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Task Plan to Evaluate the Effectiveness of In Situ Grouting of an ORNL Waste Burial Trench with a Cement-Based Grout

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EXECUTIVE SUMMARY

This task will demonstrate the feasibility of using an in situ grouting technique with a particulate-grout formulation as a closure action to stabilize waste trenches in Solid Waste Storage Area (SWSA) 6. It also supports technology development for closure of other SWSAs. Earlier demonstrations have involved evaluations concerning the effectiveness and feasibility of in situ grouting with polyacrylamide and dynamic compaction techniques for the stabilization of burial trenches against subsidence. Dynamic compaction has been shown to be quite effective in improving the stability of SWSA 6 burial trenches, and in situ grouting with polyacrylamide significantly reduces the hydraulic conductivity within the trench. Dynamic compaction appears to be a relatively inexpensive stabilization approach. On the other hand, in situ grouting of uncompacted trenches with polyacrylamide seems to be expensive because of the cost of the acrylamide grouting materials and relatively large void volumes of uncompacted trenches. By using a combination of the two, dynamic compaction followed by in situ grouting with acrylamide, the costs could be significantly reduced. Recent investigations, however, reveal that low hydraulic conductivity of compacted trenches most likely limits penetration of the acrylamide grout to such an extent that in situ grouting of compacted trenches is probably not feasible. An alternative approach to waste-trench stabilization may involve the in situ grouting of burial trenches with a particulate grout.

Two trenches in the Test Area for Remedial Action site of SWSA 6 are targeted for in situ grouting with a particulate grout. Void volumes of these trenches were determined in 1987 by flooding with water. This method of determining trench void volume may enhance leaching of radionuclides and hazardous waste constituents and, therefore, is no longer practiced. Two alternative methods for measuring trench void volume will be tested and validated using the previous water-flooding determinations as target values. One method includes trench pressurization with air, using the ideal gas law to calculate void volume. The other method involves the displacement of trench ambient gases with known volumes of CO_2. Other trench characterization needs include soil penetration resistance tests as an index of ground stability and hydraulic conductivity measurements before and after grouting the trenches. Monitoring well and suction lysimeters will be installed around the perimeter of each trench to investigate water quality before and after grouting.

A particulate grout will be formulated using cement-bentonite and fly ash from a coal-fired power plant. The grout solids will be dry-blended, mixed with water, and injected (using ~5 to 10 lb/in.^{2} pressure) into five injection wells per trench. After 28 days for setting, soil penetration resistance and hydraulic conductivity measurements will be repeated for comparison to pregrouting measurements.

The primary objective of this task is to demonstrate the feasibility and effectiveness of the in situ injection of a particulate grout into waste burial trenches. Effectiveness is defined here as increased trench stability (characterized by trench penetration resistance tests) and decreased potential for leachate migration (characterized by hydraulic conductivity tests).

BACKGROUND

Oak Ridge National Laboratory (ORNL) has recently finished placing an interim covering over ~10 acres of Solid Waste Storage Area (SWSA) 6, where low-level radioactive wastes have been buried in shallow trenches. The final closure of SWSA 6 awaits the completion of its remedial investigation into the nature and extent of contamination as well as the development of effective and safe techniques to stabilize the burial trenches. Development and demonstration of these shallow-land burial stabilization technologies are being carried out under the ORNL Remedial Action Program. To develop trench stabilization and closure alternatives, a group of 19 burial trenches in SWSA 6 was identified as a demonstration and test area to (1) identify promising trench stabilization and closure techniques applicable to the ORNL setting, (2) carry out these techniques on a field scale using actual low-level-waste trenches, and (3) collect the necessary data to evaluate each technique in regard to its feasibility, effectiveness, and cost.

This project, called Test Area for Remedial Actions (TARA), is being conducted on a small hillock in the northeastern corner of SWSA 6.[1] The site was selected primarily on the basis of the following two criteria: (1) it is away from daily waste management activities, and more important (2) it is located entirely on high ground and is isolated hydrologically from any peripheral recharge areas, which would complicate conducting a site water budget and performance monitoring as part of the stabilization/closure evaluations. The water table at the site is at least 20 ft below the bottoms of the trenches, and the trenches in the area are, therefore, unsaturated throughout most of the year in contrast with being chronically or seasonally inundated, as is the case with other trench areas in SWSA 6.

