SECTION ()

SOIL-BENTONITE SLURRY TRENCH CUTOFF WALL

I. Scope of Work

This section of the specifications includes requirements for the Soil Bentonite Slurry Trench Cutoff Wall and related work as indicated in the plans and as hereinafter specified. The work consists of furnishing all plant, labor, equipment, and materials and of performing all operations as required to construct the slurry trench cutoff wall.

II. Reference Standards

The following list of standards (or newer versions of the same) will be referenced periodically in this specification and shall be considered part of these specifications as if fully repeated herein.

REFERENCE	TITLE OR DESCRIPTION
API Spec 13A	Specification for Oil-Well Drilling-Fluid Materials
API Spec 13B-1	Recommended Practice for Field Testing Water-Based Drilling Fluids
ASTM C138	Test Method for Unit Weight of Concrete
ASTM C143	Test Method for Slump of Concrete
ASTM D422	Particle-Size Analysis of Soils
ASTM D1140	Materials Finer than No. 200 Sieve
ASTM D4318	Liquid Limit, Plastic Limit and Plasticity Index of Soils
ASTM D4380	Density of Bentonite Slurries
ASTM D4381	Sand Content by Volume of Bentonite Slurries
ASTM D5084	Hydraulic Conductivity Using a Flexible Wall Permeameter

III. Abbreviations and Definitions

API – American Petroleum Institute

ASTM – American Society for Testing and Materials

Owner's Representative – The Owner's Representative of the Engineer is any individual designated by the Owner to act on its behalf in the execution of these specifications.

Engineer – The firm or individuals responsible for the design of the slurry wall. The Engineer, or designated representative, may adjust these specifications as the project demands.

Contractor – The selected company, joint venture, or group of companies chosen to perform the slurry wall installation.

Slurry Trench – A narrow, vertical-walled trench of specified width excavated by the slurry trench method and backfilled with specified materials to form a cutoff wall of low permeability. The terms "Slurry Trench" and "Slurry Wall" are used interchangeably in these specifications.

Slurry Trench Method – A method of excavating a narrow, vertical trench using a slurry mixture to support the trench sidewalls and prevent movement of groundwater into or through the excavated trench.

Bentonite-Water Slurry – A stable colloidal suspension of powdered bentonite in water. The terms "slurry" and "bentonite slurry" are used interchangeable in these specifications.

Soil-Bentonite (SB) Backfill – A homogeneous mixture of specified soil material, bentonite, and water. The terms "soil-bentonite backfill" and "backfill" are used interchangeably in these specifications.

Slurry Trench Specialist – An individual who has proven and successful experience in slurry trench construction evidenced by 5+ years of experience and who is knowledgeable of:

1 the proper methods employed to mix slurry and backfill,
2 the use, testing, and control of bentonite slurry,
3 construction equipment,
4 excavation and backfill operations, and
5 testing for slurry trench quality control.

Working Platform – The working platform is the level and stable surface of compacted fill and/or excavated ground surface from which the slurry wall is constructed.

IV. Submittals

The following information shall be submitted at least 1 week prior to construction.

A. Qualifications of Contractor

The Contractor shall submit evidence that he, his subcontractor, or his consulting advisor is experienced and competent in the construction of soil-bentonite slurry trench cutoff walls. At a minimum, the Contractor shall have five years of prior experience in slurry trench construction. Furthermore, the Contractor will submit the resumes of competent and experienced key personnel that will be used to carry out the operations specified. Key personnel shall include, at a minimum, the slurry trench specialist and project manager. Key personnel may be replaced, if needed, upon permission by the Engineer.

The slurry trench specialist shall be onsite at all times during the slurry wall construction to supervise the wall construction, slurry preparation, and quality control. The slurry trench specialist shall have at least five years of experience, including a minimum of five projects in successful construction of slurry trenches.

The company name and qualifications of the Contractor's off-site laboratory shall be submitted. The laboratory will have previous experience with slurry trench materials, experienced laboratory technicians, and modern permeability testing equipment.

