

TREATABILITY STUDY: ACID PIT STABILIZATION AT THE IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY

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ABSTRACT

In a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) treatability study, engineers at the Idaho National Engineering and Environmental Laboratory (INEEL) stabilized contaminated soil in situ using an INEEL-developed technique called nonreplacement jet grouting. The technique consists of injecting specially prepared grouts under high pressure into a waste site to create a series of underground columns that form a monolith. The monolith simultaneously contains waste in the site and blocks the flow of water through the contaminated zone, ensuring effective long-term protection against contaminant leaching and airborne release. The stabilized area at the INEEL is known as the Acid Pit. It is a mixed waste disposal site primarily contaminated with mercury of unknown speciation and with low levels of radioactive materials including cesium-137 at 125 pCi/g as well as transuranics at only a few pCi/g. Core samples of the cured monolith showed thorough waste encapsulation by the grout. Nonreplacement jet grouting is applicable to a radioactive environment at reasonable cost.

INTRODUCTION

This paper presents the results of a CERCLA treatability study performed at the INEEL involving in situ stabilization of a buried waste site called the Acid Pit. The Acid Pit is a mixed waste disposal site at the Subsurface Disposal Area of the INEEL's Radioactive Waste Management Complex. During the 1960s and 1970s, radioactive inorganic and organic liquids were periodically placed in the roughly 30 × 60-m (100 × 200-ft) pit and covered with soil and/or lime. Once the pit was closed, it was backfilled and mounded with clean soil. The pit is approximately 5 m (17 ft) deep, including approximately 1.5 m (5 ft) of clean overburden.

At 5 m (17 ft) below the surface, there is the beginning of essentially 150 m (500 ft) of basaltic flows below which is an immense layer of water-bearing rock called the Snake River Plain Aquifer. During 1991 (1), cores were obtained from the pit, and subsequent evaluation of the cores resulted in the finding that mercury of unknown speciation was the primary contaminant of concern with the highest concentration of 5320 ppm. Radioactive materials included cesium-137 at 125 pCi/g and transuranics at only a few pCi/g.

One of the options to protect the Snake River Plain Aquifer from contaminant migration was to stabilize the waste in situ with a specially designed grout using an INEEL-developed grouting

technique called nonreplacement jet grouting. To investigate this remediation option for the Acid Pit, a treatability study was performed in 1997 to examine whether creating a monolith by jet grouting would decrease the leachability of contaminants in order to pass toxicity characteristic leaching procedure (TCLP) testing and provide a durable monolith that is chemically compatible with the surrounding environment (2).

TECHNOLOGY DESCRIPTION/BACKGROUND

The technology of in situ stabilization consists of nonreplacement jet grouting to form a monolith out of the buried waste site by injecting under high pressure specially formulated grouts in a specially designed grid pattern shown schematically in Fig. 1.

