline of the working surface.

****

Slurry trench construction shall be accomplished from the working surface, as shown on the drawings. If the Contractor's operations require a wider

working surface, the reason for the change shall be submitted. If approved, a wider working surface may be constructed at no additional cost to the Government. Working surface material and compaction requirements are described in Section [_____]. In the event that the static ground water table is encountered at a depth of [_____] 1 m 3.0 foot or less below the designated working surface, at the direction of the Contracting Officer, raise the working surface to a height of [_____] [1] m [3] feet above the measured static ground water level with approved fill material. The working surface thus constructed shall be utilized as a basis for measurement for payment.

3.3 SLURRY TRENCH EXCAVATION

****

NOTE: For shallow (less than 15 m 50 feet) slurry walls, most excavation equipment can round trench corners with a 30 m 100 foot turning radius. For trenches deeper than 15 m 50 feet, consult with Contractors about the required turning radius.

****

The excavation shall begin from the working surface and shall provide a vertical (within 2 percent) continuous [_____] 900 mm 3 foot minimum width trench to the required depth along the centerline of the excavation. [The slurry trench shall key [_____] 600 mm 2 feet into the [_____] stratum.] The Contracting Officer may direct the Contractor to modify the trench depth based on examination of bucket cuttings or drive samples. The toe of the slope of the trench excavation shall not precede the toe of the S-B backfill slope by less than [_____] 9 meters 30 feet or more than [_____] 30 meters 100 feet. At the intersection of 2 straight line segments, the trench excavation shall extend a minimum of [_____] 1500 mm 5 feet beyond the outside of the intersection at all depths. If trench excavation overlaps into previously completed slurry trench, the excavation shall extend a minimum of [_____] 3 meters 10 feet into the previously placed S-B backfill at all depths. Any removed section of completed slurry trench shall be refilled with S-B backfill at no additional expense to the Government.

3.3.1 Confining Stratum Excavation

****

NOTE: If the confining stratum is a competent low permeability bedrock, a very small penetration into the bedrock may be satisfactory. High costs may result by requiring a 600 mm 2 foot key into competent bedrock. Remove this paragraph if not required in the project.

****

The confining stratum shall be excavated the full trench width to the depths shown [or to the depth of refusal] [or as otherwise directed]. [Any [sandstone] [_____] lenses encountered at the minimum excavation depth shall be removed for the full width of the trench and into the underlying confining stratum.] The confining stratum shall then be sampled in accordance with paragraph SAMPLES OF CONFINING STRATUM. Termination of excavation will be approved by the Contracting Officer.

3.3.2 Blasting Plan

****

NOTE: Blasting, if necessary, may cause unanticipated adverse effects in the subsurface. The designer should carefully evaluate the need for blasting to remove or loosen subsurface materials. Other methods such as chiseling or modfication of slurry trench alignment or depths should be considered prior to implementation of any blasting. Remove this paragraph if not required in the project.

****

Any blasting shall be approved. Blasting shall be conducted in accordance with an approved blasting plan. The blasting plan shall include hole spacing and depths, loading, delay sequence, type of explosives, safety program, and any other pertinent information that will be necessary for the Contracting Officer's evaluation. Explosive materials [shall] [shall not] be stored on the site. [On site storage shall be at [_____].] [A drawing showing the top and bottom elevations of the [sandstone] [_____] at each blasting drill hole shall be submitted.] Submit a blasting plan, as specified, for approval.

3.4 SLURRY PLACEMENT AND TESTING

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NOTE: Sand content of the in-trench slurry is highly dependent upon the soils through which the trench is excavated. In many cases, typical values for sand content can be as high as 30 percent without impacting the quality of the installation. It should be noted that higher sand contents also lead to a higher density slurry. Adjustments should be made in Table 1 regarding slurry density and sand content limits according to site conditions. The main concern is to ensure that sand is not dropping out of the in trench slurry to the bottom of the trench in amounts so as to affect performance of the slurry trench.