B. Work Plan

The Contractor shall submit a detailed work plan describing his proposed construction procedures, equipment, and schedule. This plan shall include, but not be limited to, the Contractor's plan for:

1 Preliminary project schedule,
2 Coordination of the construction, maintenance and removal of working platforms, mixing pads, and haul roads with the Owner, general contractor or other contractors on site,
3 Proposed equipment set-up and site use layout including storage areas, haul roads and work platform dimensions,
4 Equipment: maximum depth capability of excavator, number and type of backfill mixing equipment, and details of slurry mixing equipment,
5 Procedure for bentonite slurry mixing, storage, re-circulation, and transfer,

6 Procedure for trench excavation,
7 Procedure for backfilling,
8 Procedure for cleaning the trench bottom and backfill slope (if needed),
9 Material properties and sources,
10 Control of drainage, spills, wastes, etc., and
11 Clean-up, spoils & excess slurry disposal.

C. Quality Control Plan

The Contractor shall submit a detailed quality control plan that includes details of the personnel, responsibilities, inspections, and organization for insuring the quality of construction required by these specifications. The plan shall provide a table listing testing methods, frequencies, and minimum acceptable values. The plan shall explain the methods and locations for obtaining samples for testing and reporting schedules. Copies of quality control forms shall be submitted with this plan for review and approval. For smaller projects, the QC aspects of the work may be addressed in a section of the Work Plan.

D. Bar Chart Schedule and Sequence of Operations

The Contractor shall submit a detailed schedule and sequence of operations in a bar chart format. The submittal shall include a description of the schedule including typical working hours and days and a list of tasks performed under each main operation.

E. Bench Scale Study

A bench scale study to determine a suitable mixture of site soils, borrow soils, and bentonite slurry should be performed. Preliminary results shalle be provided as they are received. Results ofany pre-construction studies are provided for the Contractor's reference only. No warranty is implied as to the accuracy or applicability of the provided results. The contractor may perform its own bench scale study, time permitting, to determine appropriate materials and material proportions needed to achieve the performance criteria.

Contractor bench scale studies shall address the following information, at a minimum:

1 Sampling Plan. A description of the methods and locations of all samples used in the bench scale testing. Material samples of the mixing water, native soils, bentonite clay, and borrow soils (if needed) should be obtained and tested.
2 Laboratory soil-bentonite design mix and trial mix reports, including proportions, density, bentonite content, moisture content, gradations, and hydraulic conductivity on at least four (4) mix compositions.
3 Source and properties (when applicable) of all materials proposed for use in the slurry and soil-bentonite backfill (water, bentonite, native soils, borrow soils, and any admixtures).

F. Reports

The following information shall be submitted to the Engineer on a regular schedule during the progress of the work.

1. Daily Report

Daily reports shall be submitted by close of business the following day. The daily report shall include the following, at a minimum:

i. Work summary – A summary of the work performed that day.
ii. Daily QC – results of all daily QC tests including the target value and recorded value for each QC parameter. At a minimum, the QC report should address the following key parts of the work:
    1. Fresh bentonite Slurry – a record of the plant mixed bentonite slurry quantities, proportions, properties, and admixtures made that day. Adjustments to the slurry mix shall be noted.
    2. Trench bentonite slurry – a record of in-trench bentonite slurry properties. Procedures and admixtures used to modify the in-trench slurry properties shall be noted.
    3. SB backfill – a record of SB backfill material quantities, properties, and mix adjustments made during construction. Locations of samples taken for laboratory testing shall be noted.
iii. Description of problems encountered.
iv. Soundings – A record of soundings taken during construction, including the depth of the excavation and the backfill slope, obtained each morning and evening by the slurry specialist. Soundings shall be taken at 10 ft intervals along the trench bottom and backfill slope. The soundings will be used to monitor for issues along the backfill slope and to generate the final as-built profile of the trench.

2. Laboratory Test Results

Laboratory test results shall be submitted within 5 days of receipt of the report from the laboratory.

3. Final Close-out Report

The final close-out report shall be submitted in a format acceptable to the Engineer within two to four weeks of completion of the work. The close-out report shall include the following, at a minimum:

i. Summary of the work performed
ii. Final project schedule, including important or milestone dates
iii. Material certificates of analysis
iv. As-built profile
v. Final survey results, if applicable

V. MATERIALS

A. Bentonite Slurry

Slurry shall consist of a stable colloidal suspension of bentonite in water and shall be controlled in accordance with the most current API Recommended Practice 13B-1, and the following requirements:

1 At the time of introduction into the trench, the slurry shall be a mixture of not less than 5% bentonite in water. Additional bentonite or admixtures may be required depending on the hardness and temperature of the water and the quality of the bentonite. The fresh slurry shall have a minimum apparent viscosity of 38 seconds reading through a Marsh Funnel Viscometer, a pH between 6 and 9 units, a minimum density of 64 pcf, (1.03 gm/cc) and a maximum filtrate loss of 25 cubic centimeters in 30 minutes at 100 psi.