Two stabilization and closure technologies have been demonstrated at this site. Five burial trenches have undergone a dynamic compaction demonstration,[3] and two have been grouted by the in situ injection of a polyacrylamide-based chemical grout. Dynamic compaction is quite effective in improving the stability of SWSA 6 burial trenches,[3,2] and in situ grouting with polyacrylamide significantly reduces the hydraulic conductivity within the trench.[3] Final closure requires sufficient stability within the trench area to ensure that subsidence will not occur after construction of trench caps and moisture barrier controls. Dynamic compaction appears to be a relatively inexpensive stabilization approach. On the other hand, in situ grouting of uncompacted trenches with polyacrylamide is expensive because of the cost of the acrylamide grouting materials ($2/gal) and relatively large void volumes to be filled with grout within uncompacted trenches (estimated cost is $50,000 per typical burial trench). However, if the two techniques were combined (dynamic compaction followed by in situ grouting with acrylamide), the costs could be substantially reduced because dynamic compaction eliminates about 80% of the trench voids. Demonstration tests during September and October 1989 revealed that the low hydraulic conductivity of compacted trenches limited penetration of the acrylamide grout to such an extent that in situ grouting of compacted trenches was not possible.

Because of (1) high costs associated with in situ grouting with acrylamide in uncompacted trenches, (2) the inability to use in situ grouting on dynamically compacted trenches, (3) the inherent risks of using the hazardous acrylamide chemicals, and (4) the unresolved concerns relating to release of contained liquids during dynamic compaction of burial trenches, there is a need to demonstrate whether in situ grouting with a nonhazardous particulate-based grout is a viable alternative that will provide long-term burial trench stability.

ORNL previously conducted demonstrations using particulate grout in waste trenches.[4] Davis et al. used a particulate grout (cement-bentonite) to fill an open (uncovered with no backfill) trench and compared its effectiveness in isolating waste in a hydrological sense with that achieved by lining the trench using reinforced Hypalon (chlorosulfonated polyethylene) fabric. They concluded that the cement-bentonite grouting treatment offered a higher degree of waste isolation than the lining technique. Tamura et al. injected a particulate-type grout made of cement, fly ash, and bentonite into a low-level-waste trench in SWSA 6. The demonstration revealed that a cement-based grout could be successfully formulated and pressure-injected into a SWSA 6 waste trench. Thirty-six injection wells (2-in.-diam lances made of Schedule 80 steel pipe) were installed at 5-ft centers in a trench measuring 56 ft long, 9 ft wide, and 12 ft deep. Five of the injection wells took 78% of the grout injected, which indicates that grout mobility in the trench was not greatly restricted. The average pumping rate was 6.1 gal/min at a pressure range of 5 to 10 $lb/in.^2$ Total volume of injected grout was 8081 gal (about 9% more than the trench's estimated void volume). The estimated voids within the trench were reduced three orders of magnitude; pumping tests with water, however, revealed significant water movement between injection wells within individual areas of the trench. Postgrouting penetration tests were conducted but were compared with penetration tests carried out on an adjacent ungrouted waste trench rather than penetration tests on the pregrouted waste trench.

DESCRIPTION OF WORK

TRENCH SELECTION

Two trenches, Nos. 151 and 170 in the TARA site (Fig. 1), are tentatively identified as candidates for in situ grouting with a particulate grout. The locations of both trenches have been surveyed and the corners of each marked. Each trench is ~15 ft deep. Trench 151 measures 38 by 14 ft and trench 170 measures ~47 by 14 ft. Their composite void volume was determined by filling with water in 1987, and there have been limited measurements of soil penetration resistance within and adjacent to these trenches. Groundwater monitoring wells are north and south of the trenches. The water table is 20 to 30 ft below the bottoms of the trenches, and thus, the trenches are unsaturated most of the year, except possibly after an extended heavy rain, when transient perched water may accumulate for a short time.

