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Acid Pit Stabilization Project (Volume 1—Cold Testing)

Guy G. Loomis
Andrew P. Zdinak
Mark A. Ewanic
James J. Jessmore

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Idaho National Engineering and Environmental Laboratory
Environmental Restoration Technologies Department
Lockheed Martin Idaho Technologies Company
Idaho Falls, Idaho 83415

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DISCLAIMER

ABSTRACT

During the summer of Fiscal Year 1997, a Comprehensive Environmental Response, Compensation, and Liability Act Treatability Study was performed at the Idaho National Engineering and Environmental Laboratory. The study involved subsurface stabilization of a mixed waste contaminated soil site called the Acid Pit using jet grouting of an innovative grouting material to form a monolith out of the contamination zone. The monolith simultaneously provides a barrier to further contaminant migration and closes voids in the soil structure against further subsidence. The grout used for this study was TECT-HG, a relatively dense iron oxide-based cementitious grout. The treatability study involved both cold testing in simulated soil pits followed by in situ stabilization of the Acid Pit at the INEEL's Waste Area Group 7 Subsurface Disposal Area. This report (Volume 1) discusses the results of the cold testing phase of this project, and Volume 2 gives the results of the Acid Pit stabilization. Cold testing included field trials in which single and multiple connected columns were created by the jet-grouting action. In addition, several different simulated soil pits were grouted using tracer material to simulate actual contaminants that exist in the Acid Pit. Drilling equipment was specially rigged to reduce the spread of contamination, and all grouting was performed under a concrete thrust block, with void space to absorb any grout returns. Data included evaluation of the grouting parameters of drill rotation rate, time at a step, grout injection pressure, grout material parameters such as viscosity, and step size. In addition, the spread of the tracer material (molybdenum powder) as a stand-in for the actual main contaminant (mercury) in the Acid Pit during grouting was evaluated by taking both air samples and surface smears. Other implementability data included thrust block reusability, grout column development and connectiveness, and grout/soil mixing.

EXECUTIVE SUMMARY

A Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Treatability Study was performed at the Idaho National Engineering and Environmental Laboratory (INEEL) involving a buried mixed waste site called the Acid Pit. The Acid Pit is a contaminated soil zone located in the Subsurface Disposal Area (SDA) at the INEEL's Radioactive Waste Management Complex (RWMC), with the main contaminant of concern mercury (mercuric oxides) and minor amounts of radiological materials such as fission products, uranium, and plutonium. The treatability study involved stabilizing the waste zone in situ with an innovative jet-grouting technique that creates a monolith out of the contamination zone. This monolith reduces the migration of contaminants from within the zone and also tends to divert any surface and groundwater away from the contamination zone. The treatability study was divided into two phases: Phase-1 testing involved cold testing to develop grouting parameters and test out contamination control strategies and assess operational readiness, and Phase 2 was the actual application of the technology in the Acid Pit. Volume 1 of this report gives the results of the Phase-1 cold testing, while Volume 2 gives the assessment of the Acid Pit stabilization. This work was performed for the Subsurface Contaminants Focus Area of the Department of Energy (DOE) Technology Development (EM-50).

The cold testing occurred at the INEEL's Cold Test Pit, which is located adjacent to the RWMC. At the Cold Test Pit, a series of grouting operations were performed in specially prepared soil zones called pits, as well as individual and connected grouting holes called field trials. The technology was originally developed for buried debris in shallow land burial sites; and as testing progressed, it became apparent that the technologies required considerably different grouting parameters when applied to a contaminated soil zone. In the prior debris pit grouting, there were large voids in the waste; and the soil was relatively loosely packed around the debris. The presence of these large voids allowed jet grouting with minimal grout returns.

The basic technology involves nonreplacement jet grouting in which the drill stem of a jet-grouting rig is driven into the waste. Once inserted, the jet grouting is started as the drill stem is withdrawn in precise increments while rotating and injecting grout through nozzles on the bottom of the drill stem. In this manner, a column of soil/grout mix is created. The process is repeated on an approximate 2-ft triangular pitch matrix, thus creating a solid monolith out of the contaminated zone. Any grout returns are collected in the void space under a specially prepared concrete block called a "thrust block." The thrust block isolates the drill rig from the surface of the soil and allows working in a "clean" area. The main object is to create a cohesive monolith, while minimizing and controlling contaminated grout returns. The treatability study was designed based on past testing in buried debris. The subject cold testing evolved into developing new grouting parameters for application at the Acid Pit, which was performed immediately following the cold testing phase. The grouting parameters included jet-grouting pressure, time on a step, drill-stem rotational speed, and step size. The grout used for the testing was a proprietary iron oxide rich cementitious grout called TECT-HG supplied by Carter Technologies of Houston, Texas. The drilling contractor for all testing and the Acid Pit stabilization was GEO-CON of Monroeville, Pennsylvania. What follows are specific results of the cold testing.

A set of parameters for application in the Acid Pit were successfully developed from a variety of testing in both pits and individual grouting campaigns. The previous experience with

grouting buried debris found that good monolith formation required considerably higher total grout delivered per foot than in soil-only sites. This differential between soil sites and debris sites was unknown when starting the program, and considerable testing of the various parameters—most notably the time on a step—was performed to balance good column formation against minimizing grout returns. This testing involved two different drill rigs: a DAVY KENT without rotopercussion and a CASA GRANDE C8 with rotopercussion. It was determined that the DAVY KENT (without rotopercussion) could not penetrate the INEEL soil fast enough. The relatively slow progress in drilling with the DAVY KENT caused excess drilling fluid flow (grout) to emanate from the drill hole, which prompted the use of the CASA GRANDE C8 drilling system (which included rotopercussion).

The CASA GRANDE C8 drilling system was found to be more than adequate for quick penetration using rotopercussion and additionally in controlling grouting parameters during grouting. By grouting two different test sites of previously disturbed soil using the thrust blocks to contain grout returns, the following grouting parameters were recommended for the Acid Pit stabilization phase: grouting pressure—6000 psi, step size—5 cm, duration on a step—2 s, revolutions of the drill stem on a step—2. These parameters created a cohesive monolith while minimizing grout returns in a previously disturbed soil site simulating the Acid Pit. In developing these parameters, a variety of field trials involving single and multiple connected holes were performed with and without the thrust block. A series of controlled experiments involving variations to the grouting parameters and physical characteristics of the grout product itself were performed to optimize the implementation process, minimize grout returns, and achieve required soil mixing and associated monolith development. Having identified the optimal grouting parameters, a final pit called the "Operational Readiness Pit" was successfully grouted (drill down 17 ft and grout out the bottom 6 ft) with essentially no grout returns. The parameters obtained from this testing were recommended for use in the Acid Pit stabilization discussed in the Phase-2 report.

It was found that the present technology using jet-grouting techniques developed for buried debris could be modified to accommodate soil-only sites consisting of relatively loose soils (15-20 blows/ft during penetration testing). However, when the soil conditions were tightly packed clays (50 blows/ft), monolith formation was not achieved and a modification of the grouting process would be required. Two general areas of testing were used in the cold testing, including one site called the "soil pit" site, another called the "debris pit" site. The "soil pit" site was previously undisturbed soil and eventually was evaluated to have up to 50 blows/ft during penetration testing. Considerable effort was made in preparing this site, including location of thrust blocks and a wind screen, to help evaluate contamination spread during grouting operations; therefore, even though field trials showed potential difficulties, testing was performed. Unfortunately, due to the highly packed clay lithology of the site, grouting caused excessive grout returns and a general ground heave. This is primarily because there was insufficient void space in the soil to accommodate the injected grout. To grout hard, tightly packed clay soils with nonreplacement jet grouting would require development of a new set of grouting protocols involving different nozzle size, grouting pressure, and other grouting parameters. The soil site was abandoned, and all further testing centered on locations at the Cold Test Pit in which the soil was previously disturbed including the debris pit area. The parameters for recommendation for the Acid Pit were developed in these disturbed sites.

Destructive examinations were performed on the field trials and "test pits" that had been grouted showing good monolith formation in both the previously disturbed and undisturbed sites. However, for those sites in tightly packed clays, there had been general ground swell and excessive grout returns in making the monoliths. A large cohesive monolith created in a previously disturbed soil site was removed intact as a unit using a front-end loader. The condition of all monoliths and field trials is similar to that observed for the soil portions of grouted debris pits in that the monolith consisted of a solid mixture of soil and grout called soilcrete, with occlusions of tightly packed clay varying in size and density depending upon grouting parameters. The grouting conditions used to generate this monolith that could be removed intact were the recommended parameters for the Acid Pit.

System cleanout procedures were successfully demonstrated that allowed cleanout in a contaminated site without creating excessive contaminated water. The TECT-HG grout required a 400-700 gal flush of all major pumping and drilling equipment to avoid clogging. A procedure was used in which the drill stem was decontaminated and attached to a special "fire hose" attachment that allowed a system flush to a catch tank. The water in the catch tank was shown to be "clean" such that it could be removed from the contaminated area and disposed of as simply a mixture of grout and water.

It was found that the viscosity of the delivered grout had a strong effect on grout returns and monolith formation and that this parameter should be considered when developing new grout formulations. There was an inadvertent variation in delivered grout viscosity (but not grout density) with variation from 2:30 to 7:40 minutes using a funnel viscometer within ± 25% error). It was found that for the lower viscosity cases for the same grouting parameters that the grout returns were reduced and that the resultant monolith had smaller and fewer occlusions of clay soil. The data are inconclusive; and because of potential variation in soil conditions used in testing, it is recommended that a parametric study be performed on the effects of grout viscosity on monolith formation.

It was found that the contamination could be contained during the operation by using a variety of contamination control devices. The contamination control systems designed into the treatability study worked as planned. The following devices were utilized: (1) a thrust block to act as a barrier between the drill rig and the top surface of the pit. In addition, the thrust block collected excessive grout returns in a cavity formed by the block and kept the surface clean for worker protection, (2) a flexible shroud was placed around the drill stem to catch any splatter of grout/soil around the rig and drill site, a catch can and catch cup were placed on the bottom of the drill stem to catch splatter of grout when moving the rig from hole to hole—in addition, the catch cup was connected to a vacuum system with a high-efficiency particulate air filter, (3) a drip pan on the surface of the thrust block to catch drippings when relocating the drill stem. Any small drops of grout that actually touched the surface of the thrust block or in the event of an excessive return of grout to the surface could easily be controlled by using "squeegees" to back the fluid into the holes on the thrust block. When spread as a film on the thrust block, this clean material quickly dried and was not prone to further spread via foot traffic on the surface of the thrust block.

An evaluation of the contaminant spread was accomplished by measuring the movement of a tracer material that had been spiked in the simulated "pit" sites. The tracer material was molybdenum powder matching the specific gravity of mercuric oxide, the suspected form of mercury contaminant in the actual Acid Pit, and the expected concentration. Smear samples were obtained on the drill stem and the surface of the thrust block for selected grouted holes. In addition, grab samples were collected from the grout returns immediately under the thrust block. High-volume air samplers strategically located around the grouting operation collected any airborne particulate that escaped from the grouting operation. The main result is that considerable tracer was found on the drill stem and under the thrust block. However, essentially none above background was collected on the air filters, suggesting that the contamination control measures designed to isolate contaminated material from workers and equipment are effective. In addition, the fluid nature of the grout tends to lock up the contaminants and movement is at a minimum even though the grouting operation involves considerable movement of personnel around the top of the thrust block.

In summary, the technique of jet grouting can now be considered applicable to certain soil conditions as well as buried debris. Thrust blocks can easily be assembled over contaminated soil sites and grout applied without excessive contamination spread. A set of grouting parameters that should create a cohesive monolith is available for application in the Acid Pit. In addition, the grouting process appears feasible for stabilization of other contaminated soil sites; however, field trials in uncontaminated but similar areas are considered mandatory to fine-tune grouting parameters.

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FIGURES

TABLES

ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	Department of Energy
EXT	external
FT	field trial
FY	fiscal year
HEPA	high-efficiency particulate air (filter)
ICP-MS	inductively coupled plasma-mass spectrometry
INEEL	Idaho National Engineering and Environmental Laboratory
PVC	polyvinyl chloride
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
TRU	transuranic

Acid Pit Stabilization Project (Volume 1—Cold Testing)

1. INTRODUCTION

During Fiscal Year 1997, a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Treatability Study was performed at the Idaho National Engineering and Environmental Laboratory (INEEL) for in situ stabilization of buried waste sites. This study focused on the in situ stabilization of the Acid Pit at the Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area (SDA) using jet-grouting methodologies developed at the INEEL. The in situ stabilization technique of jet-grouting buried waste sites to create monoliths for either long-term disposal or interim storage followed by later retrieval was developed at the INEEL for buried transuranic (TRU) waste but also can be applied to contaminated soil zones. As part of the treatability study, cold testing was performed at the INEEL Cold Test Pit, which is located immediately south of the RWMC, and the results of this cold testing are presented in Volume 1 of this report. In addition to this cold testing, the treatability study involved laboratory testing to select a grout type and hot testing in the Acid Pit, both of which are discussed in Volume 2 of this report. At the Cold Test Pit, two simulated buried waste sites were prepared, including a "soil pit" in a relatively undisturbed area and a debris pit in an area previously disturbed. Specially designed "thrust" blocks were placed over the simulated contaminated soil zones. These thrust blocks had a cavity to collect grout returns, which also isolated workers from grout returns during the jet-grouting process.

The cold testing involved multiple grouting campaigns under simulated conditions designed to gain as much experience in grouting contaminated soils prior to moving the operation into the SDA Acid Pit as a "hot" treatability study. Applying the technology in a cold test prior to going hot was mandatory because the technology had never been applied to soil only. Rather, the jet-grouting techniques developed at the INEEL's Cold Test Pit[1,2,3] had mostly related to creating monoliths in shallow land burial debris pits containing drums and boxes filled with materials with high void space (cloth, metal, concrete, asphalt, wood, sludge, and salt). The basic technology involves nonreplacement jet grouting, whereby a drill stem is driven into the contaminated zone and—once at total depth—the rotating drill stem is withdrawn in precise increments while delivering grout at 6000 psi nominal pressure. The high-pressure grout fills all the interstitial void space in the waste and soil, thus simultaneously preventing subsidence and reducing the mobility of the contaminants. This process results in a column of grout mixed with soil (soilcrete); and, by drilling the holes on a tightly packed (about 2-ft) spacing on a triangular pitch matrix, the columns can become interconnected, resulting in a solid monolith. The process is shown schematically in Figure 1.

This report describes the grouting performed with two different drilling apparatus in two basically different soil sites at the Cold Test Pit. In addition, the testing included examining the contamination control aspects of the grouting process by using nonradioactive tracer materials in the simulated contaminated soil areas and examining the spread during grouting. Also examined in the cold testing was the cleanout operations relative to the elimination of secondary waste. In addition to the evaluation of grouting and contamination control during grouting, a destructive examination of grouted regions was performed to determine the extent of column formation in soils. In general, this cold testing culminated in a full "mockup" of the hot operation prior to applying the process in the SDA's Acid Pit. What follows is a background section discussing the overall project, a procedure and sequence of events section, a results and evaluation section, and a conclusions and recommendations section.

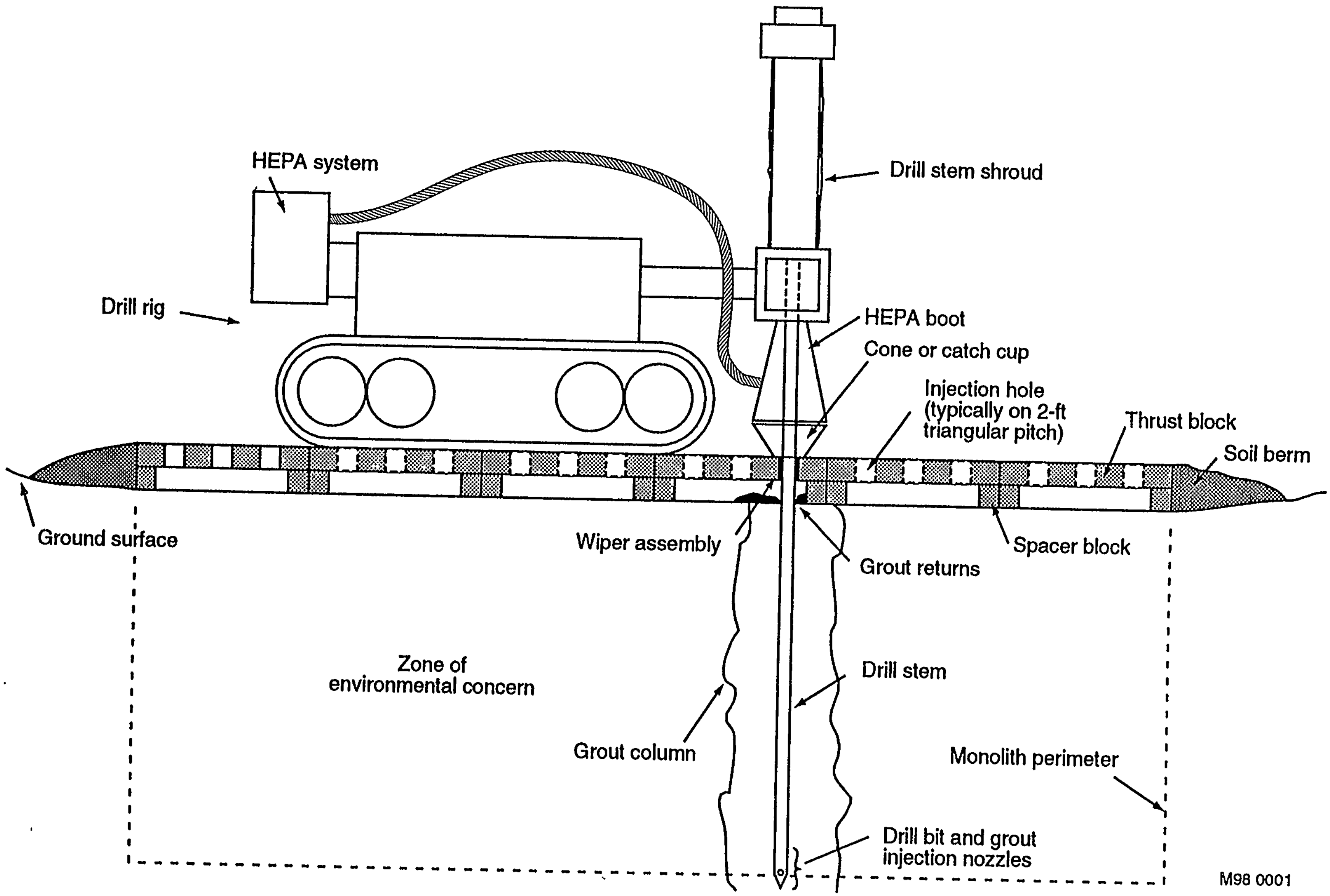


Figure 1. Schematic of jet-grouting apparatus using thrust block (Graphic M98 0001).

2. BACKGROUND

At the INEEL, the SDA contains a variety of buried waste scenarios including buried debris and contaminated soil zones. The Acid Pit is an example of a mixed waste contaminated soil zone. The main contaminate of concern is mercury in an unknown speciation but most likely mercuric oxide at a concentration in certain zones as high as 5000 ppm.[4] Only minor amounts of manmade radionuclides exist in the pit (pCi/g quantities), and 99% of the contaminants reside in the bottom 6 ft of the pit. The pit is approximately 17 ft deep and is comprised of a surface area about 197 x 104 ft. The Acid Pit was used to dispose of liquid phase acids in the highly alkaline soils by direct dumping and absorption of the liquid phase onto the soil, with some additions of unknown amounts of lime to ensure that the acids were neutralized. As the pit was used, soil layers were added, and finally a backfill of clean soil was added. The top 5 ft of the pit is essentially free of contaminants. Other pits and trenches at the INEEL's SDA contain buried TRU debris and other low-level waste materials.

The Acid Pit presented a desirable low radiological and hazardous risk site in which to perform the treatability study (to perform the treatability study in a TRU pit or trench would most likely take the entire schedule and a significant portion of the budget to obtain the permission to proceed). The only technical problem was that the technology had only been applied in a limited manner in simulated contaminated soil zones. Rather, the technology was developed for buried debris, which requires different implementation considerations due to the large void fraction in the waste to absorb excess grout during the jet-grouting operation. In past studies,[1,2,3] the technology demonstrated that the grouting operation could be performed in buried debris sites with no airborne contamination spread and that the amount of grout returns could be controlled and minimized. This body of knowledge did not exist for soil-only sites. Therefore, it was expedient to perform simulated tests in the INEEL Cold Test Pit, which is the subject of this report. What was learned from those tests was applied directly in the actual stabilization of the Acid Pit, which occurred in the fall of 1997 and will be documented in Volume 2 of this report series.

3. OBJECTIVES

The main objective of this cold testing was to evaluate the grouting process in a contaminant-free environment prior to performing the Acid Pit treatability study in the SDA.[5] The tests in the cold demonstration were conducted as part of a thorough management self-assessment. It became obvious as the testing proceeded that there were several grouting parameters that required considerable testing to perfect prior to going hot, and there were considerable field changes required for the test plan.[5] One objective involving grouting a buried debris pit was abandoned due to budget and schedule constraints. Specific objectives included (a) determining the correct grouting parameters that minimized grout returns while maintaining a proper column size, (b) determining the correct design of the thrust block to contain grout returns, (c) evaluating the spread of tracer material molybdenum powder as a stand-in for mercuric oxide, (d) evaluating the "off-the-shelf" nature of the technology by utilizing a different drilling contractor, (e) determining that the cleanout process could be accomplished with minimum secondary waste development, (f) determining the effect of grout viscosity on column formation and grout returns, and (g) evaluating site controls and process designed for "hot operations." As difficulties from site soil conditions developed, other objects evolved including determining the soil geotechnical conditions for the various areas utilized in the Cold Test Pit.

4. SEQUENCE OF EVENTS, EQUIPMENT, AND GROUTING PARAMETERS

There were four basic phases in the Cold Test demonstration:

1. Grouting performed with the DAVY KENT drilling system.
2. Grouting performed with the CASA GRANDE C8 drilling system in the soil pit and in the debris pit.
3. Grouting performed with the CASA GRANDE C8 drilling system in a specially prepared soil pit called the Operational Readiness Pit.
4. Destructive examination of the grouted regions.

What follows is a description of the equipment used in the various phases followed by a discussion of the sequence of events and grouting parameters.

4.1 Description of Equipment/Grout

In Phase 1, the drilling apparatus was a DAVY KENT DK70 nonrotopercussion drilling system as shown in Figure 2. With this system, drilling is accomplished using crowd force with a rotating drill stem. The drill stem was 3.5 in. outside diameter and the jet-grouting nozzles were 3 mm diameter located 180 degrees apart and 5 cm offset from one another on the drill stem as shown in Figure 3, along with a standard rock bit. Grout was allowed to flow out the bit during the drilling process under low (less than 100 psi) pressure. However, when the high-pressure jet was initiated, a valve automatically closed forcing all grout out the two nozzles. The drilling apparatus was connected via high-pressure hose to the high-pressure B.J. Hughes jet pump (BJU V-16 diesel-powered 750 hp), which is shown in Figure 4. The B.J. Hughes pump could deliver up to 10,000 psi grout at the exit of the pump. Grout was fed into the B.J. Hughes pump using a Moyno positive displacement pump system shown in Figure 5. Grout was delivered from a standard bulk plant truck to a hopper assembly connected to the Moyno 10 pump. The hopper included a screened (common door screen) entrance to filter out "clumps" of grout from the high-pressure pump (see Figures 6 and 7). In Phase-2 and -3 testing, the CASA GRANDE C8 drilling system was employed. This system provided rotopercussion drilling. The DAVY KENT drilling system was used only on the Phase-1 testing and the CASA GRANDE system was used on Phase-2 and -3 testing, while all three implementation phases used the same high-pressure/delivery pumping system and hoses.

Injection volumes were measured by two metering systems. High-pressure flow was measured through a Haliburton MC-II Flow Analyzer, and low-pressure flow was measured through a CRE Magnetic Flowmeter.

Special contamination control equipment was installed on and around the drill stem to reduce the spread of contaminants as shown in Figure 8 for the CASA GRANDE C8 system. A drill stem shroud was installed around the drill stem to eliminate spread of contaminants by splatter due to rotation of the drill stem. The shroud consisted of a 10-in. ducting flexible hose. A unique catch cup was attached to the mast of the drill stem (Figure 8). This catch cup was designed to contain the splatter of grout that continuously emanates (in small quantities) during

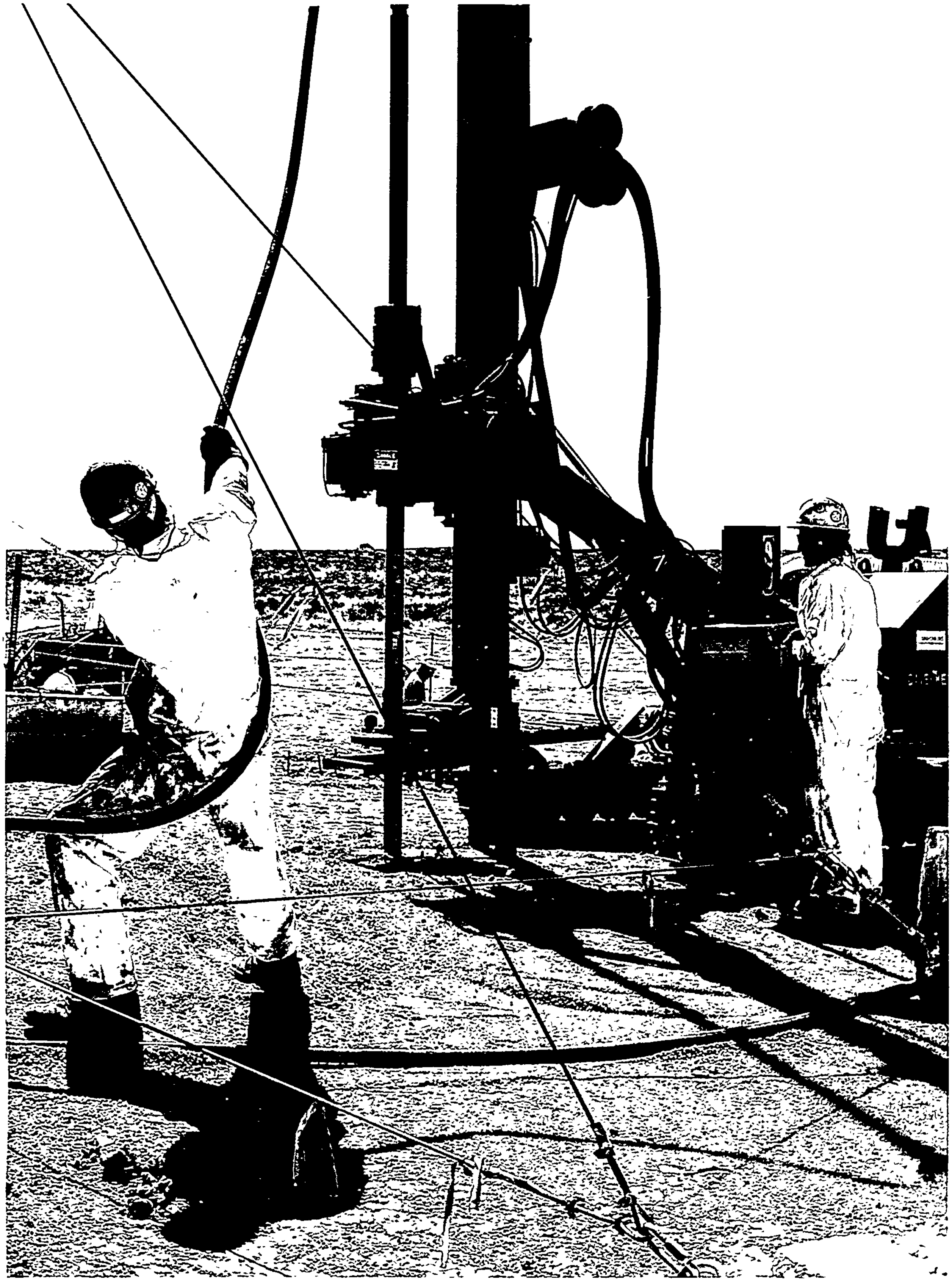


Figure 2. DAVY KENT drilling system during field trial (Photo 97-490-2-35).

Figure 3. Nozzle on drill stem showing rock bit (Photo 97-481-3-0).

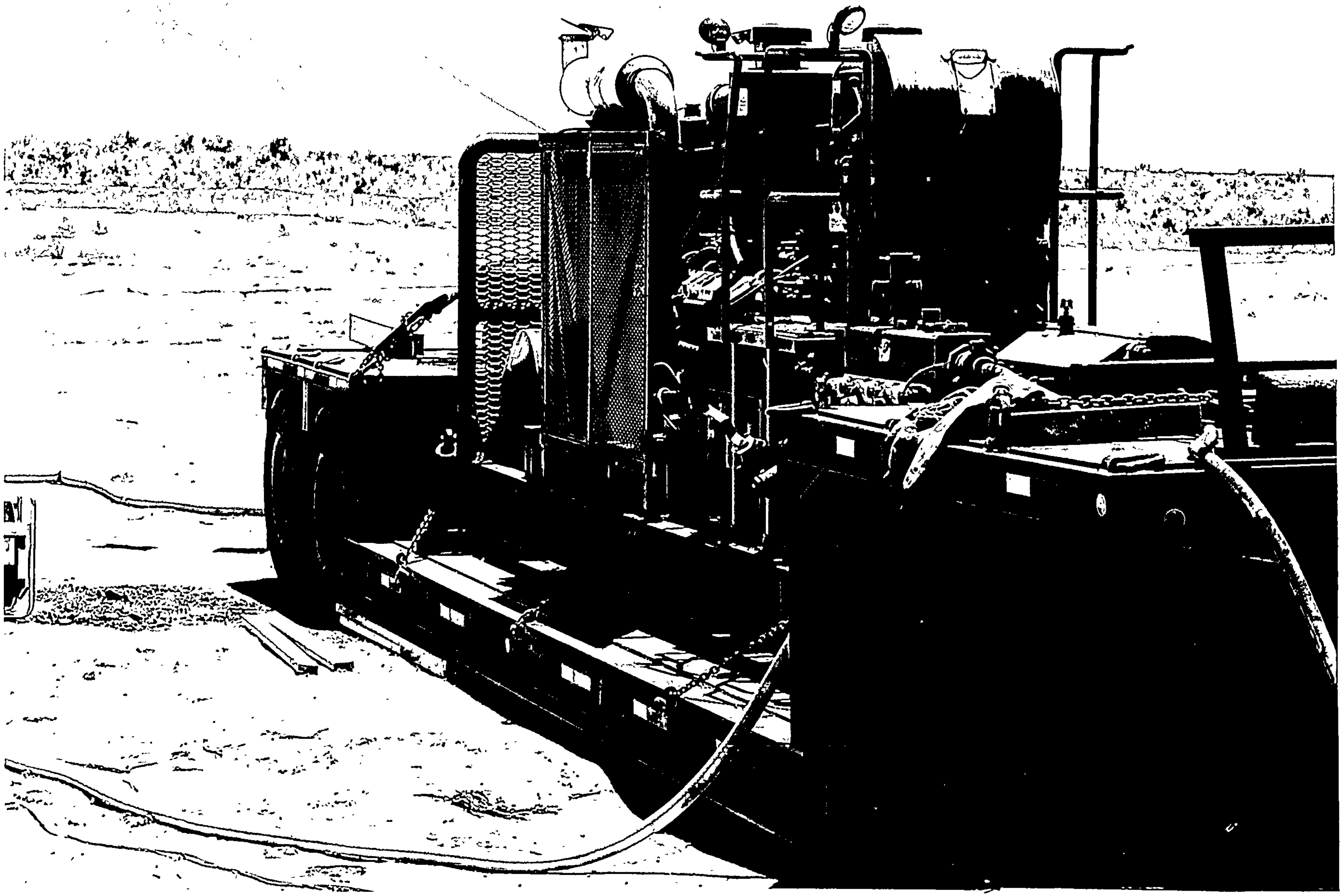


Figure 4. B.J. Hughes high-pressure injection pump (6000 psi+) (Photo 97-481-3-3).

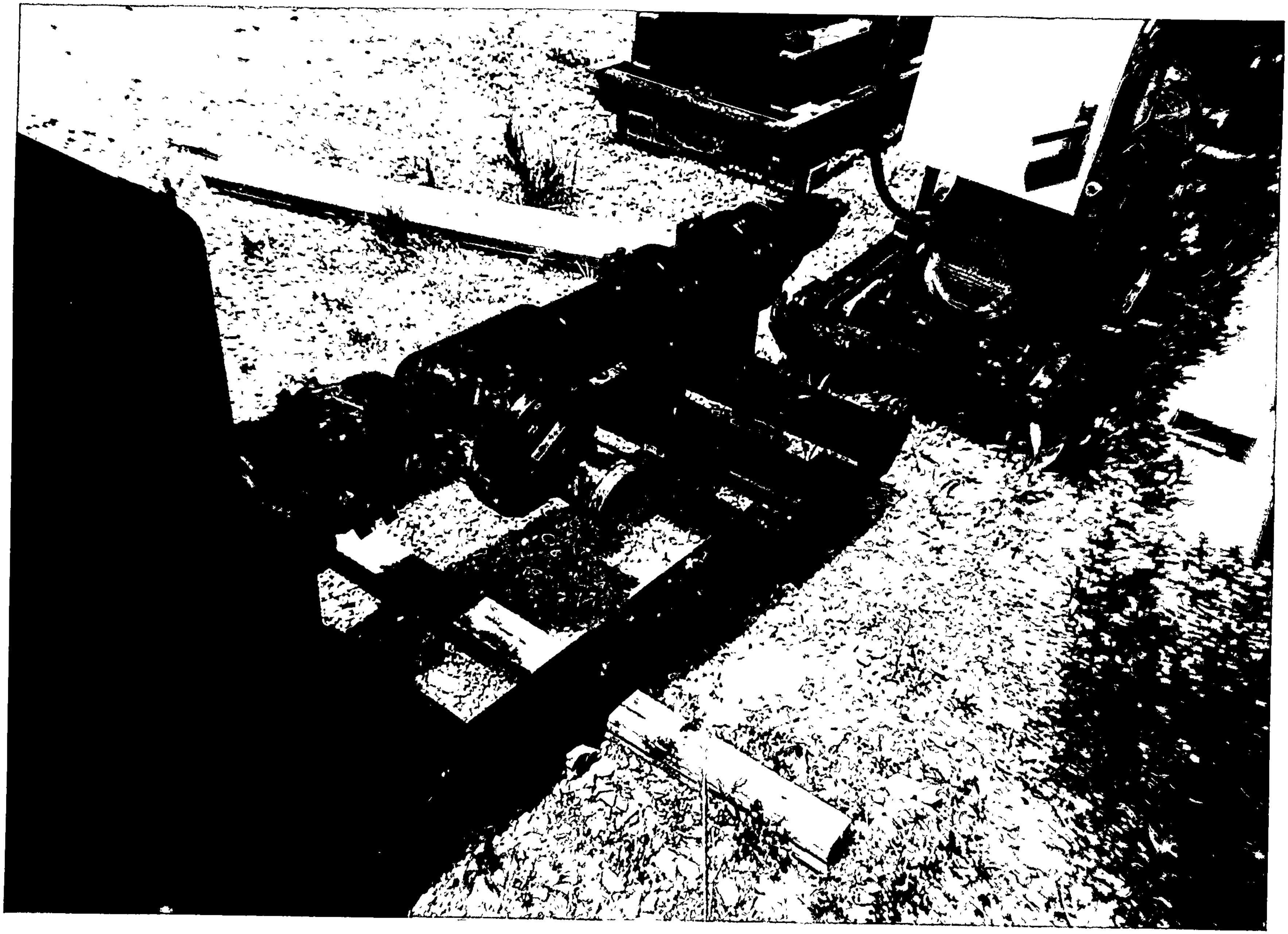


Figure 5. Moyno pump—a low-pressure delivery pump (Photo 97-449-2-23).

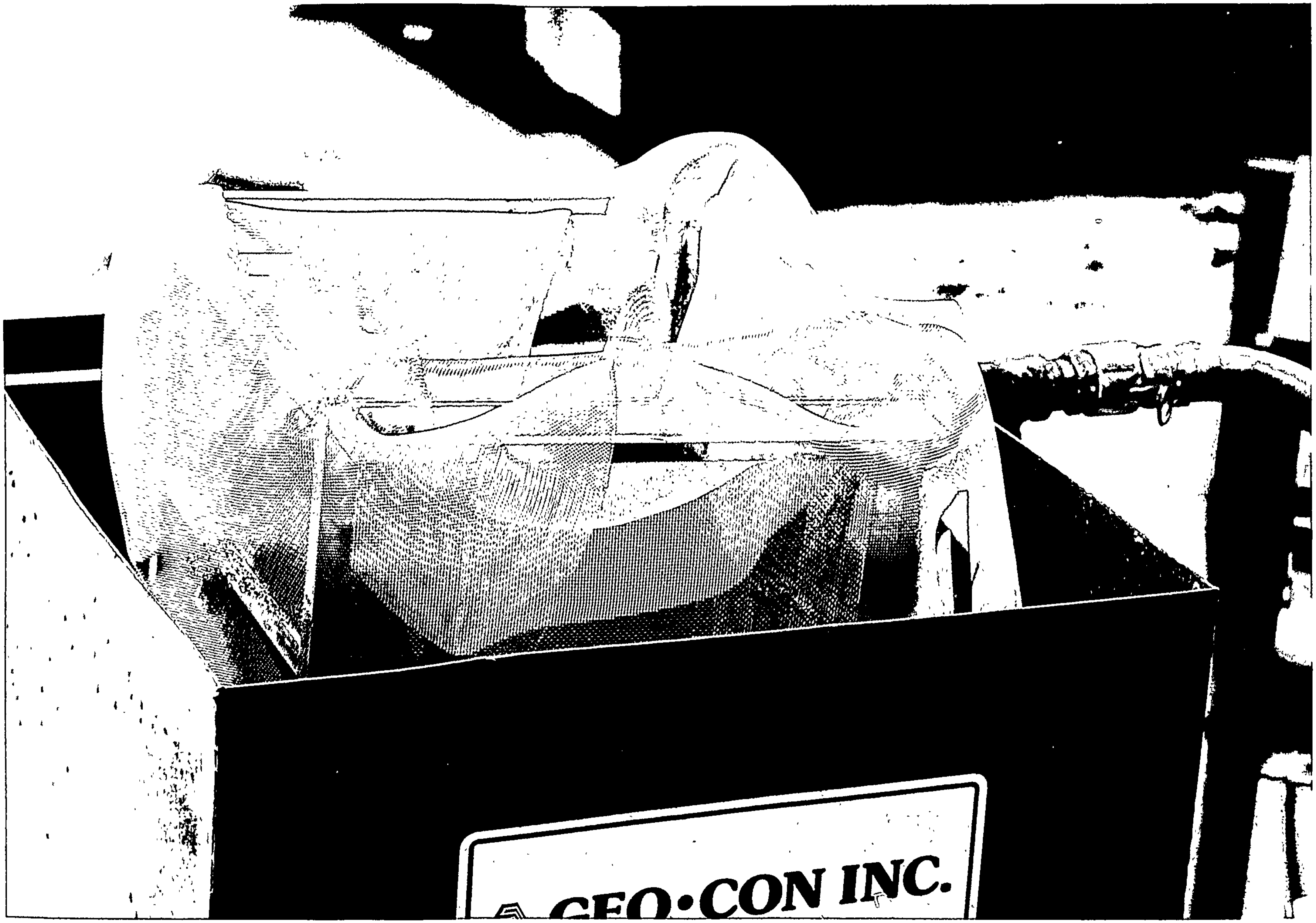


Figure 6. Filter screen for Moyno pump (Photo 97-481-3-11).

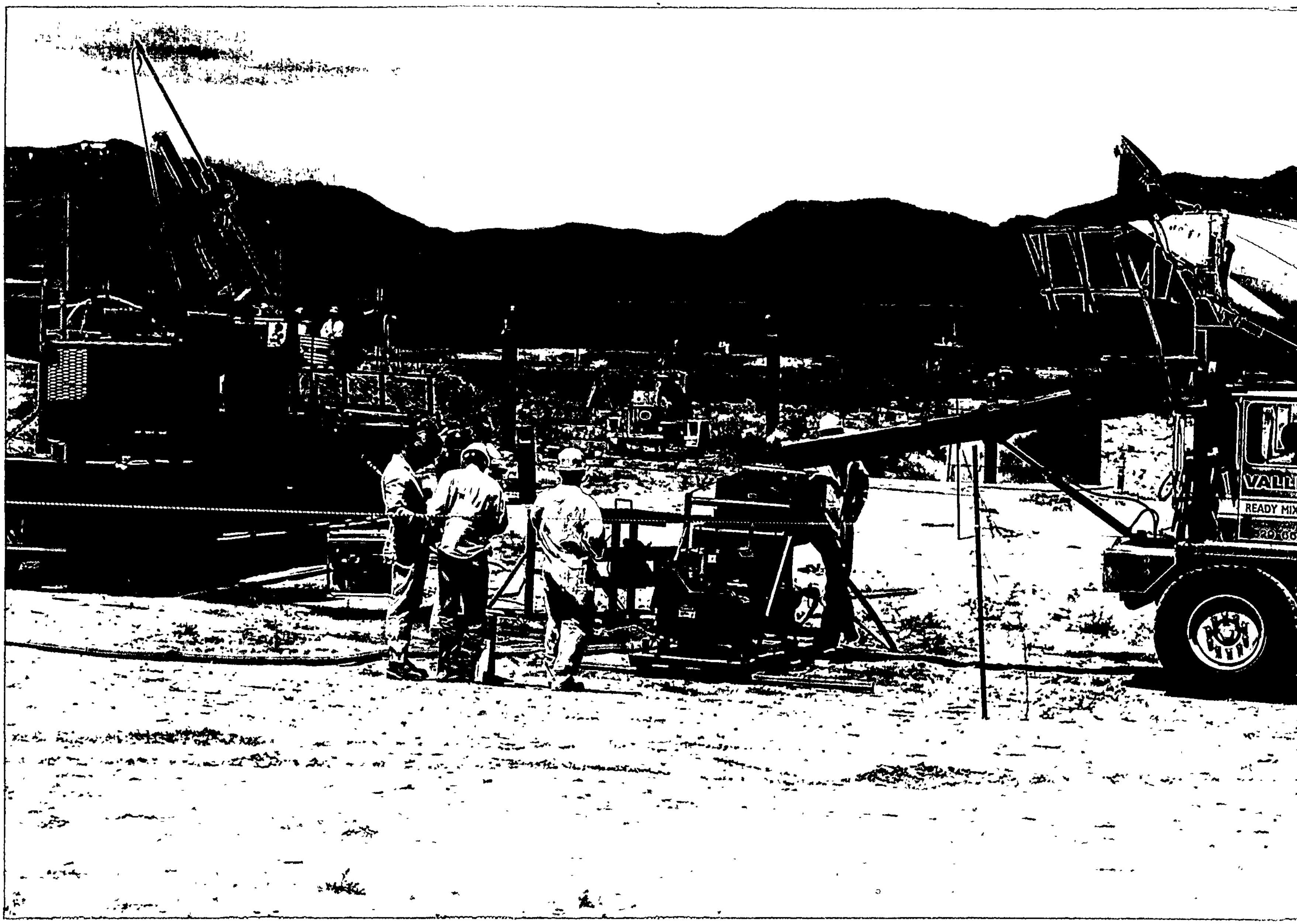


Figure 7. Bulk plant truck delivering grout to Moyno pump hopper during grouting (Photo 97-481-3-8).

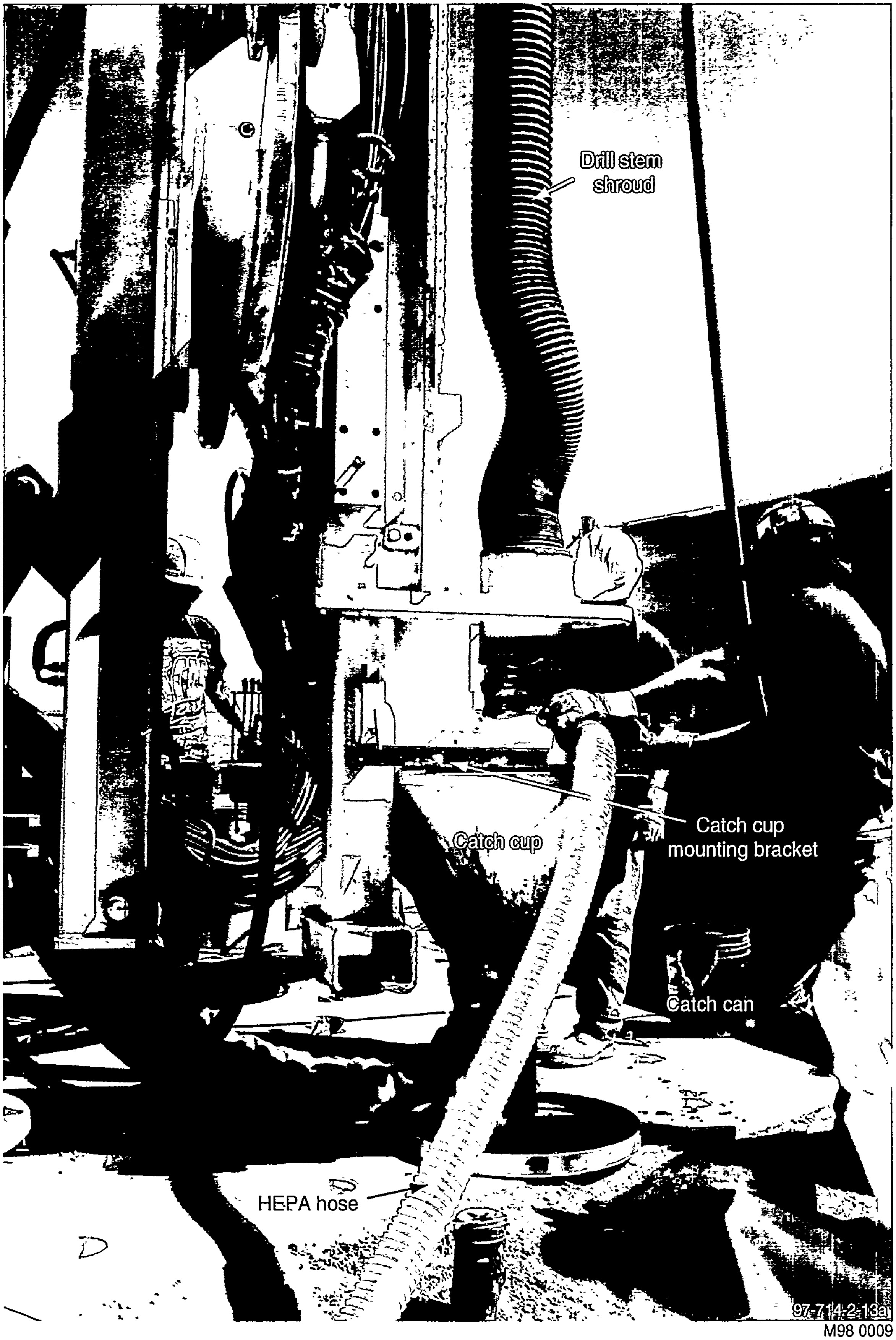


Figure 8. Features of the contamination control system for the CASA GRANDE system (Graphic M98 0009).

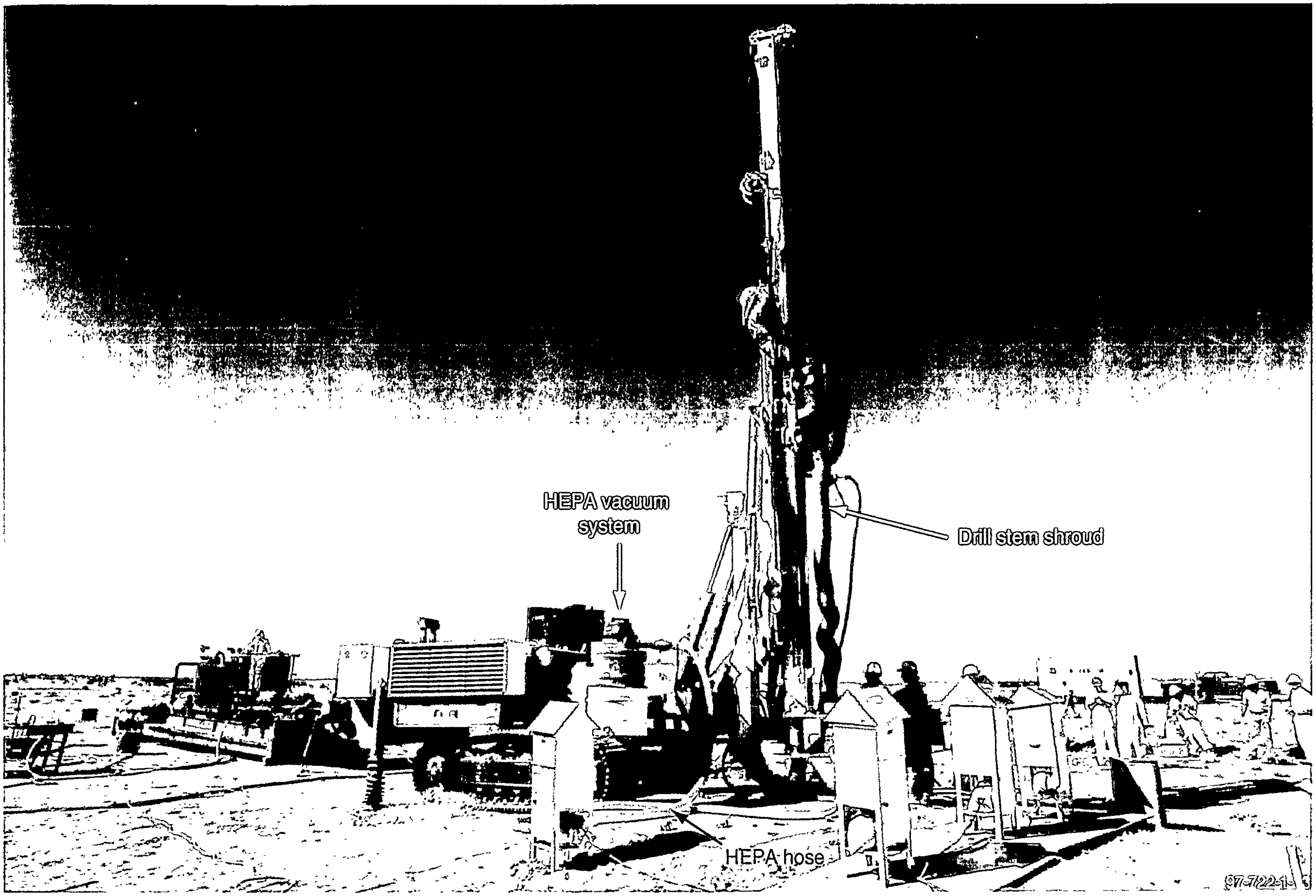
the process of moving the drilling apparatus from one hole to another. It is important in grouting operations to maintain a continuous flow in the nozzles to avoid plugging when not jet grouting. The fluid splatters against the side of the catch cup and flows out the bottom in a small controlled stream into a catch can shown to the side of the drilling apparatus in Figure 8.

Also shown in Figure 8 is a high-efficiency particulate air (HEPA) filter system hose emanating from the top of the catch cup. This system is designed to vacuum airborne contaminants and deposit them onto a HEPA vacuum system shown in Figure 9. The catch can was simply placed on two brackets on the catch cup, which allowed complete containment of the grout drippings between holes. Also installed around the thrust block hole was a portable drip pan to catch clean drippings as the drill stem/mast assembly was raised to accommodate the catch can as shown in Figure 10.

One of the main contamination control devices used for the grouting phases was a "thrust" block to simultaneously provide a plenum for grout return collection and protect the workers from the grout material. The plenum or void space under the thrust block was formed by using joists between rows of holes. This thrust block has a unique design involving reinforced concrete and preformed holes as shown schematically in Figure 11. There were preformed 5-in. inside diameter holes formed within the block by using PVC pipe cut to a precise dimension axially. A pipe clamp assembly was placed on the outside diameter of each pipe to act as an anchor for the pipe once the concrete was poured. Specialty 5000-psi concrete was used and the concrete was cured under a continuous water spray to avoid cracking. Figure 12 shows the thrust block forms just prior to pouring the concrete, and Figure 13 shows the thrust block installed over the debris pit. For the Cold Test Pit testing, there were three identical thrust blocks made using the design of Figure 11. For the debris pit, a single thrust block was placed on an approximate 6 in. deep graded to ± 1/2-in. pea gravel pad; and for the soil pit, two adjoining thrust blocks with a unique cavity between the blocks to accept an epoxy bonding material was used.