2 The slurry mixture in the trench shall have a unit weight not less than 64 pcf (1.03 gm/cc), and not greater than 15 pcf less than the backfill unit weight, or as otherwise approved by the Engineer.

B. Bentonite

Bentonite used in preparing slurry shall be pulverized powder premium grade sodium cation montmorillonite and shall meet the most current API Standard 13A, Section 9. In particular, the yield of the bentonite shall be 90 barrels per ton.

C. Water

Fresh water, free of excessive amounts of deleterious substances that may adversely affect the properties of the slurry, shall be used to manufacture the bentonite slurry. It is the responsibility of the Contractor to ensure that the slurry resulting from the water shall always meet the standards of this specification.

D. Additives

Admixtures of the type used in the control of oil-field drilling muds such as softening agents, dispersants, retardants, or plugging or bridging agents may be added to the water or the slurry to permit efficient use of the bentonite and proper workability of the slurry. The Engineer shall be advised of all additives used.

E. Backfill

The material used for trench backfilling, aka backfill, shall be composed of fresh or trench slurry, trench spoils, and selected soils obtained from a designated borrow area, if needed. Trench slurry may be disallowed if additives are not acceptable to the Engineer. The soil used in the backfill shall be friable and free from roots, organic matter, refuse, or other deleterious materials. The backfill shall be thoroughly mixed and reasonably well graded between the following gradation limits, unless otherwise approved by the Engineer:

Screen Size	**Percent Passing**
(U.S. Standard)	**By Dry Weight**
6”	100%
No. 200	>15% to < 80%

The permeability of the backfill shall be less than $5x10^{-7}$ or [insert project info] cm/sec. The slump of the backfill shall be 3 to 6 inches, and the density of the backfill shall be at least 15 pcf greater than the density of the in-trench slurry.

VI. Slurry Trench Cutoff Wall

A slurry trench cutoff wall shall be constructed to the lines, grades, and cross sections indicated on the drawings. The trench shall have essentially vertical walls, a minimum width of [insert project info] inches, and shall extend through the overburden to a depth of [insert project info]. A generalized description of the soil profile through which the slurry trench cutoff is to be constructed is provided in a document attached to this specification.

A. Tolerances

The following tolerances shall apply to the slurry trench dimensions and construction.

1 The slurry trench shall be constructed to within 3% of vertical. In order to control verticality of the slurry trench, the working platform and/or excavating equipment should be leveled.
2 The depth of the slurry trench excavation and backfill slope shall be measured and recorded to an accuracy of 0.5'. The slurry wall shall be installed to within 0.5' of the target elevation.
3 The excavating tool shall be at least as wide as the design width of the slurry trench.
4 The slurry trench shall follow the designed alignment within 2 ft of the centerline. If approved by the Engineer, the slurry trench may vary from the designed alignment, e.g. at corners or turns.
5 Construction will not be permitted when the air temperature is below 20ºF or when severe weather conditions may compromise the quality of the work. Any variances of this requirement will be subject to the approval of the Engineer.
6 Overlaps and changes in direction of the slurry trench shall require a minimum, full depth over excavation at least 5 ft beyond the centerline of the trench. In cases where the trench must be re-excavated (for example, due to an extended shutdown, cave-in, rework, etc.) the overlap into acceptable backfill shall be at least 10 ft and follow a lead-in slope to prevent sloughing of the existing backfill.

VII. Equipment

A. Trench Excavation

Excavation of the slurry trench cutoff wall shall be accomplished such that the trench can be carried to its final depth continuously along the trench alignment. The excavator shall have the capability to excavate at least 5 ft deeper than the maximum depth shown on the plans. The width of the excavating tool shall be equal to or greater than the specified minimum width of the slurry trench. The trench excavation equipment shall be capable of excavating through the expected materials to the maximum target depth.