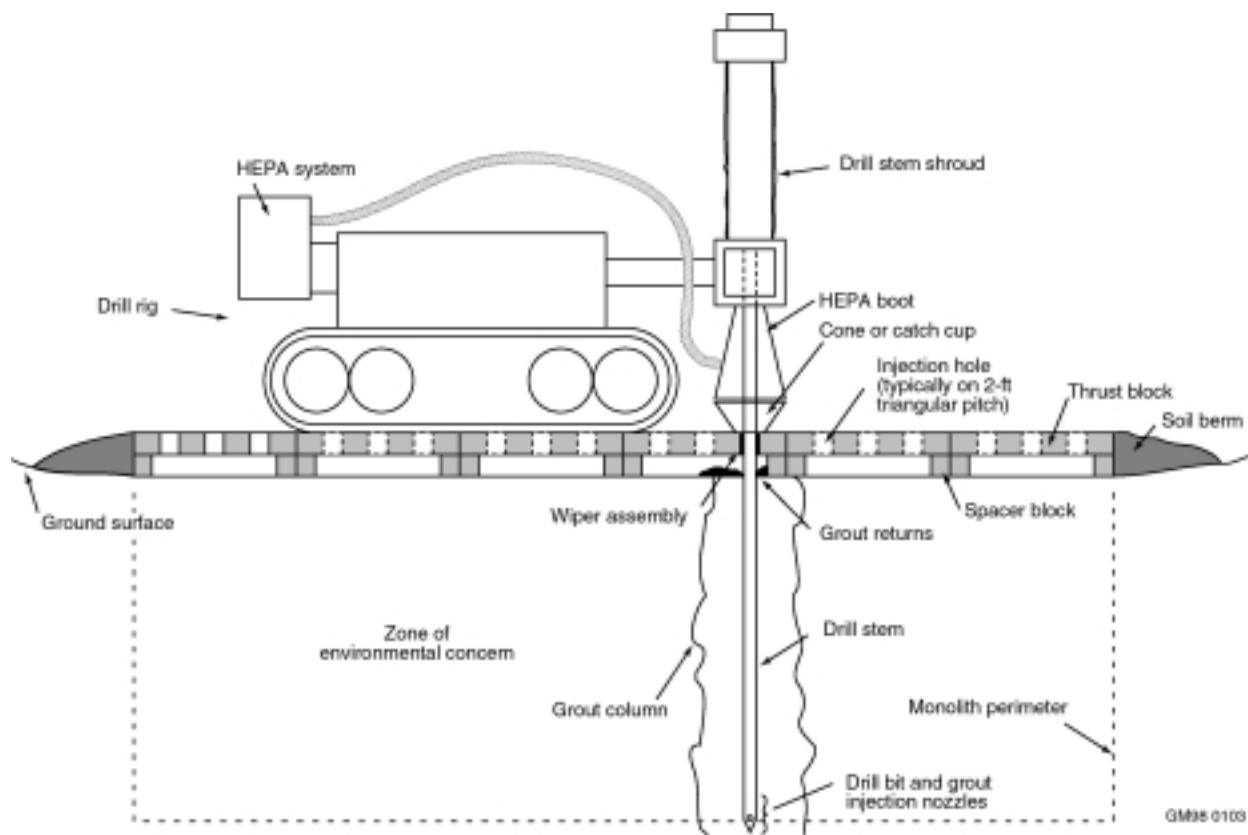


Fig. 1. Schematic of jet-grouting apparatus with thrust block (GM98 0103).

The technology was originally developed for application at buried debris sites such as the buried transuranic waste locations at the INEEL. However, in the Acid Pit stabilization project, the technology was extended to a contaminated soil site.

The jet-grouting apparatus consists of a rotopercussion drill rig, drill bit with nozzles, high-pressure positive displacement pumps, and associated supply tanks and hoses. To operate in a mixed waste environment, specially designed contamination control devices are attached to the drill rig to control the spread of contaminated grout, including any possible airborne releases.

These devices include a flexible drill string enclosure and a funnel arrangement around the bottom of the drill stem connected to a high-efficiency particulate air (HEPA) filtration system.

A thrust block is also employed to collect any grout returning to the surface during grouting. The thrust block is placed over the waste site. It consists of a reinforced concrete block with preformed holes on a particular grid pattern and a series of compartments underneath the thrust block to collect any grout returns.

The drill stem is driven through the buried waste. When fully inserted, the jet grouting is started while withdrawing the rotating drill stem in precise increments called steps. By optimizing the withdrawal rate, the size of the step, and the number of rotations of the drill stem per step, the jetting action mixes the grout with the soil into a column of soil and grout called soilcrete. Voids in the soil are essentially filled by the jetting action, resulting in the soilcrete mixture. By connecting a series of columns together in a triangular pitch pattern, a monolith is formed.

Nominal grouting parameters used for the Acid Pit stabilization project were 2 seconds on a step with a 5-cm step size and 2 revolutions of the drill stem per step. Grouting pressure was 450 bar (6000 psi). The grout used for the Acid Pit stabilization project was TECT-HG, a specially prepared grout from Carter Technologies of Houston. The grout was designed to chemically stabilize mercury and provide a solid durable monolith for long-term confinement, at the same time maintaining chemical stability with the surrounding medium.

Studies at mixed waste debris sites including the transuranic pits and trenches at the INEEL Subsurface Disposal Area have demonstrated that monoliths can be created out of buried waste sites in order to leave waste in situ in an as-disposed condition or to enhance the waste's retrievability by agglomerating the fine contaminants into larger particles not prone to contamination spread (3, 4, 5). Jet grouting was possible with essentially no grout returns, and the process was truly nonreplacement grouting.

