OSHA TECHNICAL MANUAL - SECTION V: CHAPTER 2
EXCAVATIONS: HAZARD RECOGNITION IN TRENCHING AND SHORING

I. INTRODUCTION.

Excavating is recognized as one of the most hazardous construction operations. OSHA recently revised ***Subpart P, Excavations, of 29 CFR 1926.650, .651, and .652*** to make the standard easier to understand, permit the use of performance criteria where possible, and provide construction employers with options when classifying soil and selecting employee protection methods.

This chapter is intended to assist ***OSHA Technical Manual*** users, safety and health consultants, OSHA field staff, and others in the recognition of trenching and shoring hazards and their prevention.

II. DEFINITIONS.

A. ACCEPTED ENGINEERING PRACTICES are procedures compatible with the standards of practice required of a registered professional engineer.

B. ADJACENT STRUCTURE STABILITY refers to the stability of the foundation(s) of adjacent structures whose location may create surcharges, changes in soil conditions, or other disruptions that have the potential to extend into the failure zone of the excavation or trench.

C. COMPETENT PERSON is an individual who is capable of identifying existing and predictable hazards or working conditions that are hazardous, unsanitary, or dangerous to employees, and who ***has authorization to take prompt corrective measures to eliminate or control these hazards and conditions***.

D. CONFINED SPACE is a space that, by design and/or configuration, has limited openings for entry and exit, unfavorable natural ventilation, may contain or produce hazardous substances, and is not intended for continuous employee occupancy.

E. EXCAVATION. An **Excavation** is any man-made cut, cavity, trench, or depression in an earth surface that is formed by earth removal. A **Trench** is a narrow excavation (in relation to its length) made below the surface of the ground. In general, the depth of a trench is greater than its width, and the width (measured at the bottom) is not greater than 15 ft (4.6 m). If a form or other structure installed or constructed in an excavation reduces the distance between the form and the side of the excavation to 15 ft (4.6 m) or less (measured at the bottom of the excavation), the excavation is also considered to be a trench.

F. HAZARDOUS ATMOSPHERE is an atmosphere that by reason of being explosive, flammable, poisonous, corrosive, oxidizing, irritating, oxygen-deficient, toxic, or otherwise harmful may cause death, illness, or injury to persons exposed to it.

G. INGRESS AND EGRESS mean "entry" and "exit," respectively. In trenching and excavation operations, they refer to the provision of safe means for employees to enter or exit an excavation or trench.

H. PROTECTIVE SYSTEM refers to a method of protecting employees from cave-ins, from material that could fall or roll from an excavation face or into an excavation, and from the collapse of adjacent structures. Protective systems include support systems, sloping and benching systems, shield systems, and other systems that provide the necessary protection.

I. REGISTERED PROFESSIONAL ENGINEER is a person who is registered as a professional engineer in the state where the work is to be performed. However, a professional engineer who is registered in any state is deemed to be a "registered professional engineer" within the meaning of Subpart P when approving designs for "manufactured protective systems" or "tabulated data" to be used in interstate commerce.

J. SUPPORT SYSTEM refers to structures such as underpinning, bracing, and shoring that provide support to an adjacent structure or underground installation or to the sides of an excavation or trench.

K. SUBSURFACE ENCUMBRANCES include underground utilities, foundations, streams, water tables, transformer vaults, and geological anomalies.

L. SURCHARGE means an excessive vertical load or weight caused by spoil, overburden, vehicles, equipment, or activities that may affect trench stability.

M. TABULATED DATA are tables and charts approved by a registered professional engineer and used to design and construct a protective system.

N. UNDERGROUND INSTALLATIONS include, but are not limited to, utilities (sewer, telephone, fuel, electric, water, and other product lines), tunnels, shafts, vaults, foundations, and other underground fixtures or equipment that may be encountered during excavation or trenching work.

O. UNCONFINED COMPRESSIVE STRENGTH is the load per unit area at which soil will fail in compression. This measure can be determined by laboratory testing, or it can be estimated in the field using a pocket penetrometer, by thumb penetration tests, or by other methods.

P. DEFINITIONS THAT ARE NO LONGER APPLICABLE. For a variety of reasons, several terms commonly used in the past are no longer used in revised Subpart P. These include the following:

Angle of Repose Conflicting and inconsistent definitions have led to confusion as to the meaning of this phrase. This term has been replaced by Maximum Allowable Slope.