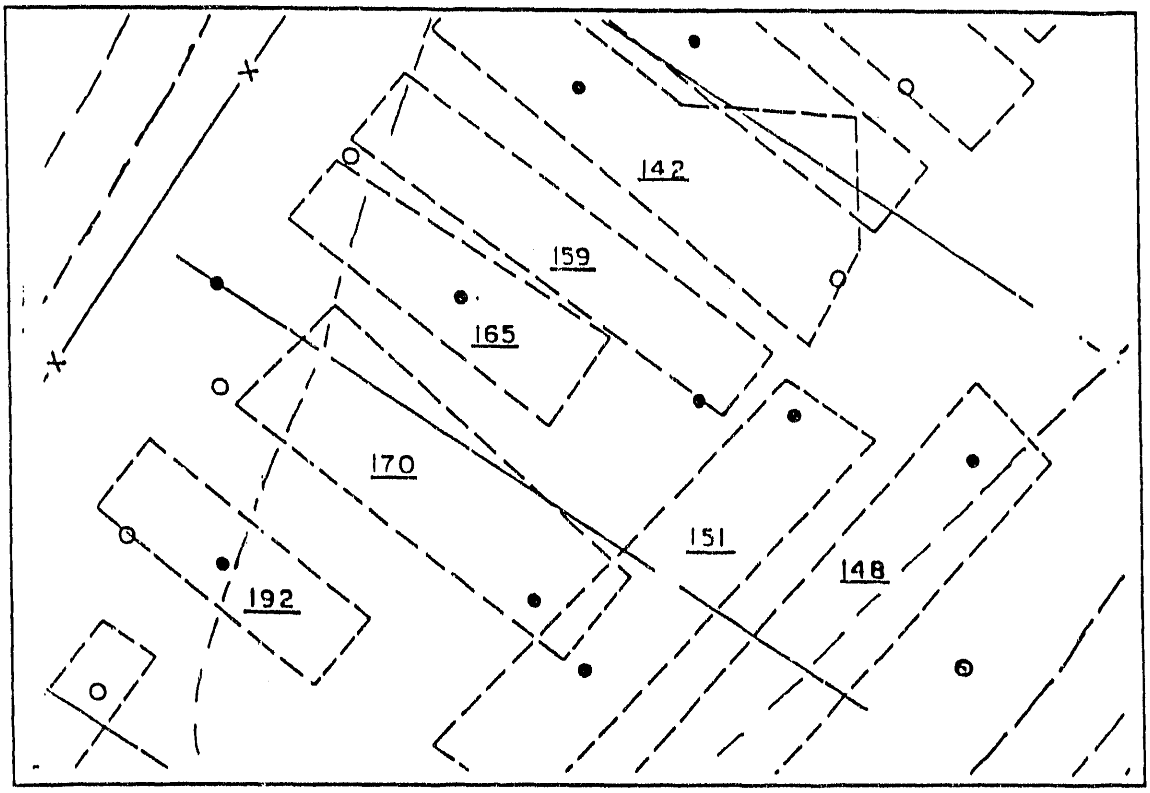

Fig. 1. Outline of waste trenches at TARA site in SWSA 6.

These trenches in a sense overlap; the southwest end of trench 170 abuts the northeast side of trench 151. This apparently occurred because trench 170 (opened July through October 1975) was constructed too close to trench 151 (opened February through April 1975), and the wall separating the two collapsed. The two are definitely connected; during void volume determinations in 1987, water was observed in trench 170 when trench 151 was approximately half-filled. For void measurements in this project, the two trenches are considered as a single trench.

TRENCH CHARACTERIZATION

Additional soil penetration tests will be determined on each of the waste trenches before the in situ grouting. A nonstandard penetration test has been developed for use over trenches to avoid augering contaminated waste to the surface as would be required in the standard American Society for Testing and Materials (D 1586-84) soil penetration test.[3] The nonstandard test uses a 140-lb drill-rig-mounted drop hammer to drive into the ground a 2-in.-diam 60° cone point attached to a 1.75-in.-diam. drill rod. The drill rod is marked at 1-ft lengths, and penetration is measured by the number of blows required to move the device each foot into the ground. Approximately ten of these penetration holes will be made in each of the two trenches. Five of the holes will be used to determine pregrouting hydraulic conductivities, and five others will be cased with specially designed well screening (0.3-in. slotted, 1.75-in.-diam polyvinyl chloride [PVC] casing) and used for monitoring and injection purposes. Postgrouting penetration holes (at least five per trench to determine the difference in soil penetration pregrouting) will also be used to assess the hydraulic conductivity of the grouted trench (Fig. 2). Monitoring wells and suction lysimeters will be installed around the perimeter of the trenches to investigate water quality before and after demonstration activities.

The combined trenches (151 and 170) had previously been filled with water to determine void volume, and losses resulting from seepage into the surrounding soil were taken into account. This practice may cause leaching of radionuclides or hazardous wastes into groundwater and induce premature settling of soil overburden into the trench. It also leaves soil within the trench near saturation levels for a significant period of time, which could have an influence on the solidification of grout introduced into the trench. Because of these reasons, flooding trenches with water is not an acceptable practice for determining trench void volume. An alternative nondestructive method is thereby needed for determining trench void volume.