As part of the Acid Pit treatability study, cold mockup testing was performed in uncontaminated soil sites near the Acid Pit. Engineers found that nonreplacement jet grouting in plain soil was much more difficult than jet grouting in debris pits. The tightly packed silty-clay soil had few voids when compared with the debris pits, and the increased grout returns from the soil presented difficulties using parameters developed in prior testing. Before stabilizing the Acid Pit, engineers therefore developed a new set of grouting parameters and redesigned the thrust block to accommodate the larger amounts of grout returns.

ACID PIT STABILIZATION

Following extensive cold testing in mockup test pits, a portion of the Acid Pit was stabilized using the developed methodology. The original evaluation of soil cores from the Acid Pit (1) showed maximum concentration of mercury basically in the middle of the pit. Therefore, grouting operations centered on a 4.27×4.27 -m (14×14 -ft) region near the center of the pit. A thrust block system with predrilled holes for grouting was set up to cover an area of approximately 7.31×7.62 m (24×25 ft), with the center oriented to cover the 4.27×4.27 -m (14×14 -ft) region of interest as shown in Fig. 2.

The jet-grouting process was accomplished in four days of grouting, resulting in a monolith approximately $4.27 \times 4.27 \times 1.52$ to 3.65 m ($14 \times 14 \times 5$ to 12 ft) deep. A total of 12455 L (3295 gal) of grout was emplaced via approximately 50 grout holes as shown in Fig. 2. This volume is equal to approximately 25% of the treated volume of the pit, which also approximately corresponds to the water accessible void volume in the soil. The process was accomplished without the spread of hazardous or radioactive material to the surrounding area, and the grouting process occurred without shutdown by the radiation control technician and industrial hygienist who monitored the testing.

Due to the tightly packed clay soil conditions within the Acid Pit, the grouting process was complicated by more than anticipated grout returns. Several contingency options were employed, including varying the (a) grouting pressure (230 – 450 bar [3500 – 6000 psi]), (b) height of the grouting operation (1.52 to 3.65 -m [5 to 12 -ft] zone of grouting), and (c) order of grouting. As grouting progressed, it became increasingly difficult to find an available hole that would accept grout without immediately returning some of the grout back up the hole. This indicated that the available voids in the pit were becoming filled with grout and/or redistributed.