B. Slurry Batching Plant

The slurry batching plant shall include equipment capable of producing a colloidal suspension of bentonite in water. The slurry batching plant shall include pumps, valves, hoes, supply lines, and all other equipment as required to adequately supply slurry to the trench. Storage ponds or tanks shall be provided to store initially mixed slurry to allow hydration, and to retain a reserve in case substantial slurry loss through underlying pervious zones occurs. Slurry held in storage shall be agitated or recirculated to maintain a homogeneous mix. All slurry for use in the trench shall be prepared using a suitable mixer. No slurry is to be made in the trench. Mixing of water and bentonite shall continue until bentonite particles are fully hydrated and the resulting slurry is homogeneous.

C. Backfill Mixing and Placing

Equipment for mixing and placing backfill may consist of any suitable earthmoving or grading equipment, such as bulldozers, or blade graders or backhoes, or blenders such as a pug mill, that are capable of thoroughly mixing the backfill materials into a homogeneous blend having the required gradation and properties and placing the material in the trench as specified. Soil clods shall be broken to 6 inch maximum size by the backfill preparation equipment and methods

employed. Deleterious materials and debris, oversize particles, shall be removed from the backfill before approval for placement.

VIII. Execution of the Work

A. Slurry Trenching

Excavation shall proceed continuously from the starting point to the finishing point. Slurry shall be introduced into the trench at the time trenching begins and shall be maintained in the trench during excavation and until backfilled. The level of the bentonite slurry shall always be maintained at least 3 ft above groundwater level and shall not be permitted to drop more than 2 ft below the surface of the working platform. The Contractor shall have personnel, equipment, and prepared slurry ready to raise the slurry level at any time. To this end, the Contractor shall have personnel on call to check and raise the slurry level at any time, weekends and/or holidays included.

B. Trench Bottom

The bottom of the slurry trench will extend to the target depth. If the excavator is unable to achieve penetration to the target elevation, the minimum penetration requirements will be modified and the trench excavation will be terminated at refusal of the excavating equipment. Refusal will be considered on any panel where less than 1' of penetration is achieved in 15 minutes of continuous excavation effort over a 20' long cut. The final depth of the trench shall be measured and checked by the Contractor and approved by the Engineer immediately following excavation.

C. Cleaning Trench Bottom

Upon completion of excavation, loose material or cuttings shall be removed from the bottom of the trench with the excavation tools. If the unit weight of the slurry in the trench exceeds the specified limits, or becomes unworkable, the heavy slurry shall be removed from the trench and replaced with fresh slurry. The trench bottom shall be cleaned of debris and excess sediment prior to backfilling. The trench shall be sounded immediately before placing backfill, and soundings shall be compared to the trench excavation soundings to verify the bottom. At a minimum, soundings shall be taken each morning and each evening and compared to monitor for cave-ins or excessive settlement.

D. Mixing Backfill

The backfill shall be mixed beside the trench. The Contractor shall control and provide sufficient equipment and work platform space to support slurry spills, trench stability, and mixing equipment operation. Unmixed materials shall not be placed or be allowed to fall into the trench. The contractor shall at all times be responsible for the quality of the backfill.

. Mixing and blending shall be performed in such a manner as to produce the required gradation of backfill. The backfill material shall be thoroughly mixed into a homogeneous mass, free of large soil clods, lumps or pockets of fines, sand, or gravel. Occasional particles of up to 6 inches in their largest dimensions will be permitted. Just prior to placing, the backfill material shall have a slump of 3 to 6 inches. To this end, the materials shall be sluiced with slurry from the trench or fresh slurry during blending operations. Sluicing with water will not be permitted. Backfill shall be sampled and tested for density and slump after preparation and samples shall be collected for offsite hydraulic conductivity testing.

E. Placing Backfill

The backfill shall be placed continuously from the beginning of the trench, in the direction of the excavation, to the end of the trench. The toe of the slope of the trench excavation shall precede the toe of the backfill slope so that the toe of the backfill shall not be closer than 20 ft to the toe of the excavation slope, or as required to permit proper cleaning of the trench bottom and as approved by the Engineer. Excavation shall not exceed 150 ft from the toe of the backfill. Excavation must permit inspection and measurement immediately after completion and prior to backfilling. Backfill placement operations shall proceed in such a fashion that the surface of the backfill below the slurry shall follow a reasonably smooth grade and shall not have hollows, which may trap pockets of slurry during subsequent backfilling. Free dropping of backfill material through the slurry is not acceptable. The backfill shall not be dropped or deposited in any manner that will cause segregation.