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3.4.1 Slurry Placement

Introduce slurry into the trench at the time excavation begins. The level of the slurry in open trenches shall be maintained a minimum of 900 mm 3 feet above ground water level and no more than 600 mm 2 feet below the top of the working surface until the placement of S-B backfill is complete. [If the density or sand content of the slurry in the trench does not conform to the standards specified in Table 1, the excess solids shall be removed from the slurry using approved methods or the slurry shall be replaced with fresh slurry.] Slurry shall not be diluted by surface water. Conditioning of the slurry may require recirculation through a shaker screen or the addition of approved additives. Provide sufficient personnel, equipment, slurry storage areas, and prepared slurry materials ready to raise the slurry level at any time in the excavated trench, weekends and holidays included.

3.4.2 Slurry Testing

The bentonite slurry in the trench shall be sampled a minimum of 2 times each [_____] [8] hour shift (near the beginning and end of each shift), at two depths; approximately 600 mm 2 feet below the slurry surface and approximately 600 mm 2 feet above the bottom of the trench. These samples shall be taken within 1500 mm 5 feet of the toe of the S-B backfill slope. Additional samples shall be obtained at the request of the Contracting Officer.

3.5 EXCAVATED MATERIAL

Material excavated from the trench [shall] [shall not] be used as backfill. [Excavated material to be used as backfill shall be stockpiled for subsequent processing in approved areas.] [Excavated trench material not used as backfill shall be placed [in the waste disposal area] [as directed].]

3.6 STABILITY

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NOTE: A stability analysis should be performed during design to determine required minimum slurry densities or levels, and to determine if any restrictions will be required regarding stockpile placement or other loading situations. Any site specific restrictions should be described below.

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The Contractor is responsible for ensuring and maintaining the stability of the excavated trench at all times, for its full length and depth, and for maintaining slurry densities and levels within specified limits. Control surcharges from all excavation and backfilling equipment, waste, berm construction, backfill stockpiles, and any other loading situations that may affect trench stability. It is the Contractor's sole responsibility to ensure that the mixing of S-B backfill and any stockpiles do not affect the open trench stability. In the event of failure of the trench walls prior to completion of backfilling, re-excavate the trench, remove all material displaced into the trench, and take corrective action to prevent further deterioration, at the Contractor's expense.

3.7 TRENCH CLEANING

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NOTE: The initial cleaning of the trench bottom can be accomplished with an excavator bucket. This method of trench cleaning will generally be sufficient for final cleaning of most projects. It is generally recommended to limit the distance between the excavated face and the toe of the S-B backfill, as required in Paragraph SLURRY TRENCH EXCAVATION, in order to assure trench stability. In some cases, the air-lift pump method may be the only way to clean certain reaches of the trench. However, the air-lift pump method can slow production, is somewhat difficult to manuver in the trench, and may not clean the trench bottom effectively in many cases.

Cleaning of the S-B backfill face can be difficult since the materials are very soft and may require the excavator to track over portions of the trench that are not yet backfilled. This procedure should only be specified when required to meet project needs.

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At a minimum, unless otherwise approved, the trench bottom shall be cleaned at the start of each [_____] [day]. [If S-B backfill placement operations have ceased for longer than [24] [_____] hours, the face of the S-B backfill slope shall be cleaned prior to the placement of additional S-B backfill.] The trench bottom shall be probed for any deposits or sloughed materials prior to cleaning. The trench bottom shall be cleaned by using an [excavator bucket,] [air lift pump] or other approved equipment to ensure removal of sand, gravel, sediment, and other material left in the trench during excavation or which has settled out of the slurry. Cleaning equipment shall not remove material from the walls of the trench. The Contracting Officer may require more frequent cleaning. [After the trench bottom has been cleaned, sample the trench bottom with a [drive tube] [split tube] [_____] sampler approved by the Contracting Officer. Rock surfaces that cannot be penetrated by a [drive tube] [split spoon] sampler shall not be required to be sampled. After examining the samples, the Contracting Officer will either approve the excavation at the points checked or require additional cleaning. If additional cleaning is required, then additional samples shall be furnished as specified above.]

3.8 S-B BACKFILL MIXING AND PLACEMENT

3.8.1 Mixing

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NOTE: It may be preferable to mix the S-B backfill in a separate mixing area rather than along the side of the trench, particularly in contaminated areas, or where off-site borrow is used for backfill materials. Other mixing methods may include the utilization of a batch plant or pugmill operation to blend materials. Although more expensive, these procedures may minimize operations in a contaminated area.