Figure 14 shows the two identical thrust blocks bonded together at the center over the soil pit. The holes through the thrust block were designed with a neoprene wiper material that allowed a friction fit around the drill stem during grouting operations, which provided another contamination control feature. The wiper provided a seal to the surface and also cleaned the drill stem as the rotating drill stem was withdrawn during grouting as shown in Figure 15. The thrust block was designed to carry the whole weight of the CASA GRANDE C8 (50,000 lbm) with a safety factor of 2.5. There were "joists" running down the length of the thrust block as shown schematically in Figure 11. These joists allowed a plenum for grout returns management during grouting. A total of 32 gal of grout was allowed for each joist, which covered 4 holes or 8 gal per hole. The outside dimensions of the thrust block were 8 ft x 12 ft 8 in., and the block was 12 in. thick with a 5-in. thick top layer. There were two access holes placed in each joist to allow overflow of grout from one cavity into another adjacent cavity to avoid overfilling of a particular cavity (see Figures 11 and 12). For the soil pit at the Cold Test Pit, a wind screen shown in Figure 16 was employed to block the prevailing wind during grouting. This improved the validity of air sampling data taken with high-volume air samplers (a total of 5 Hi-Q Environmental Products Co. HVP-3500AFC samplers were placed around the grouting operation [thrust block] behind the wind screen as shown in Figures 17 and 18.

Two basic testing areas were utilized, including the soil pit and the "debris" pit. The debris pit had actually been constructed for grouting during FY-96 but was held in reserve. The pit



M98 0010

Figure 9. HEPA vacuum system installed on CASA GRANDE C8 (Graphic M98 0010).

Figure 10. Catch can installed at bottom of catch cup and drip pan showing typical grout droppings (Graphic M98 0011).

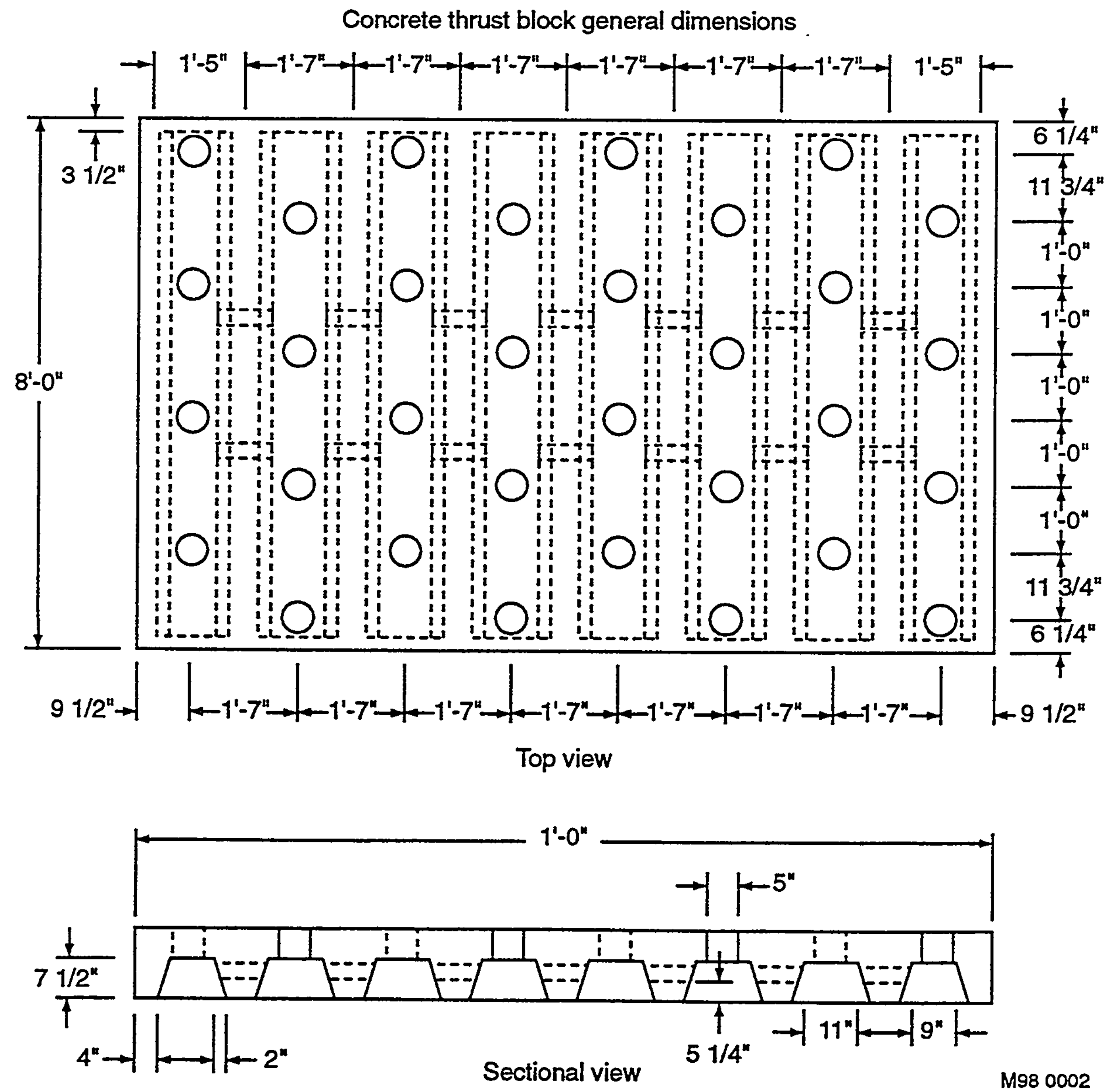


Figure 11. Design of Cold Test Pit thrust block (Graphic M98 0002).

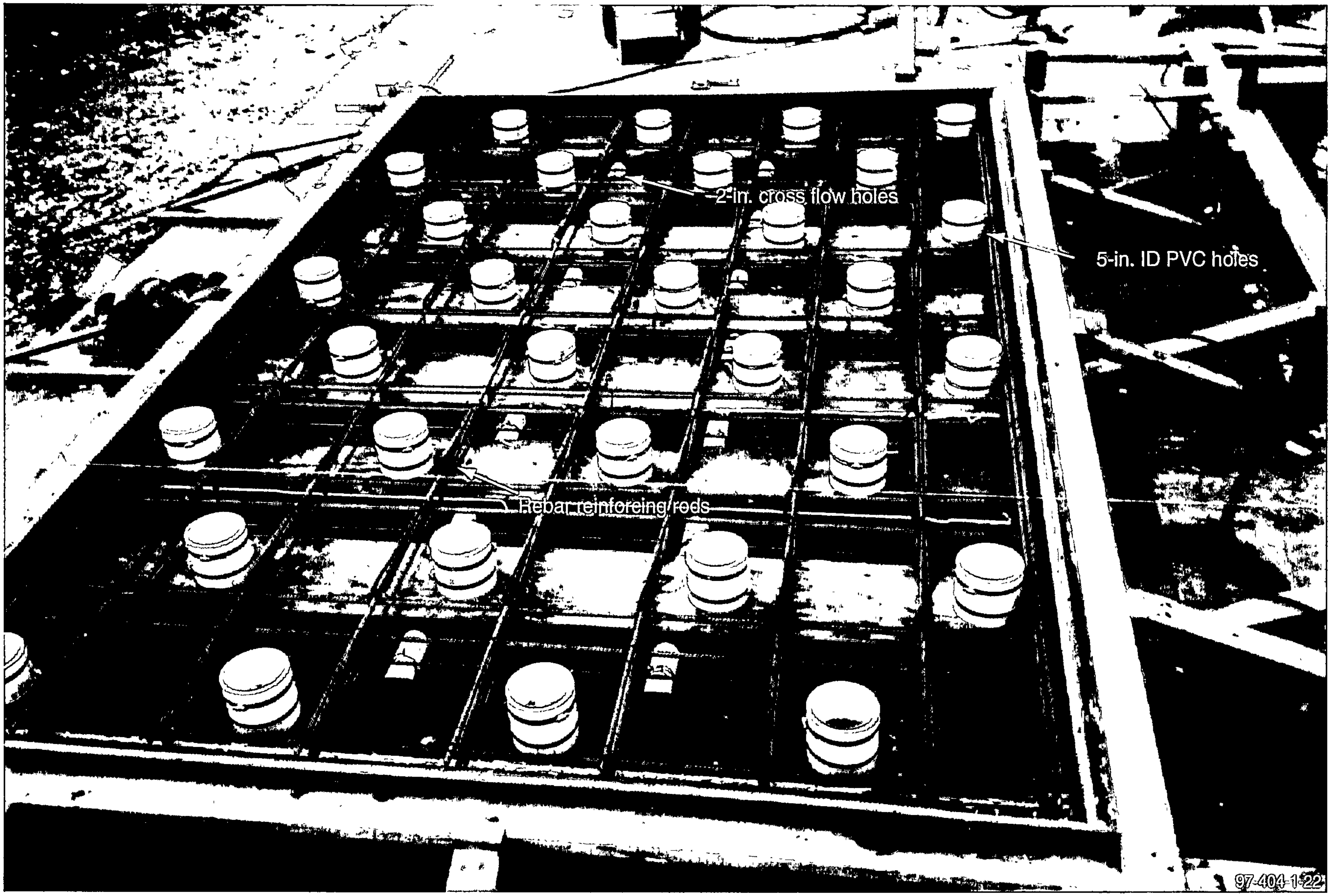


Figure 12. Thrust block under construction showing rebar (Graphic M98 0012).

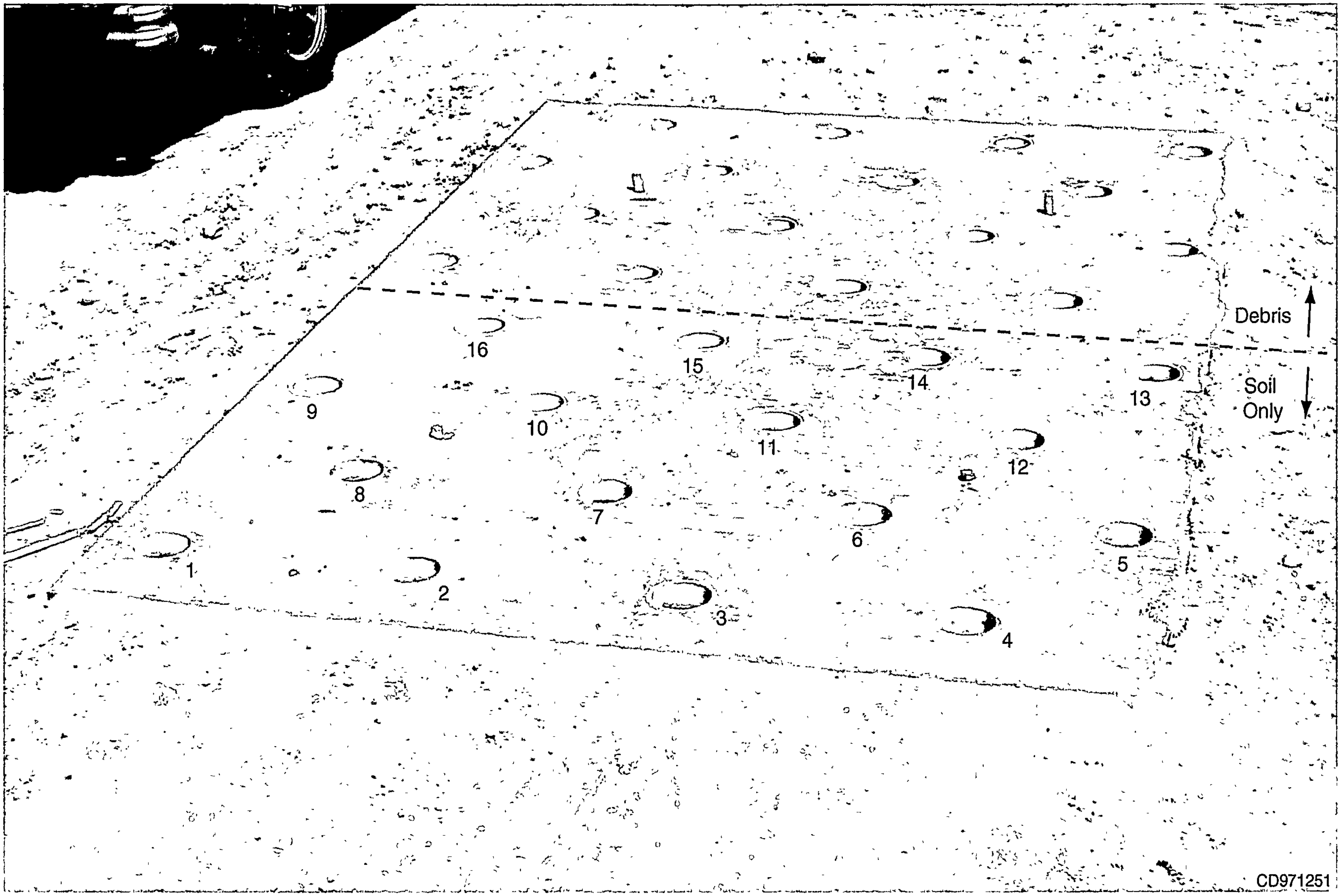


Figure 13. Thrust block over debris pit (Graphic M98 0013).

M98 0014

Figure 14. Thrust block over soil pit (Graphic M98 0014).

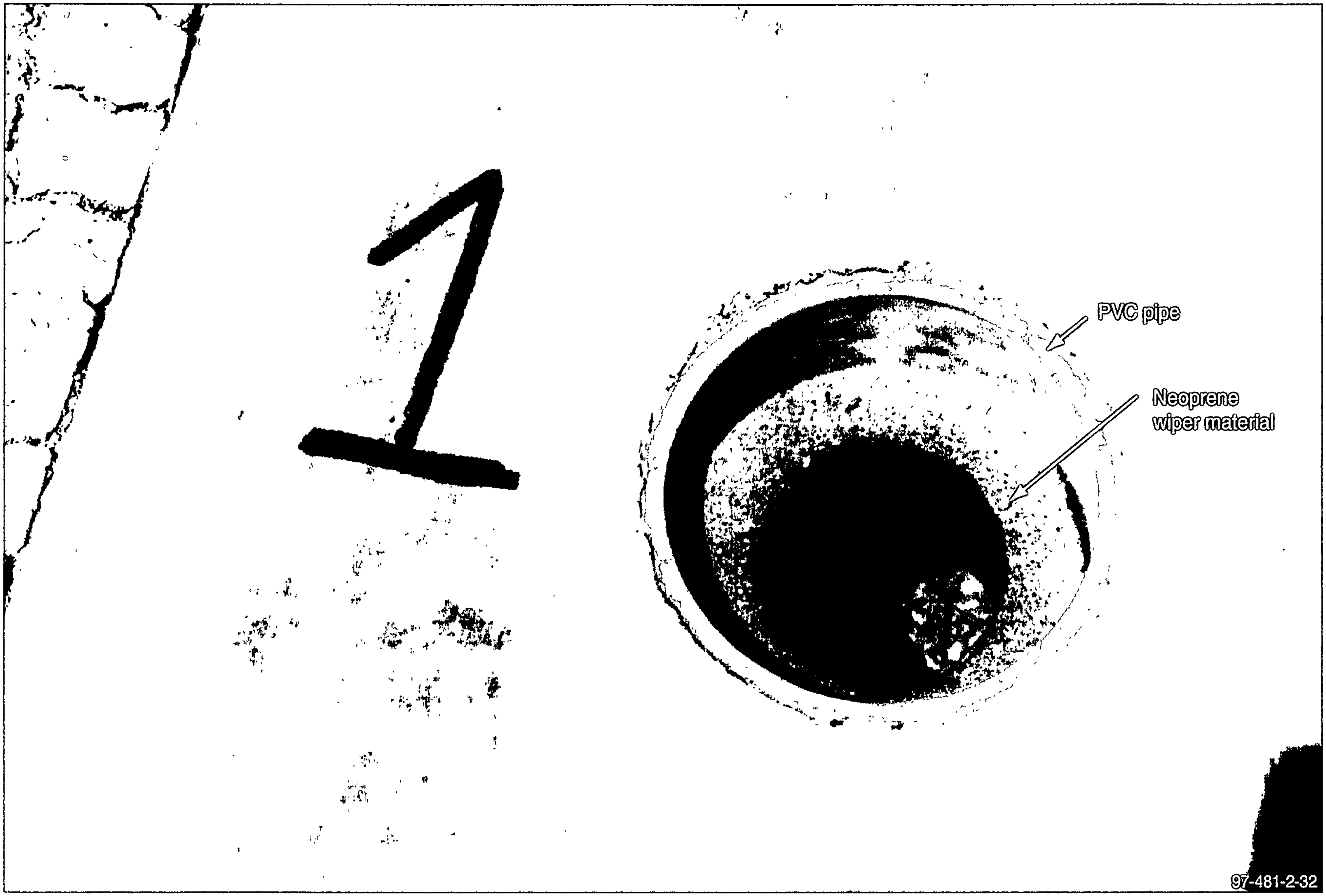


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Figure 15. Detail of surface of thrust block (Graphic M98 0015).

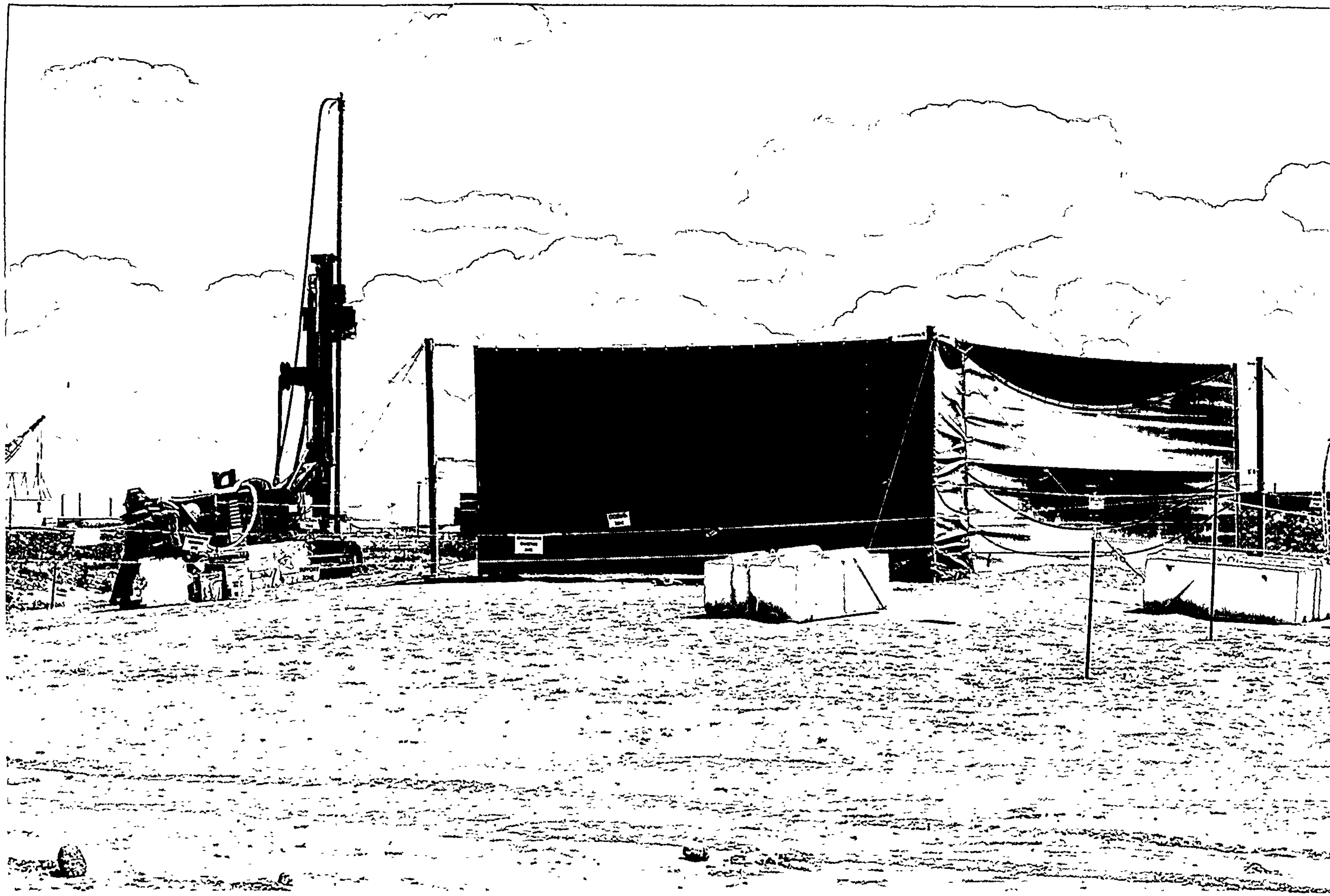


Figure 16. Wind screen on soil pit at Cold Test Pit (Photo CD971349).

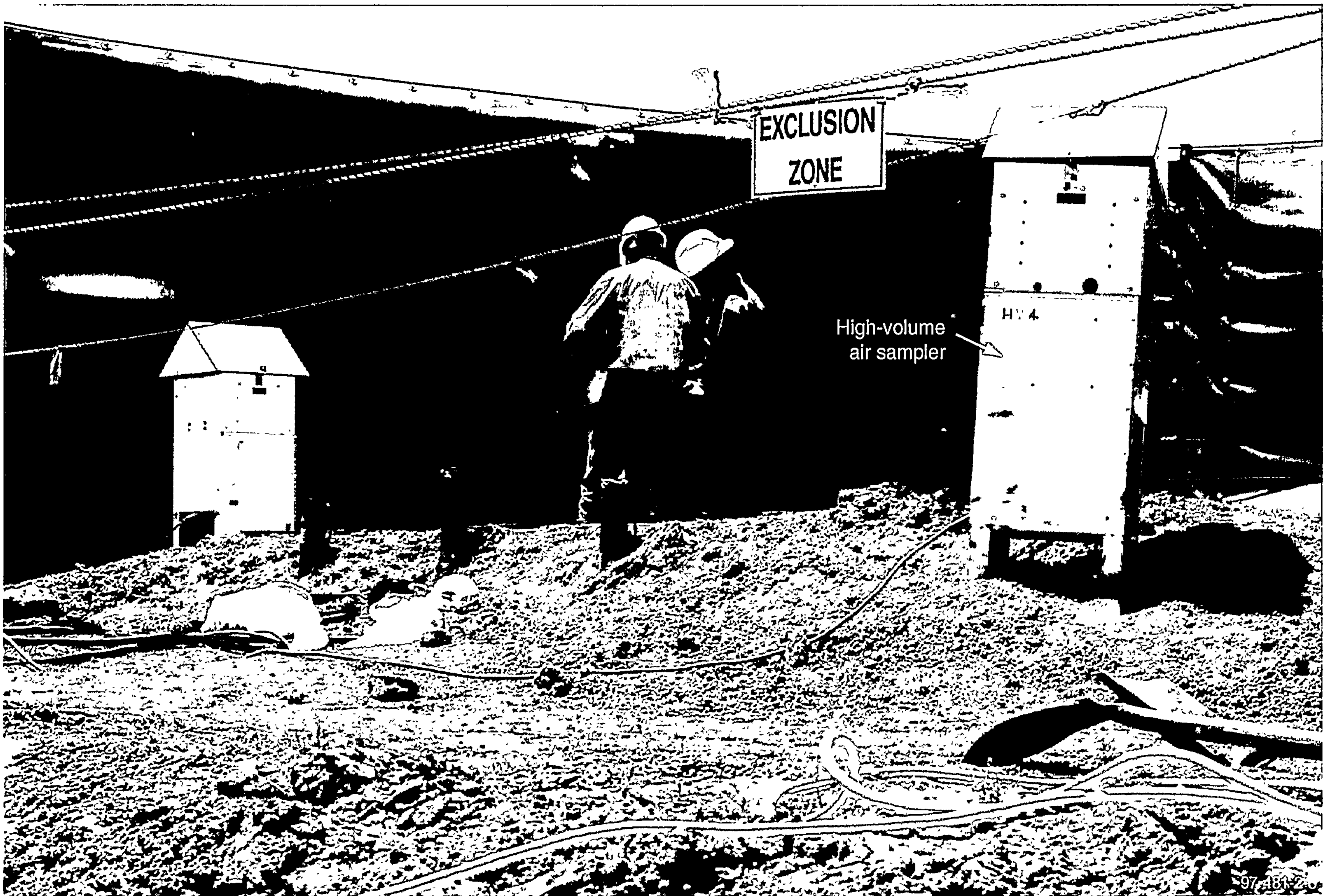


Figure 17. High-volume air sampler (Graphic M98 0016).

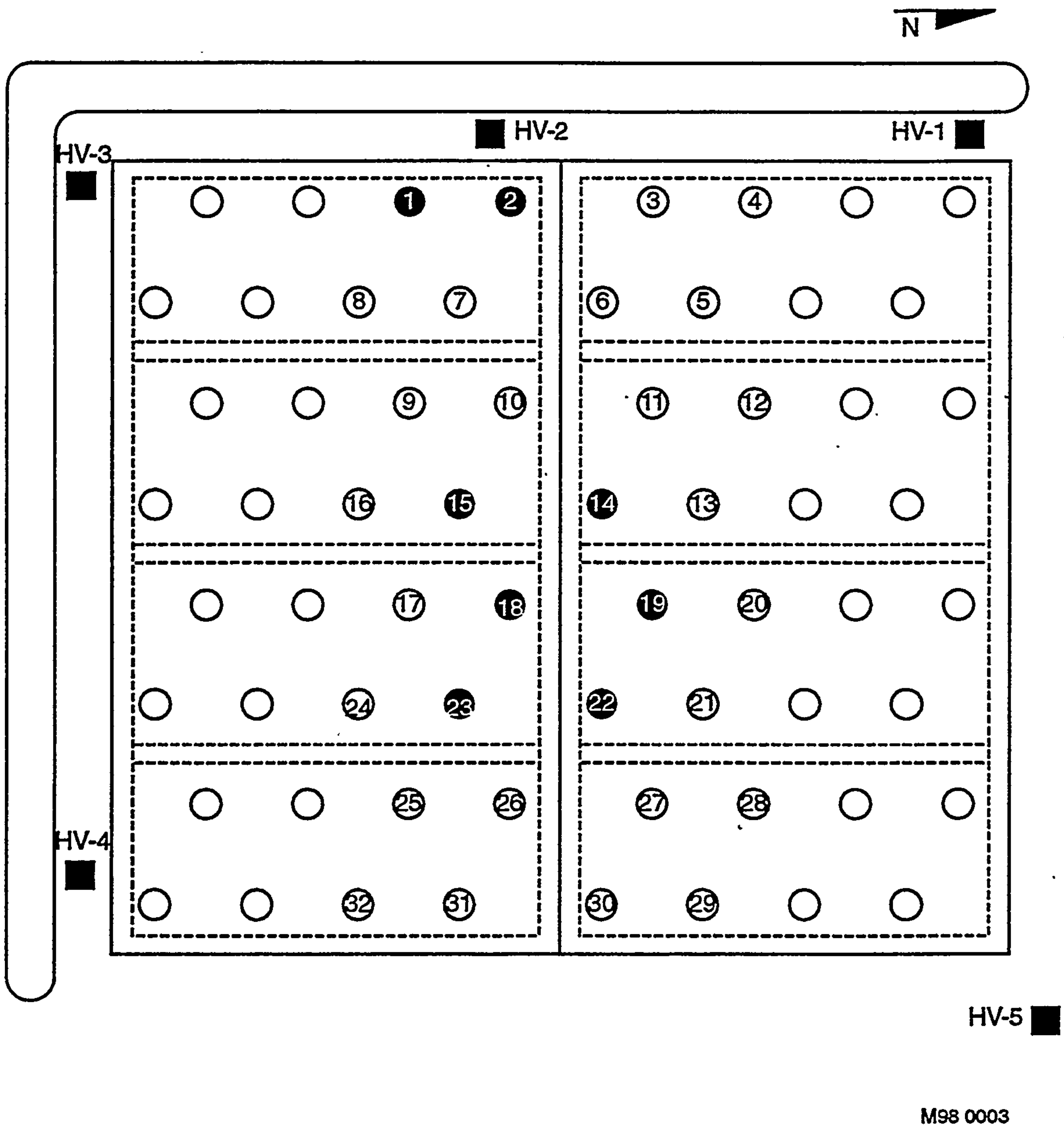


Figure 18. Orientation of high-volume air samplers (Graphic M98 0003).

simulated a TRU pit or trench in the INEEL SDA. This pit consisted of a trench that was filled with randomly dumped 30-gal cardboard and metal drums filled with typical simulated Rocky Flats waste consisting of wood, paper, cloth, sludge, asphalt, and concrete. The pit dimensions were 6 x 6 x 6 ft with 3 ft of overburden soils. The debris and pit were backfilled with INEEL soil, such that the bottom of the pit was 9 ft below grade. The thrust block module was placed over the debris pit such that exactly one-half of the holes were over the debris and the other half was in a previously disturbed soil (see Figure 13 for layout of the "debris" pit). Using boreholes, tracer material was placed within the nominal 6-ft zone of simulated contamination according to Table 1. A total of 17.67 kg of molybdenum powder as a stand-in for mercuric oxide in the Acid Pit was placed fairly evenly in three holes (6, 13, and 15 in Figure 13). The soil "pit" was placed in an area of previously undisturbed soil approximately 150 ft west and north of the "debris" pit. This pit was a simulated contaminated soil zone similar to that expected in the Acid Pit. The "soil pit" in the region to be grouted was undisturbed soil except for boreholes to introduce tracer material (molybdenum powder as a stand-in for mercuric oxide). Tracer material was introduced in boreholes corresponding to holes 3, 9, 11, 17, 19, 27, 25 in a nominally 6-ft zone as shown on Table 1 (Figure 14 shows the hole numbers). A total of 50.86 kg of pure molybdenum powder was added in equal amounts in 7 holes. This mass of molybdenum powder was to represent the same concentrations (nominally 5000 ppm) that were observed in the TRACK-2 evaluation of mercury.[4]

4.2 Description of Grout Material

The grout material used for all testing was TECT-HG, a specially blended proprietary material from Carter Technologies of Houston, Texas. The grout is a cement-based material with high iron oxide content, plus specially added surfactants and scavengers for the mercury contaminant in the Acid Pit treatability study. This type of grout had been successfully used in FY-96 documented in Reference 3. The grout is high density at nominally 18 lbm/gal; however, for the same relative density, the viscosity of the delivered grout varied greatly from one test to another (the variation, 2:32 to 7:43 minutes, was for a funnel viscometer—see Appendix A, Table A-1). Mixing of the grout was accomplished by hand-loading dry ingredients to cleaned Ready Mix trucks at a location approximately a 1.5-hour drive from the testing area. Controlling the viscosity was relatively easy in that a simple water addition to the Ready Mix truck could lower the viscosity. At the start of the program, the importance of viscosity on jet groutability was not recognized as a test variable; but as the testing unfolded, the importance of viscosity as a possible test variable gained recognition. The main problem with lower-viscosity materials was the increased tendency to "filter cake" in all pumping and drilling equipment. On one occasion, the grout vendor inadvertently brought a too low viscosity mixture—1:28 minutes for a funnel viscometer (there was excess water in the Ready Mix truck when mixing in the ingredients). The jet nozzles and pumping equipment were continuously plugged and operations had to shut down. Figure 19 shows the outlet connection to the high-pressure B.J. Hughes pump with a completely plugged outlet. Basically, when the viscosity gets below about 2:30 minutes, there is an increased tendency for the particulate material in the grout to "settle" and attach to surfaces such as observed in Figure 19.

4.3 Sequence of Events and Presentation of Grouting Parameters

Four distinct phases of testing were performed: (1) grouting with a nonrotopercussion drilling system (DAVY KENT), (2) grouting with a rotopercussion drilling system (CASA

Table 1. Total amount of molybdenum placed in debris pit and soil pit.

Hole	Depth of Molybdenum (from top of thrust block)		Total Change (kg)
Debris Pit			
6	Top	4 ft 8 in.	5.76
	Bottom	9 ft 0 in.	
13	Top	5 ft 3 in.	5.95
	Bottom	9 ft 0 in.	
15	Top	4 ft 9 in.	5.96
•	Bottom	9 ft 0 in.	
	Total		17.67 (38.87 lbm
Soil Pit			
3	Top	6 ft 8 in.	7.6
	Bottom	12 ft 0 in.	
9	Top	6 ft 8 in.	7.56
	Bottom	12 ft 0 in.	
11	Top	6 ft 8 in.	7.4
	Bottom	12 ft 0 in.	
17	Top	6 ft 8 in.	7.59
	Bottom	12 ft 0 in.	
19	Top	7 ft 4 in.	6.58
	Bottom	12 ft 0 in.	
25	Top	7 ft 8 in.	6.59
	Bottom	12 ft 0 in.	
27	Top	6 ft 7 in.	7.54
	Bottom	12 ft 0 in.	
	Total		50.86

Figure 19. High-pressure pump outlet plugged with TECT-HG (low viscosity) (Photo 97-755-1-0).

GRANDE C8) in the soil pit and debris pit, (3) grouting in a specially designed soil pit as an operational readiness using parameters obtained from Phase-1 and -2 testing, and (4) a destructive examination of the monoliths formed by the grouting operation. This testing protocol varied somewhat from the project test plan,[5] which stipulated (1) evaluation of grouting parameters in three field trial holes followed by (2) full operational assessment in the soil pit, and (3) grout application in the debris part of the debris pit, to be followed by (4) excavation, sampling, and qualitative evaluation of the grouted pits. Variations from the test plan were necessitated early in the field testing due to problems encountered with poor penetration of the undisturbed Cold Test Pit lithology utilizing the nonrotopercussion drill rig. In retrospect, it was unfortunate that an undisturbed region of the pit was identified for this testing, the rationale being that worst case soil densities needed to be experimented with prior to going into the Acid Pit. Following soil penetration work (auger drilling) performed in the region of the Acid Pit for geophysical instrumentation installation, it was determined that Acid Pit soil densities were more compatible with disturbed regions of the Cold Test Pit. This information combined with a change to a rotopercussion drilling rig guided subsequent cold testing that resulted in a defined set of grouting parameters for the Acid Pit. What follows is a description of the sequence of events and grouting parameters evaluated during various phases of the cold testing. Table A-2 in Appendix A summarizes all of the data taken during the various phases of grouting.

4.3.1 Phase-1 Testing with the DAVY KENT Drilling System.

The rotary DAVY KENT drilling system was chosen by the vendor (GEO CON) for application in the Cold Test and Acid Pit. In initial discussions with GEO CON, it became obvious that the "debris" part of the Cold Test Pit testing could not be performed using the DAVY KENT, because it would require rotopercussion to drive through the waste. Grouting of the "debris" was a secondary objective of the study, because of the lack of debris in the Acid Pit. This work was being performed, however, to further assess the performance of the technology for applicability to Waste Area Group-7 (RWMC) TRU pits and trenches—the application for which it was originally designed. Following the decision to forego grout application in the "debris," the soil portion of the debris pit was held in reserve for pre-Acid Pit testing.

A total of five field trial columns and four holes in the soil side of the debris pit were jet grouted using the DAVY KENT drilling system as shown in Figure 20. Grouting parameters are listed for this Phase-1 testing using the DAVY KENT drilling system on Table 2. It was planned[5] to drill three field trial holes on a 2-ft triangular pitch to assess the grout returns near the soil pit, then to proceed to the soil pit and grout a total of 32 holes (the hole numbers and original anticipated order of grouting are shown in Figure 14). The first field trial was attempted 26 ft north of the soil pit thrust block. The grouting parameters were based on FY-96 testing using the TECT grout and partitioning out the amount that went into the soil and the amount that went into voids in the debris.[3] This resulted in a parameter set as follows: 6000 psi drill pressure, 6 s/step, 2 rev/step, and a 5-cm withdrawal rate. These parameters were targeting 200 gal deposited in a hole where the grouted region was a 10-ft column nominally 2 ft in diameter. For the soil pit, drilling was to go 17 ft from the surface of the thrust block and grout the bottom 10 ft. These dimensions approximated those expected at the Acid Pit.

The first field trial hole essentially caused a reassessment of the grouting operations because it became apparent that with the nonrotopercussion DAVY KENT drilling system, penetration of

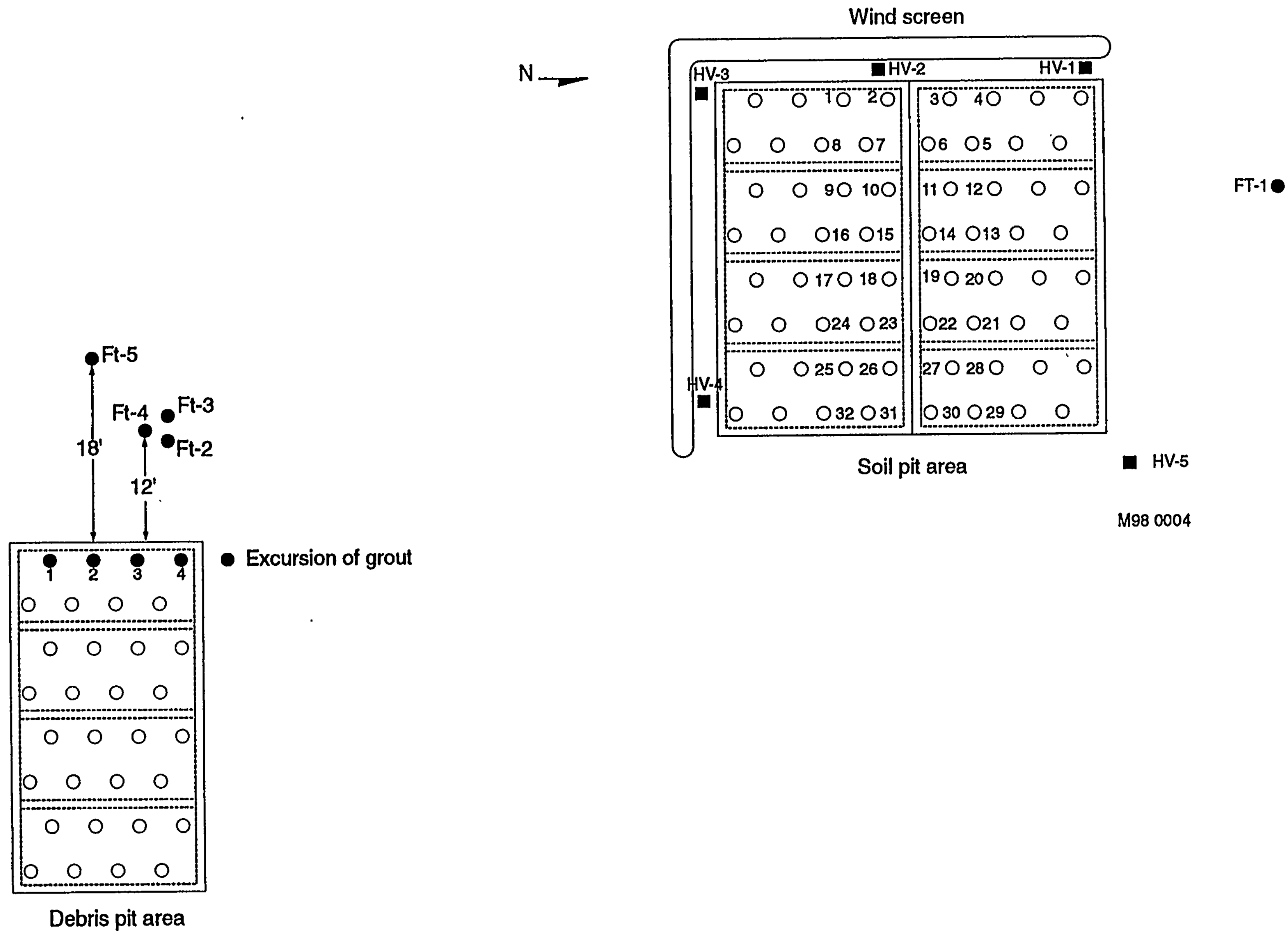


Figure 20. Grouting of soil pit and debris pit with the DAVY KENT (Phase-1 testing) (Graphic M98 0004).

Table 2. Grouting parameters for Phase-1 DAVY KENT drilling system.

Location[a]	Grouting Parameters[b]		Total Grout in Drilling/Jetting (gal)	Total Grout Returns (gal)
FT-1	6 s/s	down 13 ft up 5 ft	296	>100
FT-2	6 s/s	down 10 ft up 6 ft	201	20
FT-3	6 s/s	down 10 ft up 6 ft	162	50
FT-4	4 s/s	down 10 ft up 6 ft	118	10
Debris Pit 1	4 s/s (from top of thrust block)	down 11 ft up 6 ft	139	5[c]
Debris Pit 2	4 s/s	down 11 ft up 6 ft	146	10[c]
Debris Pit 3	4 s/s	down 11 ft up 6 ft	166	15[c]
Debris Pit 4	4 s/s	down 11 ft up 6 ft	132	15[c]
FT-5	4 s/s	down 6 ft up 4 ft	91	<1

a. See Figure 20.

b. All tests were performed at 6000 psi 2 rev/step 5 cm/step.

c. Estimated by measuring the depth in the thrust block (4 in. in joist after four holes, 2 in. in second joist, trace in remaining joists).

the soil pit area required too long to drill; and, if applied in the thrust block, the resultant large amount of drilling fluid returns to the surface (up to 100 gal of neat grout) would literally fill the cavities under the thrust block for the drilling process alone. Recall that the thrust block was designed to hold roughly 8 gal of returns per hole based on past testing in debris pits.[1,2,3] The drilling was stopped at the 13-ft level, and the bottom 8 ft was grouted with up to 100 gal of grout returns, most of which occurred during drilling (see Table 2). Several holes were drilled and grouted in disturbed soil using water as the drilling fluid with minimum grout returns, which led the research team to believe that perhaps the soil pit site as set up was a poor choice with too tightly packed clays (minimal voids); but perhaps with rotopercussion, the time to drill to depth would be reduced to the point that returns are not excessive. The only option at this point with the DAVY KENT equipment was to try grouting in a more disturbed area closer to the debris pit. Field trials 2, 3, 4, and 5 and holes 1, 2, 3, and 4 of the debris pit were successfully placed as shown in Figure 20. Grouting parameters are given in Table A-1 of Appendix A, and a discussion of the results is in a following section.

4.3.2 Phase-2 Testing

After completion of the Phase-1 testing, geotechnical evaluations of the soil conditions around the soil pit and debris pit sites were made while simultaneously investigating the potential to change out the DAVY KENT drilling system for a system including rotopercussion capability. In past testing,[1,2,3] drilling operations had taken no more than 1 minute for full insertion using the rotopercussion technique in soil; therefore, rotopercussion was thought to be mandatory. The geotechnical results are given in Appendix B. The basic result of the geotechnical evaluation (discussed in detail in the results section to follow) was that the soil site consisted of hard and compacted clays and silty clays, in some cases as high as 50 blows/ft, whereas the debris pit site was looser materials consisting of silt/sand with lower clay content with blows/ft closer to 15 blows/ft. Based on this, the grouting contractor was instructed to procure a rotopercussion drill rig, which resulted in delivery of a CASA GRANDE C8. The new plan then was to virtually start over with a series of three new connected field trials in the vicinity of the soil pit and then proceed to the 32 holes of the soil pit. Testing was to include taking drill stem smears, smears of the surface of the thrust block, air sampler filters/air volume data, and grab samples of the grout return. These data were to be used to evaluate the contamination control aspects of the technology by evaluating the movement of the molybdenum tracer. The three field trials were grouted with the new CASA GRANDE C8 with enough positive results (easy drilling and minimal grout returns) to proceed to the soil pit.

In addition to changing the drilling equipment, a major adjustment also was made to the grout delivered per foot by changing the 6 s/step to lower values. The lower numbers for time on a step minimized grout returns, and excavation of the soil column for the lower values revealed that an approximately 2-ft column in the disturbed soil area could be created. It is noted that the technology had been developed for forming monoliths in debris pits and that the void volume inherent in the debris pits could absorb excess grout, thus reducing grout returns. As a result, grouting parameters obtained from that body of testing (6 s/step, etc.) did not seem to apply to the soil-only cases. In the soil pit, it was possible to only grout eight holes as shown in Figure 21. However, a complete sampling protocol was performed, including air sampling during this operation. Results of this grouting, relative to soil conditions in the soil pit and the sampling results, are discussed in Section 5. However, because returns were excessive and original objectives for depth could not be achieved due to a particularly hard clay layer below 15 ft (even

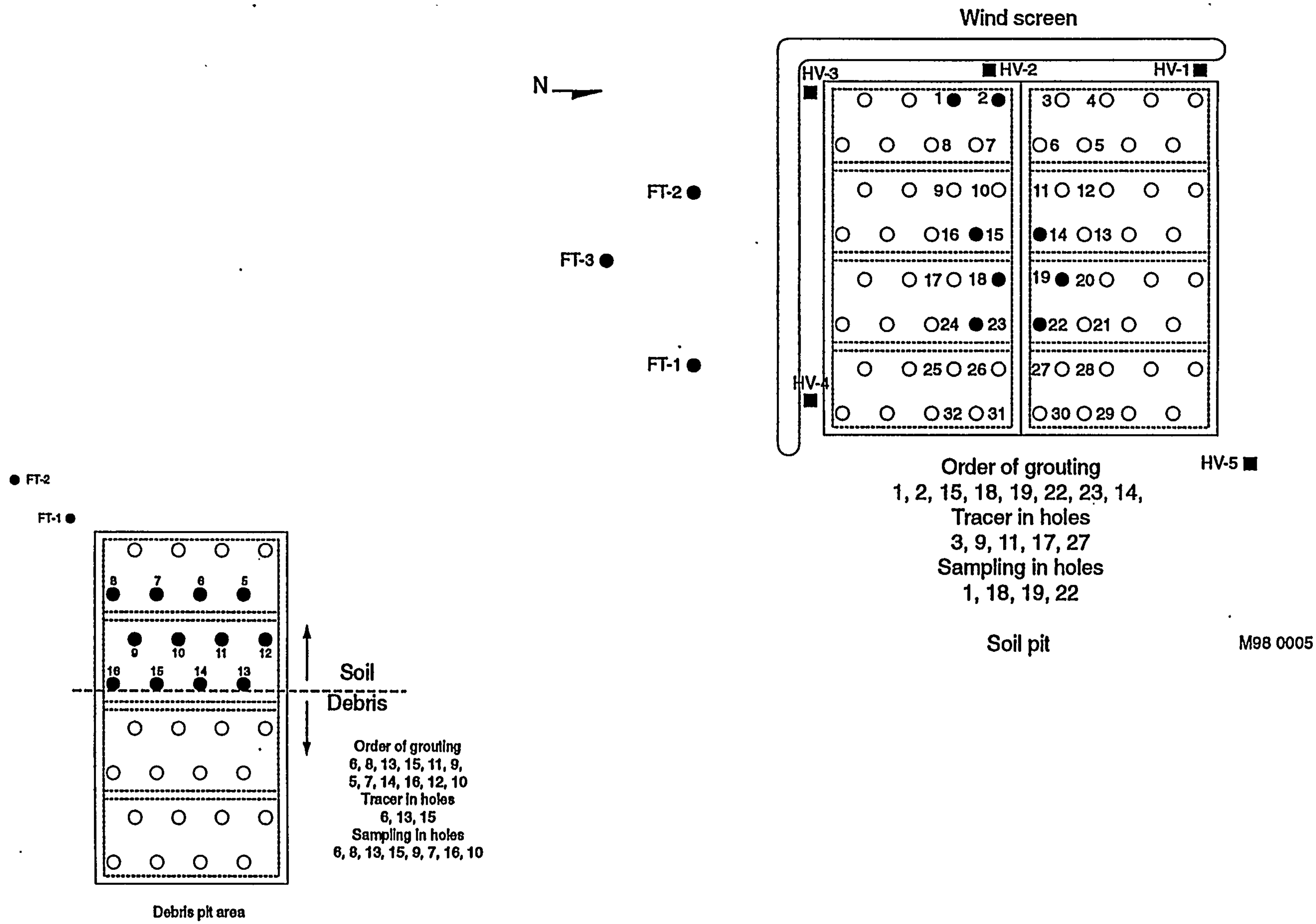


Figure 21. Grouting with the CASA GRANDE C8 drilling system (Phase-2 testing) (Graphic M98 0005).

utilizing the CASA GRANDE C8), the soil pit was abandoned and further operations concentrated on the remaining soil part of the debris pit with 12 open holes (see Figure 21).

While the CASA GRANDE C8 could easily penetrate the harder soils of the soil pit, excessive grout returns still persisted even at reduced amounts of grout injected per ft (4 s/step verses the original 6 s/step). Therefore, for the debris pit shown in Figure 21 the starting nominal grouting parameter was reduced to 3 s/step even though the soil condition was in a disturbed soil site. A total of 12 holes were grouted, with the last few holes only partially grouted due to excessive returns. The detailed results will be discussed in the results section. In the last few holes, the grouting time had been reduced to 2 s/step; and it was deemed mandatory to create two new field trials, one at 2 s/step and one at 3 s/step as shown in Figure 21. At the reduced times on a step, the resultant column sizes were still in the 24-in. diameter range. In addition, during grouting of the debris pit, smear samples were obtained on the drill stem and top surface of the thrust block as well as grab samples of grout returns for select holes, and air sampling filters/volume data were collected as the samplers were placed symmetrically around the debris pit thrust block.

4.3.3 Phase-3 Testing in the Operational Readiness Review Pit

Phase-3 testing involved a pre-Acid Pit readiness review in a specially prepared soil pit involving a total of eight adjacent holes with the CASA GRANDE C8 system as shown in Figure 22. In an area constructed immediately east of the soil pit but over previously disturbed soil, one module of the soil pit thrust block was moved over an area with at least 17 ft of soil as shown in Figure 22. The total depth from the top surface of the thrust block was 17 ft down, and jet grouting was performed for the bottom 6 feet. The parameters were based on all previous testing results with grout return management as high priorities. The grouting was set at 2 s/step with the goal of creating 2-ft diameter columns and minimal grout returns. The eight holes were grouted with no operational difficulties using the same thrust block from the original soil pit. Three solid field trials and one partial field trial as shown in Figure 22 were also formed to determine the column connectedness; however, the total depth for these columns was 12 ft high (drilling down 17 ft and grouting out the bottom 12 ft).

4.3.4 Phase-4 Testing (Destructive Examination)

Phase-4 involved excavating the three basic testing areas and all field trial holes. Several of the field trial holes had been excavated shortly after grouting to obtain guidance on what parameters to try during the next campaign. The Operational Readiness Review Pit, the debris pit, and the soil pit were first isolated from surrounding soil, then either brought out as a single unit, or sliced in 6-in. to 1-ft slices of the pit. A complete photographic record was kept of this process. The evaluation of results of the various grouting phases and the destructive examination is found in the next section.

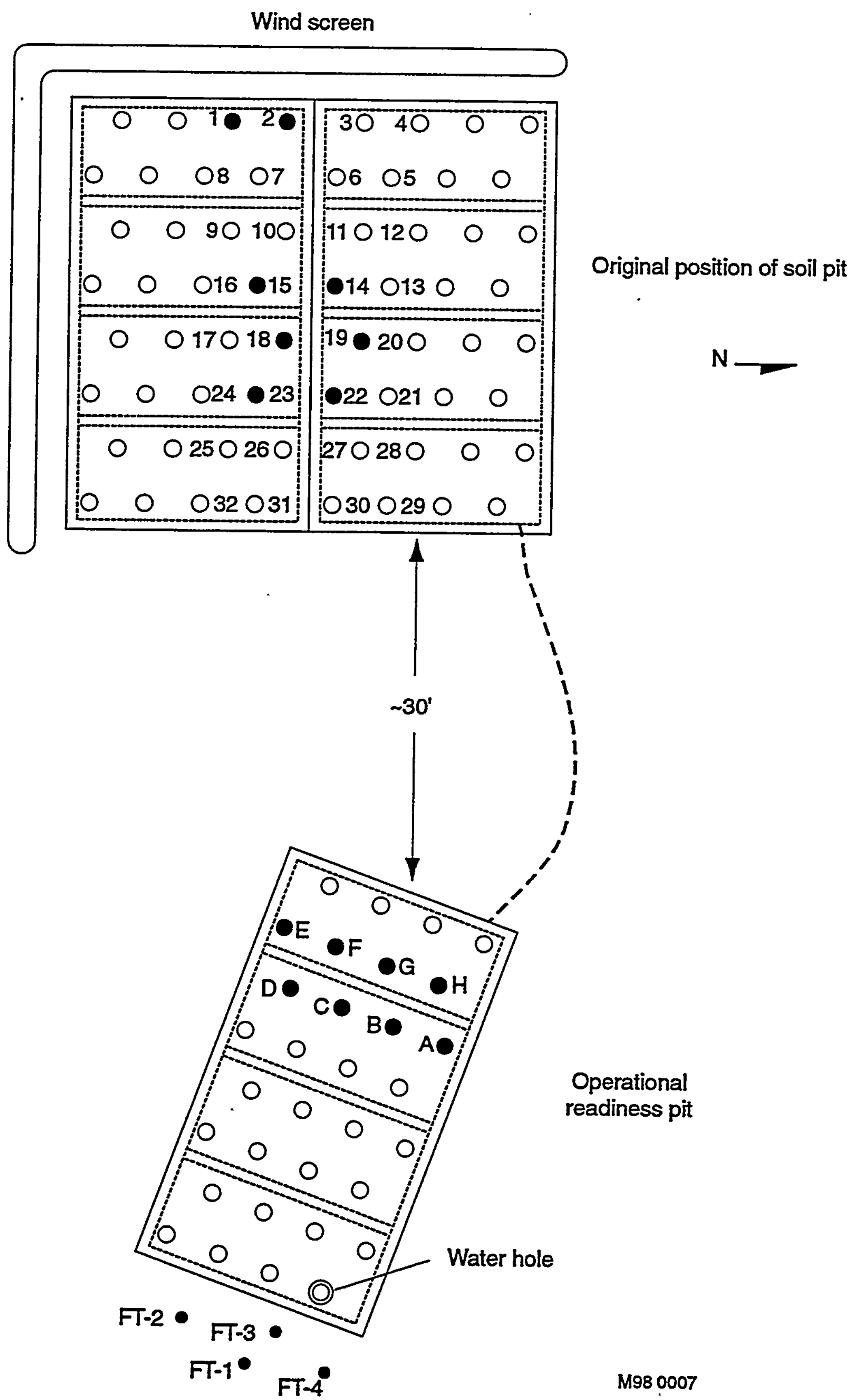


Figure 22. Second soil pit (Operational Readiness Pit) (Graphic M98 0007).