Bank, Sheet Pile, and Walls Previous definitions were unclear or were used inconsistently in the former standard.

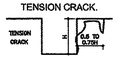
Hard Compact Soil and **Unstable Soil** The new soil classification system in revised Subpart P uses different terms for these soil types.

III. OVERVIEW: SOIL MECHANICS.

A number of stresses and deformations can occur in an open cut or trench. For example, increases or decreases in moisture content can adversely affect the stability of a trench or excavation. The following diagrams show some of the more frequently identified causes of trench failure.

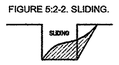
A. TENSION CRACKS. Tension cracks usually form at a horizontal distance of 0.5 to 0.75 times the depth of the trench, measured from the top of the vertical face of the trench. See Fig. 5:2-1 for additional details.

FIGURE 5:2-1. TENSION CRACK.



B. SLIDING or sluffing may occur as a result of tension cracks, as illustrated in Fig 5:2-2.

FIGURE 5:2-2. SLIDING.

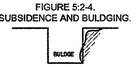


C. TOPPLING. In addition to sliding, tension cracks can cause toppling. Toppling occurs when the trench's vertical face shears along the tension crack line and topples into the excavation.

FIGURE 5:2-3. TOPPLING.

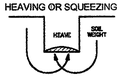
D. SUBSIDENCE AND BULGING. An unsupported excavation can create an unbalanced stress in the soil, which, in turn, causes subsidence at the surface and bulging of the vertical face of the trench. If uncorrected, this condition can cause face failure and entrapment of workers in the trench.

FIGURE 5:2-4. SUBSIDENCE AND BULDGING.



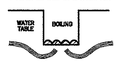
E. HEAVING OR SQUEEZING. Bottom heaving or squeezing is caused by the downward pressure created by the weight of adjoining soil. This pressure causes a bulge in the bottom of the cut, as illustrated in the drawing above. Heaving and squeezing can occur even when shoring or shielding has been properly installed.

FIGURE 5:2-5. HEAVING OR SQUEEZING



F. BOILING is evidenced by an upward water flow into the bottom of the cut. A high water table is one of the causes of boiling. Boiling produces a "quick" condition in the bottom of the cut, and can occur even when shoring or trench boxes are used.

FIGURE 5:2-6. BOILING.



G. UNIT WEIGHT OF SOILS refers to the weight of one unit of a particular soil. The weight of soil varies with type and moisture content. One cubic foot of soil can weigh from 110 pounds to 140 pounds or more, and one cubic meter (35.3 cubic feet) of soil can weigh more than 3,000 pounds.

IV. DETERMINATION OF SOIL TYPE.

OSHA categorizes soil and rock deposits into four types, A through D, as follows:

A. STABLE ROCK is natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed. It is usually identified by a rock name such as granite or sandstone. Determining whether a deposit is of this type may be difficult unless it is known whether cracks exist and whether or not the cracks run into or away from the excavation.

B. TYPE A SOILS are cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (tsf) (144 kPa) or greater. Examples of Type A cohesive soils are often: clay, silty clay, sandy clay, clay loam and, in some cases, silty clay loam and sandy clay loam. (No soil is Type A if it is fissured, is subject to vibration of any type, has previously been disturbed, is part of a sloped, layered system where the layers dip into the excavation on a slope of 4 horizontal to 1 vertical (4H:1V) or greater, or has seeping water.

C. TYPE B SOILS are cohesive soils with an unconfined compressive strength greater than 0.5 tsf (48 kPa) but less than 1.5 sf (144 kPa). Examples of other Type B soils are: angular gravel; silt; silt loam; previously disturbed soils unless otherwise classified as Type C; soils that meet the unconfined compressive strength or cementation requirements of Type A soils but are fissured or subject to vibration; dry unstable rock; and layered systems sloping into the trench at a slope less than 4H:1V (only if the material would be classified as a Type B soil).

D. TYPE C SOILS are cohesive soils with an unconfined compressive strength of 0.5 tsf (48 kPa) or less. Other Type C soils include granular soils such as gravel, sand and loamy sand, submerged soil, soil from which water is freely seeping, and submerged rock that is not stable. Also included in this classification is material in a sloped, layered system where the layers dip into the excavation or have a slope of four horizontal to one vertical (4H:1V) or greater.