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The S-B backfill shall be thoroughly mixed via disking, harrowing, bulldozing, blading, or other approved methods into a homogeneous mass, free from large lumps or clods of soil or pockets of fines, sand, or gravel. Occasional lumps of up to [_____] [75] mm [3] inches in their largest dimension will be permitted. All particles shall be coated with slurry. The S-B backfill may be sluiced with slurry during the mixing operations. Sluicing with water is not permitted. The S-B backfill shall be mixed [in a separate mixing location as shown on the drawings] [along the side of the trench]. [When mixing the S-B backfill along the side of the trench, heavy equipment such as bulldozers shall not operate in a back and forth fashion, paralleling the open trench, closer than 5 meters 15 feet from the lip of the trench. Excess slurry may be allowed to flow back into the trench].

3.8.2 Placement

Initial S-B backfill placement shall be by one of the following methods: (1) Placement by lowering S-B slurry to the bottom of the trench with crane and clamshell bucket, or tremie methods until the surface of the S-B backfill rises above the surface of the slurry trench at the end of the trench; (2) Construct a lead-in trench [1H:1V] [_____] or flatter at a point outside of the limits of work to allow a S-B backfill face to form prior to reaching the full depth of the required slurry trench. No payments will be made for the portions of trenches which lie outside of the limits of work. Placement operations shall proceed in such a manner that the slope of the initially placed S-B backfill is maintained. Free dropping of S-B backfill through the slurry is not permitted. The S-B backfill shall be placed so that it will slide down the forward face of the S-B backfill slope. The S-B backfill shall be placed in the excavated trench so that no pockets of slurry are trapped and that a constant slope is maintained. Placement shall be continuous from the beginning of the trench in the direction of the excavation to the end of the trench.

3.8.3 Mixing and Placing During Cold Weather

No mixing or placing of the S-B backfill shall be performed when the air temperature is below -7 degrees C 20 degrees F. Frozen S-B backfill shall not be placed in the trench and backfill material containing frozen lumps shall not be used to mix S-B backfill.

3.8.4 Testing

When required, additional samples for permeability testing shall be taken at [_____] intervals for the [_____] [full depth] of the completed slurry trench using 75 mm 3 inch thin wall (Shelby) tubes. [If test results do not meet the requirements listed in Table 1, corrective action, as determined by the Contracting Officer, shall be taken.]

3.9 SOUNDINGS

Take excavation and S-B backfill soundings every [_____] 6 meters 20 feet along the trench centerline using a weighted tape, cable, or other approved device. Submit a record of soundings and measurements taken during construction of the slurry trench. Soundings shall be measured to the nearest 30 mm 0.1 ft. The soundings shall measure the following:

3.9.1 Elevation of Top of Confining Stratum

The top of the confining stratum shall be determined based on examination of samples taken as described under paragraph SAMPLES OF CONFINING STRATUM. This elevation shall be subject to approval.

3.9.2 Elevation of Trench Bottom Prior to Backfilling

Determine the elevation of the trench bottom after the trench has been cleaned and approved as described under paragraph Trench Cleaning. This sounding shall not precede the toe of the S-B backfill slope more than [_____] 15 meters 50 feet. This elevation is subject to approval by the Contracting Officer.

3.9.3 Profile of S-B Backfill Slope and Trench Bottom

The S-B backfill slope and trench bottom shall be sounded at the beginning

and end of each shift, and at additional times as directed, at intervals of [_____] meters feet.

3.10 AS-BUILT PROFILE

An as-built profile of the trench bottom and S-B backfill slopes, including descriptions of materials encountered in the trench bottom, shall be continuously maintained. This profile shall indicate extent of excavation and the S-B backfill profile at the end of each work day [and after each S-B backfill batch is placed in the trench as determined from soundings]. [The S-B backfill batch numbers shall appear on the profile with the limits of each batch of material delineated as placed.] Submit a scale drawing providing a log of the subsurface materials excavated from the trench, and a profile of the completed slurry trench. [The limits of each batch of S-B backfill shall be delineated as placed.]

3.11 TREATMENT OF TOP OF SLURRY TRENCH

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NOTE: For heavy equipment crossings, it is recommended the upper portion of the S-B backfill be excavated and a clay plug be placed under the compacted trench cover. Additional support may be necessary to support the anticipated loads.