5. TEST RESULTS

This section discusses major findings of the testing program. Results are generally discussed according to what the effects of various grouting parameters (step time, viscosity of the grout, drill time, etc.) were on visible grout returns, ground heave, and composition of the resultant columns or monoliths. As part of this discussion, the performance of the thrust block is discussed. In addition, an evaluation is given on the spread of tracer material (molybdenum powder) as a stand-in for mercuric oxide in the actual Acid Pit. Finally, the effectiveness of operational procedures including the cleanout procedures as they apply to hot testing are presented.

5.1 Effect of Grouting Parameters on Technology Implementability

A large number of different grouting parameters were tried in the three phases of grouting, and considerable experience was generated. Basically, the main finding was that prior experience in grouting debris pits described in References 1, 2, and 3 did not apply in that the amount of voids present in the soil would not support the amount of grout injected, which resulted in copious grout returns and ground heave (something never experienced when grouting the buried debris regions). To complicate matters, the soil pit area in previously undisturbed soil (which eventually was determined to be hard clay in excess of 50 blows/ft) could not be grouted using existing techniques. In fact, it is clear that a different technique that allowed ground heave would be required for those type of soil regions. Another major result is that in the previously disturbed soil regions, the techniques developed in prior testing for debris could apply if certain modifications were made. An additional test variable was that the grout was delivered at different viscosities. Following a discussion of the destructive examination of resultant monoliths and field trial columns, the effect viscosity might have played on competence of the monoliths will be discussed. What follows are specific results relative to the grouting parameters. It is noted here that control of the grouting parameters was imprecise; and through repeated operations and constant checking, the operation improved. For this reason, most desired parameters were achieved +/-10%.

5.1.1 Effect of Soil Type on Groutability

The soil pit area described in Section 4 was a previously undisturbed area and was found to not be jet groutable within limits of minimal grout returns and ground heave. However, under certain grouting parameters, connected columns could be made in previously disturbed areas, like the region surrounding the debris pit. In addition, it was found that in the soil pit area, rotopercussion drilling was mandatory.

A lithologic evaluation involving the number of blows per foot and description of particle size distribution and type material was performed on both the soil pit and in debris pit areas. Complete results are given in Appendix C. In summary, the number of blows per foot and particle size evaluations show that the soil pit site was composed of hard soil that was not conducive to nonreplacement grouting. There were many regions in which the number of blows per ft exceeded 50 and the typical hydraulic conductivity was in the 10^{-5} to 10^{-7} cm/s range, where 10^{-7} is a target value for most barrier type work. Therefore, the soils in the soil pit area consisted of tightly packed fine-grained silty clay. The debris pit site, however, averaged 15 blows per foot in the region of grouting and was found to be suitable for grouting with minimal returns and ground heave during grouting.

The problem of drilling in the soil pit was accentuated by attempting the grouting campaign with the nonrotopercussion DAVY KENT drill rig. Previous studies were successfully performed using drilling equipment with rotopercussion capabilities. The project team determined that this drilling method was the most viable option for minimizing grout returns and penetrating harder soils. The amount of grout required during the drilling process (which essentially came up the hole during drilling) far exceeded the amount of space allowed for grout returns under the thrust block. Therefore, the team recommended that a rotopercussion system be employed. Once the CASA GRANDE system was procured by the drilling contractor, drilling time even in the soil pit, was reduced from over 10 minutes to achieve depth to approximately 1 minute to achieve depth.

The problem with nonreplacement jet grouting in these tight soils is to accomplish creation of an adequate soil column while allowing minimal grout returns or heave of the surrounding material. In any soil condition, if more energy is applied to the soil (by increasing the pressure or changing the nozzle size to increase the velocity of the fluid), a larger column can be created. However, there will be a general heave of the area because the grout has no place to go. If more grout is applied per foot for the same back pressure, the column size is reduced and the extra grout simply comes to the surface. In buried waste sites with large voids (debris pits can have as high as 70% voids), the problem is rarely fighting grout returns; the problem is knowing when enough grout has been injected. In fact, some cross communications as evidenced by flow of grout to the surface of adjacent grout holes is desirable as an indication of complete monolith formation.

5.1.1.1 Grouting with the DAVY KENT Drilling System. In the case of grouting in the soil pit area regardless of drilling system, both general ground heave and excessive returns were observed for a variety of grout parameters. Originally, the grouting parameters were 6 s/step, 2 rev/step, 5 cm/step and 6000 psi backpressure. For the first field trial in the soil pit with the DAVY KENT system, the grout returns were excessive (greater than 100 gal as shown in Table 2). The 6-s step was based on a calculation of the partitioned amount of grout that went into the interstitial soil in grouted debris pits during FY-96 testing documented in Reference 3. Based on this partitioning, it was desired that about 20 gal per foot was required; and, in fact, that is how much grout use was anticipated and ordered. However, after the first few grouted holes in the soil pit and debris pit with the DAVY KENT drilling system, it became apparent that the soil would not take that much grout; and the amount of time at a step had to be reduced. In Volume 2 of this report, there is an extensive discussion of grout take in soil.

Table 2 summarizes the grouting performed using the DAVY KENT drilling system in the order of grouted holes. Field trials 2, 3, and 4 in the disturbed soil area were three adjacent holes on a 2-ft triangular pitch matrix. After observing excessive grout returns for holes 2 and 3 at 6 s per step, the time at a step was reduced to 4 s for the third field trial (FT) hole (FT-4), with a marked reduction in returns. Total returns, however, were still alarming (10 gal for hole FT-4 compared with the available volume for collection under the thrust block at 8 gal). However, with the DAVY KENT drilling system, even in the relatively loose soils of the debris pit, it took excessive time to drill, resulting in excess drilling fluid pouring from the hole. Nevertheless, using the 4 s per step interval, a series of four adjacent holes (1, 2, 3, and 4 on the thrust block—see Figure 20) were grouted in the soil part of the debris pit with encouraging results. The amount of grout returns for drilling all four holes within a single joist of a thrust block did not fill the joist under the holes being grouted nor was there an excessive amount of grout collected under other joists (presumably by drainage through leakage paths caused by the imperfect seal between the thrust block joists and the sublayer of pea gravel). An interesting excursion of grout approximately 1 gal of viscous soilcrete came to the surface approximately 2 ft to the north of hole 4 (see Figure 20) during the grouting of holes 1-4 in the debris pit with the DAVY KENT system. Field trial FT-5 was then grouted in the disturbed soil area to ensure that, at 4 s per step, the column size was still adequate. Excavation of the field trial hole showed a solid grout column with dimensions approximately 20-25 in. in diameter as shown in Figure 23.

5.1.1.2 Grouting Performed with the CASA GRANDE System in the Soil Pit. Based on this positive feedback (minimal grout returns) on holes 1-4 and the desirable column size in the field trial, a new drill rig involving rotopercussion was ordered and an attempt was made to continue the planned work on the soil pit. Even though it was known that the soil conditions would be difficult, considerable investment in time had been made for the soil pit; so an attempt was made to utilize the site. However, simultaneously it was planned to grout the remaining 12 holes shown in Figure 21 in the debris pit as well.

During performance of three field trials just south of the soil pit (see Figure 21), a fracture to the surface appeared; and a continual flow of "neat" TECT grout emanated out a hole approximately 10 ft southwest of the grouting operation. Table 3 summarizes the grouting data obtained using the CASA GRANDE drilling system in the soil pit and the debris pit. Table 3 shows that the total emanation for this first field trial was 7-8 gal. Furthermore, during grouting of the other two adjacent holes, there were excessive returns (22 gal) on hole FT-2 and a general ground heave of approximately 1 ft over an area of 4 ft^2, which also fortified the idea that the soil pit area may not be groutable without considerable returns—certainly more than allowed for under the thrust block. Nevertheless, an attempt was made to perform grouting on the soil pit thrust block starting with hole number 1 at the same grouting parameters as was used for the field trials—4 s/step.

For hole 1, there was an immediate filling of the void under the joist and an obvious fracture (excursion of grout to the west side of the thrust block [see Figure 24]). Hole 2 was drilled to depth and immediately upon starting the high-pressure pump, grout emanated from the surface of the thrust block and the grouting was stopped. The decision was made to make the best monolith possible by grouting only one hole per joist on a pattern in the center of the two thrust blocks (see Figure 21—holes 14, 15, 18, 19, 22, and 23). This strategy met with mixed results in that the entire thrust block heaved in the middle about 6 in. above the initial grade. However, for the most part, there was no grout emanating to the surface even though the entire joists were filled for several positions (see Table 3 for a description of the grout returns). When grouting the last hole, there were grout returns emanated to the surface via a hole that had not even been grouted. The grout had filled an adjoining joist to overflowing for that case. The major conclusion was that even though the CASA GRANDE drill could penetrate the tightly packed soil of the soil pit quickly without the use of excessive drilling fluids, grouting at 4 s/step provided excessive returns for the thrust block as designed. As a precaution, the manufacturer of the thrust block had already been contacted and instructed to add excess volume to the thrust blocks to be used in the Acid Pit testing, which was to follow the cold testing immediately. The new blocks were to have allowed grout returns of 14 gal per hole.

Figure 23. A solid core in the field trial hole (Photo 97-490-1-21A).

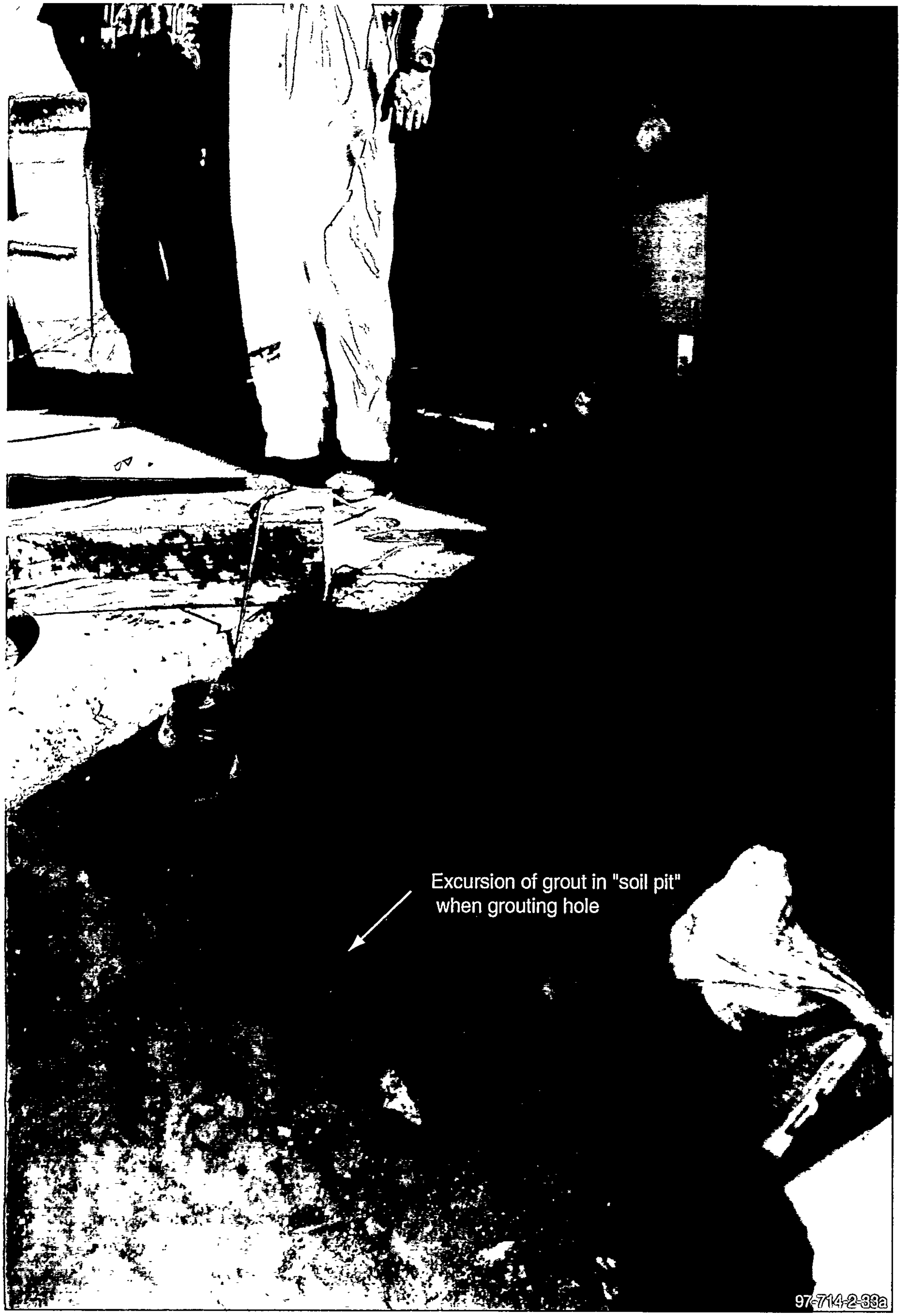
Table 3. Grouting parameters for Phase-2 CASA GRANDE test holes.

Location	Grouting Parameters	Total Grout in Drilling/Grouting (gal)	Total Grout Returns
Soil Pit			
FT-1	4 s/step down 8 ft up 5 ft[a]	163	7–8 gal
FT-2	4 s/step down 8 ft up 5 ft[a]	114	22 gal
FT-3	4 s/step down 8 ft up 5 ft[a]	109	1 ft heave over 4 ft area no returns
Hole 1	4 s/step down 10 ft up 5 ft[a]	112	Filled joist, hydro fracture west of thrust block
Hole 2	4 s/step down 10 ft up 1 ft[a]	31	Immediate returns to surface
Hole 15	4 s/step down 10 ft up 5 ft[a]	106	4 in. grout in joist
Hole 18	4 s/step down 10 ft up 5 ft[a]	89	1 in. grout in joist
Hole 19	4 s/step down 10 ft up 5 ft[a]	122	Thrust block showing cracking between modules
Hole 22	4 s/step down 10 ft up 5 ft[a]	105	Middle three joists full
Hole 23	4 s/step down 10 ft up 5 ft[a]	96	Joist on opposite module full
Hole 14	4 s/step down 10 ft up 5 ft[a]	112	Thrust block modules showed large heave 6 in. total
Debris Pit			
Hole 6[b]	3 s/step down 9 ft up 6 ft[c]	143	2 in. returns in joist
Hole 8[b]	3 s/step down 9 ft up 6 ft[c]	86	6 in. returns in joist
Hole 13[b]	3 s/step down 9 ft up 6 ft[c]	95	4 in. returns in joist
Hole 15[b]	3 s/step down 9 ft up 6 ft[c]	91	4 in. returns in joist
Hole 11[b]	3 s/step down 9 ft up 6 ft[c]	74	4 in. returns in joist
Hole 9[b]	3 s/step down 9 ft up 6 ft[c]	84	4–5 in. (half full) in joist
Hole 5[b]	2 s/step down 9 ft up 3 ft[c]	33	Stopped grouting 3 ft from bottom
Hole 7[b]	2 s/step down 9 ft up 3 ft[c]	32	Immediate grout returns to surface; raised drill stem 2 ft restarted but stopped
Hole 14[b]	2 s/step down 9 ft up 6 ft[c]	58	No grout returns small heave of thrust block
Hole 16[b]	2 s/step down 9 ft up 6 ft[c]	67	Grout emanated to top of thrust block in holes 13 and 15; see Figure 21
Hole 12[b]	2 s/step down 9 ft up 6 ft[c]	60	No data
Hole 10[b]	2 s/step down 9 ft up 6 ft[c]	15	Thrust block heaved 1–2 in. above initial grade (immediate grout returns, grouting stopped after only starting, H.P. pump)
FT-1	2 s/step down 6 ft up 4 ft	48 (12 gal/ft)	None
FT-2	3 s/step down 6 ft up 4 ft	69 (17 gal/ft)	None, ground heave

a. 2 rev/step; 5 cm withdrawal.

b. See Figure 21.

c. 2 rev/step; 6000 psi all cases.



M98 0017

Figure 24. Grout excursion to the west of the thrust block—soil pit hole 1 (Graphic M98 0017).

5.1.1.3 Grouting Performed with the CASA GRANDE System in the Debris Pit. Based on the disappointing results in the soil pit, the remaining 12 holes of the debris pit (soil side) were grouted using the CASA GRANDE drilling rig as shown in Figure 21—again with mixed results. For some of the holes, there was not excessive returns. However, when completing the grouting operation for the 12 holes, it was necessary to reduce the time on a step and shorten the length of grout column, resulting in an incomplete grouting operation and potentially incomplete monolith due to net returns that exceeded the capacity of the thrust block. Basically, even though the grouting was performed in a previously disturbed soil area with more voids to absorb grout than the soil pit testing described above, excessive grout returns to the surface and some minor thrust block heave occurred. For the initial holes, the time on a step was changed to 3 s, partly based on experience with the soil pit and also with the growing realization that the soil voids (available porosity) could not hold that much grout.

There was much confusion about the results with the DAVY KENT for holes 1, 2, 3, and 4 in the debris pit because the grout viscosity used for those holes was much lower than for other cases, and at 4 s/step there were not the excessive returns observed under the thrust block. At this point, it was only speculated that there was a potential that grout viscosity played a role in column formation and the amount of grout returns. The effect of changes in viscosity of the grout load is discussed in a following section. As the grouting operation proceeded in these 12 holes, the returns gradually became excessive to the point where the time on a step was reduced. Following grouting, it was obvious that even with a change from 4 s/step to 3 s/step for the first holes, too much grout was being placed in the ground.

Table 3 summarizes the results of the debris pit grouting campaign (holes 5-16—recall that holes 1-4 had been grouted with the DAVY KENT drilling system). The grouting was performed such that no adjacent holes in any one joist were grouted sequentially. As an example, Figure 21 shows that the order of grouting was hole 6, 8, 13, 15, etc., which appeared to not exhibit excessive returns for the first 6 holes. However, again examining Table 3, grout return management became difficult for the last six holes. In fact, the time on a step was reduced from 3 s to 2 s; and the last hole could not even be grouted as once the high-pressure pump was turned on grout returns emanated to the surface of the thrust block. It was clear at this point that in undisturbed soils the 3 s step could not be used (at least for the viscosity used for holes 5-16 of the debris pit) and that the time step should be reduced to 2 s. However, the column size at 2 s per step was unknown; so in an area to the southwest of the debris pit thrust block, two separate field trials were performed (drill down 6 ft and grout out 4 ft) also shown in Figure 21 and Table 3.

For the first field trial, 2 s/step was performed; for the second field trial, 3 s/step was performed. Interestingly enough, when excavated, both columns were similar, with FT-1 22-28 in. in diameter and FT-2 18-24 in. in diameter. It is speculated that the column size is dictated by the first revolution of the drill stem at a step; and for the second revolution, the force of the jetting action is reduced by the presence of a fluidized bed of grout and soil and does not penetrate much further into the surrounding soil. Rather, the energy is used to thoroughly mix the fluidized bed and allow more access to void space in the soils by the mixing action.

5.1.1.4 Grouting the Second "Soil" Pit (Operational Readiness Pit) in Disturbed Soil. Following the grouting of the debris pit, a new region called the Operational Readiness Pit was successfully grouted using all of the combined grouting parameter knowledge gained from the other tests.

Partially as operational readiness prior to going to the Acid Pit and partially as a check on the final grouting parameters, a new pit was formed east of the original soil pit. However, the soil was previously disturbed. For this pit, the thrust block from the original soil pit was successfully moved and the void volume under the block formed by the joists was nearly free of grout. This was largely due to the fact that the inside surface of the thrust block was sprayed with an acrylic glaze material such that the grout returns did not stick to the surfaces as shown in Figure 25. This move proved that the thrust blocks could be reused, if necessary. However, the contamination control aspects of this move were not examined.

Grouting on the Operational Readiness Pit proceeded as planned using parameters determined from all prior testing. There were virtually no grout returns, and the surface of the thrust block remained clear of grout returns. Table 4 summarizes the grouting parameters for the Operational Readiness Pit. A total of eight adjacent holes were grouted as shown in Figure 22, which were labeled A-H and grouting proceeded sequentially A-H. The holes were drilled to 17 ft and the bottom 6 ft was grouted to simulate the conditions expected in the Acid Pit. In addition, four field trials were grouted east of the thrust block to evaluate column formation for the 2-ft triangular pitch and 12-foot column length which were to be used on the Acid Pit. The grouting parameters were all the same 2 s/step, 2 rev per step, and 5 cm withdrawal per step. Examining Table 4, it is apparent that grout returns were completely managed even for grouting eight adjacent holes; and the project now had a set of parameters for application at the Acid Pit that potentially created a monolith without excessive grout returns. Approximately 6.7 gal per ft was deposited in the eight holes. Therefore, for the Acid Pit application, approximately 7 gal/ft was a target value for grouting.

5.1.2 Destructive Examinations

The Acid Pit stabilization was conducted prior to performing extensive destructive examinations of each of the test pits constructed in the Cold Test Pit. However, field trial tests were excavated following emplacement to verify completeness of mixing, column development and overlap, and micro effects of the grout injection on soil lithology. Having verified the effectiveness and operational safety of the injection process, work in the Acid Pit commenced on schedule simultaneously with further excavations of the Cold Test Pit monoliths. Resultant data provided considerable insight into the cohesiveness and pervasiveness of these monoliths.

5.1.2.1 Field Trials. Field trial holes were excavated usually within 1 day of grouting, and some of these results have been discussed in previous sections. In all cases for disturbed soil, however, single columns with nominally 24 in. in diameter are formed regardless of grouting parameters. The columns appear to consist of regions of neat grout, zones of grout and finely grained soil (soilcrete), and actual occlusions of clay soil as shown in Figure 26. In addition, when tying three columns together in either disturbed or undisturbed soil, a cohesive monolith of 36-55 in. in diameter was observed during excavation. Table 5 gives information on column formation giving as well grouting parameters for the single or triple field trial holes. In the undisturbed soil site, it was possible to get good monolith formation when grouting three field trials on a 2-ft triangular grid. Figure 27 shows the three field trials immediately south of the original soil pit, where three columns were created with 4 s/step. The photograph shows that the columns even in tightly packed clay soils are adequately tied together using the 4-s time step, which equates to roughly 20-22 gal of grout delivered per foot of column.

Figure 25. Thrust block being moved from soil pit to Operational Readiness Pit (Photo 97-748-2-8).

Table 4. Grouting parameters for Phase-3 CASA GRANDE testing (Operational Readiness Pit).

Location	Grouting Parameters			Total Grout (gal)	Total Grout Returns (gal)
A	2 s/step	2 rev/step	5 cm/step	77	None
B	2 s/step	2 rev/step	5 cm/step	74	None
C	2 s/step	2 rev/step	5 cm/step	64	None
D	2 s/step	2 rev/step	5 cm/step	61	None
E	2 s/step	2 rev/step	5 cm/step	60	None
F	2 s/step	2 rev/step	5 cm/step	66	None
G	2 s/step	2 rev/step	5 cm/step	70	None
H	2 s/step	2 rev/step	5 cm/step	67	None
FT-1	2 s/step	2 rev/step	5 cm/step	95	None
FT-2	2 s/step	2 rev/step	5 cm/step	103	None
FT-3	2 s/step	2 rev/step	5 cm/step	107	None
FT-4[a]	2 s/step	2 rev/step	5 cm/step	N/A	N/A

a. Only partially grouted; ran out of grout.

M98 0018

Figure 26. Detail of monolith typical (Graphic M98 0018).

Table 5. Field trial columns—destructive examination.

Location	Column Description	Grouting Parameters	
Soil Pit—undisturbed soil			
FT-1, 2, 3 (CASA GRANDE)	Large cohesive monolith formed by 3 columns ~50 in. across	4 s/step	~20 gal/ft
Operational Readiness Pit—disturbed soil			
FT-1, 2, 3 (CASA GRANDE)	Large cohesive monolith 36–50 in. irregular shaped	2 s/step	~7 gal/ft
Debris Pit (CASA GRANDE)—disturbed soil			
FT-1	Cohesive column 22–28 in.	2 s/step	9 gal/ft
FT-2	Cohesive column 18–24 in.	3 s/step	13 gal/ft
Debris Pit (DAVY KENT)—disturbed soil			
FT-5	Cohesive column 22–25 in. diameter	4 s/step	

Figure 27. Three field trials south of the soil pit (approximately 50 in. across) (Photo 97-755-1-13).

A similar monolith formed by three adjacent field trial columns was formed in disturbed soil using only 2 s/step near the Operational Readiness Pit in which 7 gal/ft was injected. There was no evaluation of grout density or clay occlusion density for these two examples. However, it is almost certain that the monolith formed in the tightly packed clay has a lower density of clay occlusions, even though the soil condition being grouted was tightly packed clay. This suggests that the initial force of the grout from the nozzles causes the general column size and that any grout that follows (in a second revolution of the drill stem) strikes a fluidized bed of clay and grout that greatly dissipates the force. In other words, if the kinetic energy of the initial stream of grout is increased, then column size can be increased (without increasing grout returns); but increasing only the amount of grout on a step by changing the step time only causes further mixing and more access to voids in the rubblized soil while at the same time increasing the volume of grout returns. To make bigger columns then would require a higher grouting pressure or possibly a smaller nozzle size. However, lowering the nozzle diameter to increase the velocity is limited by the potential for plugging. The 3-mm nozzle used for this testing was found in prior experiments to result in adequate column size and in no plugging for TECT grout. It is noted here that the TECT grout has a density of about 18 lbm/gal, which is a very dense material that also increases the kinetic energy in the grout stream. This is in contrast to lighter grouting material such as acrylic polymer[2] (approximately 8.3 lbm/gal) in which only 18-in. columns were formed.

5.1.3 Destructive Examination of Grouted Pits

The three grouted pits were excavated by first isolating the monolith and then performing a detailed examination of the internal integrity by shaving 6- to 12-in. sections with a standard backhoe. There was a cohesive monolith formed for both the debris pit and the Operational Readiness Pit. However, for the soil pit no discernable monolith was formed. The backhoe/front-end loader operator could easily define the boundaries of the Operational Readiness Pit and the debris pit as the resistance to digging was great, and to break into the monolith required a concentrated effort involving straining the hydraulics of these machines. However, for the soil pit, the front-end loader had difficulty finding a cohesive monolith; and a complete excavation resulted in a few 2-ft high by 24-in. diameter columns interspersed with soil laced with grout stringers. This is not surprizing when considering the grouting sequence and parameters discussed in Section 5.1.3.1. For that grouting sequence, grout was only delivered intermittently because of excessive grout returns. What follows is a discussion of the results for the destructive examination of the Operational Readiness Pit and the debris pit.

5.1.3.1 Operational Readiness Pit. Excavation of the Operational Readiness Pit revealed a nearly solid monolith with dimensions 80-94 in. long by 32 in. wide by 68 in. high as shown in Figure 28. These dimensions are consistent with the eight-hole pattern shown in Figure 22. Complete interconnecting of the columns was intermittent, with Figure 28 showing some excavated regions in which grout did not penetrate. However, the general appearance was of a freestanding monolith. The column size appeared to be nominally 20-24 in. in diameter, which resulted in small regions of ungrouted clay in column interstitial positions. Instead of slicing discrete pieces of the monolith, the decision was made to try to bring the monolith out in one piece with a 7-yard front-end loader. Figure 29 shows the front-end loader bringing the monolith out in one piece. The monolith stayed in one piece during moving, and a large crack formed when dropped from the bucket to level ground as shown in Figure 30. It is estimated that the monolith is 30% occlusions of soil and 70% soilcrete.

In Figure 30 there is a notation showing a corner missing from the monolith. This occurred during initial excavation when the surface was struck by the backhoe bucket, not during moving

Figure 28. Operational Readiness Pit—destructive examination (Graphic M98 0020).

Figure 29. Operational Readiness Pit monolith being excavated intact (Photo 97-835-1-25).

M98 0019

Figure 30. Monolith freestanding following removal (Graphic M98 0019).

the monolith with the front-end loader. The monolith appeared more competent at the bottom than at the top because the relatively violent action of moving the monolith did not disintegrate the columns. Overall, a fairly comprehensive monolith was formed with virtually no grout returns; and, even though there were regions ungrouted, they consisted of tightly packed clay material that was difficult to remove—even with a pick and shovel. It is speculated that these regions were highly compacted by the hydraulic force of the grout and would represent a low hydraulic conductivity.

5.1.3.2 Debris Pit. The monolith formed by grouting the soil side of the debris pit was easily resolved by removing surrounding soil with a backhoe. When encountering the monolith, the backhoe bucket could not penetrate the monolith unless the bucket was raised above the surface with a 6-12 in. bite and forcefully dropped onto the surface. The initial effective dimensions of the monolith were 96-98 in. wide, 78-96 in. long, and 96 in. high as shown in Figure 31. The destructive examination of this monolith proceeded from west to east in 6-12 in. slices. Recall that the first four holes or the westernmost side of the debris pit was performed with the DAVY KENT drilling system at 4 s/step and that the next 12 holes (three rows of four holes—see Figure 21) were grouted using the CASA GRANDE system, with between 2 s/step to 3 s/step. The initial excavation revealed a dense monolith with very small (1/8 in.) occlusions of clay soil, with a few occlusions in the 3/4 in. range. In fact of all the TECT monoliths examined, including that described in Reference 3, this was the most difficult to excavate with the standard backhoe bucket dropped onto the top surface.

In general, for the western face of the monolith only a few inches of the face could be broken off at a time using a standard backhoe. Figure 32 shows detail of the monolith 48 in. from the row containing hole 12. Figure 32 shows a dense cohesive monolith with almost no occlusions of soil. This dense layer of cured TECT/soil persisted for approximately 26 in. in from the west face, at which point the number and size of soil occlusions increased as shown in Figure 33. The farther into the debris pit the poorer the monolith appeared. In fact, at 36 in. into the face, evidence of a solid monolith was intermittent as shown in Figure 34. At this point, the front-end loader was used to topple the remaining monolith. Examination of the rubble showed virtually no loose soil; rather, the rubble was quite "glued" together with the TECT grout and the pieces ranged from 1 ft in average diameter to 3 ft as shown in Figure 35. Figure 35 also shows the instrumentation pipe imbedded into the debris pit into hole 12.

Overall, the westernmost one-third of the monolith was very cohesive, with minimal occlusions of soil; the middle one-third of the monolith was cohesive, with larger soil occlusions; and the last one-third was intermittent competent monolith and ungrouted soil. In general, the westernmost row was grouted at a consistent 4 s/step with a relatively low-viscosity grout, whereas the easternmost positions used less time on a step (and thus less grout delivered).

5.1.4 Surface Grout Control and Clearing the System of Grout—"Cleanout"

5.1.4.1 Surface Grout Control. The catch cup/catch can arrangement designed to contain the flow of grout from the nozzles between grouting operations worked as planned. The system is shown in Figures 8 and 10. There is always at least a gravity head of grout flowing out the nozzles. This is to ensure that the nozzles do not become stagnant and plug in between grouting operations. Even though the flow of grout emanating from the nozzles is expected to be clean grout (except the extreme case where a "hot" particle may be entrained in the flow),

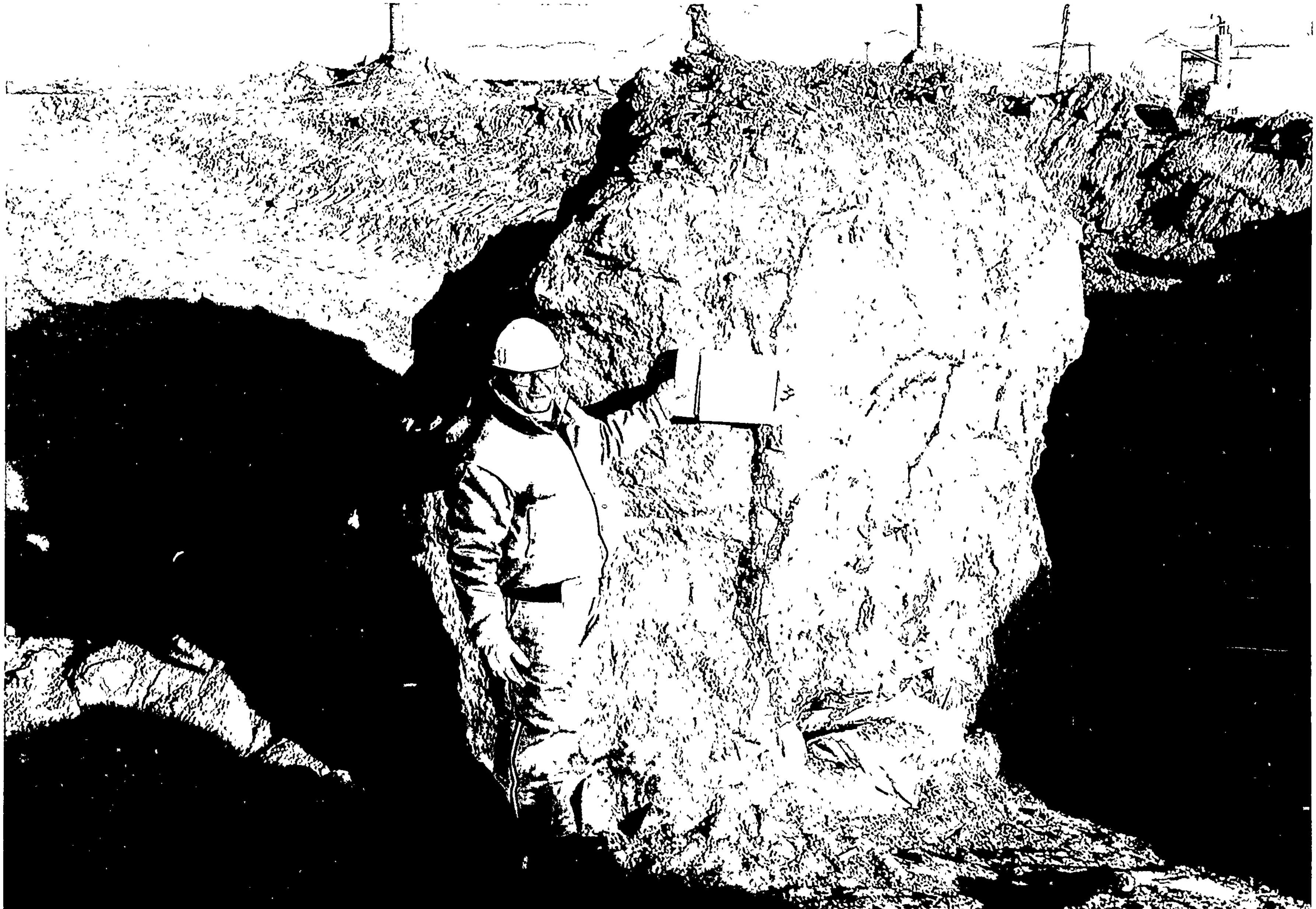


Figure 31. Initial monolith for debris pit (Photo 97-835-1-8).

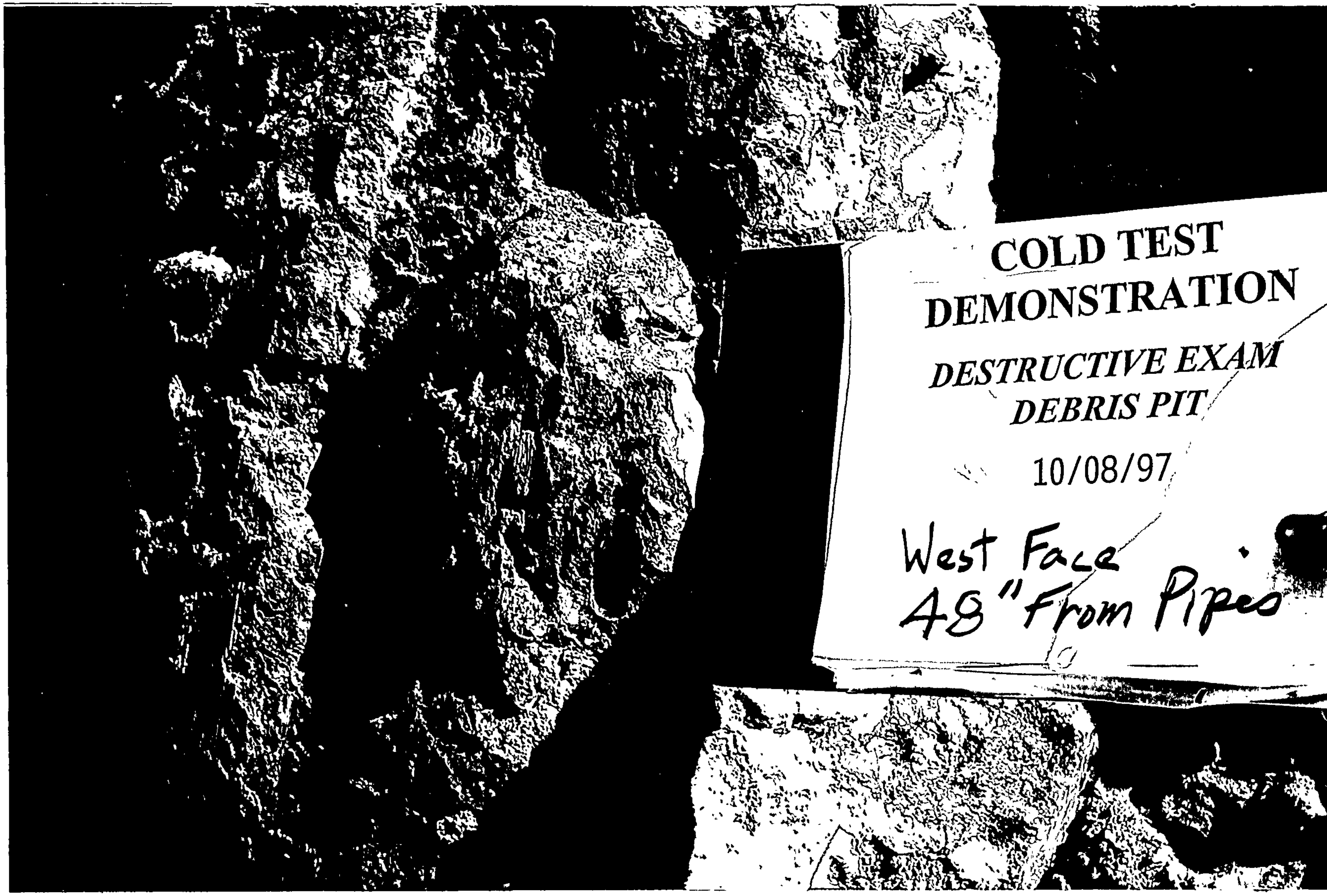


Figure 32. West face of debris pit (Photo NF971987).

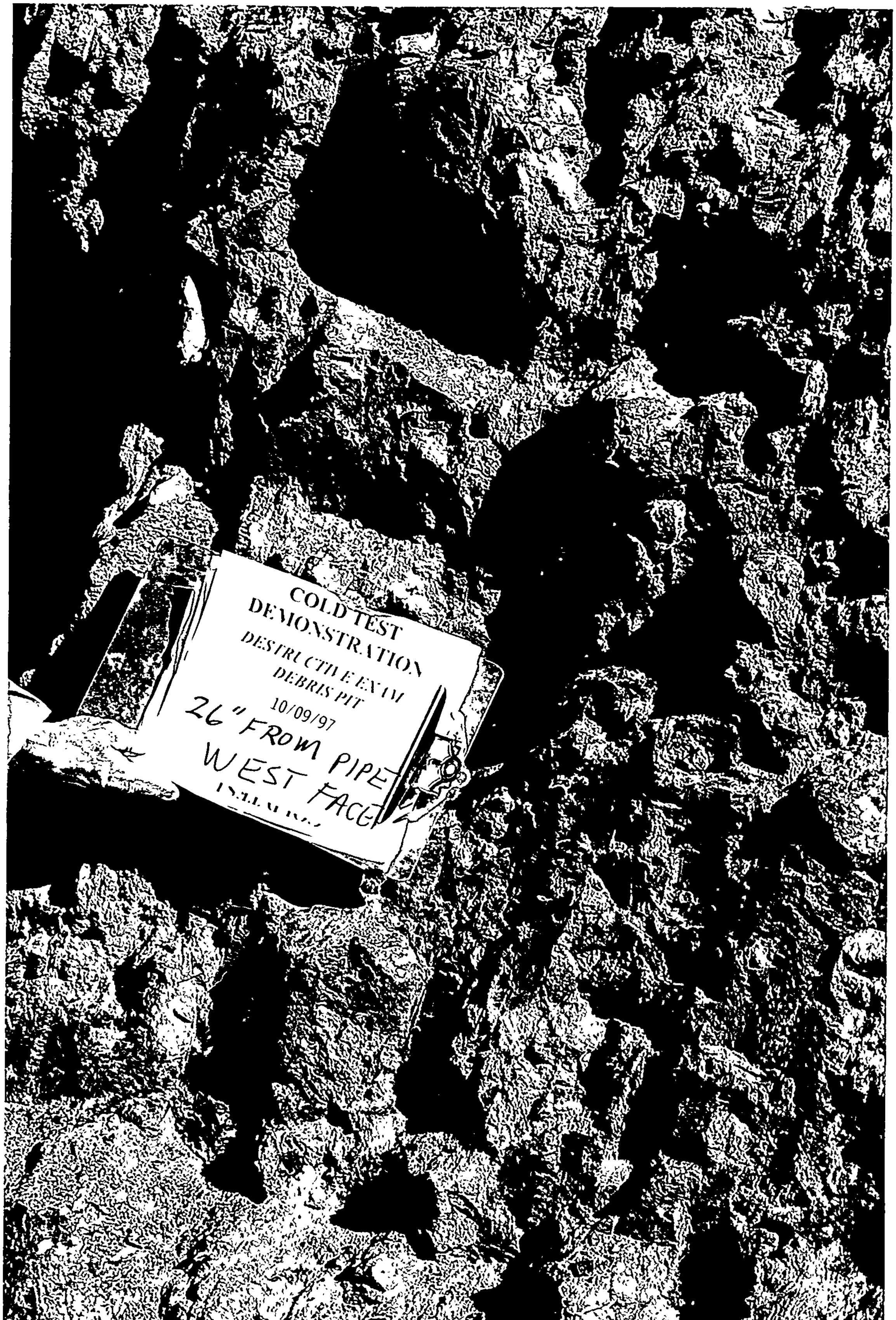


Figure 33. Debris pit 26 in. in from the initial west face (Photo NF972010).

Figure 34. Debris pit 36 in. in from the original west face (Photo NF972014).

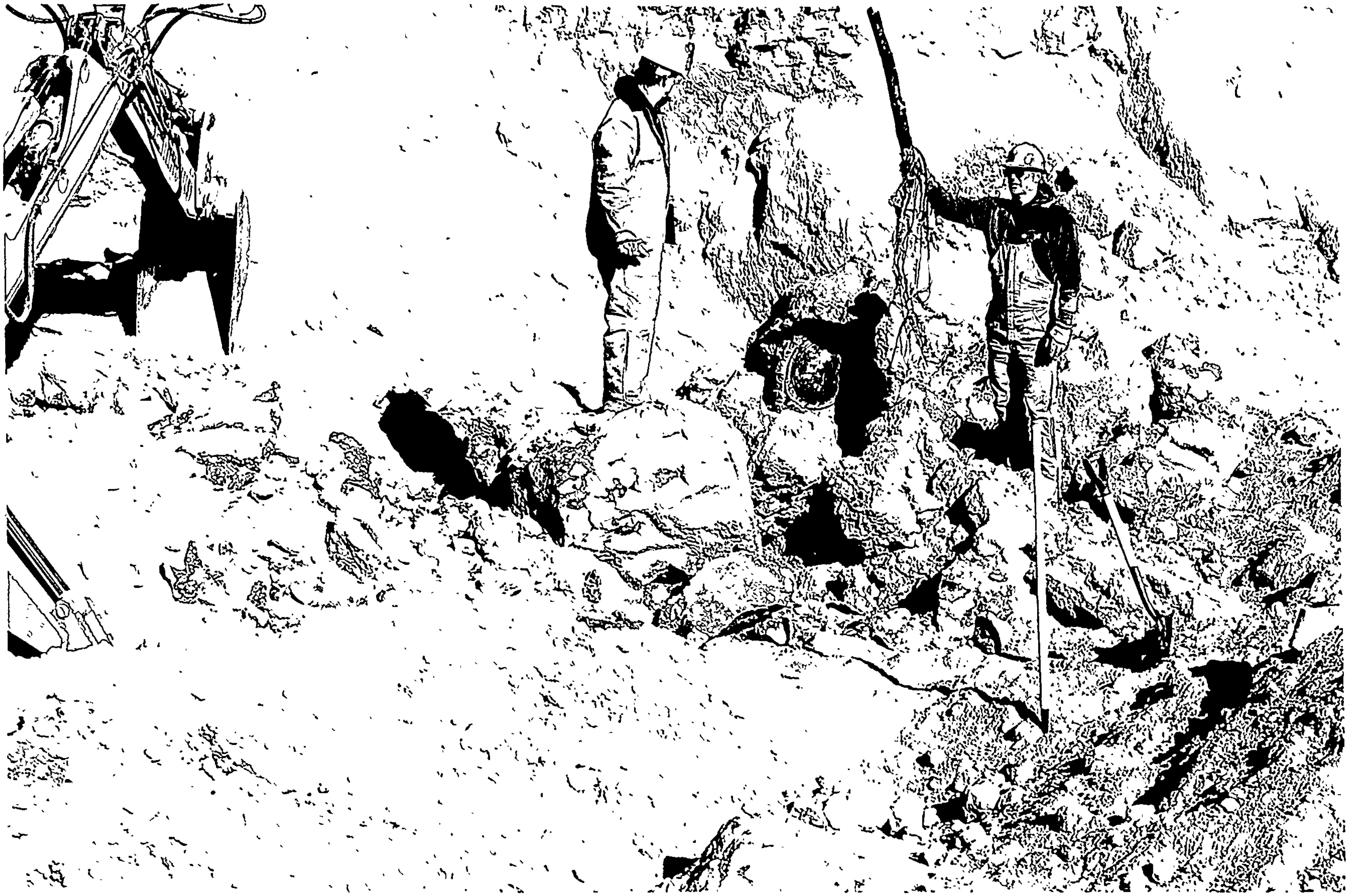


Figure 35. Debris pit rubble following pushing over the remaining monolith at 36 in. from the west wall (Photo NF972030).

management of this grout improves the chances of controlling contamination spread on the surface of the thrust block. During early testing with the DAVY KENT system on the debris pit (holes 1-4) there was some minor dripping that occurred as the drill string was raised and the catch can was placed on the catch cup.

Figure 36 shows the amount of clean grout on the surface for this operation. To mitigate this, a drip pan was fabricated as shown in Figures 8 and 10 to catch the drippings. This was only partially effective because grout still leaked around the hole and some grout was smeared around the hole. A modification was made in that a piece of blotter paper was placed under the drip pan to collect any grout that went down the center hole. These techniques were not totally controlling the drips, so eventually a rubber "squeegee" was used to scrape the small amount of excess grout back into the thrust block hole. In fact, the "squeegee" was used whenever grout emanated to the surface as a surface return. Interestingly enough, within 10 minutes of this operation the surface of the thrust block was dry in an area that had been squeegeed and there was little potential to spread grout around the surface and on equipment such as the tracks on the drill rig. One operational difficulty occurred as the HEPA filter pulled air into the catch cup. When the catch cup was seated into the hole in the thrust block, at times a seal would form; and in several cases the dripping grout was entrained up into the catch cup and in some cases actually entered the HEPA hose arrangement. Upon examination of the HEPA filters, no grout had penetrated that far.

5.1.4.2 System Cleanout Procedures. Purging the system of grout following the day's grouting while minimizing potential secondary waste was found to be fairly straightforward and mostly followed the procedures listed in the test plan.[5] Cleanout of the system by water purge is mandatory at the end of each grouting campaign, because the entire system could become caked with curing grout. The procedure involved maneuvering the drill rig over a catch tank as shown in Figure 37. Next, a rubber "donut" was placed around the drill stem approximately 2 ft above the nozzle assembly breakout point, and the area around the breakout was cleaned with a demineralized water and soap mixture using a chem wipe. The donut kept any contaminated material from flowing down the drill stem and contaminating the cleanout procedure. The drill stem was wiped clean and broken out.

The actual breakout was difficult and was accomplished by using a specially designed pri-bar attached to the drill rig and breakout wrenches. The drill stem required repeated blows of a mallet to facilitate the breakout (standard oil field practice). Once the assembly containing the nozzles was twisted free, a special assembly with a firehose attachment was placed on the drill stem and the fire hose was connected to a portable collection tank. Neat grout was then expelled to the portable collection tank. The system was cleaned out using the Moyno pump and also the high-pressure pump. Cleanout involved about 400-700 gal of flow through the system. The pumping systems were not near the contamination zone and were cleaned out without regard to contamination spread. Excess fluid draining to the ground was controlled using catch bins, since the application of the grouting would eventually be in a radioactive site that disallowed water flowing onto the site. This fluid mixture was managed with absorption material and disposed of a clean administrative waste.

The test plan called for a new "sub" assembly (the assembly at the bottom of the drill stem containing the nozzle) after each cleanout and the old sub became secondary waste. For this cold testing the sub nozzles were cleaned and reused. The neat grout/water mixture in the portable collection tank was sampled for the contaminant molybdenum and found to have a nondetect (see next section for a discussion of contamination control evaluation) following the cleanout

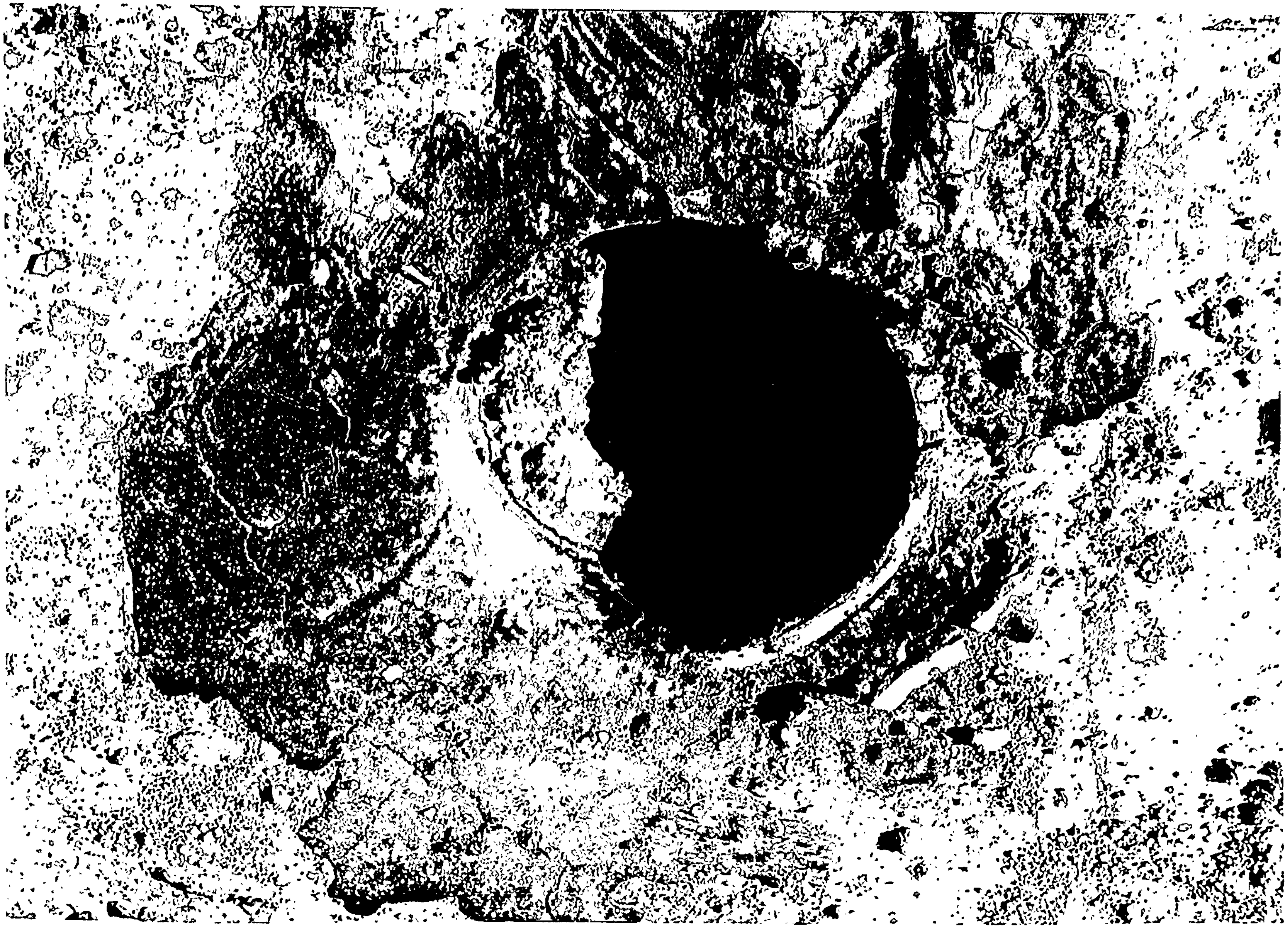


Figure 36. Grout droppings on the surface of the thrust block for grout holes 1-4 in the debris pit (Photo 97-490-1-2A).