E. LAYERED GEOLOGICAL STRATA. Where soils are configured in layers, i.e., where a layered geologic structure exists, the soil must be classified on the basis of the soil classification of the weakest soil layer. Each layer may be classified individually if a more stable layer lies below a less stable layer, i.e., where a Type C soil rests on top of stable rock.

V. TEST EQUIPMENT AND METHODS FOR EVALUATING SOIL TYPE.

Many kinds of equipment and methods are used to determine the type of soil prevailing in an area, as described below.

A. POCKET PENETROMETER. Penetrometers are direct-reading, spring-operated instruments used to determine the unconfined compressive strength of saturated cohesive soils. Once pushed into the soil, an indicator sleeve displays the reading. The instrument is calibrated in either tons per square foot (tsf) or kilograms per square centimeter (kPa). However, Penetrometers have error rates in the range of ± 20-40 %.

1. Shearvane (Torvane). To determine the unconfined compressive strength of the soil with a shearvane, the blades of the vane are pressed into a level section of undisturbed soil, and the torsional knob is slowly turned until soil failure occurs. The direct instrument reading must be multiplied by 2 to provide results in tons per square foot (tsf) or kilograms per square centimeter (kPa).

2. Thumb Penetration Test. The thumb penetration procedure involves an attempt to press the thumb firmly into the soil in question. If the thumb makes an indentation in the soil only with great difficulty, the soil is probably Type A. If the thumb penetrates no further than the length of the thumb nail, it is probably Type B soil, and if the thumb penetrates the full length of the thumb, it is Type C soil. The thumb test is subjective and is therefore the least accurate of the three methods.

3. Dry Strength Test. Dry soil that crumbles freely or with moderate pressure into individual grains is granular. Dry soil that falls into clumps that subsequently break into smaller clumps (and the smaller clumps can be broken only with difficulty) is probably clay in combination with gravel, sand, or silt. If the soil breaks into clumps that do not break into smaller clumps (and the soil can be broken only with difficulty), the soil is considered unfissured unless there is visual indication of fissuring.

B. PLASTICITY OR WET THREAD TEST. This test is conducted by molding a moist sample of the soil into a ball and attempting to roll it into a thin thread approximately 1/8 inch (3 mm) in diameter (thick) by 2 inches (50 mm) in length. The soil sample is held by one end. If the sample does not break or tear, the soil is considered cohesive.

C. VISUAL TEST. A visual test is a qualitative evaluation of conditions around the site. In a visual test, the entire excavation site is observed, including the soil adjacent to the site and the soil being excavated. If the soil remains in clumps, it is cohesive; if it appears to be coarse-grained sand or gravel, it is considered granular. The evaluator also checks for any signs of vibration.

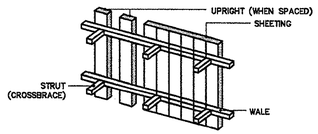
During a visual test, the evaluator should check for crack-line openings along the failure zone that would indicate tension cracks, look for existing utilities that indicate that the soil has previously been disturbed, and observe the open side of the excavation for indications of layered geologic structuring.

The evaluator should also look for signs of bulging, boiling, or sluffing, as well as for signs of surface water seeping from the sides of the excavation or from the water table. If there is standing water in the cut, the evaluator should check for "quick" conditions (see Paragraph III. F. in this chapter). In addition, the area adjacent to the excavation should be checked for signs of foundations or other intrusions into the failure zone, and the evaluator should check for surcharging and the spoil distance from the edge of the excavation.

VI. SHORING TYPES.

Shoring is the provision of a support system for trench faces used to prevent movement of soil, underground utilities, roadways, and foundations. Shoring or shielding is used when the location or depth of the cut makes sloping back to the maximum allowable slope impractical. Shoring systems consist of posts, wales, struts, and sheeting. There are two basic types of shoring, timber and aluminum hydraulic.

FIGURE 5:2-7. TIMBER SHORING.

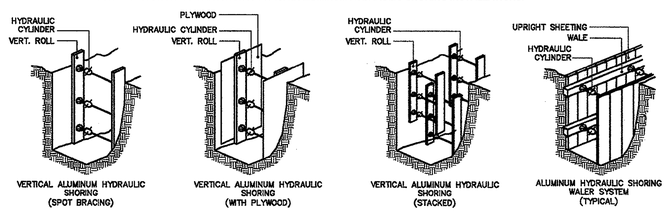


A. HYDRAULIC SHORING. The trend today is toward the use of hydraulic shoring, a prefabricated strut and/or wale system manufactured of aluminum or steel. Hydraulic shoring provides a critical safety advantage over timber shoring because workers do not have to enter the trench to install or remove hydraulic shoring. Other advantages of most hydraulic systems are that they:

- Are light enough to be installed by one worker;
- Are gauge-regulated to ensure even distribution of pressure along the trench line;
- Can have their trench faces "preloaded" to use the soil's natural cohesion to prevent movement; and
- Can be adapted easily to various trench depths and widths.