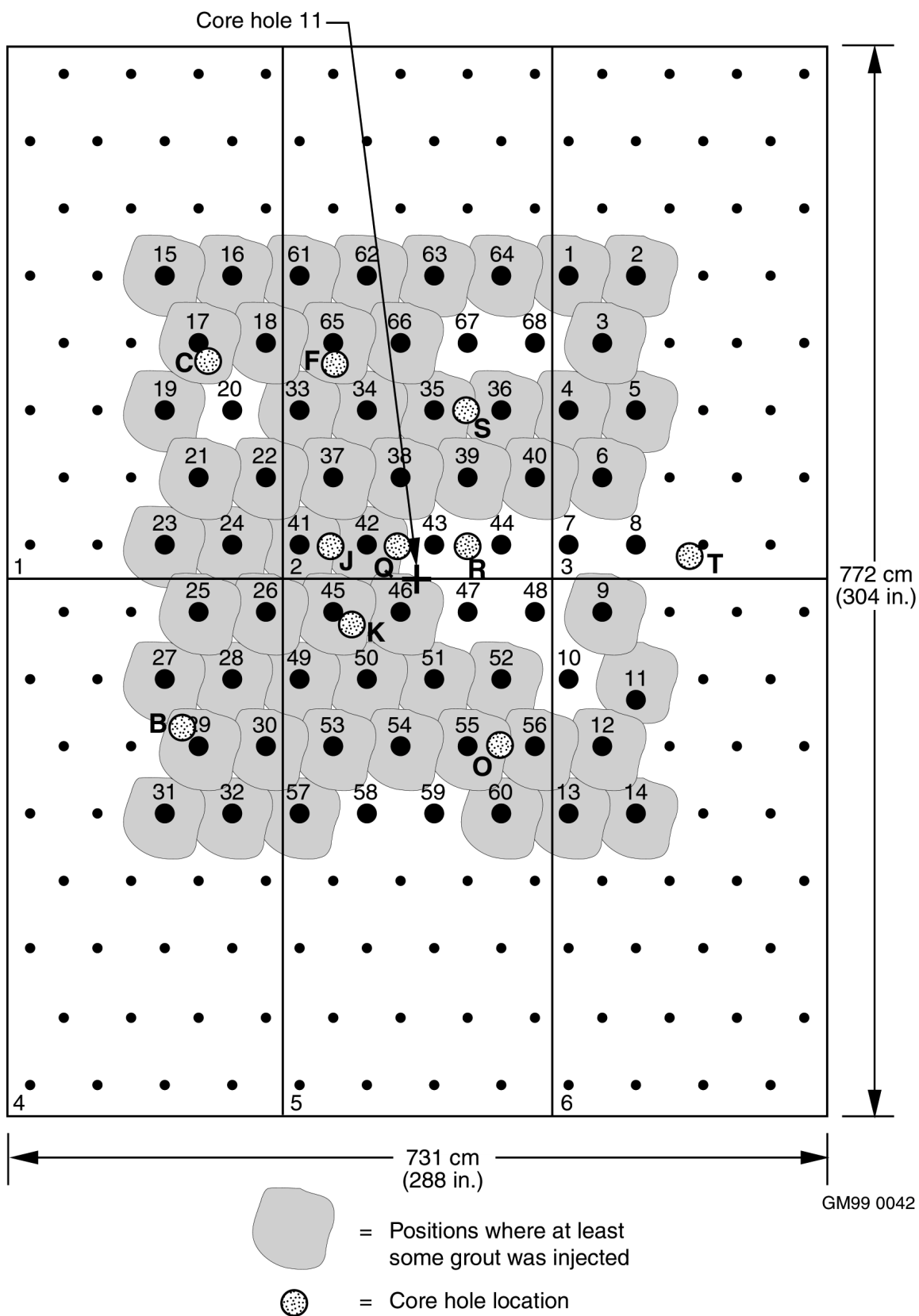


Fig. 2. Thrust block panels for Acid Pit stabilization (GM99 0042).

In the first two days of grouting, approximately 9072 L (2400 gal) of grout was emplaced. During the last two days of grouting, only approximately 3024 L (800 gal) of grout could be emplaced. The hydraulic pressure of the emplaced grouts appeared to compress the surrounding soils such that when grouting was attempted in adjacent regions, grout returns proliferated. Fig. 2 shows those regions in which no grout was injected. Even so, engineers controlled grout returns by controlling grouting pressure and the distance grouted. Grout that reached the surface was easily removed with a squeegee. Any contaminants in the grout remained locked in the slurry of grout and soil, and the surface quickly dried and was covered with plywood to prevent contact with vehicle and personnel traffic.

Online air monitoring for mercury and volatile organics resulted in low values relative to action limits. Therefore, the project was never delayed because of industrial or radiological releases. In addition, the radiation control technician monitored the entire grouting process and found no radioactive materials above background. Online mercury measurements varied between 0-0.061 ppm, and volatile organics were measured between 0-0.7 ppm at the breathing zone.

Smears on the drill stem of the drilling equipment and on the top surface of the thrust block, grab samples of the grout returns under the thrust block, and high-volume air-monitoring filters were collected and analyzed for both radioactive and hazardous contaminants for select grouting holes. Although there were both mercury and radioactive materials in small amounts on the drill stem and in the thrust block grab samples, essentially no contaminants above background were detected on the high-volume filters surrounding the grouting area (K-40 was the only radionuclide detected, and it is known to have high backgrounds in the surrounding soils). Grout returns averaged 0.831 ppm mercury; and the thrust block top surface smear was below detection limits for all but one reading (0.021 μg per smear with a smear weighing less than 1 g), and the drill stem (covered by the drill string enclosure) averaged 0.182 μg per smear.

POSTGROUTING EVALUATION

The grouted pit was allowed to cure, then evaluated to assess the stated objectives relating to leachability and stability of the resultant monolith. One study involved obtaining cores of the monolith using sonic drilling and evaluating the cores for TCLP protocol for mercury. Another examined the extent of grout penetration in the monolith.