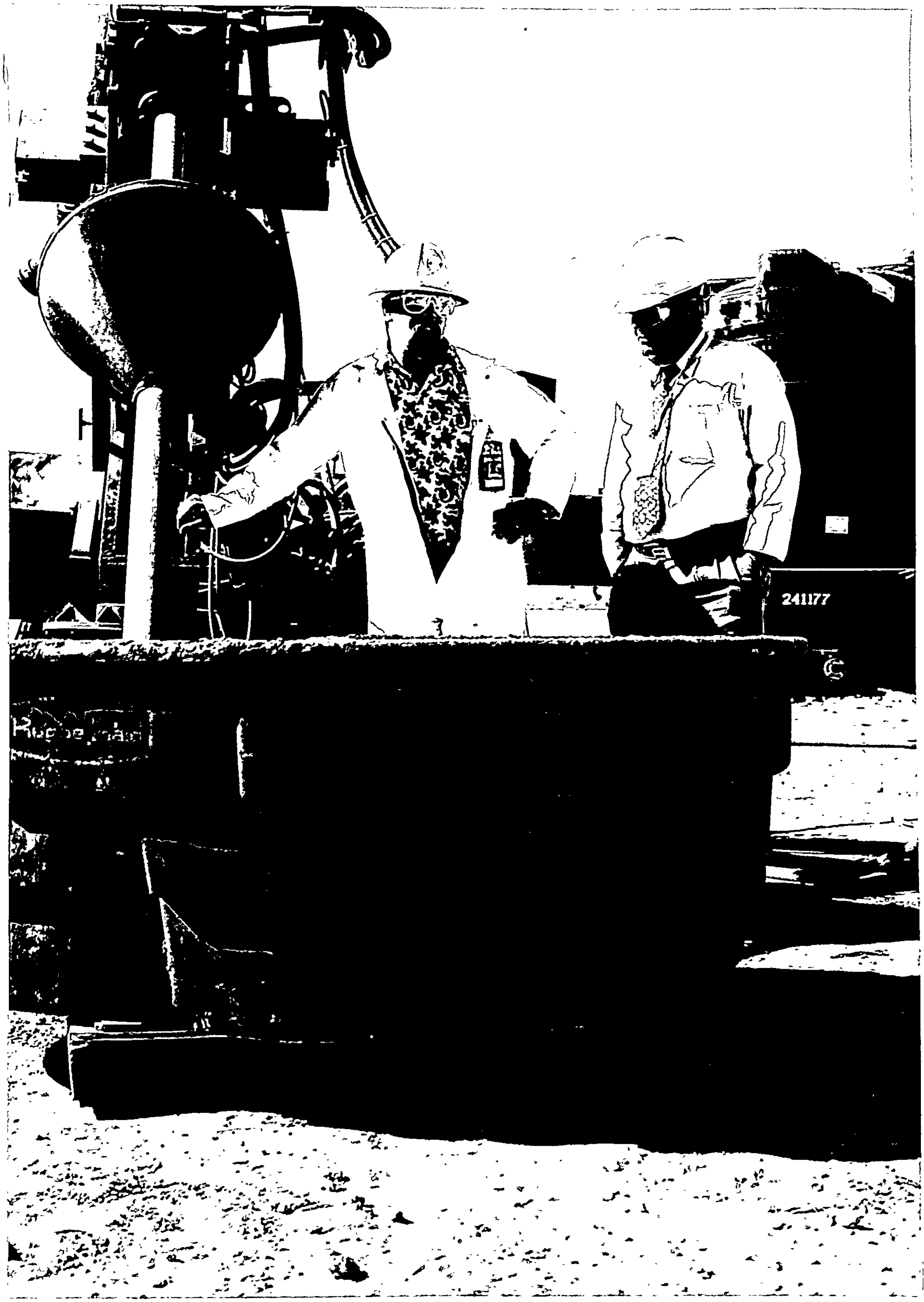


Figure 37. Cleanout catch tank and drill system angled for cleanout (Photo 97-491-2-24).

procedure. Therefore, the collection water could be considered clean for hot operations and could be temporarily stored and then disposed of as clean material. For the first few cleanout procedures, it became apparent that waiting for the drill stem to gravity drain of fluid greatly reduced the amount of fluid material that flowed into the catch tank during breakout. As more experience was gained, the amount of fluid was reduced to a few gallons during breakout.

5.1.5 Evaluation of Thrust Block Performance

The thrust block performed as planned, except that there were much higher than anticipated grout returns, which caused filling of the void space created by the joists down the rows of holes. In addition, the wiper material was found to have too tight of a fit around the drill stem; and the rotational action of the drill stem tended to destroy the wiper during grouting. Both of these deficiencies are easily corrected by simply designing more volume under the thrust block and using a looser fit on the neoprene wiper material. In fact, to make the technology more applicable to contaminated soil sites, the grout returns should be encouraged to ensure that the columns are interconnected. It is recommended that the joists be designed such that the area under the thrust block be grouted in quadrants one at a time. Following initial testing with resultant too high grout returns, the design of the thrust blocks for application in the Acid Pit was changed to include more volume. For the initial design, only 8 gal per hole of grout returns was used; and, in the Acid Pit, the redesign allowed 14 gal per hole. Another modification that would have greatly improved the ability to keep grout under the thrust block would be to block or seal all adjacent positions being grouted with a plug in the holes. This would force grout to flow in the joist, evenly distributing the return rather than coming to the surface near the grouting operation.

5.1.6 Evaluation of Grout Viscosity Effect on Formation of Monolith, Grout Returns

In the development phase of the project and test planning, grout viscosity was assumed to be fixed by the grout vendor; however, using a funnel viscometer, the delivered grout was found to vary between 2:32 to 7:43 minutes. This number is the time for the grout to drain out of a special funnel and a relatively high time correlates to a higher viscosity-thicker material. It is noted that for all viscosities tested, the density of the TECT grout remained at about 18 lbm/gal. Changing from on the order of 2 to 7 minutes in viscosity is enough of a change to visually see the difference in the grout as it flowed out of the viscometer. Since there were many problems with grout returns and heave during grouting, it became apparent that perhaps grout viscosity had an effect on groutability and on the capability of the grout to penetrate the tightly packed clay soils. Table 6 summarizes the data correlating the viscosity, the grout returns, and the description of the resultant monoliths.

The main indication that grout viscosity may affect groutability became apparent when comparing grouting operations for the debris pit holes 5-16 with the CASA GRANDE system with the initial data obtained in holes 1-4 for the debris pit with the DAVY KENT system. Recall that for holes 1-4 in the debris pit the joist never filled with grout during the grouting operation even though they were grouted in the space of a few hours. For this case, the viscosity was on the low end at 2:49 to 3:18 minutes. In addition, recall that in the destructive examination the resultant monolith in that region was the most free of soil occlusions and was the most difficult to retrieve, indicating excellent penetration and mixing of the grout and soil.

Table 6. Effect of grout viscosity on grout returns and resultant column size (grouting in the disturbed soil region).

Viscosity (minutes)	Pit/Field Trial	Description of Grout Returns	Description of Monolith
High-Grout Injected Cases 3–4 s/step 16–24 gal/ft			
2:49–3:18	Disturbed soil field trial (single hole DAVY KENT)	None	Cohesive solid column 22–25 in. average diameter
2:49–3:18	Pit DAVY KENT (debris pit holes 1–4)	Minor <2 in. in joist after grouting 4 holes in a row	Solid cohesive, tight small occlusions of soil
4:02–7:43	Pit (debris pit—CASA GRANDE holes 5–16)	Major returns filled joists of debris pit using "every other" hole strategy	Cohesive but had large 2–4 in. occlusions of soil
7:43	Field trial (debris pit—CASA GRANDE)	None—area heaved during grouting	Cohesive column 18–24 in. diameter
Low-Grout Injected Cases 2 s/step 6.6–10.5 gal/ft			
2:32–2:45	Pit (ORR soil pit—CASA GRANDE holes A–H)	None—8 contiguous holes	Formed large cohesive monolith that was movable as a unit
2:32–2:45	Field trial (ORR soil pit—CASA GRANDE)	None—3 holes triangular pitch	Formed cohesive monolith 36–50 in. irregular shaped well tied together
7:43	Field trial (debris pit—CASA GRANDE)	None—area heaved during grouting	Cohesive column 22–28 in. diameter

Furthermore, the grouting parameters for holes 1-4 were 4 s/step, with nominally 20 gal of grout delivered per foot of column.

For holes 5-16, the grout viscosity was on the high end at 4:02 to 7:43 minutes; and there were joists filling with grout and eventually the grout could not even be emplaced. This grouting operation was performed at a lower grout delivery rate using 3 s/step and eventually 2 s/step (see previous discussion). Even the field trial holes FT-1 and 2 showed some ground heave at the higher viscosity (the viscosity was measured at 7:43 shortly after the field trials were completed). Additionally, when examining the destructive examination data, it was clear that the debris pit monolith east of the row of holes 1-4 had increasingly poorer competence. It is not clear why the viscosity varied significantly from load to load. It was, however, easy to change the viscosity from a too high viscosity to a lower value simply by adding water to the Ready Mix supply tank and mixing.

Additional data are in the Operational Readiness Pit in which eight contiguous holes were grouted at a relatively low viscosity of 2:32-2:45 minutes. A cohesive monolith was formed, and virtually no grout returns occurred, even though the eight holes were continuously grouted in sequence. The basic idea is that the low-viscosity material can more readily access the fine void space of the tightly packed clay materials, resulting in fewer grout returns and better monoliths manifested by fewer inclusions of clay soil.

5.2 Evaluation of Contamination Control

Even though tracer material simulating contaminants was brought to the surface, no uncontrollable spread of the tracer occurred. Contamination control for the grouting operation was evaluated by measuring for the tracer molybdenum (elemental molybdenum powder) in air filters, smears of various surfaces (drill stem and top of thrust block), and grab samples of grout returns.

For both the soil pit operation and the debris pit operation, samples were collected in preselected holes. Overall, there was tracer material brought to the interior surface of the thrust block in the grout returns. Further, there was tracer found on the drill stem. In some cases, minor amounts of tracer were detected on the surface of the thrust block. However, the tracer did not spread to filters in high-volume air samplers strategically spaced around the grouting operation. The basic contamination control strategies employed included a shroud completely surrounding the drill stem connected to a catch cup to focus grout dripping into a catch can, all under relatively negative pressure from a HEPA vacuum, the use of blotter paper, and a drip pan on the surface of the thrust block. In a sense, the thrust block was an additional contamination control device as was the neoprene wiper material in each hole. These systems, shown in Figures 8, 9, 10, and 11, worked as planned to reduce or control the spread of tracer material, suggesting that the system was ready for actual contaminated sites. In addition to evaluating the spread during grouting in the soil pit and debris pit, the spread of tracer material to the water cleanout tanks was also evaluated.

5.2.1 Soil Pit

For the limited amount of holes grouted in the soil pit (holes 1, 2, 14, 15, 18, 19, 22, 23—see Figure 20), smear samples were taken for holes 1, 18, 19, and 22, with the result that large amounts of molybdenum tracer were found in the grab samples of grout under the thrust block and on the drill stem following grouting of a hole. However, very little tracer was found in smears of the surface of the thrust block or in the filters for the high-volume air samplers.

Table 7 gives a summary of inductively coupled plasma-mass spectrometry (ICP-MS) evaluation of smear samples for the drill stem and surface of the thrust block, as well as the grab samples taken below the thrust block. The drill stem samples were obtained by removing a portion of the shroud and smearing the drill stem. An attempt was made to obtain a 100-cm^2 sample for both the drill stem and surface of the thrust block, and 250-mL jars were used to collect material under the thrust block. Examining Table 7, it is seen that the surface of the thrust block remained clean for all holes within 3 standard deviations and for most holes within 1 standard deviation statistics for the ICP-MS process and background levels.

For the grab samples under the thrust block, hole 22 had 10 times background values of the delivered grout and hole 19 had 100 times background; however, holes 18 and 14 had essentially background values of tracer. Hole 1 had virtually no tracer on the drill stem nor the surface of the thrust block nor in a hydrofracture to the west of the pit (discussed in the section on grouting). This is not surprising in that the nearest hole containing tracer was hole 3, which is approximately 4 ft away from grouting. Other tracer holes were 9, 11, 17, and 27. When evaluating samples from hole 18 again, there was no tracer above background even though hole 17 was an adjacent hole. It is speculated that the column size did not extend to the centerline of the tracer hole and therefore did not entrain tracer-rich soil into the grout returns.

However, for hole 19, proximity to a tracer hole was similar to holes 1 and 18 in that the nearest tracer hole was about 4 ft away, even though 100 times background was found in the grab sample of the grout returns. It is possible that the grout during the grouting operation broke through weaknesses in the soil and interacted with a hole that had been spiked with tracer. Interestingly enough, the drill stem smear showed a nondetect for tracer even though the grab sample showed a strong hit. It appears that the wiper material in the thrust block worked for that hole. Hole 23 also showed tracer above background (10x) in the grout returns under the thrust block, which is speculated to have come from hole 19, indicating that the two columns were interconnected (not shown in the destructive examination) at least at some points. Hole 19 is also adjacent to hole 27, which is also a possible source of the simulated contamination.

Examination of the high-volume air filter data shows no tracer above background, even though the tracer material was found on the drill stem and in the grout returns under the thrust block. Table 8 summarizes the air filter ICP-MS evaluations, showing similar results for backgrounds and values taken for exposed filters during grouting.

5.2.2 Debris Pit

Evaluation of the smear and grab samples in the debris pit revealed that, for most positions, there were positive detects of the tracer material. However, for some positions, a large detect for the grout returns did not necessarily lead to tracer spread to the surface. In addition, there was some evidence that the drill stem wiper material worked as designed, in that holes with large detects in the thrust block grout returns had little or no detect on the drill stem smears. The debris pit was spiked with tracer in three holes labeled holes 6, 13, and 15 in Figure 21.

Table 7. Summary of smear and grab sample data for grouting of soil pit (molybdenum analysis).

Location/Type	µg/smear or ppm	Comments
Detection Limit 0.34 µg/smear; 1σ = 0.11 µg/smear		
Background drill stem smear	0.145	Nondetect
Background limit block smear	0.03	Nondetect
Grout sample	2.8 ppm	Base grout sample
Grout return sample hole 1[a]	2.8 ppm	Grout returns in hole 1
Grout returns out hydrofractured hole when grouting hole 1	2.4 ppm	Hydrofracture outside of thrust block when grouting hole 1
Smear thrust block hole 1	0.138	Nondetect
Smear drill stem hole 1	0.025	Nondetect
Smear thrust block hole 18	0.38	Nondetect within 1 σ
Smear drill stem hole 18	0.24	Nondetect
Grab sample of grout returns hole 18	3.0 ppm	Near background grout value
Smear-thrust block hole 19	0.26	Nondetect
Smear-drill stem hole 19	0.21	Nondetect
Grab sample of grout returns hole 19[a]	234.38 ppm	High detect
Smear thrust block hole 22[a]	0.67	Detect at 1 σ nondetect at 3 σ
Smear drill stem hole 22[a]	1.43	Positive hit
Grab sample of grout returns hole 22[a]	24.2 ppm	Ten times background grout sample
Grab sample of grout returns hole 14	3.8 ppm	Barely above background

a. See Figure 21 for order of grouting and hole location.

Table 8. Summary of air filter data for grouting of soil pit (molybdenum analysis).

Location	μg/Filter	μg/m³ Air	Comments
Detection limit ≈ 4 μg/filter			
Background			
HV-1[a]	2.243	0.0251	Nondetect
HV-2[a]	0.518	0.0062	Nondetect
HV-3[a]	1.56	0.0176	Nondetect
HV-4[a]	-0.326	—	Nondetect
HV-5[a]	2.263	0.0264	Nondetect
Grouting Soil Pit (see Figure 21 for grouted holes)			
HV-1[a]	2.327	0.02449	Nondetect
HV-2[a]	0.985	0.01075	Nondetect
HV-3[a]	2.074	0.0213	Nondetect
HV-4[a]	5.568	0.0574	Below detection limit at 1 σ
HV-5[a]	0.664	0.0069	Nondetect

a. See Figure 18 for position of samplers.

However, a total of 12 holes were grouted (holes 5-16—recall holes 1-4 had been grouted with the DAVY KENT system prior to spiking with tracer material).

Examining Figure 21, it is clear that by spiking holes 6, 13, and 15, and further grouting in the order 6, 8, 13, 15, 11, 9, 5, 7, 14, 16, 12, 10, virtually all positions could be influenced by the holes with tracer either by penetrating the actual tracer hole, adjacent positions where the column penetrated the hole, or simply being in a position in a row of holes sharing the thrust block cavity formed by the joists with a hole that had tracer material flowing from a hole that had tracer. As expected, grout holes 6, 13, and 15 all showed large detects for tracer in the grab sample under the thrust block as shown in Table 9, which summarizes all the ICP-MS data from the debris pit grouting campaign. For hole 6, as expected, there was a large detect above background for all three sample locations—drill stem, thrust block surface, and grout returns. However, for hole 8, which is in the same joist as hole 6, there was a large detect for the grout returns (probably from hole 6 grouting); but the drill stem sample was below background, meaning the wiper had worked. Another example of that phenomenon was seen in hole 16 (large detect for the grout returns and a nondetect for the drill stem sample).

Even though there was considerable tracer material on the surface of the thrust block, on the drill stem, and in the returns under the block, no airborne tracer above background was detected in the air filters that were strategically placed around the debris pit thrust block. Table 10 summarizes the data for the air filters, showing that, within 3 standard deviation statistics of the ICP-MS lower levels of detection, there was no tracer collected on the filters. This result was important to the Acid Pit stabilization work for showing that the grouting process could produce some grout returns, even on the surface of the thrust block; however, this material should not be expected to spread to regions beyond the thrust block nor be aerosolized into the worker breathing zone.

5.2.3 Evaluation of the Cleanout Water Sample

The cleanout water portable collection tank was also evaluated for molybdenum tracer and was found to be at the nondetect level as shown in Table 11. Table 11 compares the rinsate water tracer level to that from a sample taken from the collection tank, and both were at nondetect levels. This gave confidence that the cleanout process was valid and that within the boundaries of the INEEL Subsurface Disposal Area, cleanup system flush water could be controlled and removed from the area without monitoring, except for routine health physics monitoring for radioactive materials.

Table 9. Summary of smear and grab sample data for grouting of debris pit (molybdenum analysis).

Location	μg/Filter or ppm	Comments
Detection Limit Smear 0.34 μg/smear; 1 σ = 0.11 μg/smear		
Background drill stem smear	23.3	High background compared to soil pit
Background thrust block smear	0.221	Nondetect
Smear drill stem hole 6[a]	99.5	Large detect
Smear thrust block hole 6	37.7	Large detect
Grab sample grout returns hole 6	144 ppm	Large detect
Smear drill stem hole 8	2.4	Nondetect
Smear thrust block hole 8	0.2067	Nondetect
Grab sample grout returns hole 8	121.51	Large detect
Smear drill stem hole 13	2.039	Detect beyond 3 σ
Smear thrust block hole 13	1.063	Detect within 3 σ
Grab sample grout returns hole 13	567 ppm	Large detect
Smear drill stem hole 15	1.7	Detect beyond 3 σ
Smear thrust block hole 15	1.2	Detect beyond 3 σ
Grab sample grout returns hole 15	443 ppm	Large detect
Smear drill stem hole 9	34.6	Large detect
Smear thrust block hole 9	3.136	Minor detect
Grab sample grout returns hole 9	13 ppm	Minor detect
Smear drill stem hole 7	91.49	Large detect
Smear thrust block hole 7	0.2065	Nondetect
Grab sample grout returns hole 7	259 ppm	Large detect
Smear drill stem hole 16	0.196	Nondetect
Smear thrust block hole 16	4.2	Detect beyond 3 σ
Grab sample grout returns hole 16	494 ppm	Nondetect
Smear drill stem hole 10	0.309	Nondetect
Smear thrust block hole 10	17.0 ppm	Large detect
Grab sample grout returns hole 10	619 ppm	Large detect
Duplicate drill stem 10	2.45	Small detect
Duplicate grab sample 10	589 ppm	Large detect
Blank smear (field packaged)	0.07	Nondetect
Blank smear (field packaged)	0.21	Nondetect

a. See Figure 21 for grouted holes and order of grouting in debris pit.

Table 10. Summary of air filter data for grouting of debris pit (molybdenum analysis).

Location	μg/Filter	μg/m³ Air	Comments
Detection limit ≈ 3.957 μg/filter			
Background			
HV-1	7.188	0.0552	Nondetect within 3 σ
HV-2	2.074	0.0169	Nondetect
HV-3	-0.328	—	Nondetect
HV-4	-0.755	—	Nondetect
HV-5	0.731	0.0056	Nondetect
Grouting Debris Pit (see Figure 21 for grouted holes)			
HV-1	1.328	0.00922	Nondetect
HV-2	3.8	0.0275	Nondetect
HV-3	7.83	0.0532	Detect at 1 σ Nondetect at 3 σ
HV-4	7.017	0.0477	Detect at 1 σ Nondetect at 3 σ
HV-5	3.88	0.0236	Nondetect
Blank filter (field sample)	-2.276	—	Nondetect
Blank filter (field packaged)	3.068	—	Nondetect

Table 11. Summary of water sample evaluation of molybdenum.

Sample	μg/l	Comments
Equipment rinsate	-2.4	Nondetect
Water sample from cleanout tank	-0.296	Nondetect

6. DISCUSSION OF RESULTS—RELEVANCE OF DATA

The importance of cold testing prior to performing hot activities was demonstrated with the testing performed at the INEEL Cold Test Pit in support of the Acid Pit stabilization. Although besieged with multiple problems, testing at the Cold Test Pit culminated in the successful grouting of the Operational Readiness Pit. The results of that grouting campaign gave confidence that a set of parameters had been developed that were applicable to the Acid Pit stabilization, which was scheduled immediately after the Operational Readiness Pit. The problems that the project had faced were compounding and included (1) an unfortunate choice for the soil site with the tightly packed clays, (2) the original drill system (DAVY KENT) could not efficiently penetrate the soils, (3) grouting parameters obtained from prior grouting in debris did not apply to soil only and development was required. Additionally, it was originally planned to use the cold testing results to help define any needed design changes to the thrust block for application. Based on testing, it was decided that the volume between the joists should be increased to allow 14 gal of grout returns per hole. Without the process of eliminating problems during cold testing, the hot demonstration would have encountered unacceptable problems. Because of this, it is highly recommended that any hot operations in the SDA be checked out in full-scale cold testing before proceeding.

A different technique would be required to create monoliths in tightly packed hard clay soils (nominally where the number of blows per foot approached 50). There are several ideas that may facilitate the creation of columns in the tightly packed clay soil zones. One idea is to allow more cavity volume under the thrust block and use more energy (grouting pressure). One potential problem with this idea is that there may be a tendency for total ground heave under the thrust block when applying more energy. Another idea is to use a smaller nozzle size and more time on a step, although the nozzle size can only become so small before plugging occurs. All of these new ideas would require further testing prior to application. Without further testing, there is a current limit of the technology to areas where the soil is more loosely packed (nominally where the number of blows per foot are on the order of 20). The thrust-block concept protects workers from potentially contaminated grout returns and also allows easy viewing of grout drippings and/or returns that may encounter the surface due to the contrast of the grout on top of the thrust block. Evidence suggests that contaminated grout in the form of returns or present on surfaces that encounter the waste directly acts to bind or preclude contaminant spread as in the monolith structure. The wiper material was effective at cleaning the drill string surface, but it appeared to have been too tight on the drill stem. A simple fix would be to use a looser tolerance on the drill stem.

Although no organized parametric study was performed on the effect of grout viscosity on monolith formation, it is suspected that TECT grout viscosity played a large role in groutability (grout returns and quality of the monolith). The grouting contractor could control grout density easily because there was very little variation in grout density even though the grout viscosity varied as much as a factor of 3. The viscosity could be changed by adding small amounts of water. The basic indication is that the lower viscosity materials had lower surface tension and could more easily access voids in the soils. Another phenomenon is that with the lower viscosity fluids, particulate tended to not stay in solution as well; and the pumping system tended to filter cake and cause work stoppage due to plugging.

When comparing the size of the excavated monoliths versus the volume of grout injected, there was considerable difference between the Operational Readiness Pit and the debris pit. For the debris pit, the total amount of emplaced grout (grout injected minus grout returned to the surface) was 1280 gal or 171 ft^3, while the monolith volume was 522 ft^3. This resulted for the debris pit in a calculated void filling of 32%. The Operational Readiness Pit had a total emplaced grout volume of 72 ft^3, while the volume of the monolith was approximately 133 ft^3 or a void filling of 54%. Again, the viscosity may have played a role in accessing more voids in the Operational Readiness Pit, which had a relatively low-viscosity grout compared with that used for most of the debris pit (average viscosity for the Operational Readiness Review Pit was 2:30 minutes and the debris pit was 4-7 minutes). Grout viscosity alone cannot explain the differences because there were other competing factors, including the fact that there was more grout delivered per foot on average for the debris pit (15 gal/ft) compared with the Operational Readiness Pit (6–7 gal/ft). It would be expected that, with the higher amount of grout delivered on any step, the surrounding soils could have been mixed more effectively, resulting in a grout-rich monolith which does not agree with the comparison of grout emplaced versus the monolith size. A full evaluation of the actual density of the grout columns is required to correctly evaluate this phenomenon and, unfortunately, is beyond the scope of this study.

Overall, even though many physical and technical difficulties developed during the Cold Test Pit testing, following grouting of the Operational Readiness Pit, there was generated a high degree of confidence that the technology was ready for actual application in the Acid Pit, assuming that the Acid Pit soils proved to be similar to the disturbed soils at the Cold Test Pit.

7. CONCLUSIONS/RECOMMENDATIONS

Below are five conclusions followed by general recommendations:

1. The technique of creating monoliths out of contaminated soil sites by jet grouting is practicable; however, adjustments to the grouting parameters compared with grouting in buried debris sites are required. Generally, when grouting soil only, there is a higher grout return than when grouting debris.

2. Soil sites can be grouted without spreading airborne contaminants, primarily because the contaminants are locked into a grout matrix and because of the combined use of contamination control devices, such as the thrust block with wiper assemblies, the drill stem shroud, the catch can and cup and drip pan, and blotter paper.

3. Thrust blocks can be easily manufactured and transported to remote sites and can be built to withstand 50,000 lbm drill rigs with tracked wheels. In addition, it was demonstrated that the thrust block can be reused.

4. Cleanup of grouting equipment can be accomplished without spread of contaminants to rinse waste and cleanup collection tanks, and application to a hot site is straightforward.

5. When creating monoliths out of tightly packed contaminated clay soil sites, rotopercussion drilling is mandatory. This is primarily because the time for drilling to depth is shortened with rotopercussion, and the amount of drilling fluid (grout) that extends to the surface is minimized. A CASA GRANDE C8 class drilling rig was used for this testing; however, a CASA GRANDE C6 class drilling rig with rotopercussion is adequate.

6. Application of this technology in undisturbed tightly packed hard clays (with nominally 50 blows/ft) compaction would require a separate development effort involving variations in nozzle size, pumping pressure, and grout return management. In addition, penetration of these sites requires large drive force devices with minimal drilling fluid.

It is recommended that the thrust block be redesigned to accommodate more volume under the block. In addition, it is recommended that a single quadrant be completed first and that grouting parameters be set to ensure some interaction among the various holes under the block. It is further recommended that a packer system or simple plug be used in the ungrouted holes to prevent high-viscosity grout material from flowing to the surface of the thrust block. It is also recommended to reduce the tolerance of the wiper material to allow more durability during drilling/grouting.

It is recommended that for the TECT grout a parametric study be performed involving variations in TECT grout viscosity, nozzle size (and number), revolutions per step, and step time relative to column size. This parametric would involve both single and multiple connected holes.

It is recommended that the technology be pursued for hot sites such as the INEEL Acid Pit, where stabilization is the Record of Decision. It is further recommended that, for these applications, a geotechnical evaluation involving the number of blows per foot, soil size, and estimated void space be obtained before setting grouting parameters and thrust block design in a cold site with similar geotechnical conditions as the hot site.

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Appendix A

Viscosity, Density Measurements—Cold Test Demonstration

Table A-1.

Viscosity and Density Measurements -- Cold Test Demonstration

Cold Test Demonstration - Phase I

Date	Time	Density (lbs/gal)	Viscosity (min:sec)	Comments
06/23/97	1430	18.5	3:49	Batch sample before grout emplacement. Grouting problems, material sent back to Idaho Falls for reuse on 06/24/97.
06/24/97	1015	17.7	3:18	Mixture from 06/23/97. Batch sample before grout emplacement.
	1410	17.6	2:49	Batch sample after completion of grout emplacement.

Cold Test Demonstration - Phase II

Date	Time	Density (lbs/gal)	Viscosity (min:sec)	Comments
08/27/97	1340	18.1	4:59	Batch sample before grout emplacement.
08/28/97	0945	16.5	1:28	Batch sample before grout emplacement.
	0955	14.7	1:33	Added 30 gallons of water.
	1410	15.4	1:33	Bad load mixture. Load not used for grout emplacement. Returned to Idaho Falls.
08/29/97	1000	17.8	7:23	Batch sample before grout emplacement. Mixture too viscous, added 40 gallons of water to lower viscosity.
	1015	17.7	5:20	Added 30 gallons of water to lower viscosity.
	1040	17.5	4:02	Added 20 gallons of water to lower viscosity.
	1405	17.7	7:43	Batch sample after completion of grout emplacement. Observed separation of grout components.

Cold Test Demonstration - Phase III

Date	Time	Density (lbs/gal)	Viscosity (min:sec)	Comments
09/12/97	1045	18.2	2:45	Batch sample before grout emplacement
	1315	17.8	2:32	Batch sample after grout emplacement

Table A-2. Cold Test Demonstration--Phase I.

Date	Location	Hole No.	Drill Depth	Drill Time	Drill Grout Volume: Gallons	Drill Grout Volume: Gallons per foot	Grouting Interval: Depth Interval	Grouting Interval: Time to Grout	Grouting Volume: Pumping pressure (psi)	Grouting Volume: Gallons	Grouting Volume: Gallons per foot	Grout Returns	Comments
06/23/97	Soil Pit	FT-1	13'	16:00	115	7.2	5 - 13'	NR	'6000	181	22.6	Not recorded Excessive returns	Difficult drilling conditions, used over 100 gallons for drilling through tight soils. Copious returns discharged from test hole.
06/24/97	Debris Pit	FT-1	10'	1:10	67	6.7	5 - 10'	NR	6000	134	26.8	20 gal	Step Rate = 6 sec/step Viscous grout return Problems with system plugging, used more grout for drilling than expected.
		FT-2	10'	1:17	28	2.8	5 - 10'	NR	6000	134	26.8	50 gal	Step Rate = 6 sec/step Viscous grout returns FT-2 connected to FT-1
		FT-3	10'	2:21	28	2.8	5 - 10'	NR	6000	90	18.0	10 gal	Step rate reduced from 6 sec/step to 4 sec/step. Difficult drilling bottom 2' of hole.
		32	11'	2:03	34	3.1	5 - 11'	NR	6000	105	17.5	Row 1: 1"	Step Rate = 4 sec/step Low viscosity returns No surface returns
		30	11'	3:18	42	3.8	5 - 11'	NR	6000	104	17.3	Row 1: 2" Row 2: 0.5" Row 3: 0.25" Row 4: Dry	Step Rate = 4 sec/step Low viscosity returns No surface returns Downtime for 1 hour to allow grout to partially cure.
		31	11'	3:20	21	1.9	5 - 11'	NR	6000	99	16.5	Row 1: 3.5" Row 2: 1.75" Row 3: 1.0" Row 4: 0.75" Row 5: trace	Step Rate = 4 sec/step Low viscosity returns No surface returns Used 67 gal of total fluid for drilling, ~46 gal used to unplug jet nozzles.
		29	11'	2:58	25	2.3	5 - 11'	NR	6000	107	17.8	Row 1: 4.0" Row 2: 2.0" Row 3: 0.5" Row 4: 0.25" Row 5: 0.25" Row 6: 0.25" Row 7: Dry	Step Rate = 4 sec/step Low viscosity returns No surface returns No visible heave of thrust block
		FT-5	6'	1:07	20	3.3	2 - 6'	NR	6000	71	17.8	No returns	Step Rate = 4 sec/step Pump failure after completion of hole.

COLD TEST DEMONSTRATION - PHASE II

Date	Location	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
08/27/97	Soil Pit	FT-1	8'	0:30	NR	-	3 - 8'	2:22	6000	163	32.6	SR: 7 to 8 gal SW of test area & 0.5 gal inFT.	Hydrofracturing, grout discharging from surface ~10' southwest of test area. Drill stem pulled out of hole to unplug nozzles. Roto-per: 6 - 8'
		FT-2	8'	NR	NR	-	3 - 8'	2:24	6000	114	22.8	FT-2: 22 gal FT-1: 0.5 gal	Viscous grout return Roto-per: occ
		FT-3	8'	NR	NR	-	3 - 8'	2:25	6000	109	26.8	No grout returns	Surface heave around test area, ~1' high covering 4' area.
	Soil Pit	1	10'	0:30	15	1.5	5 - 10'	2:17	6000	97	19.4	Blk: SR 1 gal Blk Westside: 0.25 gal	Copious surface returns. Joist nearly full of viscous grout. Returns also from Seismic Source Hole #6.
		2	10'	1:15	7	0.7	9 - 10'	NR	6000	31	31.0	SR	Stopped grouting due to excessive surface returns.
		15	10'	0:45	11	1.1	5 - 10'	2:42	6000	106	21.2	Hole 15: 4" Hole 16: Dry	No surface returns Tight at bottom of hole.
		18	10'	1:01	17	1.7	5 - 10'	2:40	6000	89	17.8	Hole 17: 1" Hole 19: 1"	Thrust block separated (heave?) Roto-per: Bottom 2' (32 sec) No surface returns
		19	10'	1:00	21	2.1	5 - 10'	2:50	6000	102	20.4	Hole 20: 0.5"	Erratic pump flow, pump problems? Thrust block heaved No surface returns Roto-per: Bottom 4' (40 sec)
		22	10'	0:40	11	1.1	5 - 10'	2:45	6000	105	21.0	Hole 16: Full Hole 17: Full Hole 22: Full	No surface returns Roto-per: Bottom (15 sec)
		23	10'	0:41	14	1.4	5 - 10'	2:30	6000	96	19.2	Hole 22: SR Hole 24: 3" Hole 21: Full N of 21: Full	Roto-per: None
		14	10'	1:00	9	0.9	5 - 10'	2:55	6000	112	22.4	Hole 13: Dry	No surface returns Roto-per: Bottom (30 sec) Thrust block: 6" heave in center & 1" separation between the blocks.
08/28/97	Debris Pit	6A	9'	2:00	38	4.2	-	-	6000	-	-	-	Pumping problems, bad grout mixture plugged high pressure pump. Shutdown for day to return grout mixture and clean out pump & lines. Roto-per: Surface to TD, resistive drilling.

					Drill Grout Volume		Grouting Interval		Grouting Volume				
Date	Location	Hole No.	Drill Depth	Drill Time	Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot	Grout Returns	Comments
08/29/97	Debris Pit	6B	9'	NR	19	2.1	6 - 9'	1:45	6000	80	26.7	Hole 5: 2"	Step Rate = 3 sec/step Total grout volume = 99 gal System plugging, pulled out drill stem to cleanout nozzles.
		6C	9'	NR	5	0.83	3 - 6'	0:45	6000	39	13.0	Hole 5: 2"	Step Rate = 3 sec/step Total grout volume = 44 gal Completed grouting of Hole 6 in stages.
		8	9'	1:00	3	0.33	3 - 9'	2:41	6000	78	13.0	Hole 5: 2" Hole 8: 6"	Step Rate = 3 sec/step Total grout volume = 86 gal Problem with reaching high pressure quickly (1 to 2 min before starting grouting). Possible thrust block heaving? Roto-per: Surface to TD (30 sec).
		13A	9'	0:30	8	0.89	7 - 9'	NR	6000	48	24.0		Step Rate = 3 sec/step Total grout volume = 62 gal Downtime for 40 min to replace plugged screen on Moyno pump.
		13B	7'	0:21	20	2.2	3 - 7'	1:44	6000	72	18.0	Hole 13: 4" Hole 14: 5"	Step Rate = 3 sec/step Total grout volume = 95 gal Unsure if grout volume are accurate due to plugging problems.
		15	9'	0:46	6	0.66	3 - 9'	2:12	6000	82	13.6	4" under thrust block	Step Rate = 3 sec/step Total grout volume = 91 gal Roto-per: Smooth drilling, no roto-percussion
		11	9'	1:15	8	0.89	3 - 9'	1:51	6000	70	11.7	4" under thrust block	Step Rate = 3 sec/step Total grout volume = 86 gal Roto-per: Smooth drilling, no roto-percussion
		9	9'	0:40	9	1.0	3 - 9'	1:49	6000	69	11.5	4-5" in joist	Step Rate = 3 sec/step Total grout volume = 84 gal Roto-per: Smooth drilling, no roto-percussion
		5	9'	0:55	1	0.11	6 - 9'	0:42	6000	27	9.0	SR	Changed step rate from 3 sec/step to 2 sec/step. Stopped grouting after 3' due to excessive grout returns to surface. Thrust block heaving - 1" Total grout volume = 33 gal

Date	Location	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/29/97	Debris Pit	7A	9'	0:43	3	0.33	8 - 9'	0:20	6000	7	7.0	SR	Stopped grouting after 1' due to excessive surface returns. Raised drill stem 2' & attempted to complete grouting Step Rate = 2 sec/step Total grout volume = 15 gal
		7B	-	-	-	-	6 -6'	NR	6000	15	-	SR: 3 gal	Immediate surface returns when started grouting. Abandoned hole. Step Rate = 2 sec/step Total grout volume = 22 gal
		14	9'	0:47	4	0.44	3 - 9'	1:16	6000	49	8.2	No returns	Step Rate = 2 sec/step Total grout volume = 58 gal Thrust block heaved during grouting.
		16	9'	0:35	8	0.89	3 - 9'	1:25	6000	55	9.2	Hole 13: SR Hole 15: SR	Step Rate = 2 sec/step Total grout volume = 67 gal Surface returns at the end of grouting from Holes 13 & 15.
		12	9'	NR	7	0.78	3 - 9'	1:13	6000	48	8.0	SR	Step Rate = 2 sec/step Total grout volume = 60 gal
		10	9'	0:40	8	0.89	9 - 9'	NR	6000	1	-	SR	Stopped grouting due to immediate surface returns. Thrust block raised 1-2". Step Rate = 2 sec/step Total grout volume = 15 gal
	Debris Pit	FT-1	6'	-	8	1.3	2 - 6'	-	6000	35	8.8	-	Step Rate = 2 sec/step Total grout volume = 48 gal Area heaved during grouting
		FT-2	6'	-	8	1.3	2 - 6'	-	6000	55	13.8	-	Step Rate = 3 sec/step Total grout volume = 69 gal Area heaved during grouting

COLD TEST DEMONSTRATION - PHASE III

Date	Location	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/12/97	ORR Pit	A	17'	1:38	11	0.65	11-17'	1:27	6000	63	10.5	No surface returns Hole A: 1 gal	Step Rate: 2 sec/step Total grout volume = 77 gal Took 20 sec to reach HP Watery grout mixture Grout used for setting parameters Roto-per: 7 - 11'
		B	17'	1:54	25	1.5	11- 17'	1:10	6000	48	8.0	-	Step Rate: 2 sec/step Total grout volume = 74 gal Took 4 sec to reach HP Roto-per: 0 - 1' & 5 -10'
		C	17'	1:16	18	1.1	11 - 17'	1:01	6000	43	7.2	No grout returns, surface spillage around hole	Step Rate: 2 sec/step Total grout volume = 59 gal Took 4 sec to reach HP Roto-per: 5.5 - 13'
		D	17'	1:06	12	0.71	10 - 17'	1:09	6000	46	6.6	Minor surface spillage	Step Rate: 2 sec/step Total grout volume = 61 gal HP immediately Turned off HEPA to drain access hole (vacuum causing surface spillage). Roto-per: No roto-percussion
		E	17'	1:38	16	0.94	11 - 17'	1:02	6000	41	6.8	Minor surface spillage	Step Rate: 2 sec/step Total grout volume = 60 gal HP immediately Roto-per: 0 - 3', 4 - 6', & 11 - 14'. Major resistance from 11 - 14'.
		F	17'	1:44	17	1.0	11 - 17'	1:06	6000	46	7.7	Minor surface spillage	Step Rate: 2 sec/step Total grout volume = 66 gal HP immediately Roto-per: 1' - TD. Near surface resistive layer caused rig to lift & spraying of drill foot with grout.
		G	17'	2:38	22	1.3	11 - 17'	1:06	6000	44	7.3	Minor surface spillage	Step Rate: 2 sec/step Total grout volume = 70 gal HP immediately Roto-per: 1' - TD, major at 5'
		H	17'	2:37	23	1.4	11 - 17'	0:58	6000	41	6.8	Minor surface spillage	Step Rate: 2 sec/step Total grout volume = 67 gal HP immediately Roto-per: 5' - TD

Date	Location	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/12/97	ORR Pit	FT-1	17'	1:05	14	0.82	5 - 17'	1:59	6000	78	6.5	-	Step Rate: 2 sec/step Total grout volume = 95 gal HP immediately Roto-per: 8' - TD
		FT-2	17'	1:33	16	0.94	5 - 17'	2:01	6000	83	6.9	-	Step Rate: 2 sec/step Total grout volume = 103 gal HP immediately Roto-per: 5.5 - 13'
		FT-3	17'	1:15	15	0.88	5 - 17'	2:12	6000	89	7.4	-	Step Rate: 2 sec/step Total grout volume = 107 gal HP immediately Roto-per: 5.5 - 13'

ACID PIT STABILIZATION

Date	Grout Sequence No.	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/22/97	1	31	16'	2:00	10	0.63	5 - 16'	2:03	6000	82	7.5	Hole 32: 0.25"	Used 3 gallons to set grouting parameters. Total grout volume = 98 gal. Total time to grout hole = 18 min. Roto-percussion: O- 7'
	2	29	17'	2:00	9	0.53	5 - 17'	2:13	6000	84	7.0	Hole 30: 0.38" Hole 32: 2"	Total grout volume = 96 gal. Total time = 12 min. Roto-percussion: 0- 7' Viscous grout return
	3	27	17'	2:00	11	0.65	5 -17'	2:31	6000	94	7.8	Hole 28: 0.5" Hole 30: 4.5" Hole 32: 2"	Total grout volume = 109 gal. Total time = 15 min Roto-per at top, no resist to TD. Holes 30 & 32 - viscous grout
	4	25	17'	NM	13	0.76	5 - 17'	NM	6000	100	8.3	Hole 28: 4.5" Hole 30: 3" Hole 32: NM Hole 26: 2"	Total grout volume = 116 gal. Total time = 15 min Holes 28, 30 & 32 - viscous grout
	5	23	16'	2:00	10	0.63	5 - 16'	2:09	6000	81	7.4	Hole 28: 9" Hole 30: 4" Hole 32: 2"	Total grout volume = 94 gal. Total time = 16 min Holes 25 & 26 - joist is full of viscous returns. Grout visible in all southeast access holes.
	6	21	15.5'	NM	10	0.65	9 - 15.5'	1:50	6000	56	8.6	Hole 26: SR	Stopped grouting, surface returns from Hole 26. Total grout volume = 69 gal. Total time = 28 min [clean up of returns]. Joist full of viscous grout for Holes 32, 30, 28, 26, 25. Changed grouting interval to 8'.
	7	19	16'	NM	14	0.88	8 - 16'	1:53	6000	60	7.5	Hole 22: 7.5" Hole 21: 8.5" Hole 19: Dry	Total grout volume = 76 gal. Total time = 14 min.
	8	17	16'	2:00	12	0.75	8 - 16'	1:35	6000	56	7.0	Hole 21: 11" Hole 22: 9"	Total grout volume = 71 gal. Total time = 10 min.
	9	15	16'	2:00	9	0.56	8 - 16'	1:37	6000	58	7.3	Hole 18: 7.5" Hole 21: 2"	Total grout volume = 71 gal. Total time = 10 min. Viscous grout returns
	10	16	16'	2:00	9	0.56	8 - 16'	1:18	6000	50	6.3	Hole 18: 8" Hole 21: Full Hole 20: 3.5" Hole 22: 9"	Total grout volume = 61 gal. Total time = NM

Date	Grout Sequence No.	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/22/97	11	18	16'	2:00	10	0.63	8 - 16'	1:28	6000	52	6.5	Hole 18: Full of neat grout Hole 22: 9.5" Hole 61: 0.5"	Total grout volume = 65 gal. Total time = 10 min. Northside filled with 0.5" of grout.
	12	20	16'	NM	9	0.56	Not grouted	-	-	-	-	Hole 18: SR	Did not grout. Neat grout came up Hole 18 when drilling to TD.
	13	32	15.5'	4:00	9	0.58	8 - 15.5'	1:40	6000	53	7.1	Hole 27: 9"	Total grout volume = 65 gal. Total time = 10 min. Moved to east side of joist. No obvious grout returns. @1:53 grout in Hole 27 had partially cured (stiff).
	14	30	15.5'	1:00	9	0.58	8 - 15.5'	1:25	6000	53	7.1	Hole 27: SR Hole 29: 6"	Total grout volume = 66 gal. Total time = 9 min.
	15	28	16'	1:00	10	0.63	10 - 16'	1:10	6000	36	6.0	Hole 29: SR Hole 53: Dry Hole 22: 9"	Stopped grouting at 10' due to grout returns. Total grout volume = 49 gal. Total time = 17 min. (Return cleanup) Grout in Hole 27 had harden (cured or set up).
	16	24	16'	1:00	9	0.56	8 - 16'	1:26	6000	47	5.9	Hole 28: Minor SR Hole 22: 8.5" Hole 25: Full	Avoided Hole 26 due to concerns of grout returns to surface. Total grout volume = 57 gal. Total time = 10 min.
	17	20	16'	NM	6	0.38	Not grouted	-	-	-	-	-	Hole 20 connected to Hole 18. Abandoned Hole.
09/23/97	18	22	15.5'	2:00	5	0.32	8 - 15.5'	1:34	6000	61	8.1	Hole 21: Full	Total grout volume = 68 gal. Total time = NM Watery grout mixture (low viscosity grout)
	19	20	16'	NM	6	0.38	Not grouted	-	-	-	-	-	Abandoned.
		26	-	-	-	-	-	-	-	-	-	-	Did not grout, abandoned hole. Concerns with grout returns to surface (joist full & connection between grout holes).
	20	57	15'	2:00	6	0.4	8 - 15'	1:26	6000	53	7.6	Hole 58: 0.25"	Total grout volume = 61 gal. Total time = 11 min

Date	Grout Sequence No.	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/23/97	21	53	15.5'	NM	4	0.26	8 - 15.5'	1:33	6000	51	6.8	Hole 58: 3.5" Hole 54: 0.5" Hole 57: 5"	Total grout volume = 57 gal. Total time = 9 min Some grout coming up adjacent joist. Roto-per: 3 - 7'
	22	49	16'	NM	7	0.44	8 - 16'	1:46	6000	63	7.9	Hole 22: SR (2-3 gal) Hole 54: 3.5" Hole 50: 0.5"	Total grout volume = 72 gal. Total time = 15 min Covered thrust block to prevent rig contamination Roto-per: 3 - 7'
	23	58	15.5'	2:00	5	0.32	8 - 15.5'	NM	6000	66	8.8	Hole 58: 5" Hole 50: 0.5"	Total grout volume = 74 gal. Total time = 9 min Thick (viscous) returns in Hole 58. Roto-per: 3 - 8'
	24	54	15.5'	2:00	3	0.19	8 - 15.5'	1:36	4500	59	7.9	Hole 53: Full Hole 50: 3"	Total grout volume = 65 gal. Total time = 14 min Cut back pressure to 4500 psi. Roto-per: 2 - 6'
	25	50	15.5'	2:00	4	0.26	11- 15.5'	1:10	4500	37	8.2	Hole 50: SR	Stopped grouting at 11', surface returns up Hole 50. Total grout volume = 43 gal. Total time = 17 min Roto-per: 3 - 8' & 9-10'
	26	61	16'	2:00	4	0.25	8 - 16'	1:45	4500	62	7.8	Hole 62: 1.5"	Total grout volume = 69 gal. Total time = 9 min No visible returns Roto-per: 3 - 8'
	27	65	16.5'	2:00	6	0.36	8 - 16.5'	NM	4500	66	7.8	Hole 61: 4"	Total grout volume = 75 gal. Total time = 12 min No surface returns Roto-per: 2 - 8'
	28	62	16.5'	2:00	4	0.24	8 - 16.5'	1:50	4500	71	8.3	Hole 61: 9"	Total grout volume = 79 gal. Total time = 11 min No surface returns Roto-per: 4 -7' (hrd)
	29	45	16'	2:00	3	0.19	11 - 16'	0:54	6000	36	7.2	Hole 49: SR	Stopped grouting, surface returns up Hole 49 Total grout volume = 41 gal. Total time = 26 min Joist full for Holes 50, 51, & 52 Roto-per: 3-8' Adjusted parameters - increased pressure to 6000 psi

Date	Grout Sequence No.	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/23/97	30	60	15'	2:00	3	0.20	8 - 15'	1:27	6000	59	8.4	Hole 59: 8"	Changed grouting sequence - every other hole & every other row. Total grout volume = 65 gal. Total time = 13 min Joist nearly full with grout returns Roto-per: 5 -11' & 14.5'-TD.
	31	52	16'	2:00	3	0.19	10 - 16'	1:07	6000	42	7.0	Hole 59: SR	Stopped grouting at 10' due to surface returns up Hole 59. Total grout volume = 50 gal. Total time = 8 min Joist full under Holes 52 & 59. Roto-per: 2 - 8'
	32	44	16'	NM	8	0.50	Not grouted	-	6000	1	-	Hole 52: SR	Hole not grouted, surface returns up Hole 52 when started high pressure injection. Total grout volume = 12 gal. Total time = 10 min Roto-per: 1.5 - 3.5'
	33	36	16'	NM	9	0.56	8 - 16'	1:20	6000	56	7.0	Hole 34: 1" Hole 35: 1.5"	Total grout volume = 68 gal. Total time = 12 min Roto-per: 3-5', 10' (hard from surface - 3')
	34	64	16.5'	6:00	4	0.24	8 - 16.5'	1:43	6000	70	8.2	Hole 63: 2.5"	Total grout volume = 78 gal. Total time = 9 min Viscous grout returns Roto-per: 3.5 -5'
	35	02	16'	NM	3	0.19	8 - 16'	1:32	6000	63	7.9	No returns in joist	Total grout volume = 69 gal. Total time = 15 min Roto-per: 3 -6'
	36	05	16.5'	NM	4	0.24	8 - 16.5'	1:29	6000	60	7.1	Hole 4: 1"	Total grout volume = 69 gal. Total time = 9 min Connected to Hole 2 (grouting interaction) Roto-per: 3 -7'
	37	11	16'	NM	6	0.38	8 - 16'	1:31	6000	63	7.9		Total grout volume = 73 gal. Total time = 11 min No surface returns Roto-per: 2.5 -5'
	38	14	15.5'	NM	4	0.26	8 - 15.5'	1:28	6000	59	7.9	Hole 13: 0.5"	Total grout volume = 67 gal. Total time = 13 min No surface returns Roto-per: 4 -8'

Date	Grout Sequence No.	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/23/97	39	37A	16'	NM	4	0.25	15 - 16'	-	6000	7	7	Hole 22: SR	Surface returns, stopped grouting after 1 ft Total grout volume = 14 gal. Total time = NM Roto-per: 3 -7', Drill stem angled due to hard drilling conditions at bottom of hole.
09/24/97	40	41	16'	NM	5	0.31	8 - 16'	1:52	6000	72	9.0	Hole 34: 2"	Total grout volume = 80 gal. Total time = 16 min
	41	33	16'	2:00	6	0.38	9 - 16'	1:37	6000	52	7.4	Hole 41: SR	Stopped grouting at 9', surface returns up Hole 41. Total grout volume = 62 gal. Total time = 15 min Filled whole joist for Holes 33, 34, &3 36. Hole 22. Roto-per: 3 -10.5'
	42	09	16'	2:00	5	0.31	8 - 16'	1:27	4000	50	6.3	Hole 48: 2" (2" for joist)	Reduced pressure to 4000 psi Total grout volume = 59 gal. Total time = 9 min No surface returns Roto-per: 3 -9'
	43	06	16'	2:00	6	0.38	8 - 16'	1:39	4000	57	7.1	Hole 09: Joist full	Total grout volume = 66 gal. Total time = 16 min Interconnection between grout holes observed even at reduced pressure. Roto-per: 3 -9.5'
	44	03	16'	2:00	3	0.19	8 -16'	1:30	4000	50	6.3	No returns in adjacent joist	Total grout volume = 57 gal. Total time = 10 min Roto-per: No per until TD.
	45	12	15.5'	2:00	4	0.26	8 - 15.5'	1:36	3500	47	6.3	Hole 44: SR (5 gal)	Total grout volume = 55 gal. Total time = 18 min Surface returns up Hole 44. Pressure reduced to 3500 psi Roto-per: 3-11' & 14-TD
	46	59	-	-	5	-	-	-	-	-	-	-	Unable to penetrate top surface of Hole 59. Access hole filled with cured grout.
	47	66	16'	2:00	5	0.31	8 - 16'	1:40	3500	48	6.0	No surface returns	Total grout volume = 57 gal. Total time = 14 min Roto-per: NR

Date	Grout Sequence No.	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/24/97	48	37B	14'	NM	12	0.86	11.5-14'	NM	3500	15	4.3	Hole 41: SR Hole 44: SR	Reattempted to grout Hole 37, drilled to 14' & grouted until surface returns up Holes 41 & 44. Total grout volume = 30 gal. Total time = 18 min Roto-per: 4-6' & 13.5 - 14' (drilling grout?)
	49	63	16'	NM	5	0.31	11 - 16'	0:59	3500	31	6.2	Hole 68: SR	Grouted to 11' & stopped when surface grout returns came up Hole 68 via Hole 66 (Returns stopped flowing when pressure was reduced) Total grout volume = 39 gal. Total time = 16 min Roto-per: 1-9'
	50	01	16'	NM	6	0.38	8 - 16'	1:36	3500	50	6.3	No surface returns	Total grout volume = 59 gal. Total time = 12 min Edge of pit O.K. Roto-per: 1-7'
	51	13	15.5'	2:00	7	0.45	8 - 15.5'	1:26	3500	46	6.1	No surface returns	Total grout volume = 56 gal. Total time = NM Roto-per: NR
Drilled out Holes 42, 43, 55, 56, & 59 to remove cured grout filling access holes.													
09/25/97	52	46	16'	NM	7	0.44	10 - 16'	1:10	3500	38	6.3	No surface returns Hole 38: 3" Hole 45: 2.5"	Grout hole located in area of highest reported contamination levels (Track 2). Changed grouting interval to 10' Total grout volume = 49 gal. Total time = 17 min High viscous grout returns Downtime to clear plugged line Roto-per: 3.5-10'
	53	34	16'	7:00	20	1.25	10 - 16'	1:15	3500	36	6.0	No surface returns	Total grout volume = 60 gal. Total time = 14 min Roto-per: Hard drilling, Surface - TD. Nozzle plugging almost every hole.
	54	35	16'	8:00	6	0.38	10 - 16'	1:20	3500	44	7.3	No surface returns	Total grout volume = 54 gal. Total time = 15 min Roto-per: Hard drilling, Surface -TD.
	55	42	-	-	6	-	-	-	-	-	-	-	Abandoned hole, hard drilling & fluid discharge from access hole. Total grout volume = 6 gal
	56	43	-	-	6	-	-	-	-	-	-	-	Abandoned hole, hard drilling & fluid discharge from access hole. Total grout volume = 6 gal

Date	Grout Sequence No.	Hole No.	Drill Depth	Drill Time	Drill Grout Volume		Grouting Interval		Grouting Volume			Grout Returns	Comments
					Gallons	Gallons per foot	Depth Interval	Time to Grout	Pumping pressure (psi)	Gallons	Gallons per foot		
09/25/97	57	38	16'	5:00	5	0.31	10 - 16'	0:54	3500	32	7.1	Surface returns	Grouted bottom 1.5' & stopped with surface returns. Raised 1' & grouted 4.' Total grout volume = 42 gal. Total time = 16 min Roto-per: NR
	58	67	-	-	9	-	-	-	-	-	-	-	Abandoned, could not penetrate access hole filled with cured grout.
	59	39	-	-	-	-	-	-	-	-	-	-	Abandoned
	60	40	16'	NM	4	0.25	14.5-16'	0:25	3500	17	6.8	Hole 37: SR Hole 39: SR	Grouted to 14.5', stopped when surface returns from Holes 37 & 39. Total grout volume = 19 gal. Total time = NM Roto-per: NR
	61	04	16'	NM	2	0.13	15 - 16'	0:13	3500	4	4	Surface returns	Grouted to 15', stopped due to surface returns. Total grout volume = 10 gal. Total time = NM Roto-per: NR
	62	55	15'	3:44	4	0.27	10 - 15'	1:00	3500	31	6.2	Hole 45: SR	Grouted to 10', stopped due to surface returns up Hole 45. Total grout volume = 31 gal. Total time = NM Roto-per: NR
	63	10	16'	NM	10	0.63	15 - 16'	0:15	3500	7	7.0	NR	Pump failure & abandoned remainder of grout holes. Difficult drilling last two feet (grout drilling?). Total grout volume = 20 gal.
		8	16'	-	-	-	-	-	-	-	-	-	Drilled to insert geophysical probe. Hole manually backfilled with grout.
		7	-	-	-	-	-	-	-	-	-	-	Abandoned
		47	-	-	-	-	-	-	-	-	-	-	Abandoned
		48	-	-	-	-	-	-	-	-	-	-	Abandoned
		51	-	-	-	-	-	-	-	-	-	-	Abandoned
		56	-	-	-	-	-	-	-	-	-	-	Abandoned
		68	-	-	-	-	-	-	-	-	-	-	Abandoned

Viscosity and Density Measurements – Acid Pit Stabilization

Acid Pit Stabilization

Date	Time	Density (lbs/gal)	Viscosity (min:sec)	Comments
09/22/97	1020	18.5	5:02	Batch sample before grouting.
	1200	17.7	3:16	Batch sample to test viscosity.
	1440	17.8	3:20	Batch sample after grouting.
09/23/97	0755	17.8	5:08	Batch sample before grouting.
	0930	17.8	3:35	Batch sample for retesting.
	1310	18.0	4:15	Batch sample after grouting.
09/24/97	0805	17.7	3:09	Batch sample before grouting.
	1230	18.2	3:05	batch sample after grouting.
09/25/97	0805	18.2	5:45	Material from 09/24/97. Batch sample before grouting.
	1235	18.4	5:05	Batch sample after grouting.