Initial placement of the backfill will be completed using a lead-in trench. The lead-in trench shall begin at a point outside of the limits of work and provide sufficient distance for the backfill face to form, by placing the backfill into the trench, before the toe of the backfill reaches the point where the cut-off is required. The lead-in trench shall have a maximum 1V:1H slope. Steeper slopes may be possible if site conditions limit the lead-in slope length.

F. Treatment for Top of Backfill

The surface of the backfill shall not be allowed to desiccate prior to placing the final cap. A temporary covering may be used to protect the backfill prior to placing the final cap. The temporary covering shall consist of at least 1 foot of uncompacted backfill placed within two days of SB backfill placement. A temporary covering of extra thick compacted soil or trench plates shall be used at heavy equipment crossings. Any depressions or settlement shall be repaired by placing additional backfill or during the permanent cap placement.

Upon completion of backfill placement and before desiccation of the backfill surface can occur, the cutoff trench shall be covered in accordance with any final cap details shown on the drawings.

G. Clean-up

After completion of the backfill placement and capping, all remaining excavated material and slurry shall be removed and the surface shall be cleaned and leveled as directed by the Engineer. Excess slurry shall be disposed of by drying, mixing with dry materials or spreading in thin layers on adjacent areas designated by the Engineer. No slurry shall be left in ponds, all ponds shall be pumped dry and backfilled in a controlled manner.

IX. Quality Control

The Contractor shall maintain his own QC for the cutoff wall construction. Minimum testing requirements are specified herein. Table 1 summarizes the QC tests and frequencies.

A. Trench Continuity and Key

The Contractor shall be responsible for demonstrating that the trench is continuous and extends to the target depth. The Engineer will be available onsite to verify these measurements and to call key, if applicable. Trench continuity shall be assured by the movement of the trench excavation equipment such that the digging tools can be passed vertically from top to bottom of the trench as

well as moved horizontally along the axis of the trench without encountering unexcavated material. Excavation to the desired elevations shall be demonstrated using a weighted sounding cable at 10 ft. centers.

B. Materials

1 Bentonite: Certificates of Analysis (COAs) with the specification shall be obtained from the manufacturer for each shipment of bentonite delivered to the site.
2 Water: Water for slurry mixing shall be tested once per source for:
   a. pH
   b. Hardness
   c. TDS
3 Prepared Backfill: Soil-bentonite backfill shall be tested prior to placement in the trench by conducting tests to determine slump and density. Laboratory testing of the backfill for hydraulic conductivity shall be conducted once for every 500 CY of backfill placed or once per day, whichever is more frequent. Hydraulic conductivity testing shall be performed to verify the prepared material meets the performance criteria.
4 Fresh Slurry: A complete series of tests shall be conducted from the mixer or tank containing fresh slurry ready for introduction in the trench at least twice per shift.
5 Trench Slurry: Slurry in the trench shall be tested at least twice per shift. Samples shall be obtained from the mid-depth of the trench near the toe of the backfill slope.

C. Soundings

Soundings shall be taken every 10 ft along the trench centerline using a weighted tape, cable or other device. Soundings shall be recorded to the nearest 0.5'. Soundings shall record the following:

1 Top of Key – The Engineer will be onsite to call when the top of the key has been reached, if applicable. The Contractor will record the top of key elevation and install the trench the minimum specified distance into the key layer or to the design target elevation.
2 Bottom of Excavation - The elevation of the trench bottom shall be determined subject to approval by the Engineer.
3 Bottom of Excavation Prior to Backfilling - Soundings shall be used to monitor for sidewall collapse and accumulation of sediments.
4 Profile of Backfill Slope: The SB backfill slope and trench bottom shall be sounded at the beginning and end of each shift and converted to an as-built drawing. This drawing shall be reviewed daily as an indication of trench collapse, excessive settlement or sloughing.