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Prior to placement of the compacted trench cover, a temporary [non-compacted soil] [plastic sheeting] cover shall be placed over the trench to prevent desiccation. The temporary cover material shall be placed within [2] [_____] days after S-B backfill placement is completed over each 30 meter 100 foot reach. If any depression develops within the completed slurry trench area, it shall be repaired by placing and compacting additional trench cover soil. After a minimum [two] [_____] weeks, the temporary trench cover shall be removed and replaced by a final compacted trench cover. A final compacted trench cover [_____] mm feet wide and [_____] mm ft deep shall be placed [as specified in Section [_____]] [to a dry density of [_____] [90] percent of maximum density at optimum moisture to plus 3 percent in accordance with ASTM D698]. Heavy construction equipment and machinery shall only be driven over the slurry trench at approved heavy equipment crossing points.

3.12 QUALITY CONTROL TESTING

Provide Quality Control Inspectors as necessary for bentonite slurry preparation and maintenance, trench excavation, and S-B backfill preparation and placement. Submit all test results.

3.12.1 Bentonite Tests

A minimum of 1 test for each specified requirement shall be performed for each truck or rail car shipment delivered to the site.

3.12.2 Water Tests

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NOTE: Acceptable slurries can generally be made from most water sources; however, any suspect water should be tested during pre-construction tests. Water with high hardness

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A minimum of [_____] [1] test[s] for each specified requirement shall be performed for each water source used. Testing shall be performed as specified in Table 1.

3.12.3 Backfill Material Tests

One set of backfill material tests, as specified in Table 1, shall be performed for every [_____] 500 cubic meters yards used.

3.12.4 Slurry Properties

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NOTE: It is generally recommended that after high shear mixing, the slurry be allowed to hydrate for 8 hours before use in the trench. This process assures that the bentonite is fully hydrated and is uniform throughout. Shorter hydration times may be allowed if it can be shown that the prepared slurry meets or exceeds project requirements.

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[Slurry shall be required to hydrate a minimum of [8] [_____] hours prior to use.] The initial bentonite slurry shall be tested prior to placing in the trench and a minimum of 2 times each [_____] [8] hour shift per mixing plant. Submit a record of bentonite slurry mix quantities, proportions of additives utilized, and adjustments for each batch.

3.12.5 S-B Backfill Tests

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NOTE: The confining pressure used to perform permeability testing should be representative of site conditions. To simulate site conditions, the confining pressure specified should be representative of the upper quarter to one-half of the wall depth.

Shelby tube, split spoon, or other sampling devices may be pushed into the completed slurry trench to obtain samples for quality control testing; however, it can be difficult to obtain quality samples of many S-B backfills, especially if there are coarse materials in the S-B backfill. As a result, samples of S-B backfill obtained just prior to placement in the trench are used for QA/QC, and samples of the S-B backfill from the completed wall, if taken, may be used for QA or for information only. The designer should determine what samples are necessary to meet project requirements. It should be noted that permeablity tests may take several days before results are known.

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Sampling and testing shall be performed, in accordance with the approved Preconstruction Testing Plan, just prior to placing S-B backfill in the trench as shown in Table 1. [The density of the S-B backfill shall be calculated using a 101.6 mm 4 inch cylindrical mold as described in

Paragraph 6 of ASTM D698. S-B backfill shall be placed in the mold and rodded 10 times. Additional S-B backfill shall then be added to fill the mold. The weight and volume of the molded S-B backfill shall then be used to determine the density.] [The density of the S-B backfill shall be determined using a mud balance.] Density shall be determined at a rate of 1 test for every [_____] [1000] cubic meters yards. A sample of S-B backfill for permeability testing shall be taken just prior to placement in the trench for every [1000] [_____] cubic meters yards. Submit a Plan providing a list of test equipment, procedures, and materials to be used to [verify] [develop] the mix design for the S-B backfill and an S-B Backfill Test Report containing the results of the tests performed, a report summarizing the procedures and results of the Pre-construction S-B backfill mix tests. The report shall include a description of mix proportions, gradations, slumps, densities, permeabilities, and moisture contents of [_____] 3 samples of the final S-B backfill mix using the bentonite and backfill materials proposed for use.. Submit a minimum of 22.5 kg 50 pounds of each type of proposed borrow soil at least [1] [_____] month prior to use.