Appendix B

Raw Data for Smears, Filters, Grab/Water Samples

Sheet1

James Jessmore				
Smear Samples Set #2				
ICP-MS Run Log				
Sample ID	Y 89	Mo 95	Mo 98	In 115
Cal 0	0.038	0.276	0.029	99.493
Cal 1	24.985	25.143	25.108	99.035
Cal 2	99.762	98.581	99.893	97.722
Cal 3	499.800	499.590	499.990	98.409
ICB	0.035	0.186	0.139	93.853
ICV	0.066	102.190	102.460	92.977
CSP00701MU	100.370	37.714	37.097	100.130
CSP01401MU	100.800	17.087	17.067	110.610
CSP00901MU	102.780	1.063	1.118	112.020
CSP02701MU	100.080	2.422	2.298	108.760
CSP07401MU	100.830	0.221	0.063	106.060
CSP07501MU	100.590	23.345	23.409	104.950
CSP01301MU	97.655	4.231	3.950	109.220
CSP01101MU	94.356	3.136	3.447	104.490
CSP07301MU	101.210	0.359	0.179	104.250
CSP03301MU	98.724	0.309	0.168	104.680
CCB 1	0.054	0.138	-0.037	102.200
CCV 1	0.024	99.192	99.673	97.161
CSP03201MU	98.032	0.196	0.182	100.880
Media Blk	99.355	0.242	-0.013	101.320
Smear LCS	97.561	92.293	92.461	99.180
CSP02801MU	99.157	2.039	1.862	98.784
CSP03701MU	97.248	2.455	2.242	102.340
CSP02601MU	98.212	99.529	101.030	103.400
CSP01801MU	98.260	27.194	27.402	105.460
CCB 2	0.037	0.157	-0.025	102.520
CCV 2	0.041	96.645	95.996	99.608
Blank Summary	Y 89	Mo 95	Mo 98	
ICB	0.035	0.186	0.139	
CCB 1	0.054	0.138	-0.037	
CCB 2	0.037	0.157	-0.025	
Std. Dev.	0.010	0.024	0.098	
3 Sigma	0.031	0.072	0.294	
Sample D. L. (ug/filter)		0.233	0.294	
Sample Analysis	(ug/filter)	(ug/filter)	Flags	Flags
Sample ID	Mo 95	Mo 98	Mo 95	Mo 98
CSP00701MU	37.714	37.097		
CSP01401MU	17.087	17.067		
CSP00901MU	1.063	1.118		
CSP02701MU	2.422	2.298		
CSP07401MU	0.221	0.063	>D. L.	>D. L.
CSP07501MU	23.345	23.409		
CSP01301MU	4.231	3.950		
CSP01101MU	3.136	3.447		

Sheet1

CSP07301MU	0.359	0.179		>D. L.
CSP03301MU	0.309	0.168		>D. L.
CSP03201MU	0.196	0.182	>D. L.	>D. L.
Media Blk	0.242	-0.013		>D. L.
Smear LCS	92.293	92.461		
CSP02801MU	2.039	1.862		
CSP03701MU	2.455	2.242		
CSP02601MU	99.529	101.030		
CSP01801MU	27.194	27.402		
	% Error from Actual			
Q C Summary	Mo 95	Mo 98		
ICV	2.19	2.46		
CCV 1	-0.81	-0.33		
CCV 2	-3.36	-4.00		
Media Blank	0.242	-0.013		
Smear LCS	92.293	92.461		
% Recovery	92.29	92.46		

Filter Smear Samples					
Sept. 12, 1997					
ICP-MS Run Log					
Sample ID	Y 89	Mo 95	Mo 98	In 115	
Cal 0	-0.00663	0.03596	0.00707	97.603	
Cal 1	24.839	25.1	25.08	97.533	
Cal 2	100.75	102	100.99	94.937	
Cal 3	500.18	500.84	500.17	96.208	
ICB	0.00222	0.15118	0.09922	94.381	
ICV	0.01358	101.86	102.11	92.376	
CSP02301MU	97.446	0.21045	0.15887	94.518	
CSP00101MU	98.563	0.032752	0.30509	97.263	
CSP02901MU	96.619	1.7903	1.8587	97.462	
CSP02001MU	97.012	0.14557	0.16825	96.16	
CSP01001MU	95.87	1.2152	1.0196	97.677	
CSP00801MU	95.58	0.20671	0.29159	99.846	
CSP03001MU	95.634	34.637	34.252	89.212	
CSP03801MU	97.536	0.07817	0.01895	97.784	
CSP02101MU	97.451	0.02552	0.03865	97.523	
CSP01201MU	94.772	0.2065	0.15189	96.493	
CCB 1	-0.00231	0.15584	0.07622	94.423	
CCV 1	0.03226	95.835	95.836	92.294	
Media Blank	91.116	0.12471	0.04002	96.47	
CSP00201MU	94.727	0.13842	0.08971	93.745	
CSP00301MU	92.33	0.38006	0.48011	93.681	
CSP01901MU	98.278	0.21895	0.14684	92.297	
CSP02401MU	92.296	1.4344	1.3319	93.925	
CSP00401MU	92.993	0.26507	0.31549	90.264	
CSP03101MU	91.46	106.04	105.85	89.405	
CSP02201MU	92.789	0.24816	0.15276	90.862	
CSP00501MU	87.758	0.6714	0.66381	89.543	
Smear LCS	93.516	93.112	91.429	87.928	
CCB 2	0.01583	0.34891	0.18993	84.693	
CCV 2	0.0598	92.375	91.483	84.96	
Blank Summary	Y 89	Mo 95	Mo 98	In 115	
ICB	0.00222	0.15118	0.09922		
CCB 1	-0.00231	0.15584	0.07622		
CCB 2	0.01583	0.34891	0.18993		
Std. Dev.	0.009441	0.112838	0.060121		
3 Sigma	0.03	0.34	0.18		
Inst. D.L. (ug/filter)		0.34	0.18		
	Recovery				
	Standard	(ug/ filter)	(ug/ filter)	Flags	Flags
Sample Analysi	Y 89	Mo 95	Mo 98	Mo 95	Mo 98
CSP02301MU	97.45	0.21	0.16	<D.L.	<D.L.
CSP00101MU	98.56	0.03	0.31	<D.L.	
CSP02901MU	96.62	1.79	1.86		
CSP02001MU	97.01	0.15	0.17	<D.L.	<D.L.
CSP01001MU	95.87	1.22	1.02		
CSP00801MU	95.58	0.21	0.29	<D.L.	
CSP03001MU	95.63	34.64	34.25		
CSP03801MU	97.54	0.08	0.02	<D.L.	<D.L.
CSP02101MU	97.45	0.03	0.04	<D.L.	<D.L.
CSP01201MU	94.77	0.21	0.15	<D.L.	<D.L.
Media Blank	91.12	0.12	0.04	<D.L.	<D.L.
CSP00201MU	94.73	0.14	0.09	<D.L.	<D.L.
CSP00301MU	92.33	0.38	0.48		
CSP01901MU	98.28	0.22	0.15	<D.L.	<D.L.
CSP02401MU	92.30	1.43	1.33		
CSP00401MU	92.99	0.27	0.32	<D.L.	

CSP03101MU	91.46	106.04	105.85		
CSP02201MU	92.79	0.25	0.15	<D.L.	<D.L.
CSP00501MU	87.76	0.67	0.66		
			% Error		
Q. C. Summary	Mo 95	Mo 98	Mo 95	Mo 98	
ICV	101.86	102.11	1.86	2.11	
CCV 1	95.835	95.836	-4.17	-4.16	
CCV 2	92.375	91.483	-7.63	-8.52	
Media Blank	0.12471	0.04002	<D.L.	<D.L.	
Smear LCS	93.112	91.429			
% Recovery	93.1	91.4			

Sheet1

Grouted Material							
ICP-MS							
Sept. 11, 1997							
ICP-MS Run Log							
Sample ID	Mo95	Mo98	In 115				
Cal 0	0.16134	-0.00927	98.502				
Cal 1	25.631	24.85	98.511				
Cal 2	101.95	101.24	97.183				
Cal 3	500.93	501.2	97.628				
ICB	0.31079	0.17132	94.235				
ICV	102.44	103.3	95.631				
CSP04701MU dup	577.25	576.17	83.678				
CSP04701MU	455.79	459.71	81.187				
CSP04501MU MS	144.03	143.37	82.467				
CSP04501MU MS	172.57	172.38	86.34				
CSP05201MU	650.67	650.47	86.999				
CSP04801MU	454.33	454.36	86.243				
CSP04501MU	67.793	67.685	86.446				
CSP03901LA	2.7603	2.3163	87.653				
CSP04301MU	24.211	24.577	86.197				
CSP04601MU	121.51	120.23	86.585				
CCB 1	0.09909	0.0337	96.527				
CCV 1	101.05	99.583	98.355				
CSP05001MU	303.3	302.05	88.19				
CSP04101MU	3.0068	2.3517	83.865				
CSP05101MU	497.62	500.34	88.707				
CSP04901MU	13.092	12.963	86.558				
CSP04401MU	3.8926	3.7919	84.125				
CSP04001MU	2.5823	2.0416	82.914				
CSP05601MU	589.43	592.08	86.624				
CSP04201MU	234.38	234.47	81.89				
CSP04002MU	2.4434	2.4301	82.073				
CCB 2	0.43144	0.13796	89.139				
CCV 2	99.979	99.75	90.632				
Blank Summary	Mo95	Mo98					
Cal 0	0.16134	-0.00927					
ICB	0.31079	0.17132					
CCB 1	0.09909	0.0337					
CCB 2	0.43144	0.13796					
Std Dev.	0.14972	0.085175					
3 Sigma	0.449161	0.255526					
Sample D. L. (ug)	0.449161	0.255526					
			soln conc (ng/ml)		Sample Concentration (ug/g)		
Sample Results	Wt (g)	Dil Factor	Mo95	Mo98	Mo95	Mo98	
CSP04701MU dup	1.0165	1000	577.25	576.17	567.9	566.8	
CSP04701MU	1.0046	1000	455.79	459.71	453.7	457.6	
CSP04501MU MS	1.0034	1000	144.03	143.37	143.5	142.9	
CSP04501MU MS	1.0274	1000	172.57	172.38	168.0	167.8	
CSP05201MU	1.0507	1000	650.67	650.47	619.3	619.1	
CSP04801MU	1.0248	1000	454.33	454.36	443.3	443.4	
CSP04501MU	1.0168	1000	67.793	67.685	66.7	66.6	
CSP03901LA	1.0026	1000	2.7603	2.3163	2.8	2.3	
CSP04301MU	1.056	1000	24.211	24.577	22.9	23.3	
CSP04601MU	1.0093	1000	121.51	120.23	120.4	119.1	
CSP05001MU	1.1692	1000	303.3	302.05	259.4	258.3	
CSP04101MU	1.013	1000	3.0068	2.3517	3.0	2.3	
CSP05101MU	1.0062	1000	497.62	500.34	494.6	497.3	
CSP04901MU	1.0038	1000	13.092	12.963	13.0	12.9	
CSP04401MU	1.0132	1000	3.8926	3.7919	3.8	3.7	
CSP04001MU	1.0103	1000	2.5823	2.0416	2.6	2.0	
CSP05601MU	1.0033	1000	589.43	592.08	587.5	590.1	

Sheet1

CSP04201MU	1.0936	1000	234.38	234.47	214.3	214.4	
CSP04002MU	1.0074	1000	2.4434	2.4301	2.4	2.4	
			% Error				
Q.C Samples	Mo95	Mo98	Mo95	Mo98			
ICV	102.44	103.3	2.4	3.3			
CCV 1	101.05	99.583	1.1	-0.4			
CCV2	99.979	99.75	0.0	-0.2			
CSP04701MU	453.7	457.6					
CSP04701MU dup	567.9	566.8					
% RPD	22.4	21.3					
CSP04501MU	66.7	66.6					
CSP04501MU MS	143.5	142.9					
% Recovery	76.9	76.3					
CSP04501MU	66.7	66.6					
CSP04501MU MS	168.0	167.8					
% Recovery	101.3	101.2					

Sheet1

Std. Dev.	1.319	0.824			
3 Sigma	3.957	2.471			
Sample D.L. (ug/filter)	3.957	2.471			
	Dilution Factor = 1000				
Air Filter	(ug/filter)	(ug/filter)	Flag	Flag	
Sample Analysis	Mo 95	Mo 98	Mo 95	Mo 98	
CSP06201MU	3.068	2.393	<D.L.	<D.L.	
CSP06003MU	7.834	7.415			
CSP05701MU	2.243	2.132	<D.L.	<D.L.	
CSP05804MU	5.568	5.009			
CSP05705MU	2.263	2.139	<D.L.	<D.L.	
CSP06005MU	3.884	4.000			
CSP05703MU	1.560	1.583	<D.L.	<D.L.	
CSP05801MU	2.327	2.573	<D.L.	<D.L.	
CSP05702MU	0.518	0.781	<D.L.	<D.L.	
CSP06004MU	7.017	7.956			
CSP06002MU	3.848	4.237	<D.L.		
CSP05805MU	0.664	1.139	<D.L.	<D.L.	
CSP05802MU	0.985	1.785	<D.L.	<D.L.	
CSP05803MU	2.074	2.740	<D.L.		
CSP05704MU	-0.326	0.453	<D.L.	<D.L.	
CSP06001MU	1.328	2.330	<D.L.	<D.L.	
CSP05905MU	0.731	1.147	<D.L.	<D.L.	
CSP05902MU	2.074	3.082	<D.L.		
Air Filter LCS	72.662	72.291			
CSP05903MU	-0.131	1.010	<D.L.	<D.L.	
CSP05901MU	7.188	7.912			
CSP05904MU	-0.755	0.243	<D.L.	<D.L.	
Liquid	(ug/liter)	(ug/liter)	Flag	Flag	
Sample Analysis	Mo 95	Mo 98	Mo 95	Mo 98	
CSP06901MU *	-0.298	0.226	<D.L.	<D.L.	* Diluted 1 to 10 not compensate
CSP07201MU	-2.479	-1.534	<D.L.	<D.L.	
CSP07601MU	-2.276	-1.435	<D.L.	<D.L.	
CSP07601MUMS	91.756	93.607			
CSP07601MUMSD	91.929	91.473			
CSP07601MUDIL	-2.340	-1.466	<D.L.	<D.L.	

Sheet1

Air Filters and Waters							
Sept. 9, 1997							
ICP-MS Run Log	(ug/liter)	(ug/liter)					
Sample ID	Mo 95	Mo 98	In 115				
Cal 0	0.036	-0.012	98.382				
Cal 1	23.767	24.216	99.416				
Cal 2	94.189	92.811	100.220				
Cal 3	497.740	495.590	94.630				
ICB	-0.161	-0.025	99.303				
ICV	95.860	95.923	101.120				
CSP06201MU	3.068	2.393	80.475				
CSP06003MU	7.834	7.415	82.322				
CSP05701MU	2.243	2.132	87.584				
CSP05804MU	5.568	5.009	90.924				
CSP05705MU	2.263	2.139	94.643				
CSP06005MU	3.884	4.000	95.791				
CSP05703MU	1.560	1.583	101.410				
CSP05801MU	2.327	2.573	101.680				
CSP05702MU	0.518	0.781	111.920				
CCB1	-1.487	-0.872	112.590				
CCV1	92.189	93.372	114.350				
CSP06004MU	7.017	7.956	122.510				
CSP06002MU	3.848	4.237	124.350				
CSP05805MU	0.664	1.139	122.620				
CSP05802MU	0.985	1.785	122.160				
CSP05803MU	2.074	2.740	123.430				
CSP05704MU	-0.326	0.453	127.690				
CSP06001MU	1.328	2.330	129.350				
CSP05905MU	0.731	1.147	132.710				
CSP07601MU	-2.276	-1.435	136.820				
CSP06901MU	-0.296	0.226	126.880				
CCB2	-2.584	-1.630	157.570				
CCV2	89.731	90.221	156.680				
CSP07601MUMS	91.756	93.607	152.340				
CSP07601MUMSD	91.929	91.473	157.340				
CSP07201MU	-2.479	-1.534	153.780				
CSP07601MUDIL	-2.340	-1.466	149.900				
CSP05902MU	2.074	3.082	153.170				
Air Filter LCS	72.662	72.291	161.060				
CSP05903MU	-0.131	1.010	160.470				
CSP05901MU	7.188	7.912	163.650				
CSP05904MU	-0.755	0.243	164.530				
CCB3	-2.797	-1.700	159.750				
CCV3	90.910	90.090	160.410				
Blank Summary	Mo 95	Mo 98					
Cal 0	0.036	-0.012					
ICB	-0.161	-0.025					
CCB1	-1.487	-0.872					
CCB2	-2.584	-1.630					
CCB3	-2.797	-1.700					

INEL

FORM L-0114 (Rev. 7-95)

8139

ENVIRONMENTAL RESTORATION PROGRAM
CHAIN OF CUSTODY FORM

Sampler/Field Team Leader: (Printed) BRUCE MILLER

Sampler/Field Team Leader: (Signature) [signature]

Project Name: IN SITU STABILIZATION TREATABILITY STUDY

Characterization Plan No: INEL/EXT-97-00558

Statement of Work No: ER-SOW-231

Laboratory Shipped To: IRC

Sample No.	Sample Date	Sample Time	Comp	Grab	Sample Location	Aqueous	Solid	Rad	Metals	Volatiles	Semi Volatiles	Molybdenum ICP-MS					Preservative	Remarks (Depth)	
CSP04401 MU	8/27/97	1810		X	COLD TEST PIT THRUST BLOCK	X						X					4°C	BH #14	
CSP02001 MU	8/26/97	1508		X	Drill String		X					X					NONE	BASELINE	SMEAR
CSP00101 MU	8/26/97	1459		X	THRUST Block Surface		X					X						BASELINE	SMEAR
CSP00201 MU	8/27/97	1614		X			X					X						BH #1	
CSP00301 MU		1720		X			X					X						BH #18	
CSP00401 MU		1732		X			X					X						BH #19	
CSP00501 MU		1743		X			X					X						BH #22	
CSP02101 MU		1612		X	Drill String		X					X						BH #1	
CSP02201 MU		1720		X			X					X						BH #18	
CSP02301 MU		1732		X			X					X						BH #19	
CSP02401 MU		1744		X			X					X						BH #22	
CSP05801 MU		1834		X	High Volume Air Filter		X					X						Vol 95.30 m³	FILTER
CSP05802 MU		1836		X			X					X						Vol 91.64 m³	FILTER

Special Instructions: ① Vol = Volume of Air Flow in m³

Cooler Numbers:

Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time	Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time
[signature]	8/28/97	0600	[signature]	8/28	10:30						

Distribution: Original & Yellow: Accompany shipment to laboratory Pink: Forward to Administrative Records and Document Control Green: Retained by Project File

SEP-15-1997 15:40 STOLLER/IDAHO FALLS P.02

INEL

FORM L-0114 (Rev. 7-95)

ENVIRONMENTAL RESTORATION PROGRAM
CHAIN OF CUSTODY FORM

8140

Sampler/Field Team Leader: (Printed) BRUCE MILLER

Sampler/Field Team Leader: (Signature) [signature]

Project Name: IN SITU STABILIZATION TREATABILITY STUDY

Characterization Plan No: INEL/EXT-97-00558

Statement of Work No: ER-SOW-231

Laboratory Shipped To: IRC

Sample No.	Sample Date	Sample Time	Comp	Grab	Sample Location	Aqueous	Solid	Rad	Metals	Volatiles	Semi Volatiles	Molybdenum ICP-MS				Preservative	Remarks (Depth)
CSP05803MU	8/27/97	1837		X	High Volume Air Filter		X					X				NONE	VOL 97.33 M³, FILTER
CSP05804MU	↓	1838		X	↓		X					X				↓	VOL 96.88 M³, FILTER
CSP05805MU	↓	1833		X	↓		X					X				↓	VOL 95.1 M³, FILTER

BM 8/27/97

Special Instructions: ① VOL = VOLUME of AIR FLOW IN M³

Cooler Numbers:

Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time	Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time
[signature]	8/28/97	0600	[signature]	8/28	10:30						

Distribution: Original & Yellow: Accompany shipment to laboratory Pink: Forward to Administrative Records and Document Control Green: Retained by Project File

COLD TEST PIT

IRC

INEL

FORM L-0114 (Rev. 7-95)

ENVIRONMENTAL RESTORATION PROGRAM
CHAIN OF CUSTODY FORM

7079

Page 1 of 3

Sampler/Field Team Leader: (Printed) BRUCE MILLER

Sampler/Field Team Leader: (Signature) [signature]

Project Name: IN SITU STABILIZATION TREATABILITY STUDY

Characterization Plan No: INEL/EXT-97-00558

Statement of Work No: ER-SOW-231

Laboratory Shipped To: IRC

Sample No.	Sample Date	Sample Time	Comp	Grab	Sample Location	Aqueous	Solid	Rad	Metals	Volatiles	Semi Volatiles	Molybdenum (ICP-MS)	METALS (TAL)	Preservative	Remarks (Depth)
CSP05701MU	8/26/97	1328		X	COLD TEST PIT SOIL PIT		X					X		NONE	FILTER, VOL 87.62 M³
CSP05702MU	↓	1329		X	↓		X					X		↓	FILTER, VOL 83.94 M³
CSP05703MU	↓	1330		X	↓		X					X		↓	FILTER, ~~83.94~~ 88.67 VOL M³
CSP05704MU	↓	1331		X	↓		X					X		↓	FILTER, VOL 88.36 M³
CSP05705MU	↓	1332		X	↓		X					X		↓	FILTER, VOL 85.55 M³
CSP00101MU	8/26/97	1459		X	↓		X					X		↓	Filter, 47 mm Dia Thrust Block
CSP00201MU	8/26/97	1508		X	↓		X					X		↓	Filter, 47 mm Dia Drill String
CSP03901LA	8/21/97	1330		X	Cold Test Air Grout Tank	X							X	4°C	1st Grout Batch
CSP04001MU	↓	1612		X	COLD TEST PIT THRUST BLOCK	X						X		4°C	Grout Returns
CSP04002MU	↓	1602		X	↓	X						X		4°C	HydroFracture
CSP04101MU	↓	1720		X	↓	X						X		4°C	BH #18
CSP04201MU	↓	1733		X	↓	X						X		4°C	BH #19
CSP04301MU	↓	1744		X	↓	X						X		4°C	BH #22

Special Instructions: (1) Vol = Volume of Air Flow in M³

Cooler Numbers:

Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time	Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time
[signature]	8/28/97	0600	[signature]	8/28	10:30						

Distribution: Original & Yellow: Accompany shipment to laboratory Pink: Forward to Administrative Records and Document Control Green: Retained by Project File

INEL

FORM L-0114
(Rev. 7-95)

ENVIRONMENTAL RESTORATION PROGRAM
CHAIN OF CUSTODY FORM

8142

SEP-15-1997 15:43 STOLLER/IDAHO FALLS

Sampler/Field Team Leader: (Printed) Bruce P. Miller

Sampler/Field Team Leader: (Signature) [signature]

Laboratory Shipped To: IRC

Project Name: In-Situ Stabilization Treat Study

Characterization Plan No: INEL/Ext-97-00558

Statement of Work No: ER-SOW-231

Sample No.	Sample Date	Sample Time	Comp	Grab	Sample Location	Aqueous	Solid	Rad	Metals	Volatiles	Semi Volatiles	Molybdenum ICP-MS				Preservative	Remarks (Depth)
CSP06901MU	8/29/97	1431		X	Equip Clean-out Water	X						X				4°C	Clean-out Tank Water
CSP05001MU	8/29/97	1218		X	Soil/Debris Pit BH#7	X						X				4°C	Grout Return BH#7
~~CSP056~~																	
CSP05601MU	8/29/97	1318		X	Soil/Debris Pit BH#10	X						X				4°C	Grout Return BH #10 -Dup-
CSP05201MU	8/29/97	1317		X	Soil/Debris Pit BH#10											4°C	Grout Return BH #10
CSP03201MU	8/29/97	1241		X	Soil/Debris Pit BH#16		X					X				NA	Drill String BH #16
CSP03701MU	8/29/97	1315		X	Soil/Debris Pit BH#10		X					X				NA	Drill String BH #10-Dup-QC
CSP03301MU	8/29/97	1315		X	Soil/Debris Pit BH #10		X					X				NA	Drill String BH #10
CSP03001MU	"	1146		X	Soil/Debris Pit BH #9		X					X				NA	Drill String BH #9
CSP01101MU	"	1146		X	Soil/Debris Pit BH#9		X					X				NA	Thrust Block BH#9
CSP03101MU	"	1217		X	Soil/Debris Pit BH#7		X					X				NA	Drill String BH #7
CSP01201MU	"	1217		X	Soil/Debris Pit BH#7		X					X				NA	Thrust Block BH #7
CSP01301MU	"	1244		X	Soil/Debris Pit BH#6		X					X				NA	Thrust Block BH #16

Special Instructions:

Cooler Numbers:

Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time	Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time
[signature]	8/29/97	1700	[signature]	8/29/97	1700						

Distribution: Original & Yellow: Accompany shipment to laboratory Pink: Forward to Administrative Records and Document Control Green: Retained by Project File

INEL

FORM L-0114 (Rev. 7-95)

ENVIRONMENTAL RESTORATION PROGRAM
CHAIN OF CUSTODY FORM

8143

Sampler/Field Team Leader: (Printed) Bruce Miller

Sampler/Field Team Leader: (Signature) [signature]

Project Name: In-Situ Stabiliz. Treatability Study

Characterization Plan No: INEL-EXT-97-00558

Statement of Work No: ER-SOW-231

Laboratory Shipped To: IRC

Sample No.	Sample Date	Sample Time	Comp	Grab	Sample Location	Aqueous	Solid	Rad	Metals	Volatiles	Semi Volatiles	Molybdenum				Preservative	Remarks (Depth)
CSP01801MU	8/29/97	1317		X	Soil/Debris Pit BH10		X					X				NA	Dup - QC BH 10
CSP00901MU	8/29/97	1110		X	Soil/Debris Pit BH13		X					X				NA	Thrust Block. BH 13
CSP02901 MU	8/29/97	1120		X	Soil/Debris Pit BH 15		X					X				NA	Drill String: BH #15
CSP01001MU	8/29/97	1119		X	Soil/Debris Pit BH15		X					X				NA	Thrust Block Surf. BH #15
CSP01401MU	8/29/97	1316		X	Soil/Debris Pit BH10		X					X				NA	Thrust Block Surf. BH #10
CSP02801MU	8/29/97	1110		X	Soil/Debris Pit BH13		X					X				NA	Drill String BH #13
CSP03801MU	8/29/97	1458		X	BLANK		X					X				NA	BLANK - Smear
CSP01901MU	8/29/97	1459		X	BLANK		X					X				NA	BLANK, ~~Filter~~ SF-Sr
CSP06201MU	8/29/97	1458		X	BLANK		X					X				NA	BLANK, Filter
CSP05902MU	8/29/97	0822		X	Soil/Debris Pit HV2		X					X				NA	Vol. 125.24 m³, Filter
CSP05905MU	8/29/97	0829		X	Soil/Debris Pit HV5		X					X				NA	Vol. 130.16 m³, Filter
CSP06004MU	8/29/97	1342		X	Soil/Debris Pit HV4		X					X				NA	Vol 147 m³, Filter
CSP06001MU	8/29/97	1325		X	Soil/Debris Pit HV1		X					X				NA	Vol 144.4 m³, Filter

Special Instructions: (1) Vol = Volume of Air flow in M^3

Cooler Numbers:

Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time	Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time
[signature]	8/29/97	1700	[signature]	8/29/97	1700						

Distribution: Original & Yellow: Accompany shipment to laboratory Pink: Forward to Administrative Records and Document Control Green: Retained by Project File

INEL
FORM L-0114
(Rev. 7-95)

ENVIRONMENTAL RESTORATION PROGRAM
CHAIN OF CUSTODY FORM

8141

Sampler/Field Team Leader: (Printed) BRUCE MILLER
Sampler/Field Team Leader: (Signature)
Project Name: IN SITU STABILIZATION TREATABILITY STUDY
Characterization Plan No: INEL/EXT-97-00558
Statement of Work No: ER-SOW-231
Laboratory Shipped To: IRC

Sample No.	Sample Date	Sample Time	Comp	Grab	Sample Location	Aqueous	Solid	Rad	Metals	Volatiles	Semi Volatiles	Molybdenum ICP-MS					Preservative	Remarks (Depth)
CSP04501MU	8/29/97	0950		X	Soil/Debris pit, BH#6	X						X					4°C	BH #6 Grout Ret
CSP04601MU			1007		X		X						X					4°C	BH #8 Grout Ret
CSP07501MU			0830		X	Drill String		X					X						2nd BACKGROUND
CSP07401MU			0816		X	THRUST Block		X					X						2nd BACKGROUND
CSP07301MU	8/28/97	0950		X	Soil/Debris Thrust Block		X					X						BACKGROUND
CSP02601MU	8/29/97	0950		X	Drill String		X					X						BH #6
CSP02701MU			1006		X			X					X						BH #8
CSP00701MU			0950		X	THRUST Block		X					X						BH #6
CSP00801MU			1006		X			X					X						BH #8
CSP04901MU	8/29/97	~~1105~~ 1147		X	Soil/Debris Pit, BH #9	X	~~X~~					X					4°C	Grout Return BH #9
CSP04701MU	"	1110		X	Soil/Debris Pit, BH #13	X						X					4°C	Grout Return BH #13
CSP05101MU	8/29/97	1245		X	Soil/Debris Pit, BH #16	X						X					4°C	Grout Return BH #16
CSP04801MU	8/29/97	1121		X	Soil/Debris Pit, BH#15	X						X					4°C	Grout Return BH #15

Special Instructions:

Cooler Numbers:

Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time	Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time
	8/29/97	1700		8/29/97	1700						

Distribution: Original & Yellow: Accompany shipment to laboratory Pink: Forward to Administrative Records and Document Control Green: Retained by Project File

INEL

FORM L-0314 (Rev. 7-95)

ENVIRONMENTAL RESTORATION PROGRAM
CHAIN OF CUSTODY FORM

8144

SEP-15-1997 15:44

STOLLER/IDAHO FALLS

Sampler/Field Team Leader: (Printed) Bruce Miller

Sampler/Field Team Leader: (Signature) [signature]

Project Name: In-Situ Stabilit. Treatability Study

Characterization Plan No: INEL-EXT-97-00558

Statement of Work No: ER-SOW-231

Laboratory Shipped To: IRC

Sample No.	Sample Date	Sample Time	Comp	Grab	Sample Location	Aqueous	Solid	Rad	Metals	Volatiles	Semi Volatiles	Molybdenum	ICP-MS				Preservative	Remarks (Depth)
CSP06003MU	8/29/97	1341		X	Soil/Debris Pit, HV-3		X					X					NA	Vol. 147.46 m³ / filter
CSP06005MU	8/29/97	1343		X	Soil/Debris Pit, HV-5		X					X					NA	Vol. 164.45 m³ / filter
CSP05904MU	8/29/97	0828		X	Soil/Debris Pit, HV-4		X					X					NA	Vol. 133 m³, filter
CSP05903MU	8/29/97	0824		X	Soil/Debris Pit, HV-3		X					X					NA	Vol. 122.2 m³, filter
CSP05901MU	8/29/97	0821		X	Soil/Debris Pit, HV-1		X					X					NA	Vol. 130.52 m³, filter
CSP07601MU	8/29/97	1551		X	Field Blank QC	X						X					4°C	HNO₃ < pH of 2.0 Field Blank
~~CSP06002MU~~	8/29/97	1326		X	Soil/Debris Pit, HV-2		X					X					NA	Vol. 138.68, filter

BM 8/29/97

Special Instructions: Vol = Volume of Air in M³

Cooler Numbers:

Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time	Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time
[signature]	8/29/97	1700	[signature]	8/29/97	1700						

Distribution: Original & Yellow: Accompany shipment to laboratory Pink: Forward to Administrative Records and Document Control Green: Retained by Project File

INEL

FORM L-0184 (Rev. 7-95)

ENVIRONMENTAL RESTORATION PROGRAM
CHAIN OF CUSTODY FORM

7126

Page 1 of 1

Sampler/Field Team Leader: (Printed) Bruce Miller

Sampler/Field Team Leader: (Signature) [signature]

Project Name: In Situ Stabilization Treatability Study

Characterization Plan No: INEL/EXT-97-00085

Statement of Work No: ER-SOW-231

Laboratory Shipped To:

Sample No.	Sample Date	Sample Time	Comp	Grab	Sample Location	Aqueous	Solid	Rad	Metals	Volatiles	Semi Volatiles	[illegible]				Preservative	Remarks (Depth)
CSP07201MU	8/28/97	0937		X	Soil Test Pit	X						X				4°C, HNO3 to pH<2	Equipment Rinsate

Bruce Miller
Fax 525-3364
phone 525-9358

Special Instructions:

Cooler Numbers:

Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time	Relinquished by: (Sig)	Date	Time	Received by: (Sig)	Date	Time
[signature]	9/2/97	4:10 pm	Ilea Thompson	9/2/97	4:10 pm	Ilea Thompson	9/2/97	4:32 pm	Barbara [signature]	9/2/97	4:3?

Distribution: Original & Yellow: Accompany shipment to laboratory Pink: Forward to Administrative Records and Document Control Green: Retained by Project File

Sheet1

James Jessmore				
Smear Samples Set #2				
ICP-MS Run Log				
Sample ID	Y 89	Mo 95	Mo 98	In 115
Cal 0	0.038	0.276	0.029	99.493
Cal 1	24.985	25.143	25.108	99.035
Cal 2	99.762	98.581	99.893	97.722
Cal 3	499.800	499.590	499.990	98.409
ICB	0.035	0.186	0.139	93.853
ICV	0.066	102.190	102.460	92.977
CSP00701MU	100.370	37.714	37.097	100.130
CSP01401MU	100.800	17.087	17.067	110.610
CSP00901MU	102.780	1.063	1.118	112.020
CSP02701MU	100.080	2.422	2.298	108.760
CSP07401MU	100.830	0.221	0.063	106.060
CSP07501MU	100.590	23.345	23.409	104.950
CSP01301MU	97.655	4.231	3.950	109.220
CSP01101MU	94.356	3.136	3.447	104.490
CSP07301MU	101.210	0.359	0.179	104.250
CSP03301MU	98.724	0.309	0.168	104.680
CCB 1	0.054	0.138	-0.037	102.200
CCV 1	0.024	99.192	99.873	97.161
CSP03201MU	98.032	0.196	0.182	100.880
Media Blk	99.355	0.242	-0.013	101.320
Smear LCS	97.561	92.293	92.461	99.180
CSP02801MU	99.157	2.039	1.862	98.784
CSP03701MU	97.248	2.455	2.242	102.340
CSP02601MU	98.212	99.529	101.030	103.400
CSP01801MU	98.260	27.194	27.402	105.460
CCB 2	0.037	0.157	-0.025	102.520
CCV 2	0.041	98.645	95.996	99.608
Blank Summary	Y 89	Mo 95	Mo 98	
ICB	0.035	0.186	0.139	
CCB 1	0.054	0.138	-0.037	
CCB 2	0.037	0.157	-0.025	
Std. Dev.	0.010	0.024	0.098	
3 Sigma	0.031	0.072	0.294	
Sample D. L. (ug/filter)		0.233	0.294	
Sample Analysis	(ug/filter)	(ug/filter)	Flags	Flags
Sample ID	Mo 95	Mo 98	Mo 95	Mo 98
CSP00701MU	37.714	37.097		
CSP01401MU	17.087	17.067		
CSP00901MU	1.063	1.118		
CSP02701MU	2.422	2.298		
CSP07401MU	0.221	0.063	>D. L.	>D. L.
CSP07501MU	23.345	23.409		
CSP01301MU	4.231	3.950		
CSP01101MU	3.136	3.447		

Sheet1

Air Filters and Waters								
Sept. 9, 1997								
ICP-MS Run Log	(ug/liter)	(ug/liter)						
Sample ID	Mo 95	Mo 98	In 115					
Cal 0	0.036	-0.012	98.382					
Cal 1	23.767	24.216	99.416					
Cal 2	94.189	92.811	100.220					
Cal 3	497.740	495.590	94.630					
ICB	-0.161	-0.025	99.303					
ICV	95.860	95.923	101.120					
CSP06201MU	3.068	2.393	80.475					
CSP06003MU	7.834	7.415	82.322					
CSP05701MU	2.243	2.132	87.584					
CSP05804MU	5.568	5.009	90.924					
CSP05705MU	2.263	2.139	94.643					
CSP06005MU	3.884	4.000	95.791					
CSP05703MU	1.560	1.583	101.410					
CSP05801MU	2.327	2.573	101.680					
CSP05702MU	0.518	0.781	111.920					
CCB1	-1.487	-0.872	112.590					
CCV1	92.189	93.372	114.350					
CSP06004MU	7.017	7.956	122.510					
CSP06002MU	3.848	4.237	124.350					
CSP05805MU	0.664	1.139	122.620					
CSP05802MU	0.985	1.785	122.160					
CSP05803MU	2.074	2.740	123.430					
CSP05704MU	-0.326	0.453	127.690					
CSP06001MU	1.328	2.330	129.350					
CSP05905MU	0.731	1.147	132.710					
CSP07601MU	-2.276	-1.435	136.820					
CSP06901MU	-0.296	0.226	126.880					
CCB2	-2.584	-1.630	157.570					
CCV2	89.731	90.221	156.680					
CSP07601MUMS	91.756	93.607	152.340					
CSP07601MUMSD	91.929	91.473	157.340					
CSP07201MU	-2.479	-1.534	153.780					
CSP07601MUDIL	-2.340	-1.466	149.900					
CSP05902MU	2.074	3.082	153.170					
Air Filter LCS	72.662	72.291	161.060					
CSP05903MU	-0.131	1.010	160.470					
CSP05901MU	7.188	7.912	163.650					
CSP05904MU	-0.755	0.243	164.530					
CCB3	-2.797	-1.700	159.750					
CCV3	90.910	90.090	160.410					
Blank Summary	Mo 95	Mo 98						
Cal 0	0.036	-0.012						
ICB	-0.161	-0.025						
CCB1	-1.487	-0.872						
CCB2	-2.584	-1.630						
CCB3	-2.797	-1.700						

Sheet1

CSP07301MU	0.359	0.179		>D. L.
CSP03301MU	0.309	0.168		>D. L.
CSP03201MU	0.196	0.182	>D. L.	>D. L.
Media Blk	0.242	-0.013		>D. L.
Smear LCS	92.293	92.461		
CSP02801MU	2.039	1.862		
CSP03701MU	2.455	2.242		
CSP02601MU	99.529	101.030		
CSP01801MU	27.194	27.402		
	% Error from Actual			
Q C Summary	Mo 95	Mo 98		
ICV	2.19	2.46		
CCV 1	-0.81	-0.33		
CCV 2	-3.36	-4.00		
Media Blank	0.242	-0.013		
Smear LCS	92.293	92.461		
% Recovery	92.29	92.46		

Sheet1

Std. Dev.	1.319	0.824			
3 Sigma	3.957	2.471			
Sample D.L. (ug/filter)	3.957	2.471			
	Dilution Factor = 1000				
Air Filter	(ug/filter)	(ug/filter)	Flag	Flag	
Sample Analysis	Mo 95	Mo 98	Mo 95	Mo 98	
CSP06201MU	3.068	2.393	<D.L.	<D.L.	
CSP06003MU	7.834	7.415			
CSP05701MU	2.243	2.132	<D.L.	<D.L.	
CSP05804MU	5.568	5.009			
CSP05705MU	2.263	2.139	<D.L.	<D.L.	
CSP06005MU	3.884	4.000			
CSP05703MU	1.560	1.583	<D.L.	<D.L.	
CSP05801MU	2.327	2.573	<D.L.	<D.L.	
CSP05702MU	0.518	0.781	<D.L.	<D.L.	
CSP06004MU	7.017	7.956			
CSP06002MU	3.848	4.237	<D.L.		
CSP05805MU	0.664	1.139	<D.L.	<D.L.	
CSP05802MU	0.985	1.785	<D.L.	<D.L.	
CSP05803MU	2.074	2.740	<D.L.		
CSP05704MU	-0.326	0.453	<D.L.	<D.L.	
CSP06001MU	1.328	2.330	<D.L.	<D.L.	
CSP05905MU	0.731	1.147	<D.L.	<D.L.	
CSP05902MU	2.074	3.082	<D.L.		
Air Filter LCS	72.662	72.291			
CSP05903MU	-0.131	1.010	<D.L.	<D.L.	
CSP05901MU	7.188	7.912			
CSP05904MU	-0.755	0.243	<D.L.	<D.L.	
Liquid	(ug/liter)	(ug/liter)	Flag	Flag	
Sample Analysis	Mo 95	Mo 98	Mo 95	Mo 98	
CSP06901MU *	-0.296	0.226	<D.L.	<D.L.	* Diluted 1 to 10 not compensate
CSP07201MU	-2.479	-1.534	<D.L.	<D.L.	
CSP07601MU	-2.276	-1.435	<D.L.	<D.L.	
CSP07601MUMS	91.756	93.607			
CSP07601MUMSD	91.929	91.473			
CSP07601MUDIL	-2.340	-1.466	<D.L.	<D.L.	

Filter Smear Samples					
Sept. 12, 1997					
ICP-MS Run Log					
Sample ID	Y 89	Mo 95	Mo 98	In 115	
Cal 0	-0.00663	0.03596	0.00707	97.603	
Cal 1	24.839	25.1	25.08	97.533	
Cal 2	100.75	102	100.99	94.937	
Cal 3	500.18	500.84	500.17	96.208	
ICB	0.00222	0.15118	0.09922	94.381	
ICV	0.01358	101.86	102.11	92.376	
CSP02301MU	97.448	0.21045	0.15887	94.518	
CSP00101MU	98.563	0.032752	0.30509	97.263	
CSP02901MU	96.619	1.7903	1.8587	97.462	
CSP02001MU	97.012	0.14557	0.16825	96.16	
CSP01001MU	95.87	1.2152	1.0196	97.677	
CSP00801MU	96.58	0.20671	0.29159	99.846	
CSP03001MU	95.634	34.637	34.252	89.212	
CSP03801MU	97.536	0.07817	0.01895	97.784	
CSP02101MU	97.451	0.02552	0.03865	97.523	
CSP01201MU	94.772	0.2065	0.15189	96.493	
CCB 1	-0.00231	0.15584	0.07622	94.423	
CCV 1	0.03226	95.835	95.836	92.294	
Media Blank	91.116	0.12471	0.04002	96.47	
CSP00201MU	94.727	0.13842	0.08971	93.745	
CSP00301MU	92.33	0.38006	0.48011	93.681	
CSP01901MU	98.278	0.21895	0.14684	92.297	
CSP02401MU	92.296	1.4344	1.3319	93.925	
CSP00401MU	92.993	0.26507	0.31549	90.264	
CSP03101MU	91.46	106.04	105.85	89.405	
CSP02201MU	92.789	0.24816	0.15276	90.862	
CSP00501MU	87.758	0.6714	0.66381	89.543	
Smear LCS	93.516	93.112	91.429	87.928	
CCB 2	0.01583	0.34891	0.18993	84.693	
CCV 2	0.0598	92.375	91.483	84.96	
Blank Summary	Y 89	Mo 95	Mo 98	In 115	
ICB	0.00222	0.15118	0.09922		
CCB 1	-0.00231	0.15584	0.07622		
CCB 2	0.01583	0.34891	0.18993		
Std. Dev.	0.009441	0.112838	0.060121		
3 Sigma	0.03	0.34	0.18		
Inst. D.L. (ug/filter)		0.34	0.18		
	Recovery				
	Standard	(ug/ filter)	(ug/ filter)	Flags	Flags
Sample Analysi	Y 89	Mo 95	Mo 98	Mo 95	Mo 98
CSP02301MU	97.45	0.21	0.16	<D.L.	<D.L.
CSP00101MU	98.56	0.03	0.31	<D.L.	
CSP02901MU	96.62	1.79	1.86		
CSP02001MU	97.01	0.15	0.17	<D.L.	<D.L.
CSP01001MU	95.87	1.22	1.02		
CSP00801MU	96.58	0.21	0.29	<D.L.	
CSP03001MU	95.63	34.64	34.25		
CSP03801MU	97.54	0.08	0.02	<D.L.	<D.L.
CSP02101MU	97.45	0.03	0.04	<D.L.	<D.L.
CSP01201MU	94.77	0.21	0.15	<D.L.	<D.L.
Media Blank	91.12	0.12	0.04	<D.L.	<D.L.
CSP00201MU	94.73	0.14	0.09	<D.L.	<D.L.
CSP00301MU	92.33	0.38	0.48		
CSP01901MU	98.28	0.22	0.15	<D.L.	<D.L.
CSP02401MU	92.30	1.43	1.33		
CSP00401MU	92.99	0.27	0.32	<D.L.	