D. Quality Control Testing Equipment

The field laboratory shall be equipment with the following equipment, at a minimum:

1 Marsh funnel and cup – 2 sets
2 Mud balance – 2 sets
3 Sounding cable – 2 sets
4 pH tape – 1 set
5 Standard Filter Press w/ graduated cylinder – 1 set
6 Slump cone and rod – 1 set
7 Sand content kit – 1 set
8 Standard #200 sieve with hot plate (or microwave oven) and balance – 1 set

E. Hydraulic Conductivity Measurements

A qualified off-site laboratory shall be engaged to perform the hydraulic conductivity tests.

Flexible wall permeability tests shall be conducted on samples of the backfill to determine compliance with these specifications. Samples of the SB backfill shall be obtained from the mixing area immediately prior to backfill placement in the trench and sent to the off-site laboratory for testing. Unless site specific calculations can be used to determine more suitable test parameters, the test parameters shall be as follows:

1 Average Effective Confining Stress = <10 psi
2 Hydraulic Gradient = <30
3 Permeant = municipal tap water

F. Documentation

Results of all tests performed shall be recorded on forms acceptable to the Engineer and signed by the Slurry Trench Specialist. These forms will be available to the Engineer at all times for his inspection. Copies of all QC documents will be submitted daily to the Engineer for his verification.

As-Built profile drawing of the trench bottom and backfill slope shall be continuously maintained by the Contractor. The profile shall indicate the extent of excavation and backfill at the end of each working day. The daily profile shall be drawn in an electronic format, e.g. using the plotting functions of Microsoft Excel.

G. Measurement and Payment

Payment for the slurry trench work shall be made according to the contract unit price applied to the actual square footage of slurry wall installed. The wall square footage is calculated by multiplying the length of the wall times the depth of the wall. The lead-in trench, overlaps, and cross-cuts will not be included in the paid square footage. Assuming the trench layout matches that expected at the time of bid, all expected lead-ins, overlaps, and cross-cuts should be accounted for in the unit price. The contract unit price shall include all costs for the construction and completion of the slurry trench. No separate payment will be made for materials, equipment, slurry, records, or quality control. Final acceptance of the slurry wall will be based on meeting all the requirements for the slurry wall dimensions, bentonite slurry, and hydraulic conductivity of the SB backfill.

Measurement for the slurry wall shall be based on the area in square feet of the completed slurry wall measured in a vertical plan through the centerline of the slurry trench from the top of work platform to the bottom of the excavated trench. Measurements shall be based on surveys and soundings taken at the site as directed and approved by the Engineer.

Table 1: Soil - Bentonite Slurry Trench Quality Control Testing

Property	Requirement	Min. Test Frequency	Test Method	Comment
Bentonite Powder				
a. YP/PV Ratio	> 3	1 per truck	API 13A Section 9	90 bbl bentonite
b. Viscometer at 600 rpm	> 30	1 per truck	" "	Certification by Manufacturer
c. Filtrate Loss	< 15 cc	1 per truck	" "	
d. Moisture Content	< 10%	1 per truck	" "	
e. Residue larger than 75 micrometers	< 4%	1 per truck	" "	
f. Certification	No peptizing	1 per truck	" "	
Water for Slurry Mixing				
a. pH	6 to 9	1 per source	API RP 13B-1	May be modified for
b. Hardness	< 250 ppm	1 per source	Hach Test	potable source or if treated
c. Total Dissolved Solids	< 500 ppm	1 per source	Hach Test	w/additives
Initial Bentonite Slurry				
a. Viscosity	> 38 seconds	2 per shift	API RP 13B-1	
b. Density	> 64 pcf	2 per shift	ASTM D-4380	
c. Filtrate Loss	< 25 cc	1 per shift	API RP 13B-1	
d. Bentonite content	> 5%	Per project	Weight-Volume	Demonstrate
In-Trench Bentonite Slurry				
a. Density	64 to 85 pcf	2 per shift	ASTM D-4380	Also 15 pcf less than backfill
b. Viscosity	> 40 seconds	2 per shift	API RP 13B-1	
SB Backfill Material				
a. Slump Cone	3 to 6 inches	2 per shift	ASTM C-143	
b. Fines Content	For record	As needed	ASTM D-1140 mod.	
c. Bentonite content	For record	As needed	Weight-Volume	Demonstrate
d. Density	15 pcf > In-trench slurry	2 per shift	ASTM C-138	
e. Hydraulic Conductivity	$< 5 \times 10^{-7}$ cm/sec	1 per shift or 500 CYs	ASTM D-5084	Laboratory test