All shoring should be installed from the top down and removed from the bottom up. Hydraulic shoring should be checked at least once per shift for leaking hoses and/or cylinders, broken connections, cracked nipples, bent bases, and any other damaged or defective parts.

FIGURE V:2-8. SHORING VARIATIONS: TYPICAL ALUMINUM HYDRAULIC SHORING INSTALLATIONS.



VERTICAL ALUMINUM HYDRAULIC SHORING (SPOT BRACING) | VERTICAL ALUMINUM HYDRAULIC SHORING (WITH PLYWOOD) | VERTICAL ALUMINUM HYDRAULIC SHORING (STACKED) | ALUMINUM HYDRAULIC SHORING WALER SYSTEM (TYPICAL)

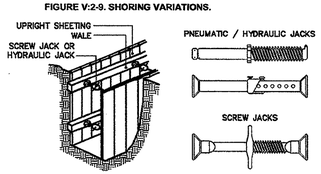
B. PNEUMATIC SHORING works in a manner similar to hydraulic shoring. The primary difference is that pneumatic shoring uses air pressure in place of hydraulic pressure. A disadvantage to the use of pneumatic shoring is that an air compressor must be on site.

1. Screw Jacks. Screw jack systems differ from hydraulic and pneumatic systems in that the struts of a screw jack system must be adjusted manually. This creates a hazard because the worker is required to be in the trench in order to adjust the strut. In addition, uniform "preloading" cannot be achieved with screw jacks, and their weight creates handling difficulties.

2. Single-Cylinder Hydraulic Shores. Shores of this type are generally used in a water system, as an assist to timber shoring systems, and in shallow trenches where face stability is required.

3. Underpinning. This process involves stabilizing adjacent structures, foundations, and other intrusions that may have an impact on the excavation. As the term indicates, underpinning is a procedure in which the foundation is physically reinforced. Underpinning should be conducted only under the direction and with the approval of a registered professional engineer.

FIGURE V:2-9. SHORING VARIATIONS.



VII. SHIELDING TYPES.

A. TRENCH BOXES are different from shoring because, instead of shoring up or otherwise supporting the trench face, they are intended primarily to protect workers from cave-ins and similar incidents. The excavated area between the outside of the trench box and the face of the trench should be as small as possible. the space between the trench boxes and the excavation side are backfilled to prevent lateral movement of the box. Shields may not be subjected to loads exceeding those which the system was designed to withstand.

FIGURE V:2-10. TRENCH SHIELD

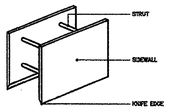
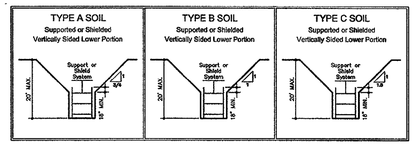


FIGURE V:2-11. TRENCH SHIELD, STACKED.

B. COMBINED USE. Trench boxes are generally used in open areas, but they also may be used in combination with sloping and benching. The box should extend at least 18 in (0.45 m) above the surrounding area if there is sloping toward excavation. This can be accomplished by providing a benched area adjacent to the box.

Earth excavation to a depth of 2 ft (0.61 m) below the shield is permitted, but only if the shield is designed to resist the forces calculated for the full depth of the trench and there are no indications while the trench is open of possible loss of soil from behind or below the bottom of the support system. Conditions of this type require observation on the effects of bulging, heaving, and boiling as well as surcharging, vibration, adjacent structures, etc., on excavating below the bottom of a shield. Careful visual inspection of the conditions mentioned above is the primary and most prudent approach to hazard identification and control.

FIGURE V:2-12. SLOPE AND SHIELD CONFIGURATIONS.



VIII. SLOPING AND BENCHING.

A. SLOPING. Maximum allowable slopes for excavations less than 20 ft (6.09 m) based on soil type and angle to the horizontal are as follows:

TABLE V:2-1. ALLOWABLE SLOPES.