Sheet1

Grouted Material			
ICP-MS			
Sept. 11, 1997			
ICP-MS Run Log			
Sample ID	Mo95	Mo98	In 115
Cal 0	0.16134	-0.00927	98.502
Cal 1	25.631	24.85	98.511
Cal 2	101.95	101.24	97.183
Cal 3	500.93	501.2	97.628
ICB	0.31079	0.17132	94.235
ICV	102.44	103.3	95.631
CSP04701MU dup	577.25	576.17	83.678
CSP04701MU	455.79	459.71	81.187
CSP04501MU MS	144.03	143.37	82.467
CSP04501MU MS	172.57	172.38	86.34
CSP05201MU	650.67	650.47	86.999
CSP04801MU	454.33	454.36	86.243
CSP04501MU	67.793	67.685	86.446
CSP03901LA	2.7603	2.3163	87.653
CSP04301MU	24.211	24.577	86.197
CSP04601MU	121.51	120.23	86.585
CCB 1	0.09909	0.0337	96.527
CCV 1	101.05	99.583	98.355
CSP05001MU	303.3	302.05	88.19
CSP04101MU	3.0068	2.3517	83.865
CSP05101MU	497.62	500.34	88.707
CSP04901MU	13.092	12.963	86.558
CSP04401MU	3.8926	3.7919	84.125
CSP04001MU	2.5823	2.0416	82.914
CSP05601MU	589.43	592.08	86.624
CSP04201MU	234.38	234.47	81.89
CSP04002MU	2.4434	2.4301	82.073
CCB 2	0.43144	0.13796	89.139
CCV 2	99.979	99.75	90.632

Blank Summary	Mo95	Mo98
Cal 0	0.16134	-0.00927
ICB	0.31079	0.17132
CCB 1	0.09909	0.0337
CCB 2	0.43144	0.13796
Std Dev.	0.14972	0.085175
3 Sigma	0.449161	0.255526
Sample D. L. (ug)	0.449161	0.255526

			soln conc (ng/ml)		Sample Concentration (ug/g)	
Sample Results	Wt (g)	Dil Factor	Mo95	Mo98	Mo95	Mo98
CSP04701MU dup	1.0165	1000	577.25	576.17	567.9	566.8
CSP04701MU	1.0046	1000	455.79	459.71	453.7	457.6
CSP04501MU MS	1.0034	1000	144.03	143.37	143.5	142.9
CSP04501MU MS	1.0274	1000	172.57	172.38	168.0	167.8
CSP05201MU	1.0507	1000	650.67	650.47	619.3	619.1
CSP04801MU	1.0248	1000	454.33	454.36	443.3	443.4
CSP04501MU	1.0168	1000	67.793	67.685	66.7	66.6
CSP03901LA	1.0026	1000	2.7603	2.3163	2.8	2.3
CSP04301MU	1.056	1000	24.211	24.577	22.9	23.3
CSP04601MU	1.0093	1000	121.51	120.23	120.4	119.1
CSP05001MU	1.1692	1000	303.3	302.05	259.4	258.3
CSP04101MU	1.013	1000	3.0068	2.3517	3.0	2.3
CSP05101MU	1.0062	1000	497.62	500.34	494.6	497.3
CSP04901MU	1.0038	1000	13.092	12.963	13.0	12.9
CSP04401MU	1.0132	1000	3.8926	3.7919	3.8	3.7
CSP04001MU	1.0103	1000	2.5823	2.0416	2.6	2.0
CSP05601MU	1.0033	1000	589.43	592.08	587.5	590.1

CSP03101MU	91.46	106.04	105.85		
CSP02201MU	92.79	0.25	0.15	<D.L.	<D.L.
CSP00501MU	87.76	0.67	0.66		
			% Error		
Q. C. Summary	Mo 95	Mo 98	Mo 95	Mo 98	
ICV	101.86	102.11	1.86	2.11	
CCV 1	95.835	95.836	-4.17	-4.16	
CCV 2	92.375	91.483	-7.63	-8.52	
Media Blank	0.12471	0.04002	<D.L.	<D.L.	
Smear LCS	93.112	91.429			
% Recovery	93.1	91.4			

Sheet1

CSP04201MU	1.0936	1000	234.38	234.47	214.3	214.4	
CSP04002MU	1.0074	1000	2.4434	2.4301	2.4	2.4	
			% Error				
Q.C Samples	Mo95	Mo98	Mo95	Mo98			
ICV	102.44	103.3	2.4	3.3			
CCV 1	101.05	99.583	1.1	-0.4			
CCV2	99.979	99.75	0.0	-0.2			
CSP04701MU	453.7	457.6					
CSP04701MU dup	567.9	565.8					
% RPD	22.4	21.3					
CSP04501MU	66.7	66.6					
CSP04501MU MS	143.5	142.9					
% Recovery	76.9	76.3					
CSP04501MU	66.7	66.6					
CSP04501MU MS	168.0	167.8					
% Recovery	101.3	101.2					

Appendix C

In Situ Waste Stabilization Project Cold Test Demonstration Geotechnical Drilling/Assessment Report

1. INTRODUCTION

Because of encountering difficult drilling conditions during grout emplacement testing for the Cold Test Demonstration, geotechnical drilling was performed to assess the subsurface conditions underneath the Soil Test Pit and Debris Test Pit. Findings were used to characterize the soil properties underneath the test areas and provide information to more accurately define drilling specifications and jet grouting parameters for the field demonstration tests.

2. METHOD

Drilling services were subcontracted with Andrews Drilling Company based in Idaho Falls, Idaho. Drilling was performed from July 9-10, 1997. Boreholes were drilled using a Mobile 51 rig equipped with hollow stem augers and split spoon sampling capabilities. ASTM Test Designation D-1586 "Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils" was followed to obtain in-place soil properties. The standard penetration test reports the number of blows to drive the 2-inch sampler one foot into undisturbed soil by using a 140-lb weight falling 30 inches. The sample was obtained by driving the sampler a distance of 18 inches. The blow count for each 6 inches of penetration was recorded separately and the standard penetration test result is the number of blows required for the last 12 inches of driving. A correlation between blow counts and soil condition is shown in Table 1 (McCarthy, 1988).

Table 1. Correlation between soil conditions and standard penetration test.

Soil	Designation	Blows/ft
Sand and Silt	Loose	0-10
	Medium	11-30
	Dense	31-50
	Very Dense	Over 50
Clay	Very Soft	0-2
	Soft	3-5
	Medium	6-15
	Stiff	16-25
	Hard	Over 25

A total of six boreholes were drilled at the site. Four holes were drilled around the Soil Test Pit to a maximum depth of 19-feet and two holes were drilled around the Debris Test Pit to a maximum depth of 11-feet. Continuous split spoon samples were collected from a few feet below surface level to a designated total depth. Location of these boreholes is shown in Figure 1.

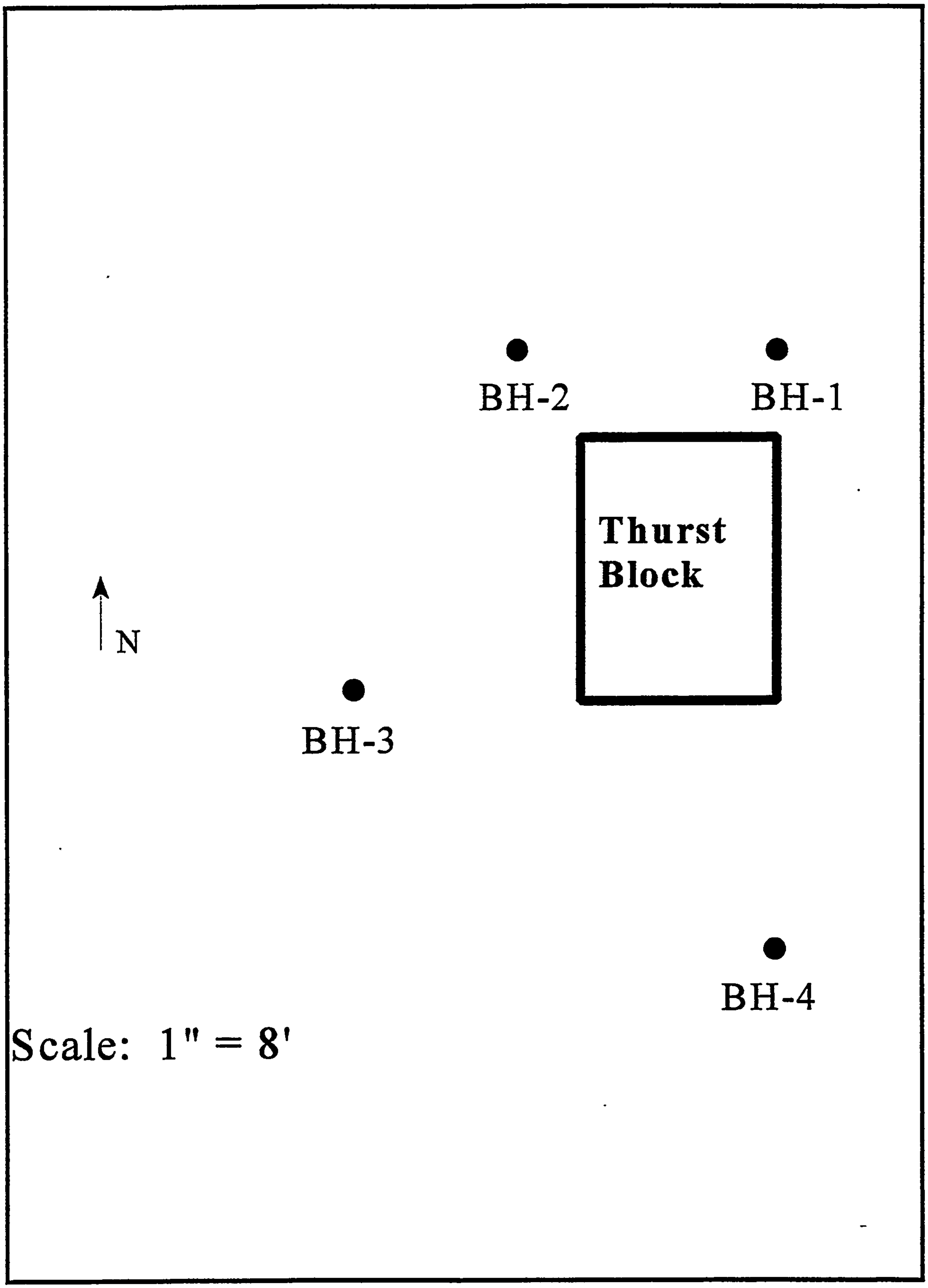


Figure 1. Location of boreholes at the Soil Test Pit.

3. RESULTS

Description of soil profile penetrated for each borehole is provided in Appendix A. Summary of penetration resistance for split spoon sampling levels are provided in Table 2.

Table 2. Standard penetration test results.

Depth (ft)	SOIL TEST PIT STANDARD PENETRATION TEST - BLOW COUNTS				Depth (ft)	DEBRIS TEST PIT STANDARD PENETRATION TEST BLOW COUNTS	
	BH-1	BH-2	BH-3	BH-4		BH-5	BH-6
2.5 - 4.0			29/21	13/23	*3.0 - 4.5*	14/10	
4.0 - 5.5	18/18	10/21	28/37	16/28	*4.5 - 6.0*	15/11	6/9
5.5 - 7.0	14/14	40/64	28/41	11/11	*6.0 - 7.5*	5/7	21/16
7.0 - 8.5	17/50	24/20	30/24	23/20	*7.5 - 9.0*	18/18	30/62
8.5 - 10.0	54/42	20/17	22/20	20/18	*9.0 - 10.5*	14/13	65R
10.0 - 11.5	28/20	20/25	21/20	20/23			
11.5 - 13.0	22/40	48/50R	37/60	29/60R			
13.0 - 14.5	52/50	80/50R	49/50R	101/50R			
14.5 - 16.0	64/60R	NS	48/48	95/50R			
16.0 - 17.5	86/50R	84/50R	43/47	45/50			
17.5-19.0	60/50R	53/50R					
R - Refusal							

To further evaluate the soil properties of the lower hard clay interval, three samples were submitted for classification of engineering properties. These soils were tested for particle-size analysis for the fine fraction (hydrometer analysis) and plasticity of the soils or Atterberg limits. Summary of the test results are shown in Table 3.

Table 3. Summary of the test results.

Borehole No.	Depth	Soil Description	Grain-Size Distribution			USCS	Liquid Limit	Plastic Index
			% Sand	% Silt	% Clay			
BH-1	14.5 - 16.0'	Lean Clay	5.0	40.2	54.8	CL	48.3	28.0
BH-2	16.0 - 17.5'	Lean Clay	5.0	59.1	35.9	CL	35.0	19.0
BH-3	13.0 - 14.5'	Lean Clay	7.7	55.7	36.6	CL	35.3	19.0

Copies of soil analysis test reports are attached in Appendix B.

4. CONCLUSIONS

The soil profiles from drilling/sampling around the Soil Test Pit were relatively uniform from the near-surface to total depth. Figure 2 is the soil profile map for the test area. These soils can be classified into three primary groups.

1. Near-surface to 8-foot interval is typically brown silty to occasionally sandy moist clay. SPT designation ranged from medium to stiff.

2. The 8-foot to 12-foot interval is light brown occasionally clayey silt to very fine-grained sand. SPT designation ranged from medium to dense.

3. The 12-foot to 20-foot is dark brown slightly silty to occasionally sandy clay. SPT designation classified this material as a hard clay.

The soil profiles from drilling/sampling around the Debris Test Pit were relatively uniform from the near-surface to total depth. These soils can be classified as brown occasionally clayey silt to very fine-grained sand. SPT designation for this soil type ranged from loose to medium.

Analysis of samples from the Soil Test Pit area classified this material as a clay with low to medium plasticity. Based on these properties, the hydraulic conductivity for this material is estimated to range from 10^{-5} to 10^{-7} cm/sec.

Soil data indicates that the difficulties encountered during drilling were the result of encountering a hard clay layer. Analytical results indicate that this material would exhibit a low permeability.

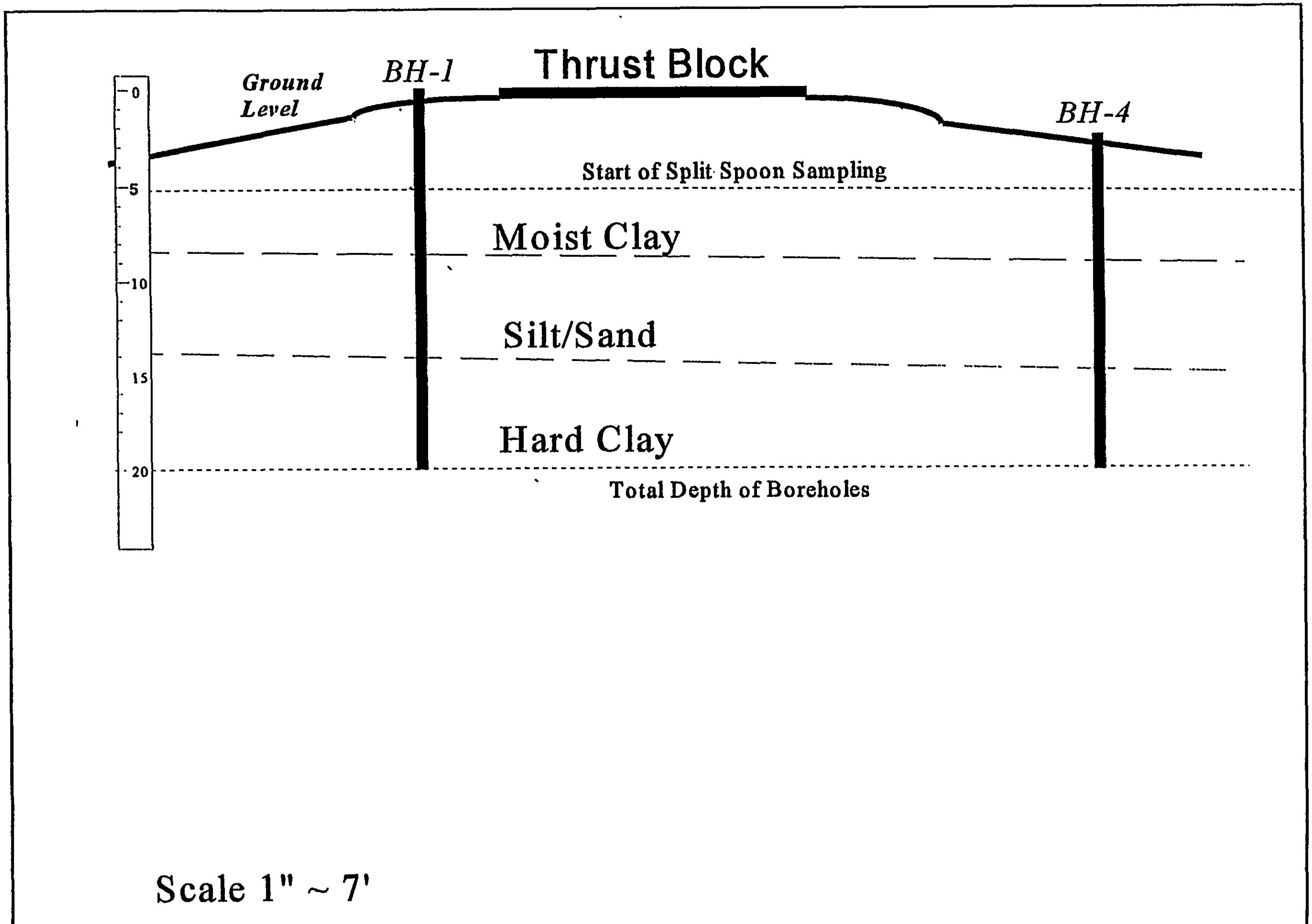


Figure 2. North-south cross section of soil profile beneath thrust block.

This clay layer was not encountered during drilling for the Debris Test Pit. SPT indicate that the material around the Debris Test Pit was significantly less resistive than soils underneath the Soil Test Pit.

Comparison of soil profile description from this investigation and the Acid Pit Track 2 Characterization strongly suggests that the soil conditions for the Soil Test Pit area are not representative of the soil conditions for the test area in the Acid Pit. Soil in the Acid Pit consists of transported and reworked fill material used for covering purposes. Only the upper portion of the soil for the Soil Test Pit was reworked or disturbed during construction of the test site. The lower portion consists of compacted and undisturbed native soil. The properties of the reworked soil used for construction of the Debris Test Pit may be more representative of the soil in the test area of the Acid Pit; therefore, not as resistive as the soil in the Soil Test Pit.

Based on these results, MSE Technology Applications, Inc. (MSE) has requested Geo-Con to modify their equipment for rotary-percussion drilling to penetrate harder soil conditions. Additionally, MSE and LMITCO are considering adjustment to the grouting strategy to lessen the volume of grout returns that may be generated when injecting into low permeability soils.

6. REFERENCES

McCarthey, David F., 1988, *Essential of Soil Mechanics and Foundations: Basic Geotechnics*, Prentice Hall, Englewood, New Jersey, 07632, 3rd Edition, pp. 614.

APPENDIX A

SOIL DESCRIPTION LOGS

SOIL TEST PIT

BOREHOLE-1

Depth	SPT	Soil Description
4.0 - 5.5'	4/18/18	Brown, silty, clay - moist
5.5 - 7.0'	7/14/14	Brown silty clay - slightly moist to clayey silt with scattered very fine grained sand and rounded gravel
7.0 - 8.5'	12/17/30	Brown silty clay grading into light brown slightly clayey silt to very fine grained sand
8.5 - 10.0'	30/54/42	Light to dark brown clayey to silty very fine grained sand
10.0 - 11.5'	20/28/20	Light brown slightly clayey silt to very fine grained sand
11.5 - 13.0'	17/22/40	Brown silty clay to clayey silt grading into silty clay
13.0 - 14.5'	35/52/50R (3")	Brown silty to occasionally sandy clay - hard, tight, & slightly moist
14.5 - 16.0'	34/64/60R (3")	Brown slightly silty clay - hard, tight & slightly moist
16.0 - 17.5'	33/86/50R (5")	Brown occasionally silty to sandy clay - hard, tight, & slightly moist
17.5 - 19.0'	19/60/50R (3")	Brown silty clay grading into clayey silt - hard, tight & dry

BOREHOLE-2

Depth	SPT	Soil Description
4.0 - 5.5'	6/10/21	Dark brown slightly silty clay - moist
5.5 - 7.0'	20/40/64	Dark brown clay - moist grading into light brown slightly clayey silt to very fine-grained sand
7.0 - 8.5'	20/24/20	Brown slightly clayey silt to very fine-grained sand
8.5 - 10.0'	13/20/17	Light brown slightly clayey silt to very fine-grained sand
10.0 - 11.5'	10/20/25	Light brown slightly clayey silt to very fine-grained sand
11.5 - 13.0'	13/48/50R (2")	Brown silty clay - slightly moist & tight
13.0 - 14.5'	20/80/50R (4")	Brown slightly silty clay - hard, tight, & slightly moist
14.5 - 16.0'		Missed Sample
16.0 - 17.5'	35/84/50R (3")	Brown occasionally silty clay - hard, tight, & slightly moist
17.5 - 19.0'	48/53/50R (2")	Brown silty clay grading into clayey silt and very fine-grained sand

BOREHOLE-3

Depth	SPT	Soil Description
2.5 - 4.0'	21/29/21	Dark brown to brown gray silty to sandy clay - moist
4.0 - 5.5'	18/28/37	Brown silty to occasionally sandy clay - moist
5.5 - 7.0'	15/28/41	Brown silty slightly clay - moist grading into light brown slightly clayey silt to very fine-grained sand
7.0 - 8.5'	24/30/24	Brown slightly clayey silt to very fine-grained sand
8.5 - 10.0'	17/22/20	Light brown clayey silt with scattered very fine-grained sand stringers
10.0 - 11.5'	13/21/20	Brown slightly clayey silt with scattered very fine-grained sand stringers
11.5 - 13.0'	26/37/60	Brown clayey silt grading into brown silty clay
13.0 - 14.5'	28/49/50R (3")	Brown silty to occasionally very fine sandy clay - hard, tight, & slightly moist with scattered coarse sand to rounded gravel
14.5 - 16.0'	26/43/48	Brown silty to sandy clay with scattered very fine-grained sand stringers
16.0 - 17.5'	31/43/47	Brown silty clay grading into clayey silt - hard, tight & dry

BOREHOLE-4

Depth	SPT	Soil Description
2.5 - 4.0'	10/13/23	Dark brown silty to sandy clay - moist
4.0 - 5.5'	7/16/28	Brown silty to sandy clay - slightly moist
5.5 - 7.0'	8/11/11	Dark brown clay -moist grading into light brown slightly clayey silt to very fine-grained sand
7.0 - 8.5'	10/23/20	Light brown slightly clayey silt to very fine-grained sand with scattered thin clay stringers
8.5 - 10.0'	12/20/18	Light brown slightly clayey silt to very fine grained sand
10.0 - 11.5'	14/20/23	Light brown clayey silt to very fine grained sand
11.5 - 13.0'	16/29/60R (2")	Light brown clayey silt to very fine grained sand grading into brown silty clay - slightly moist & tight
13.0 - 14.5'	32/101/50R (4")	Brown slightly silty clay - hard, tight, & slightly moist
14.5 - 16.0'	35/95/50R (4")	Brown slightly silty clay - hard, tight, & slightly moist
16.0 - 17.5'	23/45/50	Brown silty to sandy clay with scattered rounded gravel

DEBRIS TEST PIT

BOREHOLE-5

Depth	SPT	Soil Description
3.0 - 4.5'	15/14/10	Light brown slightly clayey silt to very fine-grained sand
4.5 - 6.0'	11/15/11	Light brown slightly clayey silt to very fine-grained sand
6.0 - 7.5'	7/5/5	Brown silt to very fine-grained sand
7.5 - 9.0'	7/18/18	Brown slightly clayey silt to very fine-grained sand
9.0 - 10.5'	10/14/13	Brown clayey silt to very fine-grained sand

BOREHOLE-6

Depth	SPT	Soil Description
4.5 - 6.0'	6/6/9	Brown silt to very fine-grained sand
6.0 - 7.5'	12/21/16	Brown slightly clayey silt to very fine grained sand
7.5 - 9.0'	17/30/62	Brown slightly clayey silt to very fine grained sand grading into brown silty clay
9.0 - 10.5'	65R (3")	Basalt rubble

APPENDIX B

SOIL ANALYSIS TEST REPORTS

MSE-HKM INC.
220 NORTH ALASKA ST.
BUTTE MT. 59702
(406) 723-3145

SAMPLE TRANSMITTAL

Project: IN-SITU WASTE STABIL.
Field No: BH-1 THRU BH-3
Date Received/By: 7/15/97 J.J

Project No: 17M431.102
Date Sampled: 7/9-7/10-97
Date Check/By: 7/21/97 J.J

Other: MSE-TA CHG # MD4K3
Sampled By: A. ZDINAK/MSE-TA
Date Completed: 7/21/97 J. Jozovich/MSE-HKM

Sample Location: PLASTIC WRAPPED SPLIT SPOON
Date To Be Completed: 7/21/97

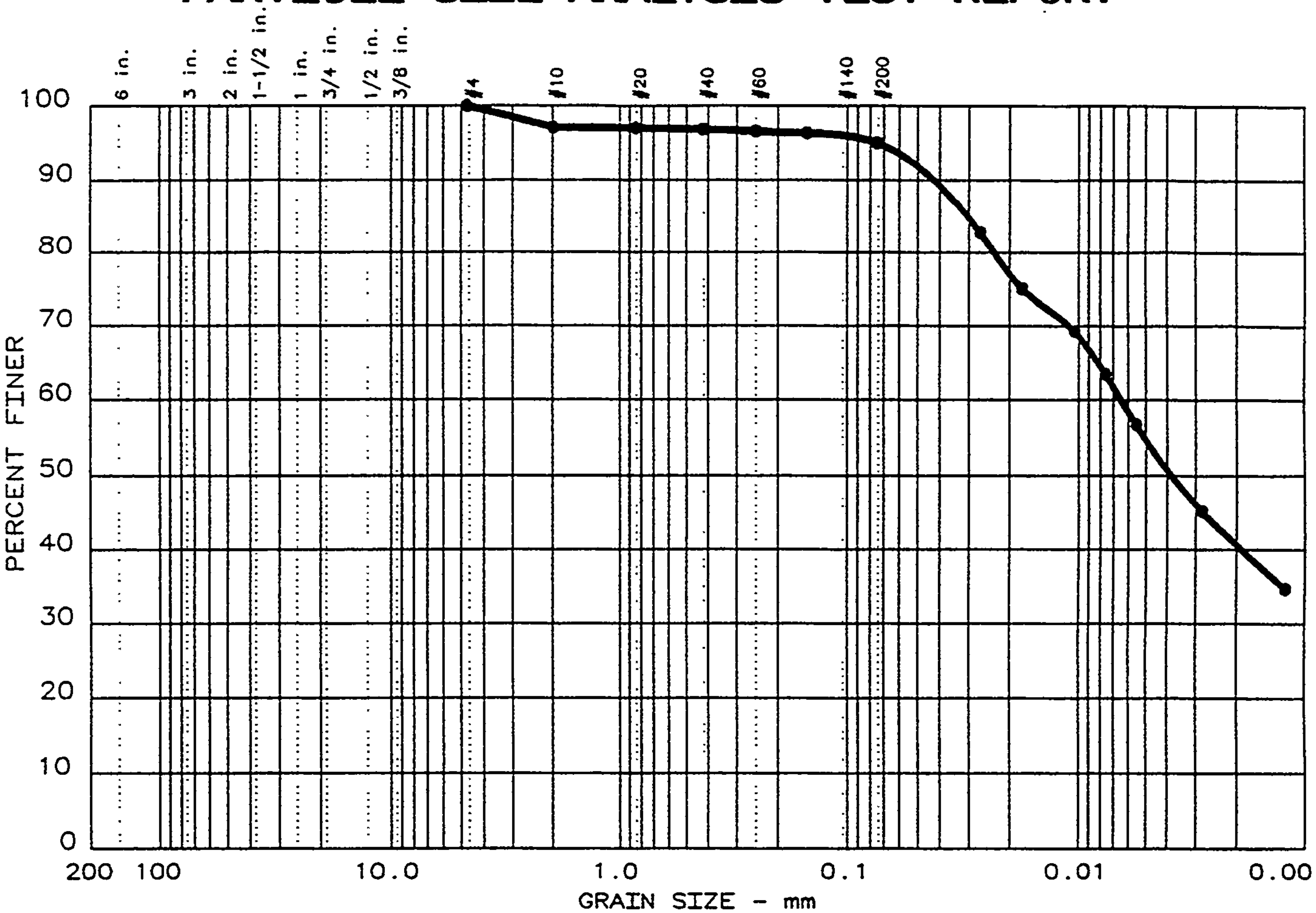
Container Type: Bucket Sack Tube Other (circled)
No of Containers: 3

Test Result Distribution: HARD COPY - SAMPLER
Containers Labeled: Yes (circled) No

Field No	Drill Hole	Depth,Ft	Visual Classification	Type	Natural Moisture S6	Gradation S12	Hydrometer S13	Proctor(std) S23	Unit Weight(soil)	Atterberg Limits S7	California Bearing Ratio S17	Unconfined Compression	Permeability	Direct Shear	Swell-Consolidation	Resistivity	Consolidation		
BH-1	1	14.5-16.0	LEAN CLAY	CL		X	X			X									
BH-2	2	16.0-17.5	LEAN CLAY	CL		↑	↑			↑									
BH-3	3	13.0-19.5	LEAN CLAY	CL		↑	↑			↑									

Remarks:

PARTICLE SIZE ANALYSIS TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	0.0	5.0	40.2	54.8	CL	48.3	28.0

SIEVE inches size	PERCENT FINER ●		
	GRAIN SIZE		
D_{60} D_{30} D_{10}			
	COEFFICIENTS		
C_c C_u			

SIEVE number size	PERCENT FINER ●		
4	100.0		
10	97.1		
20	97.0		
40	96.8		
60	96.6		
100	96.3		
200	95.0		

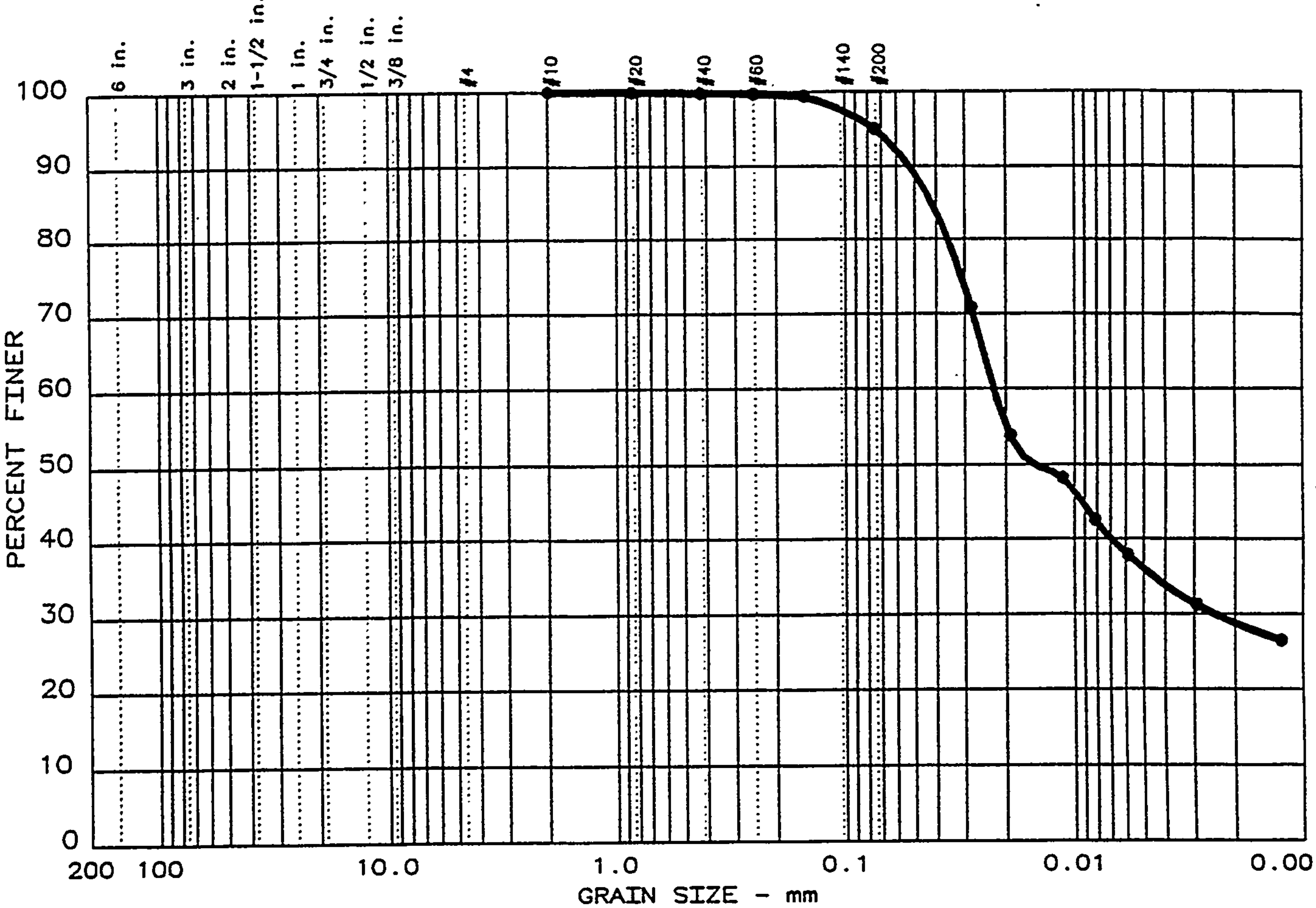
Sample information:
● LEAN CLAY
DEPTH:(14.5'- 16.0')
FIELD ID: BH-1

Remarks:
TEST METHOD:(ASTM D422)
DATE SAMPLED: 7/09/97
SAMPLED BY:A.Z./MSE-TA
LAB ID: 657

MSE-HKM, INC.

Project No.: 17M431.102
Project: IN-SITU WASTE STABILIZATION
Date: JULY 21,1997 Fig.No: 1

PARTICLE SIZE ANALYSIS TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	0.0	5.0	59.1	35.9	CL	35.0	19

SIEVE inches size	PERCENT FINER ●		
	GRAIN SIZE		
D_{60}	0.0025		
D_{30}			
D_{10}			
	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ●		
10	100.0		
20	99.9		
40	99.8		
60	99.7		
100	99.4		
200	95.0		

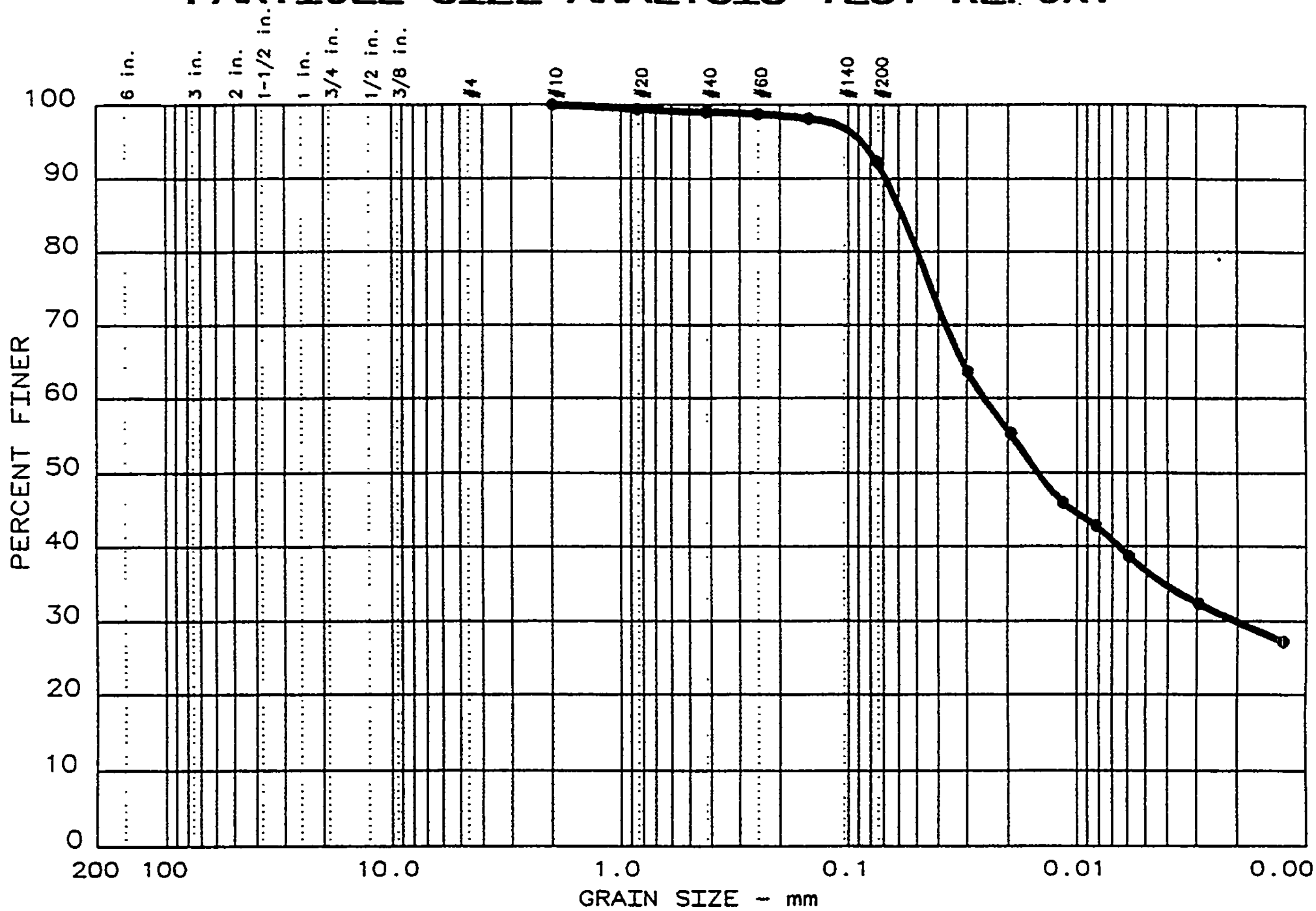
Sample information:
● LEAN CLAY
DEPTH:(16.0'- 17.5')
FIELD ID: BH-2

Remarks:
TEST METHOD:(ASTM D422)
DATE SAMPLED: 7/09/97
SAMPLED BY:A.Z./MSE-TA
LAB ID: 658

MSE-HKM, INC.

Project No.: 17M431.102
Project: IN-SITU WASTE STABILIZATION
Date: JULY 21,1997
Fig.No: 2

PARTICLE SIZE ANALYSIS TEST REPORT



	% +3"	% GRAVEL	% SAND	% SILT	% CLAY	USCS	LL	PI
●	0.0	0.0	7.7	55.7	36.6	CL	35.3	19.0

SIEVE inches size	PERCENT FINER ●		

	GRAIN SIZE		
D_{60}	0.0021		
D_{30}			
D_{10}			

	COEFFICIENTS		
C_c			
C_u			

SIEVE number size	PERCENT FINER ●		
10	100.0		
20	99.4		
40	99.0		
60	98.7		
100	98.1		
200	92.3		

Sample information:

● LEAN CLAY
DEPTH:(13.0'- 19.5')
FIELD ID: BH-3

Remarks:
TEST METHOD:(ASTM D422)
DATE SAMPLED: 7/19/97
SAMPLED BY:A.Z./MSE-TA
LAB ID: 659

MSE-HKM, INC.

Project No.: 17M431.102
Project: IN-SITU WASTE STABILIZATION

Date: JULY 21,1997 Fig.No: 3

INEEL/EXT-98-00009

Acid Pit Stabilization Project (Volume 2—Hot Testing)

Guy G. Loomis
James J. Jessmore
Andrew P. Zdinak[a]
Mark A. Ewanic[a]

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Idaho National Engineering and Environmental Laboratory
Environmental Restoration Technologies Department
Lockheed Martin Idaho Technologies Company
Idaho Falls, Idaho 83415

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Assistant Secretary for Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-94ID13223

[a] MSE Technology Applications, Inc., Butte, Montana.

ABSTRACT

During the summer and fall of Fiscal Year 1997, a Comprehensive Environmental Response, Compensation, and Liability Act Treatability Study was performed at the Idaho National Engineering and Environmental Laboratory. The study involved subsurface stabilization of a mixed waste contaminated soil site called the Acid Pit. This study represents the culmination of a successful technology development effort that spanned Fiscal Years 1994–1996, with the transfer of that technology to the intended customer, Environmental Restoration (EM-40). Research and development of the in situ grout stabilization technique were supported at the Idaho National Engineering and Environmental Laboratory by the Department of Energy's Office of Science and Technology (EM-50) through the Buried Waste Integrated Demonstration and Subsurface Contaminants Focus Area programs. Hardware and implementation techniques are currently documented in a patent pending with the United States Patent Office. The stabilization technique involved using jet grouting of an innovative grouting material to form a monolith out of the contamination zone. The monolith simultaneously provides a barrier to further contaminant migration and closes voids in the soil structure against further subsidence. This is accomplished by chemical incorporation of contaminants into less soluble species and achieving a general reduction in hydraulic conductivity within the monolith. The grout used for this study was TECT-HG, a relatively dense iron oxide-based cementitious grout. The treatability study involved cold testing followed by in situ stabilization of the Acid Pit, which is located within the laboratory's Subsurface Disposal Area. This report (Volume 2) discusses the results of the hot Acid Pit Stabilization phase of this project. Volume 1 discusses cold testing, performed as part of a "Management Readiness Assessment" in preparation for going hot. Drilling equipment was specially rigged to reduce the spread of contamination, and all grouting was performed under a concrete block containing void space to absorb any grout returns. Data evaluation included examination of implementability of the grouting process and an evaluation of the contaminant spread during grouting. Following curing of the stabilized pit, cores were obtained and evaluated for toxicity characteristic leaching procedure protocol for the main contaminant of concern, which was mercury. In addition, the cores were evaluated for the extent of mixing of the injected grout and the contaminated soil. A postgrouting geophysical evaluation of the grouted pit is presented.

EXECUTIVE SUMMARY

During the summer and fall of Fiscal Year 1997, a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Treatability Study was performed at the Idaho National Engineering and Environmental Laboratory (INEEL) to provide data for the assessment of an innovative in situ grout stabilization technique for application to buried waste sites. This study represents the culmination of a successful technology development effort that spans Fiscal Years 1994–1996, with the transfer of that technology to the intended customer, Environmental Restoration (EM-40). Research and development of the in situ grout stabilization technique were supported at the INEEL by the Department of Energy's (DOE) Office of Science and Technology (EM-50) through the Buried Waste Integrated Demonstration and Subsurface Contaminants Focus Area programs. Management for the project pursued involvement in this study from DOE Idaho Operations Office (DOE-ID) EM-40 project managers and their Environmental Protection Agency Region 10 (EPA) and Idaho Department of Health and Welfare (IDHW) counterparts, and INEEL Environmental Restoration (ER) Waste Area Group (WAG)-7 (Radioactive Waste Management Complex [RWMC]) management. WAG-7 management and their agency team aided in the selection of the Acid Pit site and provided guidance associated with the objectives and performance of the CERCLA Treatability Study.

The Acid Pit is a mixed waste contaminated soil region within the Subsurface Disposal Area, with small pCi/g quantities of radioactive materials including the main contaminant of concern of mercury at 5,320 ppm. The region of maximum contamination in the Acid Pit was selected for stabilization and the jet-grouting technology was applied to that region, which corresponds to the approximate center of the pit.

The in situ stabilization technique of jet grouting buried waste sites to create monoliths for either long-term disposal or interim storage followed by later retrieval was developed at the INEEL for buried transuranic waste but can also be applied to contaminated soil zones. The basic technology involves driving a drill stem into a buried waste site and, when fully inserted, pumping grout at high pressure into the waste while rotating and withdrawing the drill stem. The jet-grouting action causes a mixing of grout, soil, and waste, which, upon curing, results in a monolith. By using specially designed grouts, the resulting monolith can both stabilize the region against subsidence and chemically bind contaminants, essentially eliminating the potential for future migration.

As part of the treatability study, both cold and hot testing were performed at the INEEL; and a grout selection materials study was performed at Brookhaven National Laboratory. The project was supported by MSE Technology Applications, Inc. of Butte, Montana, in procurement and oversight of grouting operations. Cold testing was performed at the Cold Test Pit, which is located immediately south of the RWMC. Results of this cold testing are presented in Volume 1 of this report. Hot testing was performed at the INEEL Acid Pit located at the RWMC, and results are presented in this report (Volume 2).

The technology involves a drilling rig using rotopercussion (a CASA GRANDE C8 was used for the study), and the high-pressure pumping (3,500–6,000 psi) was accomplished using a B. J. Hughes positive displacement pump. Special contamination control features on the system included use of a drill string enclosure system including a drill stem shroud, catch can, and high-efficiency particulate air (HEPA) filter system to pull air currents through the HEPA filter from the point where the drill string enters the top surface of the pit. In addition, a specially designed concrete cap called a thrust block was used to collect any grout returns in a plenum or void space under the cap. The thrust block also allowed a level work area. The thrust block had predrilled holes lined with special wiper materials for insertion of the drill stem on a predesigned triangular pitch matrix with approximately 2 ft between holes.

Below is a summary of important findings from the hot Acid Pit CERCLA Treatability Study.

A monolith was successfully created within the zone of significant contamination using the INEEL-developed jet-grouting technique (U.S. patent pending). The process resulted in a monolith approximately 14 × 14 × 5-12 ft deep encompassing the zone of highest contamination within the Acid Pit. A total of 3,295 gal of grout was emplaced in four days of grouting, which accounts for an approximate 25% filling of the total volume (which approximately equals the accessible void volume in the soil). The process was accomplished without spread of hazardous or radioactive material to the surrounding area, and the grouting process occurred without shutdown by the radiation control technician, industrial hygienist, or safety engineers 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, and several contingency options were employed including varying the grouting pressure (3,500–6,000 psi), the height of the grouting operation (5 to 12-ft zone of grouting), and varying the order of grouting. As grouting progressed, it became more and more difficult to find an available hole that would accept grout without immediately returning some, indicating that the available voids in the pit were becoming filled and/or redistributed. In the first two days of grouting, approximately 2,400 gal of grout was emplaced. During the last two days of grouting, only approximately 800 gal of grout could be emplaced.

The hydraulic pressure of the emplaced grouts appeared to compress the surrounding soils such that when grouting an area adjacent to regions recently grouted, excessive grout returned. Even with the excessive returns, however, controlling grouting pressure and the distance grouted generally prevented grout returns from rising to the surface of the thrust block. Those positions where grout returned to the surface were easily cleaned using squeegees. Any contaminants in the returns remained locked in the slurry of grout and soil, and the surface quickly dried and was covered with plywood to protect vehicle and personnel traffic from the area.

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). Mercury concentration in the grout returns averaged 0.831 ppm, 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 under 1 g) and the drill stem (covered by the drill string enclosure) averaged 0.182 μg per smear.

The grouted pit was allowed to cure and several postgrouting evaluations were performed to assess the stated objectives, which related to leachability and stability of the resultant monolith. One study involved obtaining cores of the monolith using sonic drilling and evaluating the cores for toxicity characteristic leaching procedure (TCLP) protocol for mercury and also for determining the extent of grout penetration in the monolith. Another study involved subsurface geophysics evaluation of the extent of grouting using seismic techniques. The core evaluation study involved obtaining 11 cores in select positions within the grouted area. 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 targeting the region of maximum contamination. Examination of the cores obtained by sonic coring techniques showed that the sonic technique fractures the cores, making visual observations difficult and most analytical analysis impossible. A visual observation showed the presence of TECT-HG grout in most positions, even those not directly grouted but adjacent to the grouting area.

An analytical study was performed using marker elements that were significantly higher in the TECT-HG grout than the baseline Acid Pit soil (determined from earlier coring prior to grouting). These marker elements included calcium, iron, zinc, and lead. Assigning a value of 25% grout to represent a case that is 100% grouted resulted in an evaluation scheme in which the relative amount of grout penetration could be determined. From this, it was shown that the cores varied between 45–99% grouted, which is confirmed by the visual observations in that grout was observed in most cores. Select cores were evaluated using TCLP for mercury. For all the cores, the collected mercury in the leachate was well below action limits. The range of TCLP mercury levels in the leachate was 4.5–58.9 µg/L, with an associated regulatory action limit of 200 µg/L. This compares with an average concentration measured in the cores of 24 ppm mercury as a source term. In addition, the TCLP leachate was evaluated for heavy metals with similar low readings: arsenic (23.5–44.9 µg/L), barium (2,940–10,300 µg/L), cadmium (4.8–9.5 µg/L), chromium (2.2–5.4 µg/L), lead (1.1 µg/L), selenium (2.2–6.4 µg/L), and silver (4.4 µg/L).

A mixing study at Brookhaven National Laboratory on the TECH-HG grout showed that in the laboratory, the hydraulic conductivity of a soil/grout waste form was in the 1e-11 cm/s range, with compressive strengths approaching 2,000 psi. This Brookhaven study also showed that the initial assay for mercury in a pregrouting Acid Pit core sample was on the order of 10 ppm, which does not agree with the original assay performed in 1992 that showed 5,320 ppm mercury. It is speculated that the mercury contamination measured in the 1992 study must have been very localized to a small region (about 0.25 ft^3 of material). Even though the grout returns showed elevated mercury above background (the readings were all in the 1-ppm range), these readings do not support the source term of mercury in the Acid Pit at 5,320 ppm but rather agree more with the Brookhaven data of 10 ppm as a source term in the Acid Pit.

A geophysical evaluation of the Acid Pit confirmed the evaluation of the cores for grout penetration in that the seismic techniques showed a grouted monolith represented by zones of high velocities compared with the ungrouted portions of the Acid Pit. The technique of emplacing geophones down just grouted holes was found to be expedient.

A cost evaluation for full-scale application has been performed. The estimate includes only the cost of grouting, grout, radiation controls, and secondary waste management costs. Costs could easily double when considering permitting, management, and regulatory interface for a particular site. Costs are based on a per cubic foot of waste treated basis and have been calculated if a 6-ft or a 12-ft column was created. The 6-ft column is more expensive in that a 12-ft hole can be grouted in approximately the same time that a 6-ft hole can be grouted so that the operational costs are the same, yet the treated volume is doubled. The cost per cubic yard of waste treated for a 6-ft waste seam is $1,267 and for a 12-ft seam is $836 using the TECT-HG grout.

Overall, the treatability study demonstrated the viability of using jet grouting to stabilize a buried contaminated soil zone in situ. The study showed that stabilizing contaminated soil only is considerably more difficult than stabilizing buried debris. Implementing a few minor changes to the thrust block concept, including the use of hole packers in unused positions and slightly more void volume under the thrust block, would result in fewer grout returns to the surface and expedite the process. In addition, it is recommended that the grouting sequence be modified such that there is always an open face of soil for the grout to compress. In this manner, drill rig moves could be minimized while also minimizing grout returns. In summary, the technology can be recommended for application in buried waste sites involving contaminated soil only.

ACKNOWLEDGMENTS

The following people contributed many long hours under trying conditions to make the Comprehensive Environmental Response, Compensation, and Liability Act Treatability Study a reality. These individuals include Field Team Leader Kelly Galloway, Cold Test Pit Manager Larry Watson, and Cold Test Pit Test Engineers Mike Ancho and Elden Thompson. In addition, Ann Glenn provided mercury monitoring and S. M. Stoller's Bruce Miller and Silvia Medina aided by Dave Thompson managed field data. M. C. Pfeiffer evaluated geophysics, and John Heiser of Brookhaven National Laboratory evaluated grout materials.

The authors also wish to recognize the extended project management team, which enabled the technology to be tested at a contaminated waste site at the Idaho National Engineering and Environmental Laboratory 's Radioactive Waste Management Complex (RWMC), requiring support from Department of Energy (DOE) offices EM-50, EM-40, and EM-30. DOE Idaho Operations Office (DOE-ID) project managers for EM-50, Betsy Jonker and Aran Armstrong, DOE-ID EM-40 Project Manager Alan Jines, and DOE-ID EM-30 RWMC Facility Manager Geoffrey Beausoleil all contributed greatly to the project's success. Doug Jorgensen and Darwin Grigg represented Environmental Restoration Waste Area Group 7, and Tom Clements and his exceptional operations personnel at the RWMC ensured that the job was completed in a safe manner.

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FIGURES

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ACRONYMS

ANL	Argonne National Laboratory
API	American Petroleum Institute
ARAR	applicable and/or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
BNL	Brookhaven National Laboratory
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH	core hole
CR	core run
DF	degradation factor
DOE	Department of Energy
DOE-ID	Department of Energy Idaho Operations Office
EXT	external
FT	field trial
FY	fiscal year
GH	grout hole
HEPA	high-efficiency particulate air (filter)
ICP-MS	inductively coupled plasma-mass spectrometry
INEEL	Idaho National Engineering and Environmental Laboratory
LMITCO	Lockheed Martin Idaho Technologies Company
PPE	personal protective equipment
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area

TCLP	toxicity characteristic leaching procedure
TRU	transuranic
WAG	Waste Area Group

Acid Pit Stabilization Project (Volume 2–Hot Testing)

1. INTRODUCTION

During Fiscal Year 1997, a Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Treatability Study was performed at the Idaho National Engineering and Environmental Laboratory (INEEL) for in situ stabilization of buried waste sites. This study focused on the in situ stabilization of the Acid Pit at the Radioactive Waste Management Complex (RWMC) Subsurface Disposal Area (SDA) using jet-grouting methodologies developed at the INEEL.