The core evaluation study involved obtaining 10 cores in select positions within the grouted area as shown in Fig. 2. These cores represented regions thought to be well grouted, regions in which no grouting occurred but which were adjacent to grouted regions, and regions interstitial to grouting holes. Examination of the cores obtained by sonic coring techniques showed that the sonic technique fractures the cores, making visual observations difficult (further complicated by the fact that the soil and grout were of similar color). A visual observation shows the presence of TECT-HG grout in most positions, even for those not directly grouted but adjacent to the grouting area.

An analytical study was performed involving the use of marker elements that were significantly higher in the TECT-HG grout than in the baseline Acid Pit soil determined from earlier coring performed prior to grouting. These marker elements included calcium, iron, zinc, and lead. Table I gives the relative concentration of these marker metals in the ungrouted soil and for the

neat grout showing clearly that the marker metals are elevated in the grout relative to the pregrouted condition.

Table II gives the concentrations for the marker metals that showed elevated values in the grout relative to the ungrouted soils for the core samples. Again, the marker metals are elevated in the neat grout relative to the grouted cores. Neat grout refers to 100% pure grout material with no admixture soils.

Table I. Average total metals in soils from Core 11 (Track 2) as to elevation.

Average Concentration mg/kg				
Elevation	Calcium	Iron	Zinc	Lead
5–10 ft	40,933	13,666	107	18.3
8–13 ft	33,800	15,166	94.2	17.3
10–15 ft	34,166	13,813	102	14.7
14–15 ft	16,100	4,240	25.5	11.8
15–17 ft	11,890	14,020	56.7	23.5
13–17 ft	18,993	15,380	74.8	19.4
7–12 ft	33,800	15,166	94.2	17.3
13–16 ft	29,700	11,170	68.2	11.5
Neat grout	Calcium	Iron	Zinc	Lead
(ppm)	147,100	32,000	326	41.4

Table II. TECT marker elements: total calcium/iron/zinc/lead in core samples (soilcretes).

Core	Calcium (mg/kg)	Iron (mg/kg)	Zinc (mg/k)	Lead (mg/kg)
Neat grout	147,000	32,800	326	41.4
USGS ^a sample	—	35,130	2,500	—
B (10–15 ft)	37,000	18,700	90.4	11.3
B (15–17 ft)	43,700	19,100	90.2	10.2
C (10–15 ft)	43,600	16,200	99.4	6.4
C (15–17 ft)	34,500	12,900	82.7	5.3
C (15–17 ft)	37,300	12,800	85.6	5.1
F (14–15 ft)	55,200	15,200	127	14.4
F (14–15 ft)	17,000	9,200	53.7	12.2
F (15–17 ft)	28,000	13,700	71.8	8.3
J (8–13 ft)	34,200	15,600	81.8	10.1
J 13–17 ft)	56,000	9,630	124	10.2
O (5–10 ft)	87,600	26,100	209	24.1
O (10–15 ft)	56,900	15,300	129	18.6
Q (5–10 ft)	66,200	17,900	101	11.6
Q (10–15 ft)	38,800	15,600	89.4	11.1
R (7–12 ft)	59,400	20,300	110	13.2
S (8–13 ft)	30,000	16,100	81.1	10.8
S (13–16 ft)	33,000	15,600	87.4	11.2
a. U.S. Geological Survey.				

Cores were evaluated on an arbitrary scheme in which 25% grout content admixed with soil constitutes a “fully grouted” soil mixture. This is partly based on the fact that the void space in the Acid Pit soils approaches 25% and further that the injected volume of grout approximately equaled 25% of the treated volume. The following formula was used for the Percentage of Fully Grouted Soilcrete (%):

$$\% = \frac{100}{25} \times 100\% \left[\frac{\text{Soilcrete Marker Concentration} - \text{Soil Marker Concentration}}{\text{Neat Grout Concentration} - \text{Soil Marker Concentration}} \right]$$

Table III gives the various values for the percentage of fully grouted soilcrete mixtures. It is noted that a neat grout should be 400%, a fully grouted case should be 100%, and anything less than 100% is a partially grouted soilcrete. In addition, when the percentage of fully grouted soilcrete becomes negative, there is most likely no grout present.

From this it was shown that the cores varied between 49–99% grouted, which is confirmed by the visual observations in that grout was observed in most cores as shown in Table III.