Soil Type	*Height/Depth Ratio*	*Slope Angle*
Stable Rock	Vertical	90°
Type A	3/4 : 1	53°
Type B	1 : 1	45°
Type C	1.5 : 1	34°
Type A (short term)	0.5 : 1	63°

(For a MAXIMUM excavation of 12 foot)

FIGURE V:2-13. SLOPE CONFIGURATIONS: EXCAVATIONS IN LAYERED SOILS.

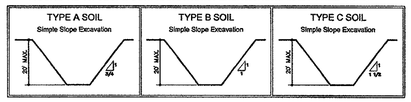


FIGURE V:2-13. SLOPE CONFIGURATIONS: EXCAVATIONS IN LAYERED SOILS. *(continued)*

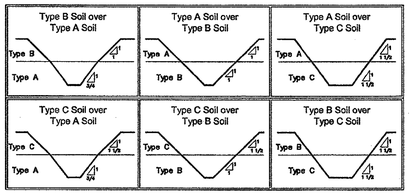
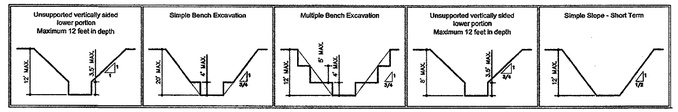


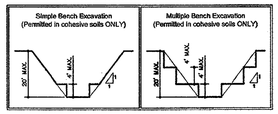
FIGURE V:2-14. EXCAVATIONS MADE IN TYPE A SOIL.



B. BENCHING. There are two basic types of benching, simple and multiple. The type of soil determines the horizontal to vertical ratio of the benched side.

As a general rule, the bottom vertical height of the trench must not exceed 4 ft (1.2 m) for the first bench. Subsequent benches may be up to a maximum of 5 ft (1.5 m) vertical in Type A soil and 4 ft (1.2 m) in Type B soil to a total trench depth of 20 ft (6.0 m). All subsequent benches must be below the maximum allowable slope for that soil type. For Type B soil the trench excavation is permitted in cohesive soil only.

FIGURE V:2-15. EXCAVATIONS MADE IN TYPE B SOIL.

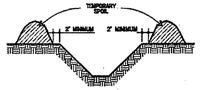


IX. SPOIL.

A. TEMPORARY SPOIL. Temporary spoil must be placed no closer than 2 ft (0.61 m) from the surface edge of the excavation, measured from the nearest base of the spoil to the cut. This distance should not be measured from the crown of the spoil deposit. This distance requirement ensures that loose rock or soil from the temporary spoil will not fall on employees in the trench.

Spoil should be placed so that it channels rainwater and other run-off water away from the excavation. Spoil should be placed so that it cannot accidentally run, slide, or fall back into the excavation.

FIGURE V:2-16. TEMPORARY SPOIL.



B. PERMANENT SPOIL. Permanent spoil should be placed at some distance from the excavation. Permanent spoil is often created where underpasses are built or utilities are buried. The improper placement of permanent spoil, i.e. insufficient distance from the working excavation, can cause an excavation to be out of compliance with the horizontal-to-vertical ratio requirement for a particular excavation. This can usually be determined through visual observation. Permanent spoil can change undisturbed soil to disturbed soil and dramatically alter slope requirements.

X. SPECIAL HEALTH AND SAFTY CONSIDERATIONS.

A. COMPETENT PERSON. The designated competent person should have and be able to demonstrate the following:
- Training, experience, and knowledge of (1) soil analysis, (2) use of protective systems and (3) requirements of ***29 CFR Part 1926 Subpart P.***
- Ability to detect (1) conditions that could result in cave-ins, (2) failures in protective systems, (3) hazardous atmospheres and (4) other hazards including those associated with confined spaces.
- Authority to take prompt corrective measures to eliminate existing and predictable hazards and to stop work when required.

B. SURFACE CROSSING OF TRENCHES. Surface crossing of trenches should be discouraged; however, if trenches must be crossed, such crossings are permitted only under the following conditions:
- Vehicle crossings must be designed by and installed under the supervision of a registered professional engineer.
- Walkways or bridges must be provided for foot traffic. These structures shall (1) have a safety factor of 4, (2) have a minimum clear width of 20 in (0.51m), (3) be fitted with standard rails and (4) extend a minimum of 24 in (.61 m) past the surface edge of the trench.