This "hot" test of a mature technology represented the culmination of a successful research and development effort that spanned Fiscal Years (FYs) 1994–1996. From its inception, in situ grouting was designed to satisfy tough waste remediation problems faced by the Department of Energy (DOE) at many of its facilities. Research and development of the in situ grout stabilization technique was supported at the INEEL by DOE's Office of Science and Technology (EM-50) through the Buried Waste Integrated Demonstration and Subsurface Contaminants Focus Area programs. Project management at the start of this study initiated transition of the technology to the intended customer, Environmental Restoration (EM-40). Involvement was sought from the DOE Idaho Operations Office EM-40 project managers, their Environmental Protection Agency Region 10 and Idaho Department of Health and Welfare counterparts, and the INEEL Environmental Restoration Waste Area Group-7 (WAG-7) management team. WAG-7 management and their agency team aided in the selection of the Acid Pit site and provided guidance associated with the objectives and performance of the CERCLA Treatability Study. Their involvement over the course of the project was invaluable, providing a needed regulatory perspective. Based on the success of this project, discussions have commenced relative to the potential involvement of in situ grouting in WAG-7 Remedial Investigation/Feasibility Study work scheduled for FY-99 and FY-00.

The in situ stabilization technique of jet grouting buried waste sites to create monoliths for either long-term disposal or interim storage followed by later retrieval was developed at the INEEL for buried transuranic (TRU) waste but also can be applied to contaminated soil zones. As part of the treatability study, both cold and hot testing were performed at the INEEL and a grout selection materials study was performed at Brookhaven National Laboratory. The project was supported by MSE Technology Applications, Inc. of Butte, Montana, in procurement, supplemental oversight of grouting operations, and geophysical monitoring.

The cold testing was performed at the Cold Test Pit, which is located immediately south of the RWMC. Results of this cold testing are presented in Volume 1 of this report. The hot testing was performed at the INEEL Acid Pit located at the RWMC. Results are presented in this report (Volume 2). What follows is a background section discussing the technology and results of the cold testing. This is followed by a procedure and sequence of events section, a results and evaluation section, a cost of implementation section, and a conclusions and recommendations section. The results section discusses (1) grouting relative to overall implementability of the technology and the amount of grout injected into the pit, (2) contamination control during grouting, (3) TECT grout in cores from the cured monolith, (4) leachability of the cured monolith for the main contaminant of concern (mercury) using toxicity characteristic leaching procedure (TCLP), and (5) geophysical aspects of the grouted pit.

2. BACKGROUND TECHNOLOGY DESCRIPTION

2.1 Basic Problem

At the INEEL, the SDA contains a variety of buried wastes including buried debris and contaminated soil zones. The Acid Pit is an example of a mixed waste contaminated soil zone. The main contaminate of concern is mercury, at a concentration in certain zones as high as 5,320 ppm. Only minor amounts of manmade radionuclides exist in the pit (pCi/g quantities), and 99% of the contaminants reside in the bottom 6 ft of the pit.

The pit is approximately 17 ft deep and consists of a surface area about 197 × 104 ft as shown in Figure 1. The Acid Pit was used to dispose of liquid phase acids in the highly alkaline soils by direct dumping and absorption of the liquid phase onto the soil, with some additions of unknown amounts of lime to ensure the acids were neutralized. As the pit was used, soil layers were added; then, a backfill of clean soil was added. The top 5 ft of the pit is essentially free of contaminants.

For the purpose of the treatability study, a small but significant portion of the Acid Pit was chosen for the grouting process. The area of interest is in the roughly geometric center of the pit; however, this region was chosen as an area representing the highest levels of contaminants within the pit based on sampling from 12 core holes (also shown in Figure 1). Based on this Track-2 study,[1] it was found that in core hole 11, the highest levels of mercury were measured (as shown in Figure 2). Therefore, an area approximately 14 × 14 ft centered about core hole 11 was treated with the grouting technology.

Soil samples collected as part of the Acid Pit Track-2 Investigation[1] were analyzed for organics, inorganics, semivolatiles, and radioactive constituents. Table 1 provides an overview of the contaminants and the maximum corresponding concentrations detected during sampling. It was determined that mercury was the primary risk driver, and the maximum mercury concentration detected during the Phase-1 sampling was 5,320 milligrams per kilogram (mg/kg).

2.2 Technology Description

The basic technology involves nonreplacement jet grouting in which the drill stem of a jet-grouting rig is driven into the waste as shown in Figure 3. Once inserted, jet grouting is started as the drill stem is withdrawn in precise increments while rotating and injecting grout through nozzles at the bottom of the drill stem. In this manner, a column of soil/grout mix is created. The process is repeated several times on an approximate 2-ft triangular pitch matrix, thus creating a solid monolith out of the contaminated zone by creating interlocking columns. Although "nonreplacement" jet grouting means grouting with no grout returns, some grout returns are inevitable. Any grout returns are collected in the void space under a specially prepared concrete cap called a "thrust block." The thrust block isolates the drill rig from the surface of the soil and allows work to proceed in a "clean" area.

The main object is to create a cohesive monolith, while minimizing and controlling contaminated grout returns. The treatability study was designed based on past testing in buried debris, and the subject cold testing evolved into developing new grouting parameters for application at the Acid Pit. This was performed immediately following the cold testing phase. Grouting parameters included jet-grouting pressure, time on a step, drill-stem rotational speed, and step size. Grout used for the testing was a proprietary iron oxide-rich cementitious grout called TECT-HG supplied by Carter Technologies of Houston, Texas. The drilling contractor for all testing and the Acid Pit stabilization was Geo-Con, Inc. of Monroeville, Pennsylvania. Geo-Con, Inc. provided grout emplacement services for the Cold Test Demonstration and Acid Pit Stabilization phases. This company's jet-grouting system consisted of the components given below.

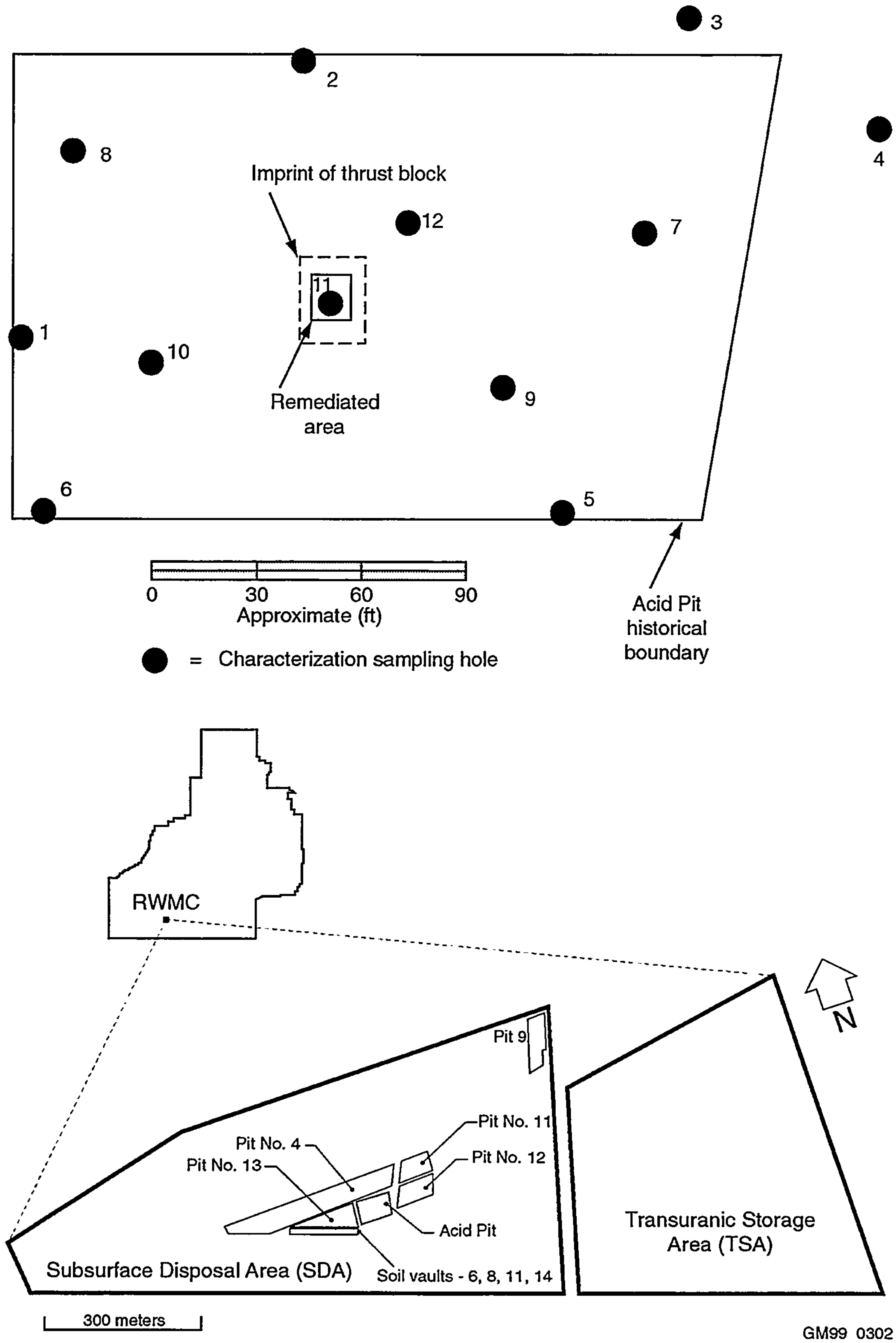


Figure 1. Above is a map of the Acid Pit remediation area. Below is a map of the Acid Pit as situated at the SDA of the RWMC at the INEEL (Graphic GM99 0302).

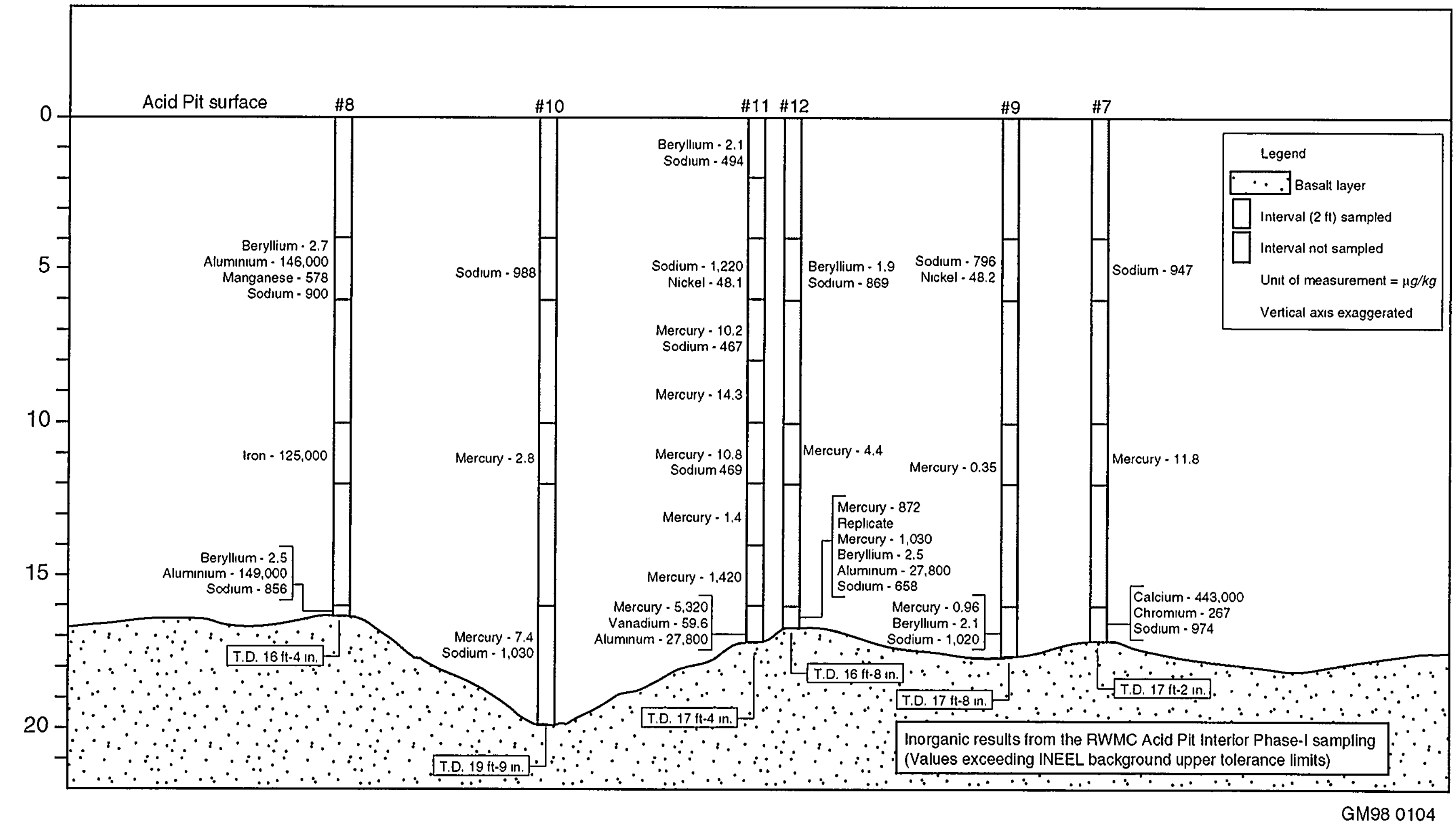


Figure 2. Inorganic results from the RWMC Acid Pit interior Phase-I sampling (Graphic GM98 0104).

Table 1. Concentration ranges for contaminants detected from core hole 11 during Phase-1 sampling.

Contaminant Group	Contaminant Compound	Concentration Range
Radionuclides	Alpha-emitting	
	U-234	1.8 to 5.0 pCi/g
	U-235	0.1 to 0.6 pCi/g
	U-238	2.0 to 7.7 pCi/g
	Pu-238	0.04 to 0.11 pCi/g
	Pu-239	0.08 to 0.24 pCi/g
	Am-241	0.1 to 0.5 pCi/g
	Gamma-emitting	
	Am-241	1.51 pCi/g
	Co-60	1.58 to 1.97 pCi/g
	Cs-137	114.0 to 125.0 pCi/g
	Eu-152	0.374 to 0.523 pCi/g
		34.4 pCi/g
	Th-234	21.8 pCi/g
	U-235	1.44 pCi/g
Metals	Mercury	1.4 to 5,320 mg/kg
	Beryllium	2.1 mg/kg
	Nickel	48.1 mg/kg
	Vanadium	59.6 mg/kg
Nonmetal Inorganics	Nitrate	0.32 to 5,590 mg/kg
	Sulfate	18.2 to 10,600 mg/kg
	Total organic carbon	5,260 to 11,400 mg/kg
	Sodium	467 to 1,220 mg/kg
Organics	Volatile Organics	
	Acetone	12 to 210 µg/kg
	Chloroform	18 to 48 µg/kg
	1,1,1- Trichloroethane	1,500 µg/kg
	Trichloroethene	18 to 39 µg/kg
	Methylene Chloride	6 to 190 µg/kg
	Carbon Tetrachloride	24 to 110 µg/kg
	Tetrachloroethene	9 µg/kg
	2-Butanone	25 µg/kg
	Semivolatile	
	Bis-(2-Ethylhexyl) phthalate	490 to 5,200 µg/kg
	Tributylphosphate	29,000 to 53,000 µg/kg
	Di-n-butylphthalate	44 to 170 µg/kg
	Butylbenzylphthalate	43 µg/kg
	2,4—Dinitrophenol	140 to 220 µg/kg
	Fluoranthene	85 µg/kg
	Pyrene	67 µg/kg
	Diethylpthalate	20 µg/kg

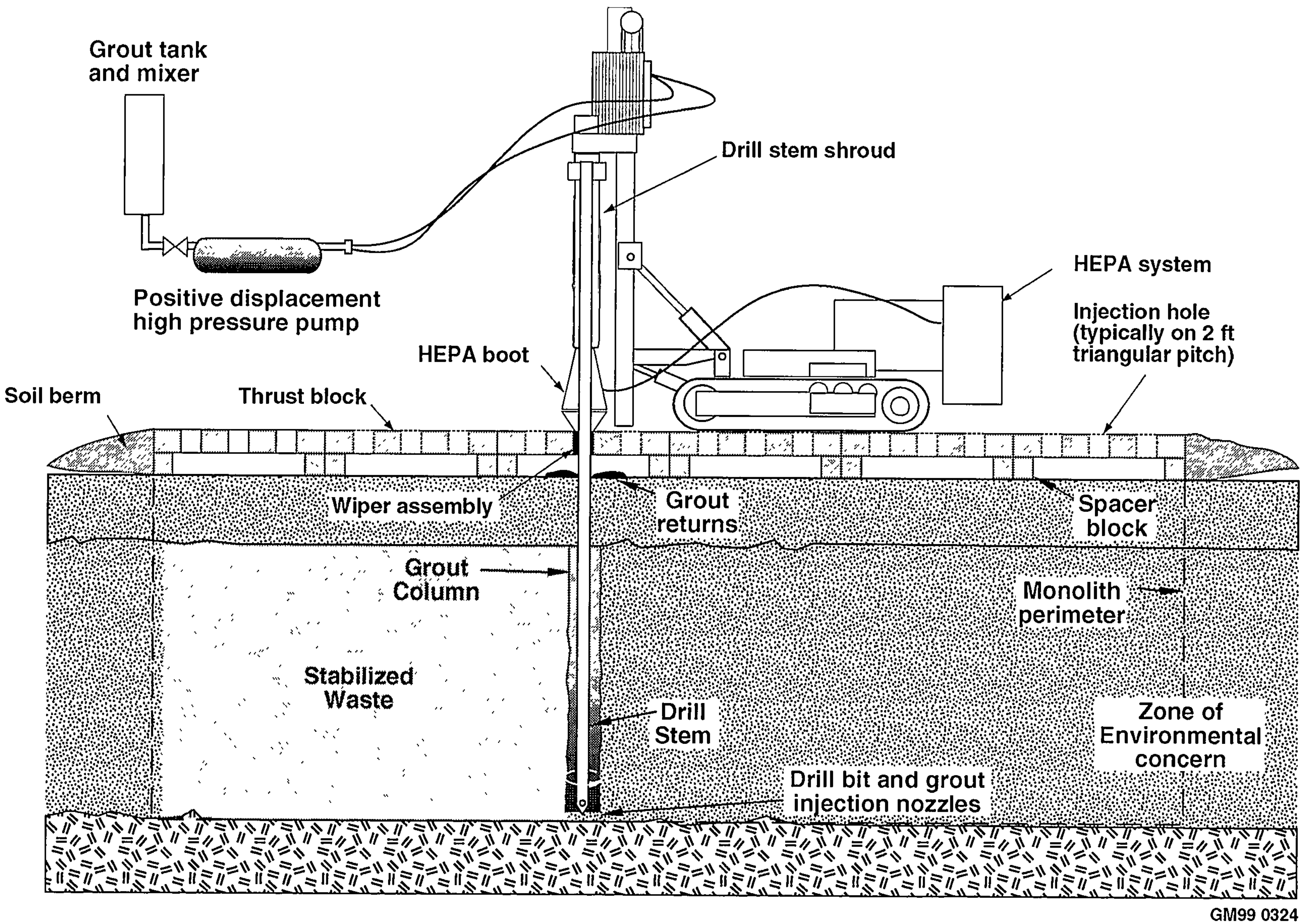


Figure 3. Schematic of the jet-grouting apparatus using the thrust block (Graphic GM99 0324).

- A CASA GRANDE C8 drill rig with rotopercussion drilling capabilities (Note: A DAVY KENT DK70 drill/jet-grouting rig was initially used during the Phase-1 Cold Test Demonstration but was later replaced by the CASA GRANDE system).

- A BJU V-16 diesel-powered 750-horsepower positive displacement pump with standard 13-speed transmission for high-pressure grout injection. This pump had a maximum injection pressure of 10,000 psi and maximum flow rate of 140 gal per minute.

- A Moyno 10 pump for transferring grout from the cement truck to the high-pressure pump. This pump had a maximum flow rate of 125 gal per minute. A hopper attachment with dual-screen inserts was attached to the pump for filtering the grout mixture from the cement truck.

- Two types of metering devices to measure injected grout volume: a Haliburton Model MC-II flow analyzer to measure high-pressure flow and a CRE Magnetic flowmeter to measure low-pressure flow.

The CASA GRANDE C8 rig was equipped with programmable instrumentation for setting the jet-grouting parameters (i.e., controlling mast movement and rotary head speed). The panel could be positioned conveniently to enable the operator to see the hole during drilling and grouting. Grout injection pressure was controlled by the pump operator, and the grouting interval was coordinated between the driller and pump operator.

A number of contamination control measures were specified by the INEEL for the field demonstrations. To control contaminant exposure to workers and the grouting equipment, the jet-grouting apparatus was equipped with a high-efficiency particulate air (HEPA) filter system, a collapsible shroud covering the drill stem, and a catch can for containment of excess grout materials. A catch cup was used to assist with containing excess grout during drill stem transfer between grout holes. Blotter paper and a spill containment pan were placed over each grout access hole to control minor drips and spills during removal of contamination control devices. Figures 4, 5, and 6 show the contamination control equipment and grouting apparatus.

Thrust block panels were placed over each test area to provide a level working surface for the jet-grouting rig and to control excessive grout returns. These blocks would also serve as a cap after completion of grout emplacement and field evaluation activities. Figure 7 shows the basic panel design of the thrust block used for the Acid Pit. The original design used in the cold testing described in Reference 2 was modified to allow approximately twice the plenum volume under the thrust block. For the Acid Pit, there was a volume associated with each hole such that approximately 16 gal of grout could come up each hole without filling the void space under the thrust block.

The working area was formed by connecting the panels together. An example of two connected panels is shown in Figure 8, which was used during Cold Test Pit studies discussed in Volume 1 of this report. Six preconstructed thrust block panels were delivered to the site and placed onto the Acid Pit. Access holes were constructed into the thrust blocks for inserting the drill stem and catch cup assemblage. These access holes were nominally 5 in. in diameter and spaced in a grid pattern approximately 19 to 24 in. apart on centers. Access holes were equipped with neoprene material to wipe and clean the drill stem as it is extracted from the grouted hole (Figure 9).

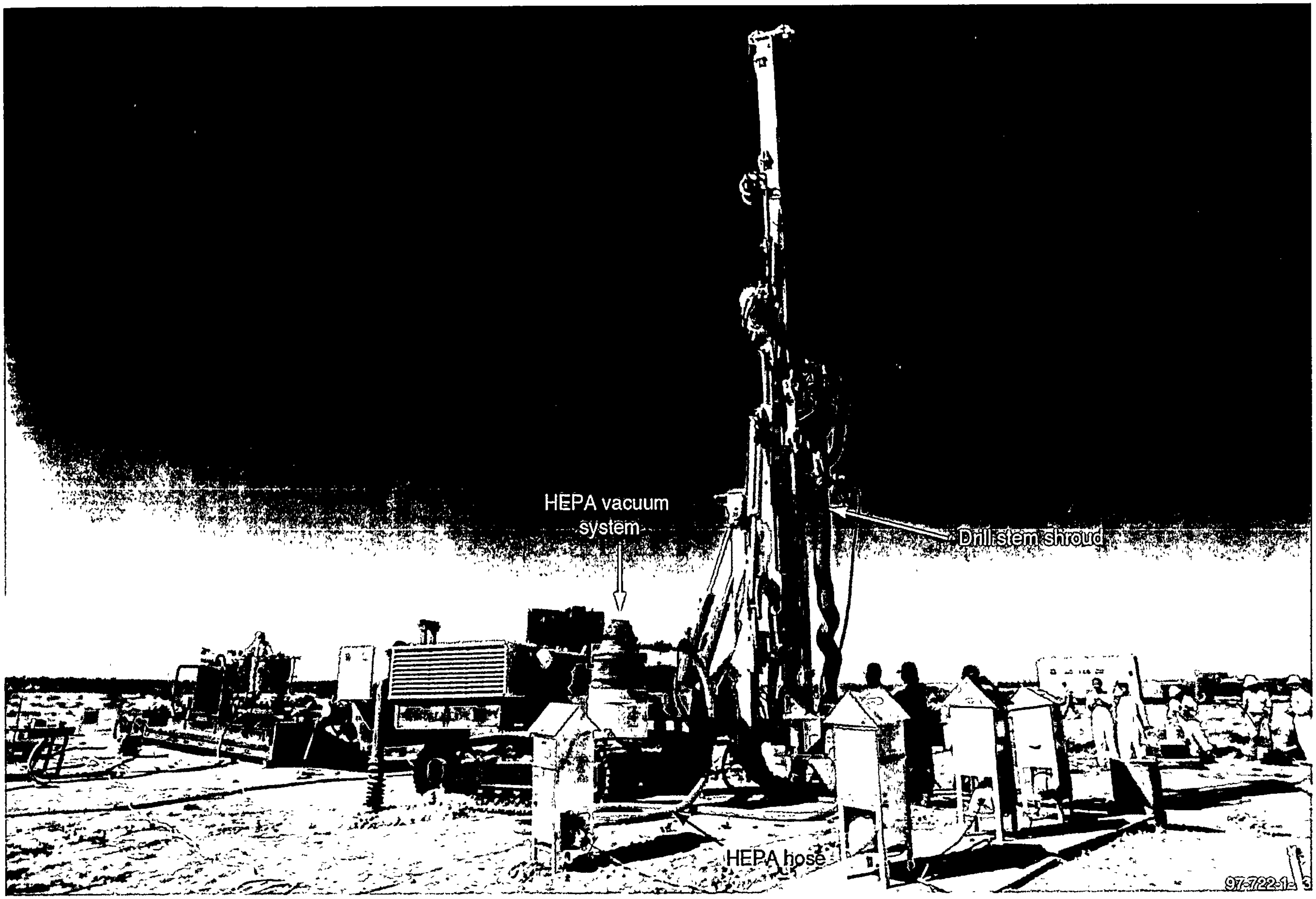


Figure 4. HEPA vacuum system installed on CASA GRANDE C8 (Graphic M98 0010).

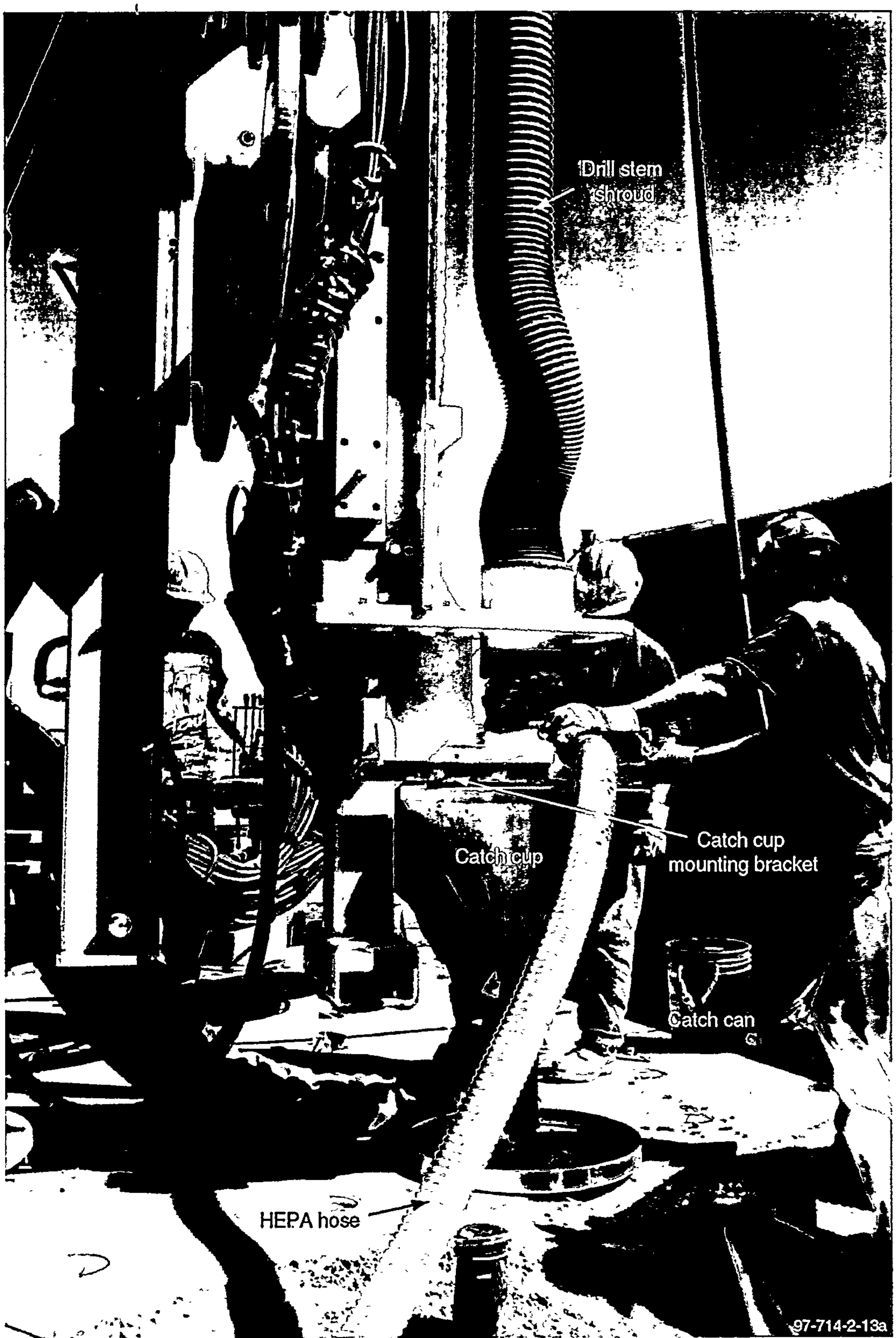


Figure 5. Features of the contamination control system for the CASA GRANDE system (Graphic M98 0009).

Figure 6. Catch can installed at the bottom of the catch cup and drip pan showing typical grout droppings (Graphic M98 0011).

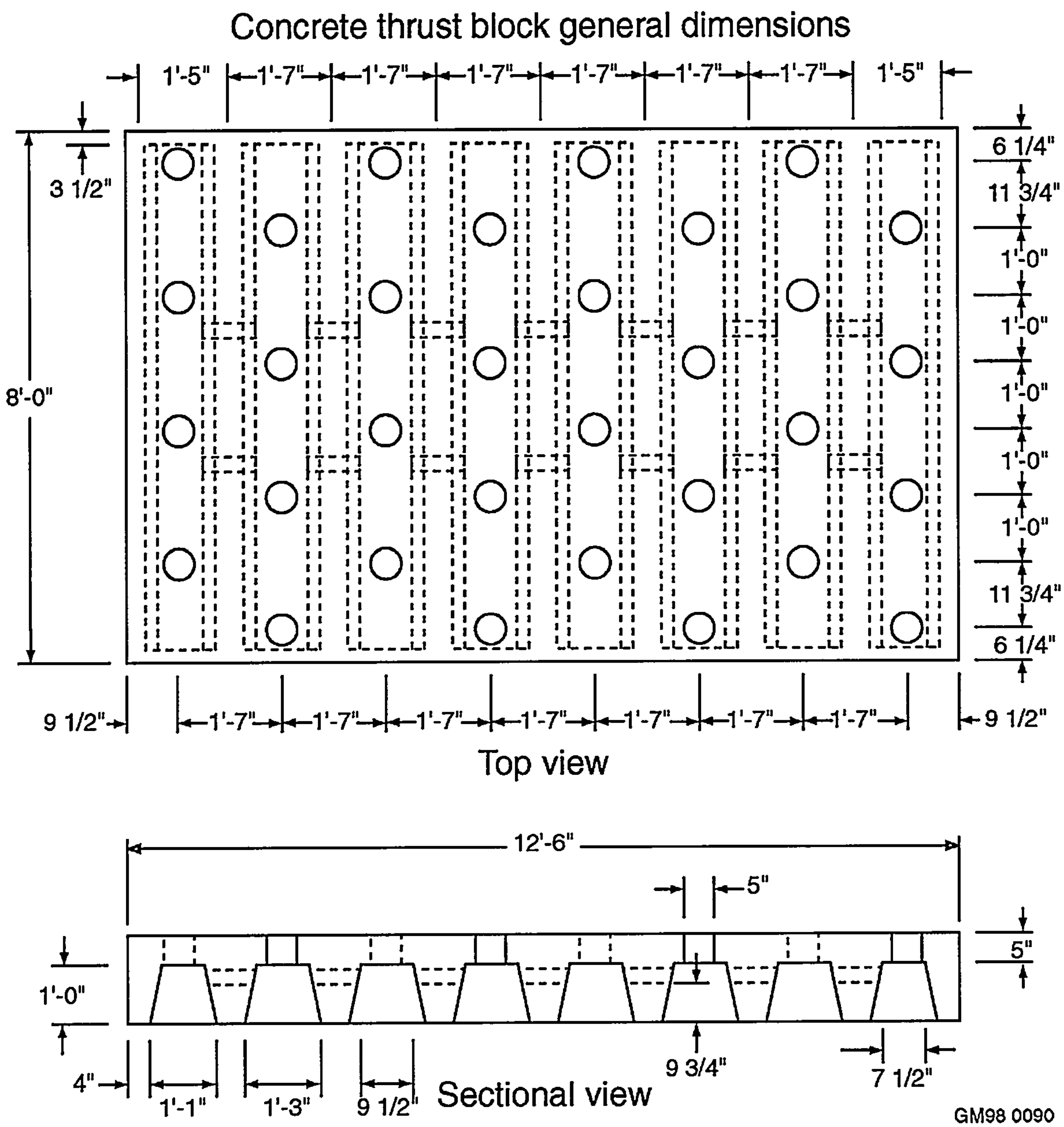
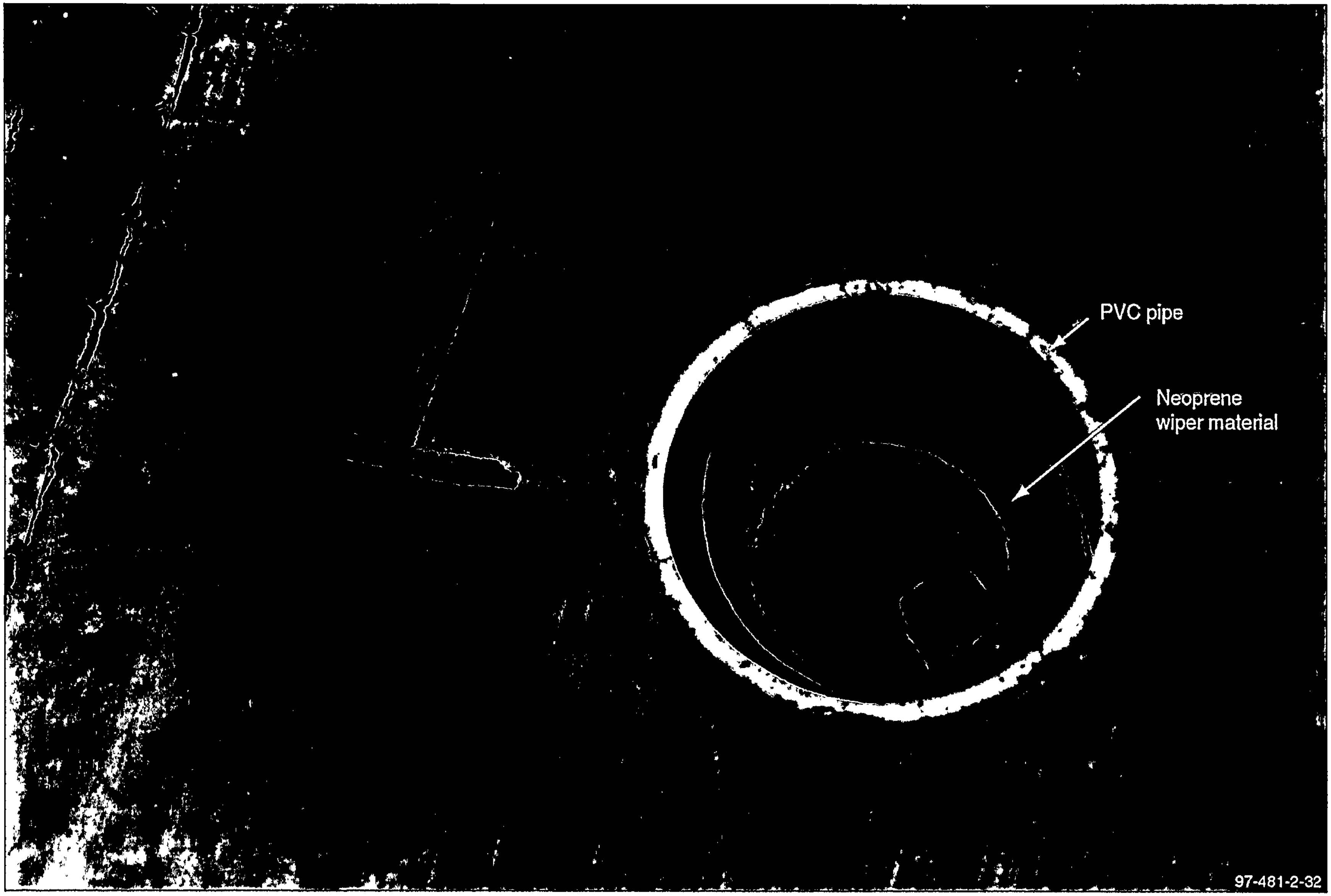


Figure 7. Basic design of the Acid Pit thrust block (Graphic GM98 0090).

Figure 8. Thrust block shown backfilled flush with surrounding soil (Graphic M98 0013).



M98 0015

Figure 9. Detail of the thrust block surface (Graphic M98 0015).

2.3 Cold Testing Results

One of the high-level requirements from the Subsurface Contaminants Focus Area was to perform a hot demonstration or treatability study during FY-97, and all buried waste sites were considered. However, it became obvious that given the schedule and budget, the Acid Pit presented a desirable low radiological and hazardous risk site at which to perform the treatability study (to perform the treatability study in a TRU pit or trench would most likely take the entire schedule and a significant portion of the budget to obtain permission to proceed). The only technical problem was that the technology had only been applied in a limited manner in contaminated soil zones. Rather, the technology was developed for buried debris, which inherently is easier to grout because of the large voids in the waste to absorb excess grout during jet grouting. In past studies,[2,3,4] the technology was demonstrated that the grouting operation could be performed in buried debris sites with no airborne contamination spread and that the amount of grout returns could be controlled and minimized. This body of knowledge did not exist for soil-only sites. Therefore, it was important to perform check-out tests in the INEEL Cold Test Pit, which are documented in Volume 1 of this report. What was learned from these tests was applied directly in the actual stabilization of the Acid Pit, which occurred in the fall of 1997. Results of the cold testing are summarized below.

The cold testing occurred at the INEEL's Cold Test Pit, which is located essentially adjacent to the RWMC. At the Cold Test Pit, a series of grouting operations were performed in specially prepared soil zones called pits, as well as individual and connected grouting holes called field trials. The technology was originally developed for buried debris in shallow land burial sites. As testing progressed, it became apparent that the technologies required considerably different grouting parameters. In the prior debris pit grouting, there were large voids in the waste; and the soil was relatively loosely packed around the debris. The presence of these large voids allowed jet grouting with minimal grout returns.

Parameters for application in the Acid Pit were successfully developed from a variety of testing in several Cold Test Pits located near the RWMC. The previous experience with grouting buried debris found that good monolith formation required considerably higher total grout delivered per foot than in soil-only sites. This differential between soil sites and debris sites was unknown when starting the program, and considerable testing of the various parameters—most notably the time on a step—was performed to balance good column formation against minimizing grout returns. This testing involved two different drill rigs: a DAVY KENT without rotopercussion and a CASA GRANDE C8 with rotopercussion. It was determined immediately that the DAVY KENT without rotopercussion could not penetrate the INEEL soil fast enough. The relatively slow drilling progress with the DAVY KENT caused excess drilling fluid flow (grout) to emanate from the drill hole (thus filling the thrust block), which prompted the use of the CASA GRANDE C8 drilling system.

The CASA GRANDE C8 drilling system was found to be more than adequate for quick penetration using rotopercussion and additionally in controlling grouting parameters during grouting. By grouting two different test sites of previously disturbed soil using the thrust blocks to contain grout returns, it was determined that the following grouting parameters could be recommended for the selected grout material: grouting pressure—6,000 psi, step size 5 cm, duration on a step-2 s, revolutions of the drill stem on a step-2. These parameters created a cohesive monolith while minimizing grout returns in a previously disturbed soil site simulating the Acid Pit. In developing these parameters, a variety of field trials involving single and multiple connected holes were performed with and without the thrust block. In some cases, grout parameters were changed in the middle of a grouting campaign to accommodate excess grout returns. Through a series of trial and error grouting efforts, a final pit called the "Operational Readiness Pit" was successfully grouted (drill down 17 ft and grout out the bottom 6 ft) with essentially no grout returns. Parameters obtained from this testing were recommended for use in the Acid Pit stabilization, which is the subject of this report. Volume 1 of this report contains all the results of the cold testing.

2.4 Grout Material Testing

A variety of grouting materials have been identified in past testing at the INEEL. These have included both cementitious materials, organic polymers, and even molten paraffin.[2,3,4] In these past cold studies, the property involving chemical fixation of contaminants was never examined. Therefore, as part of the Acid Pit stabilization, the promising grouting materials were tested at Brookhaven National Laboratory for leachability of resultant waste forms and also for durability. Detailed results of this study are given in Appendix A. Five grouting materials were tested at Brookhaven, including two commercially available materials and three innovative materials. The two commercial grouts were American Society for Testing and Materials (ASTM) Type-I and American Petroleum Institute (API) Type-H (similar to ASTM Type-V) Portland cement. The three innovative grouting systems were TECT-HG, molten paraffin wax (WaxFix), and a special magnesium/potassium/phosphate cement known as MKP. The innovative materials were formulated and provided by two different vendors. TECT-HG (the specialized additive grout for stabilizing mercury) and WaxFix were provided by Carter Technologies. MKP was supplied by Argonne National Laboratory (ANL) in Chicago. Based on mixing, leaching, and durability studies at Brookhaven, the TECT-HG material was chosen for the Acid Pit stabilization project.

TECT-HG is a specially blended proprietary material from Carter Technologies. The grout is a cement-based material with high iron oxide content, plus specially added surfactants and scavengers for the mercury contaminant in the actual hot Acid Pit. This type of grout had been successfully used in FY-96 as documented in Reference 4. The grout is high density at nominally 18 lbm/gal; however, for the same relative density, the viscosity of the grout varied greatly from one test to another (the variation was for a funnel viscometer 2:32 to 7:43 minutes).

3. OBJECTIVES

The overall treatability study objective was to provide the INEEL Environmental Restoration Program with sufficient data to evaluate the subsurface stabilization technology under the CERCLA guidance. The project objective was to successfully emplace a grout monolith to encompass a zone of environmental concern as identified in the Track-2 characterization of the Acid Pit.[1] The criteria for assessing the success of this objective included producing a monolith that:

- Decreases leachability/mobility of contaminants below accepted levels.
- Resists subsidence and maintains structural integrity.
- Is durable and resistant to degradation to provide long-term contaminant containment/encapsulation.
- Is compatible with the surrounding geochemical environment.
- Is applicable for full-scale site remediation and implementation.
- Minimizes contamination exposures during field operations.
- Is verifiable to allow for performance monitoring.
- Is retrievable at some later date, if required.
- Is economically feasible.

There were three primary phases of this treatability study. The phases were designed to ensure that the final emplacement of the monolith in the Acid Pit was efficient and safely performed and that the monolith creation had been optimized to meet the overall treatability study objectives. The three phases are:

1. Materials Testing.
2. Cold Test Demonstration.
3. Acid Pit Stabilization.

Each phase had specific test objectives. The Materials Testing phase presented in Appendix A was a Resource Conservation and Recovery Act (RCRA) Treatability Study using actual soil from the Acid Pit. This phase was used for determining optimal grout selection. The Cold Test Demonstration phase presented in Volume 1 of this document provided significant information by evaluating equipment and processes at an established, clean, nonradiological, and nonhazardous test site. Information collected from the Materials Testing and Cold Test Demonstration were fed into the Acid Pit Stabilization phase, which is the subject report.

Table 2 summarizes how the data collected for the treatability study would be used in evaluating the technology for the remedy screening/selection process in the Waste Area Group (WAG)-7 Comprehensive Feasibility Study.

Table 2. Remedial Investigation/Feasibility Study (RI/FS) Primary Evaluation Criteria and the treatability study data collection categories.

RI/FS Primary Evaluation Criteria	Data Collection Category	Measurements and Tests	Purpose and Comments
Overall Protection of Human Health and Environment	Contaminant Fixation/ Stabilization Permeability	Toxicity Characteristic Leaching Procedure (TCLP) Hydraulic Conductivity	For this criteria, analytical and hydraulic conductivity measurements will be evaluated to determine the ability of the monolith to eliminate, reduce, or control site risks associated with target contaminants. These tests will evaluate how effective the monolith reduces the target contaminant concentrations to acceptable risk levels by controlling contaminant transport and exposure pathways.
Compliance w/ Applicable and/or Relevant and Appropriate Requirements (ARARs)	Contaminant Fixation/ Stabilization	TCLP	For compliance with ARARs, test results will provide information to determine if target contaminant levels are below the maximum acceptable concentration or regulatory levels.
Long-Term Effectiveness and Permanence	Durability/ Long-Term Effectiveness and Compatibility	Wet/Dry Cycling Wet/Dry Cycling w/ Hydraulic Conductivity Tests; Compressive Strength Tests; Accelerated Leach Tests	Tests will be conducted to evaluate the ability of the monolith to resist degradation and to maintain contaminant encapsulation/containment. Degradation (i.e., cracking) will be evaluated to assess potential increased surface area for increased dissolution.
Reduction of Toxicity, Mobility, and Volume Through Treatment	Contaminant Fixation/ Stabilization Durability/Long-Term Effectiveness	TCLP Accelerated Leach Tests	Analytical tests will be conducted to evaluate the percent reduction in the leachable concentration of the targeted contaminant(s). TCLP analysis will be conducted to evaluate performance using regulatory tests. Accelerated leach testing will be used to evaluate performance under accelerated natural conditions and assess the irreversibility of the process.
Short-Term Effectiveness	Implementability Verification	Grout Emplacement Parameter Measurements Contamination Control System Monitoring Thermal Measurements—Cure Time Geophysical Surveys Core Recovery and Destructive Examinations	Grouting parameters (i.e., injection volume, injection pressure, etc.) will be measured to determine the time required for monolith emplacement. The effectiveness to protect the site and workers from exposure to contaminants will be evaluated through monitoring of the contamination control system and site personnel during grout emplacement. Thermal measurements will be evaluated to determine the time required for grout curing to produce the monolith that stabilizes the contaminants. Completeness of the grout application will be evaluated by core recovery, destructive examinations, and geophysical surveys. All these factors will be used to determine the time required to achieve the remedial objectives for full-scale application at the Acid Pit.

Table 2. (continued).

RI/FS Primary Evaluation Criteria	Data Collection Category	Measurements and Tests	Purpose and Comments
Implementability	Implementability	Grout Emplacement Parameter Measurements Field Operational Measurements Contamination Control System Monitoring	Parameter measurements for grout emplacement will allow for assessment of operational and associated application difficulties that could be encountered during emplacement of the monolith. Logistic issues associated with support systems will also be assessed for implementation of this technology. Reliability of the technology will be evaluated through the quality assurance program and verified by core evaluations and geophysical monitoring. In addressing the potential of this technology to support additional remedial actions, the retrievability will be evaluated by core recoveries and destructive examinations. Geophysical surveys and other studies may be conducted for long-term performance monitoring. An important operational issue that could affect the application of this technology at a waste site is the potential for contaminant releases during grout emplacement. Contamination control measures will be monitored to evaluate the effectiveness of engineered systems to provide adequate protection to minimize potential delays and loss of equipment.
	Verification	Geophysical Surveys Core Recovery and Destructive Examinations	
	Retrievability	Core Recovery and Destructive Examinations	
Cost	Economics	Cost Evaluations: Grout Emplacement Grout Material Site Operational Support	Full-scale direct costs will be estimated based on information obtained after completion of field activities. Based on application assumptions derived from field demonstrations, individual cost factors will be estimated for the full-scale remediation of the Acid Pit. The grout emplacement subcontractor and grout developers will provide input to this cost estimate. Site operational factors will also be considered for this cost estimate evaluation.

4. SEQUENCE OF EVENTS, EQUIPMENT, GROUTING PARAMETERS

This section discusses the sequence of events and the various grouting parameters used during the Acid Pit Stabilization phase.

Prior to mobilizing equipment to the Acid Pit, the top overburden surface of the area was excavated approximately 18 in., and the six interconnected thrust block panels were emplaced on an approximately 6-in. pad of pea gravel (one-quarter to one-half inch in diameter). The surrounding soils were bermed against the thrust block, which made the top surface of the thrust block essentially even with the surrounding soil of the Acid Pit. Figure 10 shows the basic layout for the thrust blocks, including holes for filling the void space in the unused portions of the thrust block after the grouting operation. Figure 10 also shows a numbering system for the grout holes that was developed during the planning phases of the testing. This numbering system does not reflect the rotation of grouting operations; rather, it represents a reference for keeping track of the grouting operation. In addition, the weather shield was established immediately south and west of the thrust block to provide protection for air sampling during grouting (the prevailing southwest winds were light, i.e., less than 10 mph during the entire operation). Exclusion zones were established including an equipment development area and a contamination reduction zone as shown in Figure 11. Based on anticipated levels of contamination and associated contamination control hardware demonstrated effectiveness, workers entering the contamination reduction zone were required to wear rubber overboots, latex gloves, and white coveralls as personal protective equipment (PPE). The project Health and Safety Plan[5] stipulated action levels with associated PPE upgrades should they be required. The site was continuously monitored for various contaminants by radiation control technicians and industrial hygienists during operations. In addition, all workers were expected to exit the zone through a gate system, remove PPE, and then survey for radioactive contamination.

Following extensive cold testing described in Volume 1 of this report, the drilling and pumping equipment were mobilized to the Acid Pit. The exclusion zone, established around the immediate vicinity of the Acid Pit, included enough room for moving the drill rig from hole to hole during grouting as shown in Figure 12. This figure also shows the wind screen in place and the drill rig in position to grout. Pumping equipment and grout delivery systems were outside the contamination zone, which allowed for easy access by cement trucks. Communication between the grout-supply and grout-injection operators was performed with radios and hand signals as stipulated by the project Health and Safety Plan.[5]

Grout material (TECT-HG) was mixed at the Valley Ready Mix plant in Idaho Falls, Idaho. Mixing was accomplished by hand loading dry ingredients to cleaned Ready Mix trucks located approximately 1.5 hours from the testing area. Controlling the viscosity was relatively easy in that a simple water addition to the Ready Mix truck could lower the viscosity. At the start of the program, the importance of viscosity on jet groutability was not recognized as a test variable; but as the testing unfolded, the viscosity was continuously measured. The main problem with lower-viscosity materials was the tendency to "filter cake" in all pumping and drilling equipment. During cold testing, the grout vendor inadvertently brought a too low viscosity mixture (1:28 minutes for a funnel viscometer, which was caused by excess water in the Ready Mix truck when mixing in the ingredients). In this case, the jet nozzles and pumping equipment were continuously plugged and operations had to shut down. As an example of this "filter caking," Figure 13 shows the outlet connection to the high-pressure B. J. Hughes pump with a completely plugged outlet. Basically, when the viscosity falls below about 2:30 minutes, there is an increased likelihood for the particulate material in the grout to "settle" and attach to surfaces. After arriving onsite, the cement trucks were positioned over the Moyno pump and then tested for viscosity and density. Viscosity testing was conducted according to API Procedure RP-13B-1, *Recommended Practice Standard Procedure for Testing Drilling Fluids*. Density testing was performed following ASTM D4380-84 (Reapproved 1993), *Standard Test Method for Density of Bentonitic Slurries*. Batch grout samples were also tested after the completion of daily grouting activities.