Select cores were evaluated using TCLP for mercury, and the resultant values were well below action limits. The range of TCLP values in the leachate were 4.5–58.9 µg/L, and the action limit was 200 µg/L as shown in Table IV.

CONCLUSIONS

The following conclusions were made based on an evaluation of the results of the Acid Pit treatability study:

- The technique of creating monoliths at contaminated soil sites by jet grouting is practical. However, adjustments must be made depending on how tightly packed the soil is and whether it contains buried debris.
- Contaminant spread during the grouting operation was mitigated by the multilayered system designed to control the spread. This system includes a thrust block, catch cup and can, and HEPA-filtered shroud around the drill string.
- The TECT-HG grout chemically stabilized mercury contamination in the pit, as TCLP results showed less mercury in the leachate than is allowed by regulatory limits.
- Grout penetration can be evaluated by examining cores of the monolith for marker metals high in the TECT grout but not in the soil. Examination of these marker metals shows mixed results, in that several positions that should have exhibited poor TECT penetration showed good penetration and vice versa. This is most likely caused by nonhomogeneity of the Acid Pit soil in which some regions allow more penetration of the grout stream compared with others.
- Soil properties affect the ability to successfully grout certain types of subsurface conditions. A geotechnical study is recommended to fully characterize the physical

properties of the site before grouting. Engineers can then determine proper grouting intervals and grouting parameters. If simulated testing is required, construction of test areas should reflect the geotechnical properties of the specific site to permit evaluation of the grout process, volume of grout returns, and grout column development. Minor adjustments can then be made to grouting parameters and/or techniques to optimize encapsulation of the contaminated zone.

Table III. Core marker metals analysis: percentage of a completely grouted matrix (based on local soil conditions).

Core Sample	Percentage of Fully Grouted Soilcrete			
	Calcium	Iron	Zinc	Lead
Neat grout	400%	400%	400%	400%
Fully grouted soilcrete	100%	100%	100%	100%
B (10–15 ft)	10%	102%	Negative	Negative
B (15–17 ft)	94%	108%	50%	Negative
C (10–15 ft)	33%	50%	Negative	Negative
C (15–17 ft)	66.8%	Negative	38.4%	Negative
C (15–17 ft duplicate)	75.2%	Negative	42.8%	Negative
F (14–15 ft)	119%	153%	134%	34.8%
F (14–15 ft duplicate)	5.2%	69.2%	37.6%	5.2%
F (15–17 ft)	47.6%	Negative	34.0%	Negative
J (8–13 ft)	1.2%	Negative	Negative	Negative
J (13–17 ft)	115%	Negative	78%	Negative
O (5–10 ft)	175%	259%	186%	100%
O (10–15 ft)	80.0%	31.2%	48%	58%
Q (5-10 ft)	95.2%	88.4%	Negative	Negative
Q (10–15 ft)	16.4%	37.6%	Negative	Negative
R (7–12 ft)	90.4%	116%	27.2%	Negative
S (8–13 ft)	Negative	Negative	Negative	Negative
S (13–16 ft)	26.1%	82%	29.6%	Negative
Average	65.63%	99.7%	64.1%	49.5%
	(1 of 17 cores showed no grout)	(6 of 17 cores showed no grout)	(6 of 17 cores showed no grout)	(13 of 17 cores showed no grout)

Table IV. TCLP mercury analysis.^a

Core Location	TCLP Extract Concentration (µg/L)	Regulatory ^b Level (µg/L)
B (15–17 ft)	58.9	200
C (15–17 ft)	4.5	200
F (15–17 ft)	14.8	200
J (13–17 ft)	10.3	200
O (10–15 ft)	4.5	200
Field blank	0.2	
Rinseate water	0.2	

a. Determined by cold vapor atomic absorption spectroscopy.

b. The proposed Universal Treatment Standard for wastewater is 150 µg/L and for nonwastewater is 25 µg/L.

- An extensive subsurface characterization should be conducted to determine emplacement parameters that minimize grout returns and optimize grout column development. Furthermore, this information would provide a more accurate estimate of grout volume needed for emplacement to stabilize the site.
- A packer or plug system should be employed in unused holes in the thrust block to stop viscous grout from returning to the surface.
- Material mixing should be performed onsite to produce better mixtures and avoid unnecessary disposal of unused material should operational problems occur.

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