[3.12.6 Samples of Confining Stratum

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NOTE: This paragraph is to be used if the slurry trench is to be keyed into a confining stratum. Samples of the confining stratum can be based on examination of samples taken from bucket cuttings or drive tube samplers. In many cases, examination of bucket cuttings alone will be sufficient to determine when the confining stratum has been reached. If required, samples can be obtained with drive tube samples. Drive tubes can be pushed with the excavator bucket or a drill rig. Remove this paragraph if not needed in the project.

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Samples of the confining stratum shall be taken at [_____] meter foot horizontal intervals and at additional intervals or depths as directed. Samples shall be obtained from [either] [excavator bucket cuttings] [drive tube samples]. [The sampler shall be a [_____] mm inch I.D., or larger, [drive tube sampler] with a minimum length of [_____] m feet. Samples shall be obtained by advancing the sampler a minimum of [_____] mm inches into the confining stratum. The samples shall have a minimum length [recover] of [_____] mm inches.] After examining these samples, the Contracting Officer will either approve the termination of excavation at the sample points or require additional excavation. If additional excavation is required, then additional samples shall be furnished as specified above. All samples shall be properly identified and labeled, placed in sealed plastic containers and stored in a location designated by the Contracting Officer.

]3.13 CLEAN-UP

Excavation spoil, unused S-B backfill, and excess slurry shall be removed following completion of S-B backfill placement. These materials shall be disposed of [in the waste disposal area] [at the direction of the Contracting Officer] [_____].

BENTONITE SLURRY TRENCH QUALITY CONTROL TESTING		
Property	Requirement	Test Method
Bentonite Powder		
YP/PV Ratio	[_____] [1.5] max.	API Spec 13A
Plastic Viscosity	> [_____] [10]	API Spec 13A
Filtrate Loss	< [_____] [12.5] cubic cm	API Spec 13A
Moisture Content	< [_____] [10] percent	ASTM D2216
Chemical Analysis of Water		
pH	6 to 8	API RP 13B-1
Hardness	< [_____] [50] [200] ppm	API RP 13B-1
Total Dissolved Solids	< [_____] [500] ppm	EPA 600/4-79/020 Method 160.1
VOCs	Maximum Contaminant Level (MCL)	SW-846 Method 5030B/8260B
SVOCs	MCL	SW-846 Method 3510C/8270C
TPH	MCL	SW-846 Modified 8015
Metals	MCL	SW-846 3005A/6010C
Pesticides	MCL	SW-846 3510C/8081A/8141A
Initial Bentonite Slurry		
Viscosity	> 40 sec	API RP 13B-1
Density	> 1025 kg/cubic m 64 pcf	API RP 13B-1
Filtrate Loss	< 20 cubic cm	API RP 13B-1
pH	6.5 to 10	API RP 13B-1
In-Trench Bentonite Slurry		

BENTONITE SLURRY TRENCH QUALITY CONTROL TESTING		
Property	Requirement	Test Method
Density	[____]1025-1360 kg/cubic m and at least 240 kg/cubic m less than S-B backfill density[____]64-85 pcf and at least 15 pcf less than S-B backfill density	API RP 13B-1
Viscosity	> 40 sec	API RP 13B-1
pH	6.5 to 10	API RP 13B-1
Sand Content	[____]10 percent max.	API RP 13B-1
Backfill Material		
Grain Size	Para. 2.1.3	ASTM D422
Moisture content	For record	ASTM D2216
Fines Content	Para. 2.1.3	ASTM D1140
Atterberg limits	Para. 2.1.3	ASTM D4318
S-B Backfill		
Slump Cone	100-150 mm4-6 inches	ASTM C143/C143M
Density	For Record	ASTM D698 and Para. 2.4.5
Permeability	< [1 x 10-7] [_____] cm/sec	ASTM D5084
1) If more than one (1) batching plant is being used, these frequencies shall apply to each batching plant separately.		
2) Permeability tests may be performed using an approved fixed wall permeameter except that for every 5 such tests, there shall be 1 test using a flexible wall permeameter. Fixed wall test methods and procedures shall be submitted and approved prior to use.		
3) Flexible wall permeability tests shall be performed at a maximum effective confining pressure of [_____] kPa psi and a maximum hydraulic gradient of [30] [_____].		

-- End of Section --