One alternative method to be tested is the use of CO^2 (99.5% purity) as a displacement medium for trench air. The gas has a higher density than moist air and exhibits similar behavior to that of water when pumped to the bottom of a trench. As a known volume of pure CO_2 gas is pumped to the bottom, concentrations of CO_2 will be monitored at the soil penetration holes. Void volumes of trenches can be determined from the sharp breakthrough curves in CO_2 concentration (from ambient CO_2 concentrations ranging on the order of 0.03 to 0.3% to those of >95% from the pure CO_2 injection) at these monitoring sites. This method of determining the void volume compared very favorably with methods using N_2 pressurization and the ideal gas law for a closed silo in SWSA 6 (see Table 1).

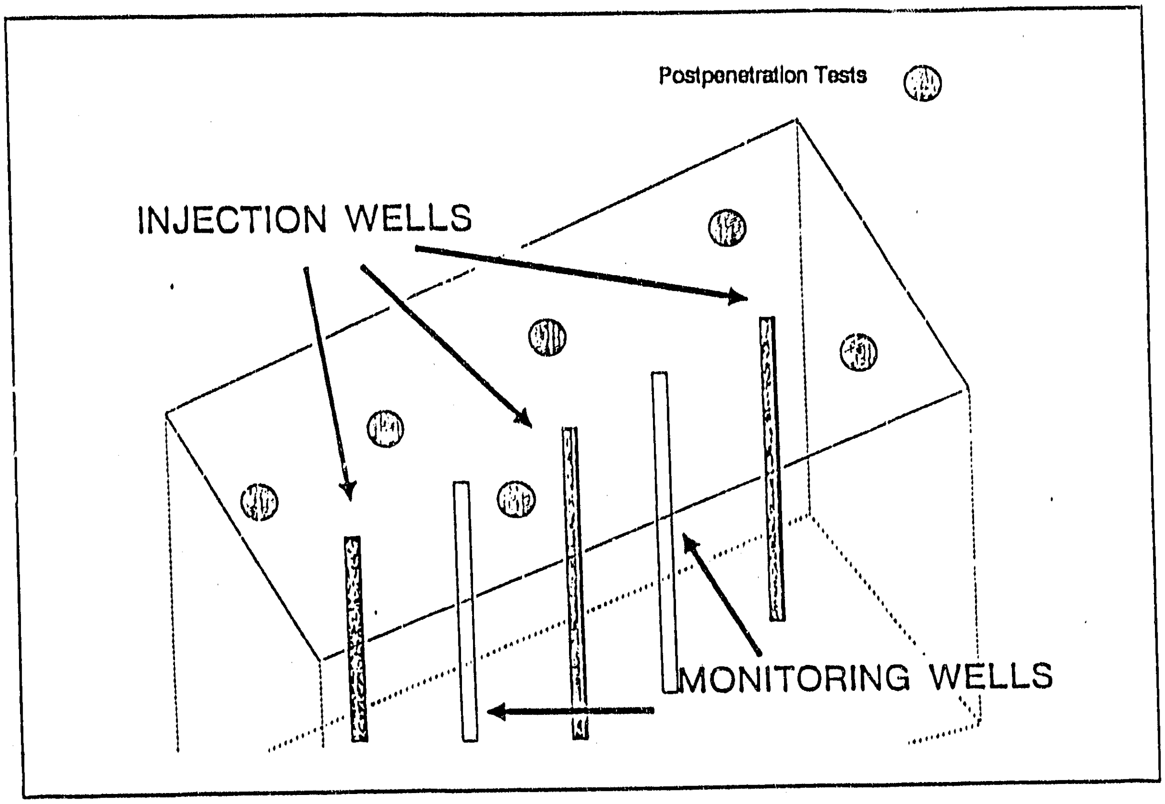

Fig. 2. Schematic of trench with injection, monitoring, and penetration wells.

Table 1. Void volume measurements conducted using CO_2 injection or N_2 pressurization techniques[a]

Technique	CO_2 or N_2 influx (L/min)		Void volume (L)
CO_2 injection	10.1–12.2		10,300–12,400
	28.9–31.9		10,400–11,500
	48.2–50.5		11,100–11,600
		Mean	11,200±800
N_2 pressurization	14.3		10,900
	22.6		11,300
	25.1		13,300
	31.0		13,200
		Mean	12,200±1,200

[a]Measurements taken on silo 527 in the ORNL SWSA 6, September 1989, by P. J. Hanson and C. W. Francis, Environmental Sciences Division.