C. INGRESS AND EGRESS. Access to and exit from the trench require the following conditions:
- Trenches 4 ft or more in depth should be provided with a fixed means of egress.
- Spacing between ladders or other means of egress must be such that a worker will not have to travel more than 25 ft laterally to the nearest means of egress.
- Ladders must be secured and extend a minimum of 36 in (0.9 m) above the landing.
- Metal ladders should be used with caution, particularly when electric utilities are present.

D. EXPOSURE TO VEHICLES. Procedures to protect employees from being eral injured or killed by vehicle traffic include:
- Providing employees with and requiring them to wear warning vests or other suitable garments marked with or made of reflectorized or high-visibility materials.
- Requiring a designated, trained flagperson along with signs, signals, and barricades when necessary.

E. EXPOSURE TO FALLING LOADS. Employees must be protected from loads or objects falling from lifting or digging equipment. Procedures designed to ensure their protection include:
- Employees are not permitted to work under raised loads.
- Employees are required to stand away from equipment that is being loaded or unloaded.
- Equipment operators or truck drivers may stay in their equipment during loading and unloading if the equipment is properly equipped with a cab shield or adequate canopy.

F. WARNING SYSTEMS FOR MOBILE EQUIPMENT. The following steps should be taken to prevent vehicles from accidentally falling into the trench:
- Barricades must be installed where necessary.
- Hand or mechanical signals must be used as required.
- Stop logs must be installed if there is a danger of vehicles falling into the trench.
- Soil should be graded away from the excavation; this will assist in vehicle control and channeling of run-off water.

G. HAZARDOUS ATMOSPHERES AND CONFINED SPACES. Employees shall not be permitted to work in hazardous and/or toxic atmospheres. Such atmospheres include those with:
- Less than 19.5% or more than 23.5% oxygen;
- A combustible gas concentration greater than 20 % of the lower flammable limit; and
- Concentrations of hazardous substances that exceed those specified in the Threshold Limit Values for Airborne Contaminants established by the ACGIH (American Conference of Governmental Industrial Hygienists).

All operations involving such atmospheres must be conducted in accordance with OSHA requirements for occupational health and environmental controls (see ***Subpart D of 29 CFR 1926***) for personal protective equipment and for lifesaving equipment (see ***Subpart E, 29 CFR 1926***). Engineering controls (e.g., ventilation) and respiratory protection may be required.

When testing for atmospheric contaminants, the following should be considered:
- Testing should be conducted before employees enter the trench and should be done regularly to ensure that the trench remains safe.
- The frequency of testing should be increased if equipment is operating in the trench.
- Testing frequency should also be increased if welding, cutting, or burning is done in the trench.

Employees required to wear respiratory protection must be trained, fit-tested, and enrolled in a respiratory protection program. Some trenches qualify as confined spaces. When this occurs, compliance with the Confined Space Standard is also required.

H. EMERGENCY RESCUE EQUIPMENT. Emergency rescue equipment is required when a hazardous atmosphere exists or can reasonably be expected to exist. Requirements are as follows:
- Respirators must be of the type suitable for the exposure. Employees must be trained in their use and a respirator program must be instituted.
- Attended (at all times) lifelines must be provided when employees enter bell-bottom pier holes, deep confined spaces, or other similar hazards.
- Employees who enter confined spaces must be trained.

I. STANDING WATER AND WATER ACCUMULATION. Methods for controlling standing water and water accumulation must be provided and should consist of the following if employees are permitted to work in the excavation:
- Use of special support or shield systems approved by a registered professional engineer.
- Water removal equipment, i.e. well pointing, used and monitored by a competent person.
- Safety harnesses and lifelines used in conformance with ***29 CFR 1926.104***.
- Surface water diverted away from the trench.
- Employees removed from the trench during rainstorms.
- Trenches carefully inspected by a competent person after each rain and before employees are permitted to re-enter the trench.

J. INSPECTIONS. Inspections shall be made by a competent person and should be documented. The following guide specifies the frequency and conditions requiring inspections:
- Daily and before the start of each shift;
- As dictated by the work being done in the trench;
- After every rainstorm;
- After other events that could increase hazards, e.g. snowstorm, windstorm, thaw, earthquake, etc.;
- When fissures, tension cracks, sloughing, undercutting, water seepage, bulging at the bottom, or other similar conditions occur;
- When there is a change in the size, location, or placement of the spoil pile; and
- When there is any indication of change or movement in adjacent structures.

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REVISIONS

PROTOTYPE

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