Another alternative method to be tested for determining trench void volume is based on trench pressurization (to treat it as a closed vessel) and calculation of its void volume from the ideal gas law. The principle is the same used in the N_2 pressurization of the closed silo in SWSA 6 (Table 1); howeve in this case ambient air (instead of N_2) will be pumped into the trench. The trench is obviously not a closed vessel, but experience during grouting exercises has revealed that pressures from 10 to 15 lb/in.^{2} can be achieved. After taking into consideration the leak rate (a process similar to that used in determining trench void volume by flooding with water), void volume can be calculated from the ideal gas law. Use of such a simple technique to determine trench void volume would be a significant accomplishment. For example, one of the most important criterion in determining the effectiveness of in situ grouting is the extent of filling voids with grout. To do this, it is imperative that the total void volume of the trench be known. Trenches 151 and 170 were selected for grouting because trench volumes have previously been determined by flooding with water, a technique that can no longer be practiced. Thus, these trenches offer an opportunity to verify the use of alternative methods to determine trench void volume.

GROUT FORMULATION

A specific grout formulation has not been designated for this work. The intent is to use the same blend of cement, bentonite, and fly ash as that used by Tamura et al.[8] The same set retarder–dispersing agent will also be used (glucono-delta-lactone, previously marketed by Halliburton as CFR-1) to improve pumpability and increase set time of the grout. This formulation is taken as an initial option in that its characteristics are known, and its selection will preclude an in-depth investigation to design and test other formulations. The formulations' mixing and pumping characteristics, for example, meet the following criteria:

Apparent viscosity	$<$50 cP
10-min gel strength	$<$100 lb_f/100 ft^2
28-d phase separation	0 vol %
28-d compressive strength	$>$60 psi

A small experimental program has been initiated to investigate the potential of using a microfine cement formulation. Use of such a formulation could be beneficial because it may have greater penetration into the smaller voids within the trench than that achieved by conventional cements. However, costs of microfine cement are ~10 times higher than those of conventional cements. A microfine cement formulation will not be used in this task unless it is demonstrated that the formulation meets the above performance criteria and that the formulation can be mixed and pumped satisfactorily.

GROUT MIXING AND INJECTION

Grout solids will be blended dry (using existing equipment at the New Hydrofracture Facility) and then mixed with water in a concrete mixing truck. Grout injection will be carried out using a progressive gravity pump to transfer grout into injection wells (about five per waste trench), which will be established by casing selected holes made in the trench during the pregrouting soil penetration tests. The grout pump has the capacity to deliver 30 gal/min of grout and can sustain pressures as high as 200 lb/in.^{2} Actual grouting pressure is expected to range between 5 and 10 lb/in.^{2} Grouting pressures in excess of 25 lb/in.^{2} indicate restricted movement of grout, and grouting will probably be stopped to minimize breakthrough at ground surface; injection wellhead containment collars will be employed to contain any breakthrough grout. Grouting will be continued at other injection wells, and monitoring of grout levels in the trench will be accomplished by using the other soil penetration holes (with special casing to detect grout levels, see Fig. 2).

POSTGROUTING CHARACTERIZATION

Postgrouting soil penetration tests and hydraulic conductivity measurements will be conducted. New penetration tests will be positioned between the monitoring and injection wells and the edge of the trench (see Fig. 2). Penetration resistance as well as hydraulic conductivity will be compared before and after grouting. Specimens of the injected field grout will be taken and tested for compressive strength, set time, phase separation, and neat permeability. Groundwater quality monitoring in and around the grouted trenches will be continued at least quarterly through FY 1991. Then a final demonstration evaluation will be reported. In FY 1991, set compatibility tests with SWSA 6 trench leachates will be performed similar to those performed on polyacrylamide grout (Spalding et al.[3]). Standardized leach tests (ANS 16.1) will also be conducted in FY 1991 to evaluate waste form performance with selected radionuclides and hazardous chemicals identified in the SWSA 6 Remedial Investigation.

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Appendix

BUDGET AND SCHEDULE

BUDGET

	FY 1990	FY 1991
Costs ($K)	400	150

SCHEDULE

Activity	Completion Date
Grout formulation designed and tested	1/30/90
Penetration tests	3/15/90
Suction lysimeters installed	3/30/90
Void measurements determined (pressure technique)	4/15/90
Void measurements determined (CO_2 technique)	5/15/90
Trenches grouted (cement-based grout)	6/30/90
Postgrouting penetration and hydraulic tests	7/30/90
Report of field demonstration	9/30/90
Report of fielu onitoring and grout performance	9/30/91

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