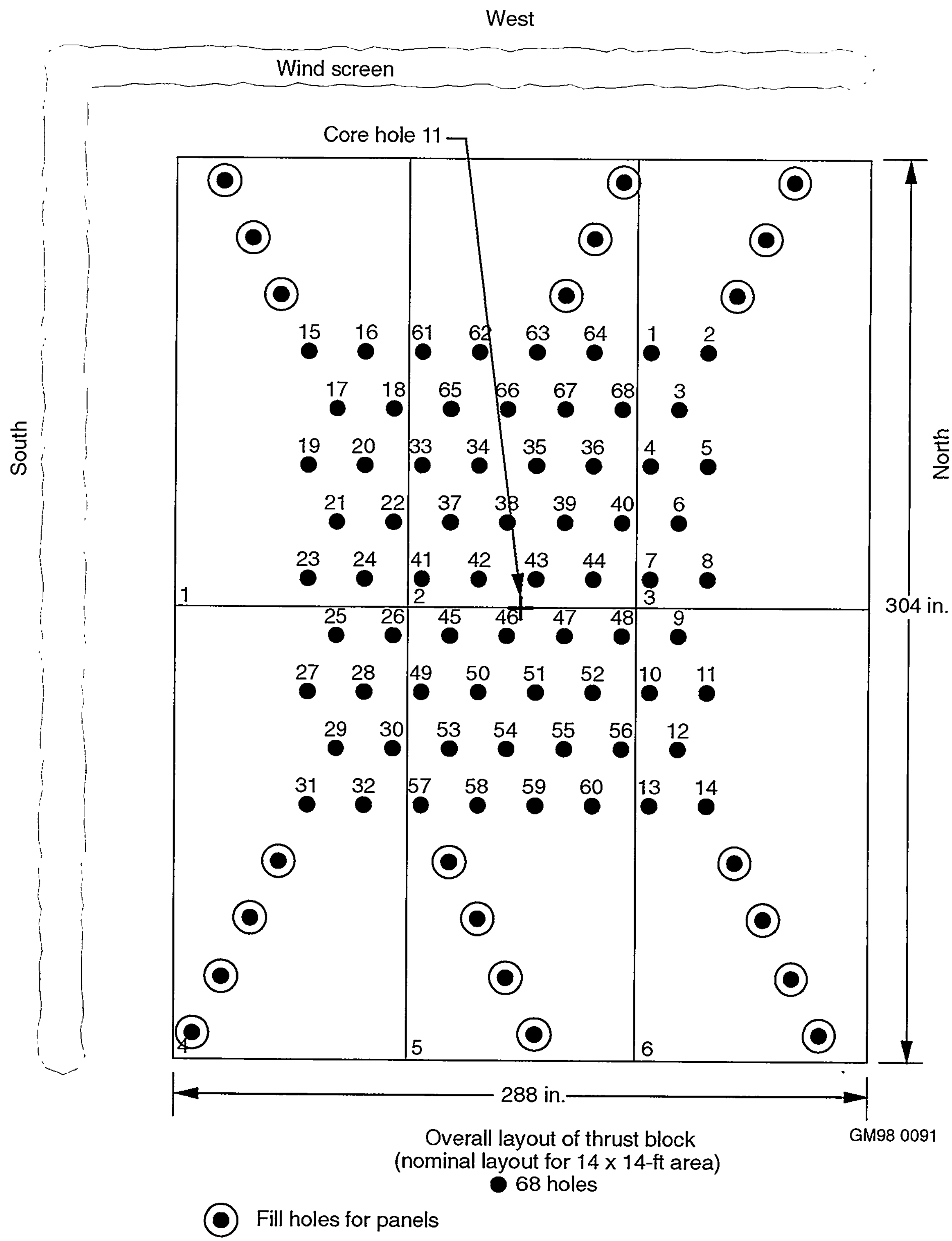


Figure 10. Grouting sequence for the Acid Pit (minimal grout returns) (Graphic GM98 0091).

Figure 11. Exclusion zones established for Acid Pit stabilization showing cement truck and pumps outside the zones (Photo 97-791-1-8).

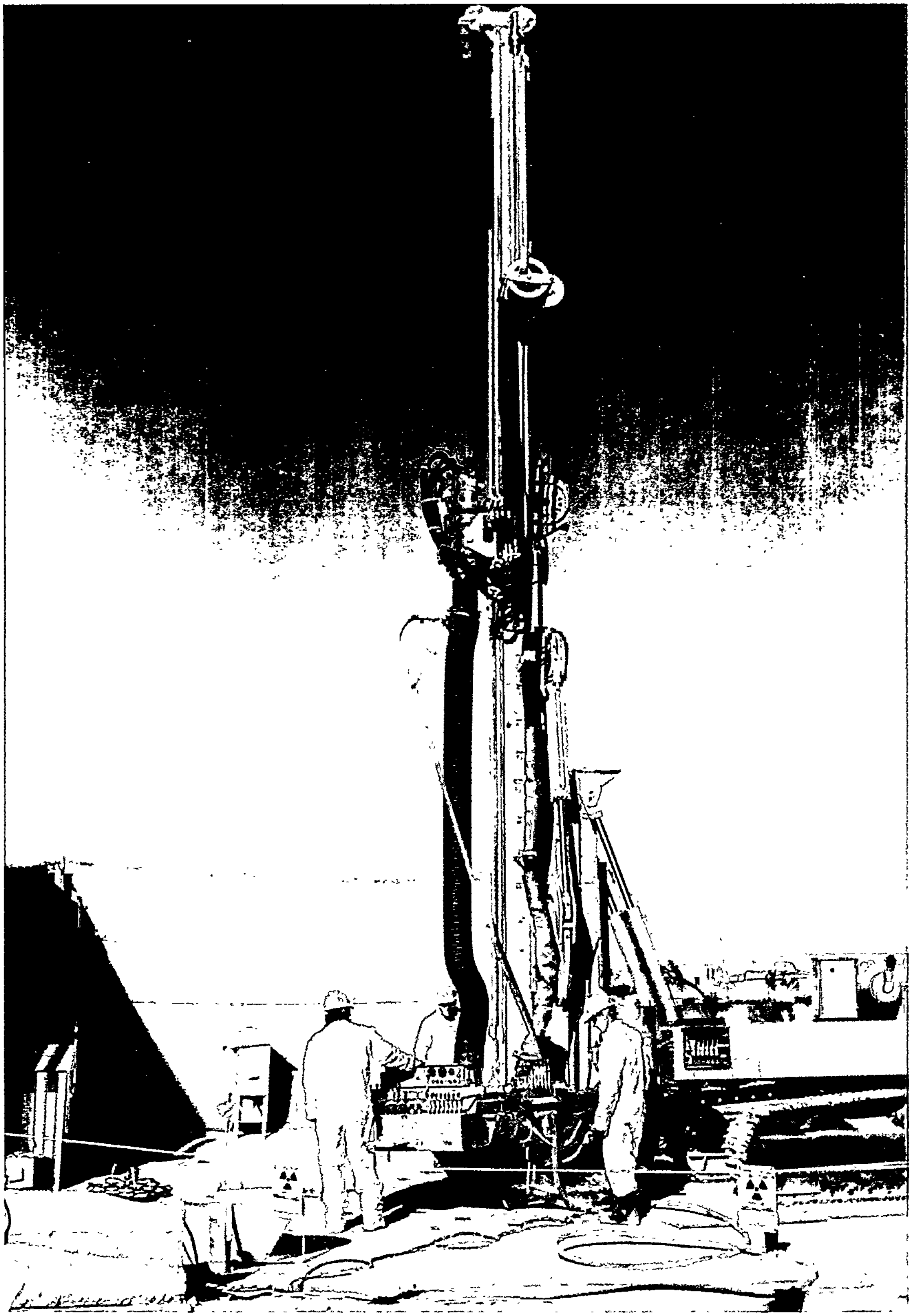


Figure 12. Grouting rig positioned within the contamination exclusion zone (wind shield in background) (Photo 97-789-1-4).

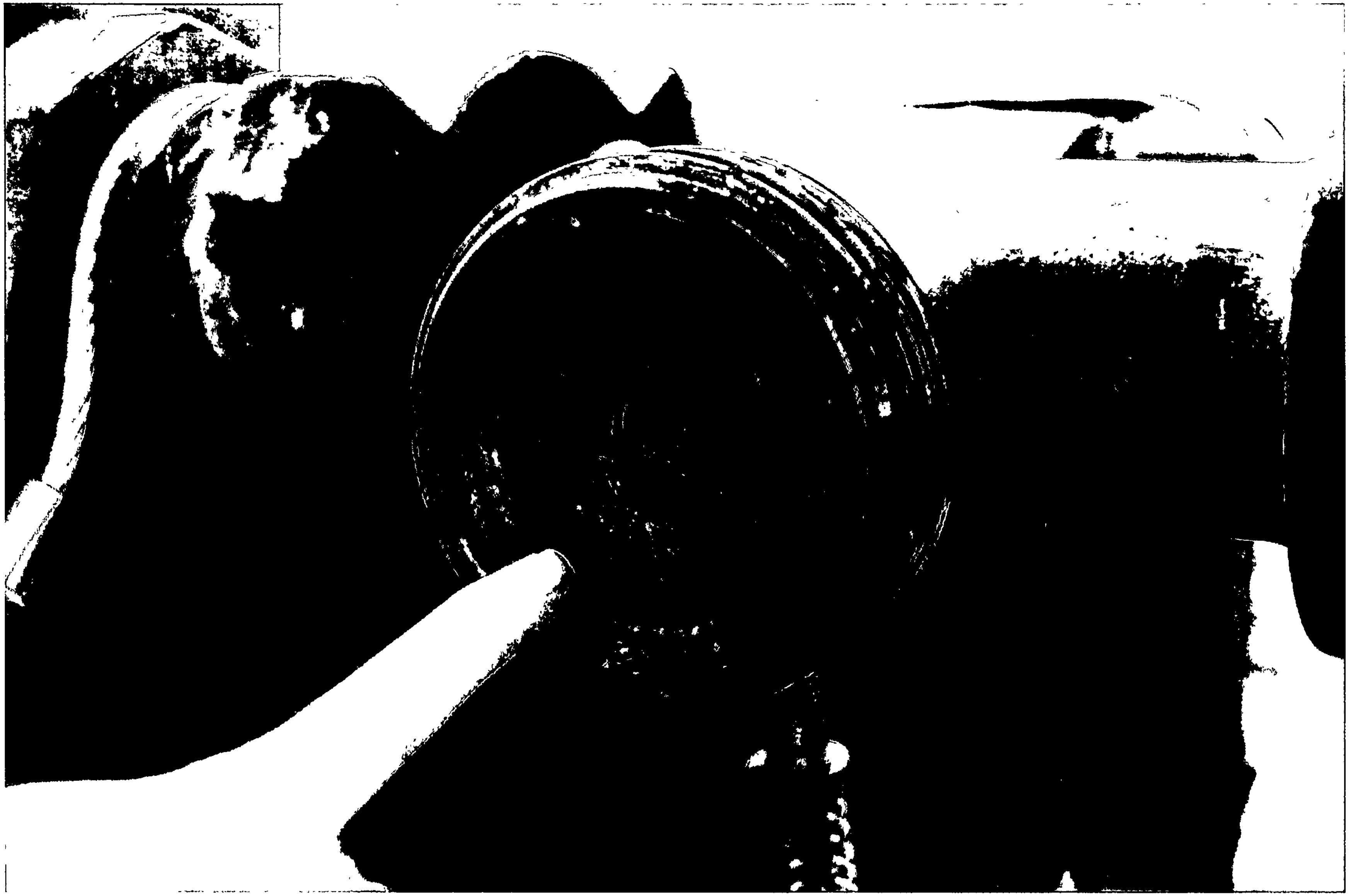


Figure 13. High-pressure pump outlet plugged with TECT-HG (low viscosity) (Photo 97-755-1-0).

4.1 Basic Procedure

For the first hole grouted during the day, the jet-grouting rig was positioned over a designated access hole in the thrust block (outside holes shown in Figure 10) to remove water that was in the system from the prior cleanout operations. The grouting system was flushed under low pressure using the Moyno pump into the access holes in the outer portions of the thrust block until grout was observed discharging from the jet nozzles. Between grouting holes, the catch can was installed to catch the trickle flow of grout. This can was removed just prior to the grouting operation, and the contents of the can (usually 2-4 gal of clean grout) was poured down one of the outside holes of the thrust block as shown in Figure 14. During this procedure, the catch cup attached to the drill rig directed flow of clean grout down into the particular hole to be grouted during this operation (also see Figure 15). After this water removal was completed, the jet-grouting rig was positioned over a grout hole; and contaminant control equipment was properly positioned to begin grouting.

The first hole grouted for each operational sequence was used to set grouting parameters. The basic injection process was as follows:

- The drill stem was extended through the thrust block to the ground surface and drilled to the designated depth. For the Acid Pit, drilling depth was to the basalt or until drilling refusal (usually 16–17 ft).

- High-pressure grout injection was started, and the drill stem was retracted according to set parameters to a prescribed depth below ground surface (operation shown in Figure 16).

- At the prescribed depth, the high-pressure pumping was discontinued and the drill stem was retracted into the catch can and allowed to drain (approximately 3 minutes).

- The catch can and drill stem were simultaneously raised, and the catch cup was connected to contain grout flow.

- The rig was moved and then positioned in a designated area to permit sampling (when required) or cleanup around the hole (operation shown in Figure 17). The spill pan and blotter paper were removed, and any grout spillage or returns were removed with squeegees (operation shown in Figure 18).

- The rig was then moved to the next hole and the procedure repeated.

Prior to shutting down, whether after completing the day's grouting activities or for maintenance purposes, the jet-grouting apparatus was flushed and cleaned to remove unused grout circulating through the system. The basic cleanout process consisted of the following:

- The drill rig was moved to the cleanout trough and positioned for removal of material under potentially contaminated conditions (operation shown in Figure 19).

- The mast was lowered and the drill stem was extended to expose the breakout joint.

- A rubber guard was installed onto the exposed drill stem above the breakout joint.

Figure 14. Worker pouring catch cup material into an unused hole in the thrust block (Photo 97-789-2-8).

Figure 15. Removing the catch can between grouting operations (note the trickle of grout into the catch pan) (Photo 97-789-1-32).

Figure 16. Worker monitors the grouting operation (Photo 97-789-1-23).

Figure 17. Moving the drill rig to a neutral position to allow sampling and changeout of the catch pan/blotter paper (Photo 97-789-1-7).

Figure 18. Placing the catch pan and blotter paper over a new hole and cleaning the old hole (Photo 97-789-1-11).

Figure 19. Positioning the drill stem over the cleanout trough (Photo 97-791-1-23).

- The exposed drill stem and jet sub/drill bit assemblage below the rubber guard was then decontaminated (operation shown in Figure 20). The exposed drill stem was surveyed for radiological contamination.

- After decontaminating the stem, the rig was moved to the second trough for cleaning under noncontaminated conditions.

- The jet sub/drill bit assemblage was broken apart and removed from the drill stem. Grout was drained from the drill stem. The jet sub/drill bit assemblage was then transferred to a designated area for further cleaning.

- The cleanout sub and hoses were attached to the cleanout tank (cleanout sub and hose shown attached in Figure 21).

- Once attached, water flushing was accomplished using the Moyno pump until clear water was observed discharging into the cleanout tank (operation shown in Figure 22).

- Finally, the hose was disconnected and the cleaned jet sub/drill bit assemblage was replaced on the drill stem.

- Prior to leaving for the night, the Moyno and high-pressure pumps were dismantled and cleaned internally.

All unused grout was discharged into a designated containment area at the Cold Test Pit. Based on Cold Test Pit results, this cleanout process did not result in contaminated water (verified by examination of tracer during cold testing); therefore, the cleanout water was simply disposed of at the Cold Test Pit containment area. In addition, as an added precaution, the cleanout water was surveyed for radiological content prior to disposal at the Cold Test Pit. The above grouting and cleanout procedures were developed and refined during the Cold Test Demonstration and implemented during the Acid Pit Stabilization phase.

4.2 Sequence of Events

This section discusses grout emplacement for the Acid Pit Stabilization phase. The grout material (TECT-HG) was delivered in a series of cement trucks each containing approximately 1,600 gal per load. The jet sub contained two 3-mm-diameter (0.12-in.) nozzles located approximately 180 degrees apart and offset by approximately 1.97 in. (5 cm). The nozzles were nominally 6 in. from the bottom tip of the drill bit.

All grouting was performed at two revolutions per step and at a step distance of 5 cm (1.97 in.) per step. Time spent or step rate was set at 2 seconds per step (based on Cold Test Pit testing—Volume 1). The drill string was strapped and footage was marked on the side of the drill mast (this footage corresponded to the depth of the jet nozzles) for recording depth measurements for drilling and grout injection. During grouting, the following data were collected and recorded:

- *Grout Hole Location:* Grout hole number and grouting location.

- *Drilling Depth*: Total depth drilled below surface level (top of thrust-block surface).

- *Grouting Interval:* Depths at which the jet-grout injection was started and stopped.

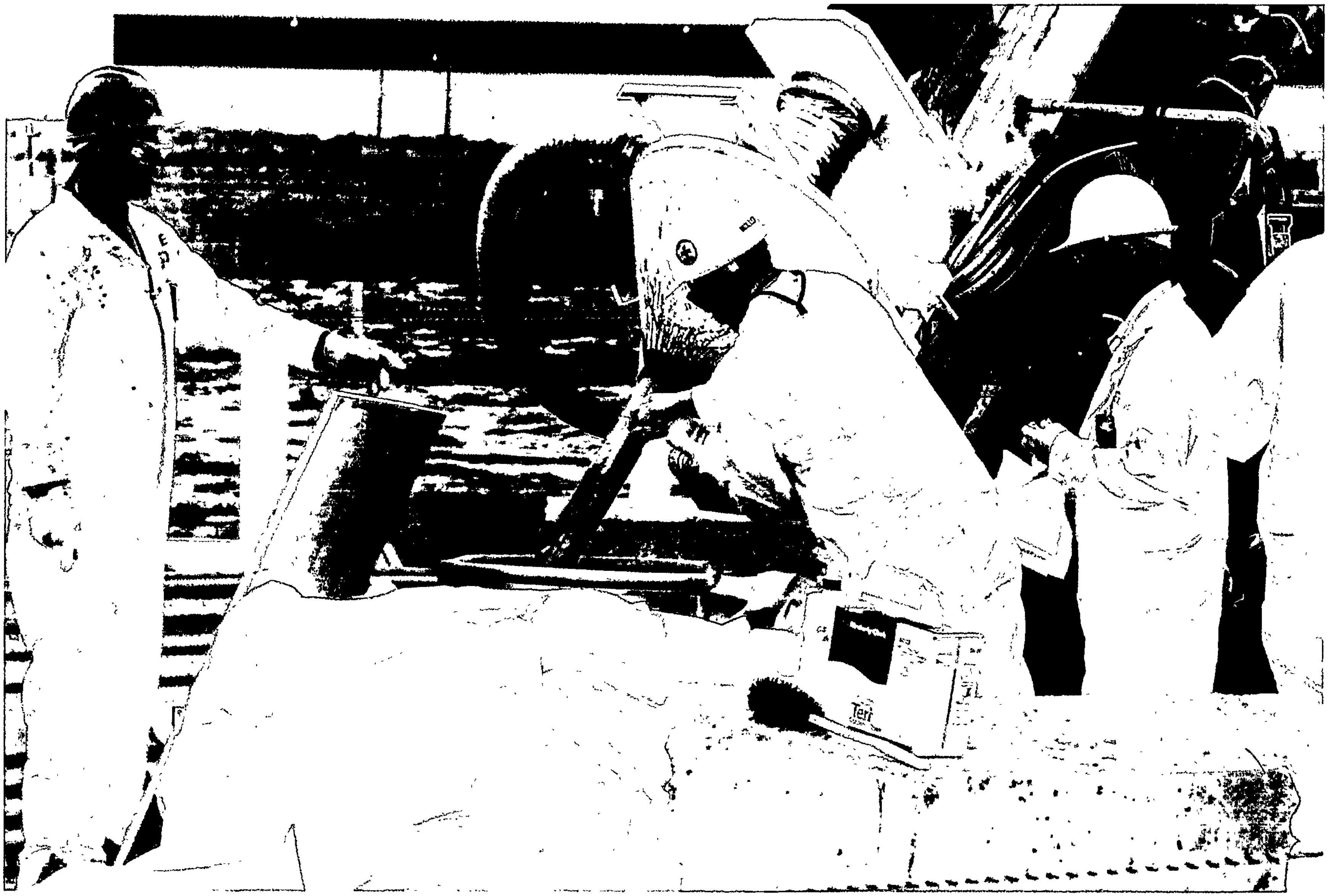


Figure 20. Decontaminating the drill stem (Photo 97-791-1-24).

Figure 21. Cleanout sub attached to the bottom of the drill stem (Photo 97-791-1-27).

Figure 22. Filling of mobile cleanout tanks following Acid Pit stabilization (97-791-1-28).

- *Grouting Parameters:* Injection pressure (psi), step distance (retrieval distance), step rate, and average drill string rotation rate.

- *Drill Rate and Grouting Time:* The time to grout each hole was tracked and recorded, which included time to drill to reach total depth, time for injection for a designated interval, and total time. Any downtime due to equipment failures or other problems was also recorded.

- *Volume of Grout Used:* The total grout used for each hole was measured with separate measurements of volume used for drilling and injected under high pressure.

- *Grout Returns:* Estimation of volume of grout returns released to the surface and into the void space under the thrust block.

The grout emplacement for the Acid Pit Stabilization phase was conducted from September 22 to September 25, 1997. It was originally planned[6-8] to grout 68 holes with a grouting interval from the basalt/soil interface (estimated at 17 ft) to 5 ft from below the surface level of the thrust block. The grouting sequence was started in the southeast corner of the thrust block at hole 31. The original plan was to use a "modified Z" pattern in which an entire row would be grouted from hole 31 west to hole 15 (see Figure 10) in the order 31, 29, 27, 25, 23, 21, 19, 17, 15 to be followed by the sequence from west to east 16, 18, 20, 22, 24, 26, 28, 30, 32, and so forth. Problems with controlling grout returns to the surface and subsequent concerns with potential contamination exposure to field workers and equipment required adjustment to the planned grouting intervals (reduced grouted interval), grouting sequence (increased spacing between holes), and in some cases total abandonment of certain troublesome grout hole locations. Only 52 of the planned 68 grout holes were grouted with at least some grout. Of these 52, 47 holes were grouted from the interval of 5 ft or greater, which thus covers the zone of highest reported contaminant concentration levels. A complete discussion of this grouting sequence is given in the results section.

Except for September 25, 1997, typical drilling consisted of rotopercussion drilling from nominally 2 to 7 ft, switching to direct drive-force drilling to the basalt interface, and rotopercussion for partial penetration of the basalt. The average drill time to reach total depth was approximately 2 minutes. Slower penetration rates were recorded on September 25, 1997. In some cases, rotopercussion was required to reach grouting depth, with drilling time taking up to 7 minutes per hole. Slower penetration was attributed to drilling through grouted regions produced during emplacement of nearby or adjacent grout holes.

As previously stated, problems with grout returns required adjustment to the planned grouting program. A summary of the grouting operation for the Acid Pit is provided in Table 3.

For this study, abandoned holes were defined as:

- Holes drilled to total depth but not grouted.

- Holes partially drilled but abandoned before reaching total depth.

- Holes with no attempt made to drill or grout.

Abandoned holes were located at (1) areas of troublesome grouting, (2) areas with filled void space under the thrust block, and (3) areas with cured grout plugging the access hole.

Below is a discussion of daily grouting activities.

Table 3. Summary of grout emplacement for the Acid Pit Stabilization phase.

Hole No./ Sequence No.	Date	Grout Emplacement Attempted	Grouted Planned Interval	Not Grouted to Planned Interval, But ≥5 ft	Not Grouted to Planned Interval, But <5 ft	Drilled But Not Grouted	Drilling Attempted, But Abandoned	Abandoned	Total Injected Grout/Drilling and Grouting (gal)
01/44	09/24	X	X						59
02/31	09/23	X	X						69
03/37	09/24	X	X						57
04/51	09/25	X			X				10
05/32	09/23	X	X						69
06/38	09/24	X	X						66
07	09/25							X	—
08	09/25							X[a]	—
09/37	09/24	X	X						59
10	09/25	X			X				—
11/33	09/23	X	X						73
12/40	09/24	X	X						55
13/45	09/24	X	X						56
14/34	09/23	X	X						67
15/9	09/22	X	X						71
16/10	09/22	X	X						61
17/8	09/22	X	X						71
18/11	09/22	X	X						65
19/7	09/22	X	X						76
20	09/22	X				X[b]			—
21/6	09/22	X		X					69
22/16[c]	09/23							X	68
23/5	09/22	X	X						94
24/15	09/22	X	X						57
25/4	09/22	X	X						116
26	09/23							X	—
27/3	09/22	X	X						109
28/14	09/22	X		X					49
29/2	09/22	X	X						96
30/13	09/22	X	X						66
31/1	09/22	X	X						98
32/12	09/22	X	X						64
33/36	09/24	X		X					62
34/47	09/25	X	X						60
35/48	09/25	X	X						54
36/29	09/23	X	X						68
37/42	09/23 09/24	X			X[d]				35
38/49	09/25	X	X						42
39/29	09/25							X	—
40/50	09/25	X			X				19
41/35	09/24	X	X						80
42	09/25	X					X		—
43	09/25	X					X		—

Table 3. (continued).

Hole No./ Sequence No.	Date	Grout Emplacement Attempted	Grouted Planned Interval	Not Grouted to Planned Interval, But ≥5 ft	Not Grouted to Planned Interval, But <5 ft	Drilled But Not Grouted	Drilling Attempted, But Abandoned	Abandoned	Total Injected Grout/Drilling and Grouting (gal)
44/1	09/23	X				X			—
45/26	09/23	X		X					41
46/46	09/25	X	X						49
47	09/25							X	—
48	09/25							X	—
49/19	09/23	X	X						72
50/22	09/23	X			X				43
51	09/25							X	—
52/28	09/23	X		X					50
53/18	09/23	X	X						57
54/21	09/23	X	X						65
55/52	09/25	X	X						31
56	09/25							X	—
57/17	09/23	X	X						61
58/20	09/23	X	X						74
59	09/24	X					X		—
60/27	09/23	X	X						65
61/23	09/23	X	X						69
62/25	09/23	X	X						79
63/43	09/24	X		X					39
64/30	09/23	X	X						78
65/24	09/23	X	X						75
66/41	09/24	X	X						57
67	09/25	X					X		—
68	09/25							X	—
Total		58	41	6	5	2	4	10	3,295

a. Drilled for installation of geophysical instrument and backfilled with grout.

b. Three grouting attempts before abandonment.

c. Suspected water in lines (first hole of the day).

d. Grouted in two stages.

On September 22, 1997, 16 grout holes (GHs) were drilled, with 12 of the holes successfully grouted to the planned interval (ranging from 5 to 8 ft below the top of the thrust block). GH-23, GH-25, GH-27, GH-29, and GH-31 were grouted to the originally planned grouting level of 5 ft below the top of the thrust block (see Figure 10 for hole numbering system). Unexpected filling of the available void space under the thrust block with grout returns required changing the planned grouting level from 5 to 8 ft below the top of the thrust block. GH-21 and GH-28 were stopped before reaching the new planned interval (8 ft below the top of the thrust block); however, the total grouted interval was greater than 5 ft. Grouting of GH-20 was attempted three times (two attempts on September 22 and one attempt on September 23) before the hole was abandoned. Excessive grout returns came to the surface of the thrust block from GH-18 during drilling of GH-20 (cross-hole communication). GH-22 was abandoned, with no attempt at either drilling or grouting due to grout returns filling all available void space under the thrust block for this area.

On September 23, 1997, 21 holes were drilled, with 16 holes successfully grouted to the new planned 8-ft level. GH-37, GH-45, GH-50, and GH-52 were partially grouted due to excessive grout returns. The grouted intervals for GH-45 and GH-52 were greater than 5 ft, and the grouted intervals for GH-37 and GH-50 were less than 5 ft. GH-37 had to be grouted in two stages, with the first stage occurring on September 23, 1997, and the second stage occurring on September 24, 1997. GH-44 was drilled but could not be grouted due to grout returns flowed from adjacent holes. GH-26 was abandoned with no attempt at either drilling or grouting due to grout returns filling all available void space under the thrust block for this area. Due to operator error, GH-50, GH-54, GH-61, GH-65, and GH-68 were grouted at a reduced pressure of 4,500 psi.

On September 24, 1997, 12 holes were drilled, with 8 holes successfully grouted to the planned 8-ft level. Grouting of GH-33, GH-37, and GH-63 was stopped before reaching the planned interval due to excessive grout returns. The grouted intervals for GH-33 and GH-63 covered greater than 5 ft, and GH-37 covered less than 5 ft. GH-59 was partially drilled but had to be abandoned due to cured grout filling the access hole, which resulted in grout encountering the surface of the thrust block. GH-33 and GH-41 were grouted at an injection pressure of 6,000 psi; GH-3, GH-6, and GH-9 were grouted at 4,000 psi; and GH-1, GH-12, GH-13, and GH-66 were grouted at 3,500 psi. Injection pressure was reduced as a method to control grout returns.

On September 25, 1997, 11 holes were drilled, with 5 holes successfully grouted to the new planned interval of 10 ft below the top of the thrust block. The grouted interval was changed from the 8-ft level to 10-ft levels as a method to control grout returns. Additionally, all grouting was conducted at an injection pressure of 3,500 psi. Grouting of GH-4, GH-10, and GH-40 was stopped before the planned interval was reached, with a grouted interval covering less than 5 ft. Drilling of GH-42, GH-43, and GH-67 was attempted but was stopped before reaching total depth. These holes had to be abandoned because cured grout backfilled the access holes, causing the discharge of grout to the surface of the thrust block. GH-7, GH-39, GH-47, GH-48, GH-51, GH- 56, and GH-68 were abandoned, with no attempts at either drilling or grouting. GH-8 was drilled but was not grouted to allow for installation of a geophysical instrument probe.

A summary of results for grout emplacement activities at the Acid Pit test area are presented below.

- Total holes planned for grouting: 68
- Total holes abandoned: 10
  (no attempt at drilling or grouting)
- Total holes attempted for grouting: 58
  (Drilled or grouted)
  Total drilling footage: 907 ft
  Total grout used: 3,344 gal
- Total holes partially drilled, not grouted: 4
  (Footage not recorded)
  Total grout used: 26 gal
- Total holes drilled to grouting depth but not grouted: 2
  Total grout used: 32 gal
  Total drilling footage: 64 ft
  (GH-20 drilled three times to 16 ft)

- Total holes grouted (partially or to planned depth): 52
  Total footage drilled: 843 ft
  Average per hole: 16.21 ft
  Total injection footage: 376 ft
  Average per hole: 7.23 ft
  Total grout used: 3,295 gal
  Total grout used for drilling: 362 gal
  Average per hole: 7 gal
  Average per foot: 0.43 gal
  Total grout injected under high pressure: 2,753 gal
  Average per hole: 52.94 gal
  Average per foot: 7.32 gal
  Total grout not used for drilling or grouting: 171 gal
  Average per hole: 3.3 gal

- Total holes with grout interval of 5 ft or greater: 47
  Total footage drilled: 764.5 ft
  Average per hole: 16.27 ft
  Total injection footage: 364.5 ft
  Average per hole: 7.76 ft
  Total grout volume used: 3,148 gal
  Total grout volume used for drilling: 326 gal
  Average per hole: 6.94 gal
  Average per foot: 0.43 gal
  Total grout volume injected under high pressure: 2,666 gal
  Average per hole: 56.72 gal
  Average per foot: 7.31 gal
  Total grout volume not used for drilling or grouting: 156 gal
  Average per hole: 3.3 gal

- Total holes with grout interval of less than 5 ft: 5
  Total footage drilled: 78.5 ft
  Average per hole: 15.7 ft
  Total injection footage: 11.5 ft
  Average per hole: 2.3 ft
  Total grout volume used: 138 gal
  Total grout volume used for drilling: 36 gal
  Average per hole: 7.2 gal
  Average per foot: 0.46 gal
  Total grout volume injected under high pressure: 87 gal
  Average per hole: 17.4 gal
  Average per foot: 7.57 gal
  Total grout volume not used for drilling or grouting: 15 gal
  Average per hole: 3 gal

- Average drill time per hole: 2 minutes and 33 seconds

- Average grout time (under high pressure) per hole: 1 minute and 32 seconds

A total of 47 holes were grouted, covering at least the bottom 5 ft of the targeted contamination zone. For these holes, a total of 3,148 gal of grout was used (326 gal for drilling, 2,666 gal injected under high pressure, and 156 gal of excess material) for an average volume of 70 gal per hole. Figure 23 shows the grouted hole locations at the Acid Pit test area for those positions in which at least some grout was delivered. The injection pressure of successfully grouted holes ranged from 3,500 to 6,000 psi. Table 4 summarizes the injection pressures for grouted intervals greater than 5 ft. Three 1,600-gal loads of TECT-HG were used for the Acid Pit Stabilization phase. The grout mixture delivered on September 24, 1997, was partially used and then redelivered for emplacement on September 25, 1997. After completion of grouting activities on September 25, 1997, the remaining grout (approximately 800 gal) was pumped to fill the void space under the thrust block. An additional 900 gal of API Type-H cement was pumped on September 26, 1998, to continue filling the void space under the thrust block.

Measurements of density and viscosity for the TECT-HG used for grouting the Acid Pit test area are listed in Table 5.

Grout density readings were fairly consistent, ranging between 17.7 and 18.5 pounds per gallon. The viscosity of the TECT-HG mixture was to be measured through the funnel viscometer at 3 minutes. However, batch sample test results showed fluctuations of viscosity readings throughout the grouting process between 2:30 minutes and 7 minutes. Separation of particulate in the grout mixture was observed on September 25, 1997, which was a redelivery of unused material from September 24, 1997. A high viscosity was measured for this material on September 25, 1997. Settling of solid material was observed during dismantling of the pumps after completion of the daily grouting activities. Pumping problems occurred on September 25, 1997, which the Geo-Con field supervisor attributed to short operating time (durations of high-pressure injection of less than 2 minutes) and long periods of downtime for cleaning of grout returns released to the surface of the thrust block (up to one-half hour per event).

4.3 Contamination Control Data

From September 22, 1997, through September 25, 1997, contaminant exposure data were obtained for field workers working within the controlled area during high-pressure grouting activities. More detailed information concerning procedures and results is included in a following section. Radiological and mercury monitoring surveys were performed after the grouting of each hole (Figure 24), after releases of grout returns to the surface of the thrust block, after jet sub and drill bit decontamination for system cleanout, and after completion of grouting activities. Direct reading instruments were used during work activities. A Jerome Mercury Vapor Analyzer and organic vapor detector (HNu) were used to detect mercury and organic vapors. No exposure problems were detected by this monitoring nor was the operation ever delayed because of survey results. Detailed contamination control data are in the results section of this report.

4.4 Postgrouting Coring Operation

A total of 10 core holes were drilled in the following sequence: three holes on April 21, 1998, four holes on April 22, 1998, and three holes on April 23, 1998. The location of core holes at the Acid Pit test area is shown in Figure 25.

Sonic drilling was used to obtain the cores primarily to avoid the possibility of potential release of contaminants with conventional core drilling techniques (through drilling fluids and dust generation). Drilling services were provided by Boart Longyear (office location in Schofield, Wisconsin). A rotary-vibratory, also referred to as "sonic," drilling technique was used (Figures 26 and 27 show views of the sonic drilling rig in operation). The sonic drilling method employs high-frequency mechanical vibration to penetrate the subsurface and take continuous core samples. The sonic rig is similar to a conventional top-drive rotary rig, with the main difference being a specially designed hydraulically powered drill head or oscillator that generates adjustable high-frequency vibrational forces down the drill steel to the face of the drill bit.

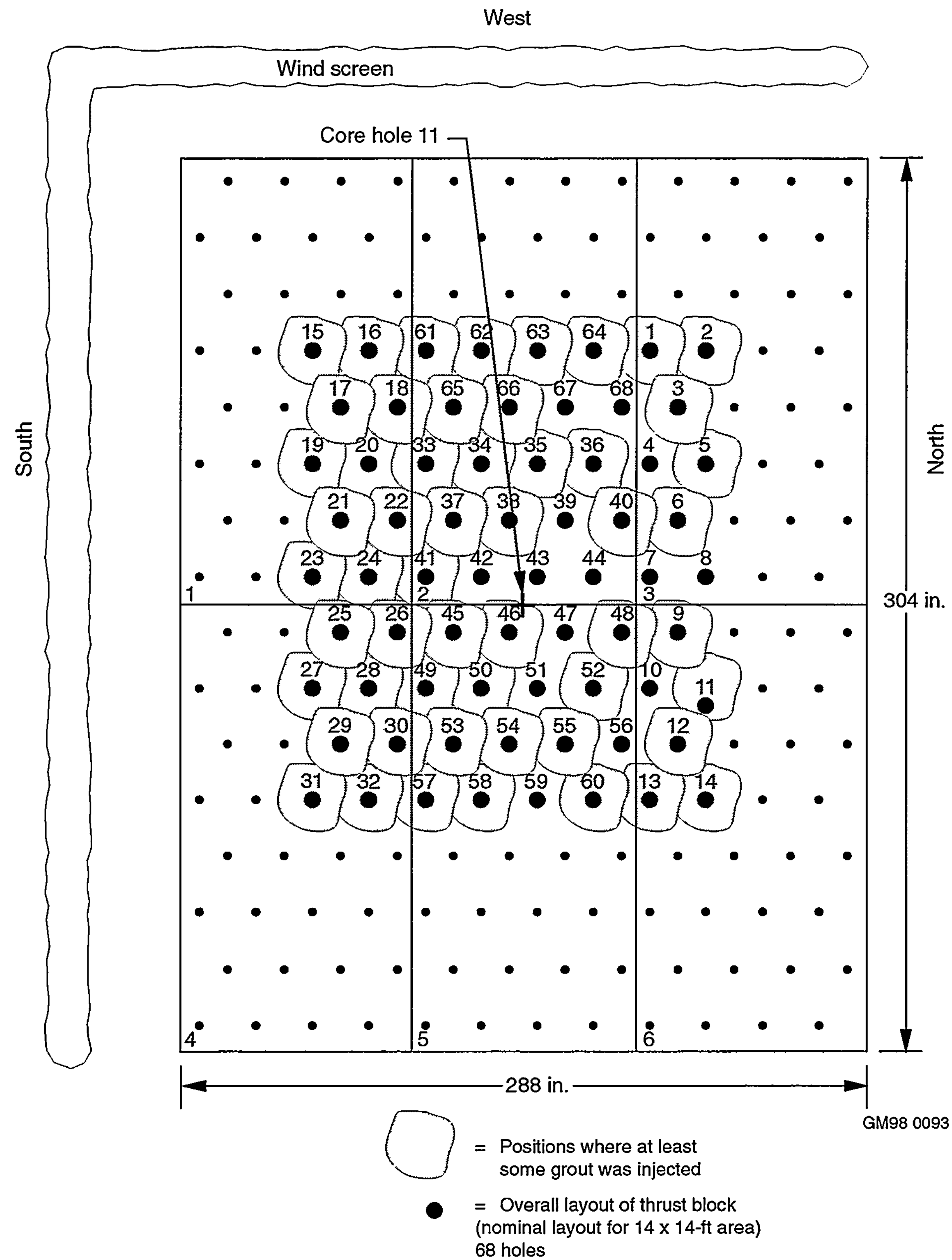


Figure 23. Positions where at least some grout was injected (Graphic GM98 0093).

Table 4. Grout injection pressures for grouting intervals of greater than 5 ft.

Total Grout Interval	Total Number of Holes Grouted	Injection Pressure 3,500 psi	4,000 psi	4,500 psi	6,000 psi
5 to 6.5 ft	10	6	0	0	4
7 to 8.5 ft	32	4	3	4	21
11 to 12 ft	5	0	0	0	5
Total	47	10	3	4	30

Table 5. Density and viscosity measurements for the Acid Pit Stabilization phase.

Date	Time	Density (lb/gal)	Viscosity (min:sec)	Comments
09/22/97	10:20	18.5	5:02	Batch sample before start of grout emplacement.
	12:00	17.7	3:16	Batch sample testing.
	14:40	17.8	3:20	Batch sample after completing grouting activities.
09/23/97	07:55	17.8	5:08	Batch sample before start of grout emplacement.
	09:30	17.8	3:35	Batch sample testing.
	13:10	18.0	4:15	Batch sample after completing grouting activities.
09/24/97	08:05	17.7	3:09	Batch sample before start of grout emplacement.
	12:30	18.2	3:05	Batch sample after completing grouting activities.
09/25/97	08:05	18.2	5:45	Material from 09/24/97. Batch sample before start of grout emplacement.
	12:35	18.4	5:05	Batch sample after completing grouting activities.

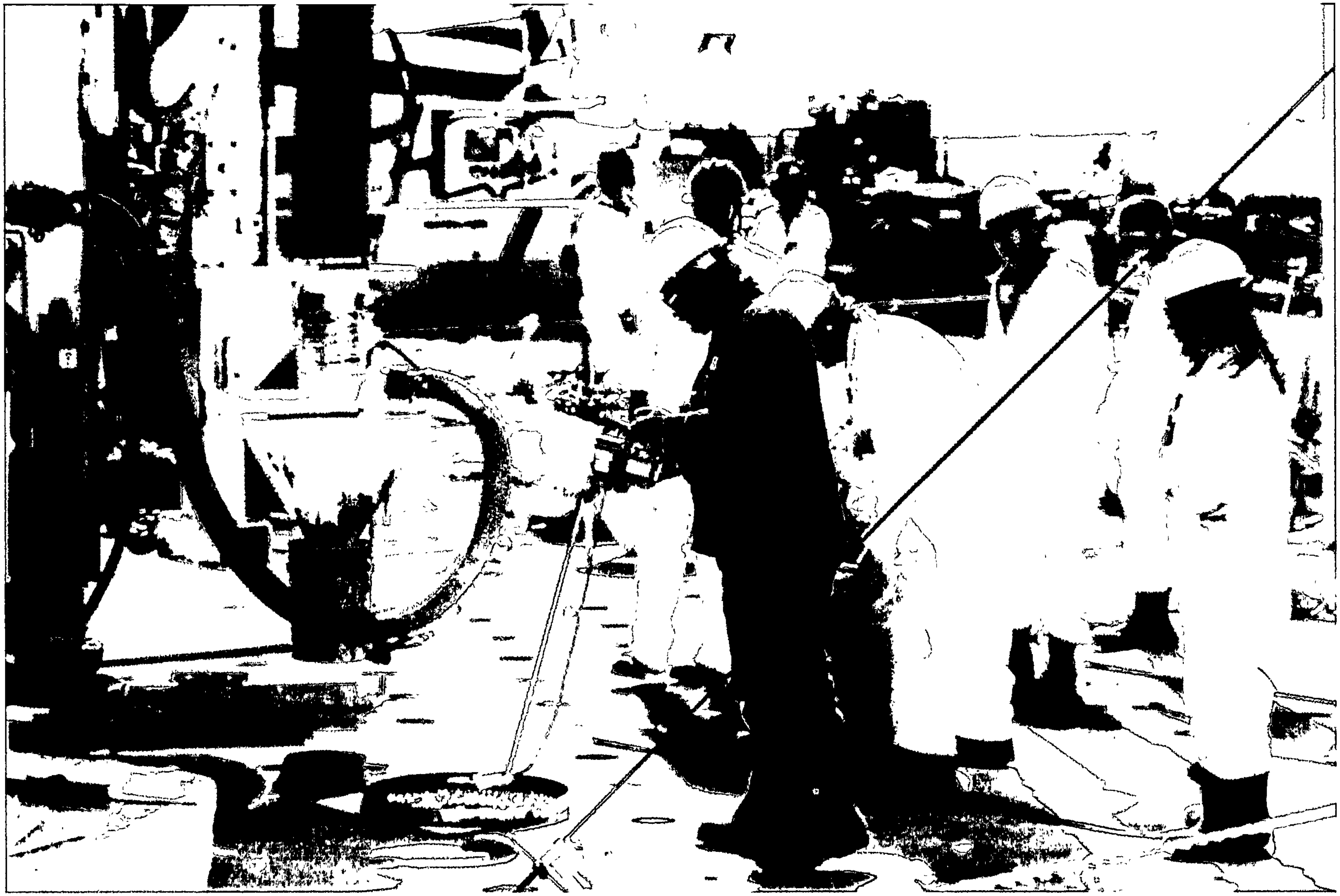


Figure 24. Online radiological measurements during Acid Pit grouting (Photo 97-789-2-2).

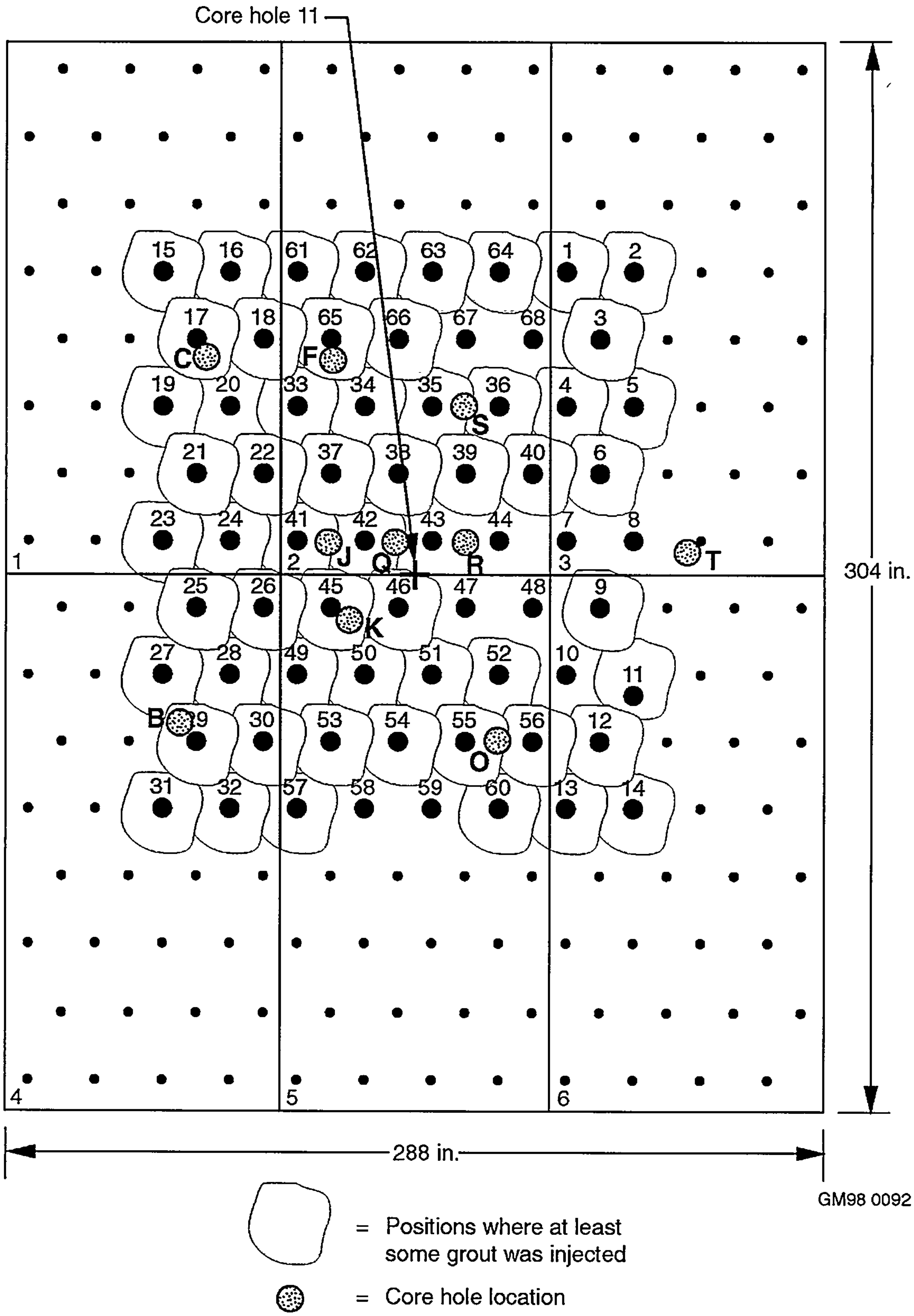


Figure 25. Location of Acid Pit core holes relative to grout holes (Graphic GM98 0092).

Figure 26. Sonic core drilling rig (Photo 98-216-1-11).

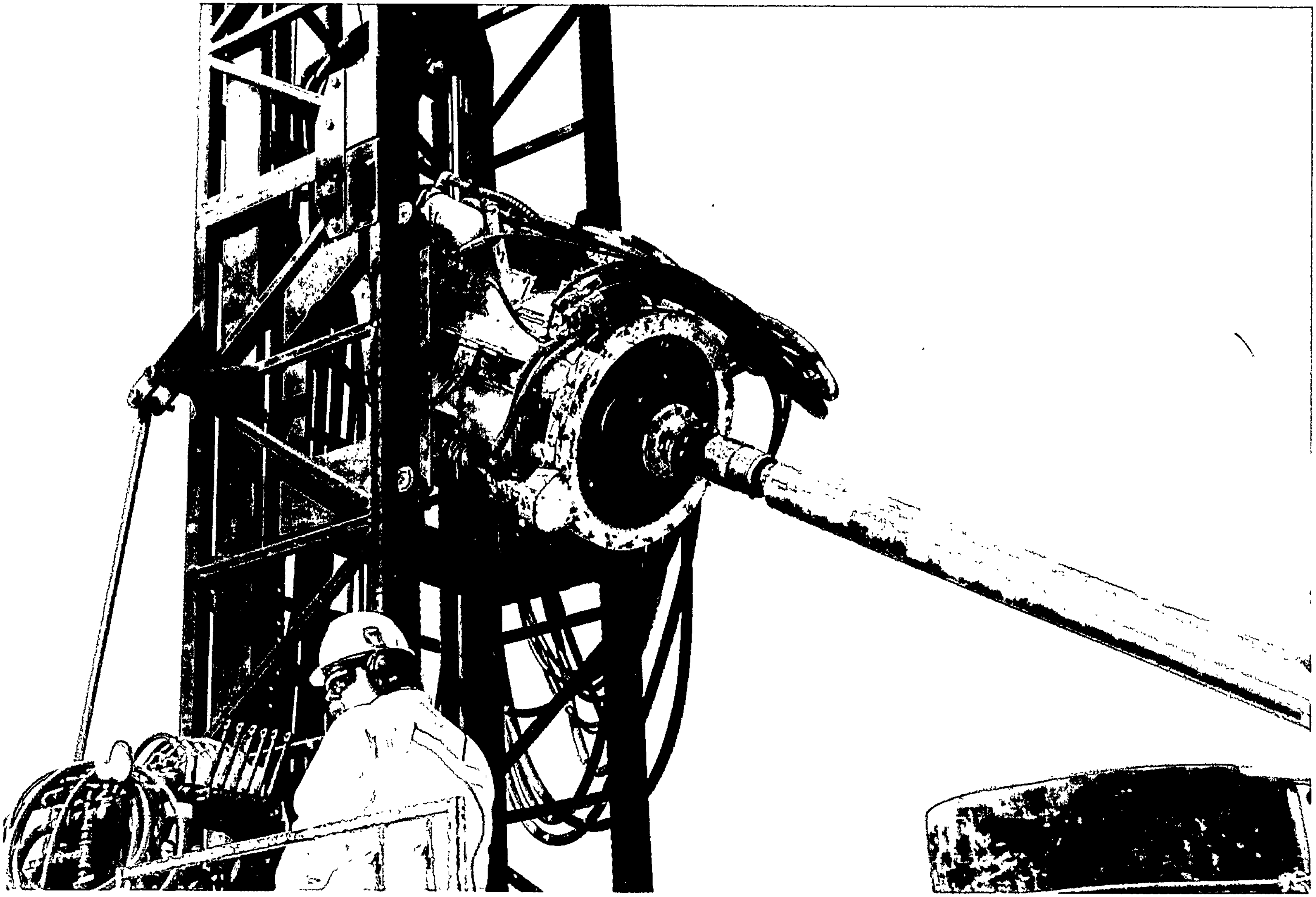


Figure 27. Core drilling rig shown rotated during drill string changeout (Photo 98-216-1-13).

This technique uses no air or fluids for drilling penetration; therefore, no cuttings or dust were generated during the drilling process.

Access holes were constructed through the thrust block at predetermined locations (see Figure 28). All drilling started at the top of the grout/cement material (nominally 5 in. below the top of the surface of the thrust block) used to fill the void space under the thrust block. Cores were obtained from the surface to a designated total depth (maximum 19 ft).

Two drilling and sampling methods were used. From surface to sampling depth, drilling was conducted using a 6-in. solid core barrel; and core samples were retrieved from the barrel into plastic sleeving. This method was used to penetrate the grout/cement material filling the void space of the thrust block (nominally 2 ft) and ungrouted soil overlying the emplaced monolith. At sampling depth, the solid core barrel was removed, and a 4.5-in. split barrel sampler with a lexan liner was installed on the drill rod (Figure 29). At the end of each core run (nominally 5 ft), the split-barrel sampler was disconnected from the drill rod and transported to a sample laydown area for retrieving the lexan tubes. Samples were collected in either plastic sleeving or lexan tubes and then transferred to the designated storage containers for more detailed evaluation at the RWMC. Description of core sample recovery was recorded on logsheets prior to transfer of samples to storage containers.

The first two core holes (core holes B and J shown in Figure 25) were drilled to enter the basalt. Basalt drilling involved removing the split-barrel sampler and installing a 4.5-in. solid core barrel. All core samples were retrieved into plastic sleeving. Due to concerns on the part of RWMC Radiation Control with encountering radioactive contamination at the basalt/soil interface, none of the remaining core holes was drilled into the basalt.

Rationale for each hole location and a brief description of drilling results are presented below. All depth measurements were from the top of the thrust block. Figure 25 shows the core holes relative to the grout holes.

4.4.1 Core Hole B (CH-B)

CH-B was located on the southwest side of GH-29 (grout interval from 5 to 17 ft at 6,000 psi). This area was cored to evaluate a well-grouted region of the monolith. CH-B was drilled to a total depth of 19 ft, and split-barrel samples were collected from 5 to 17 ft. The cored interval from 17 to 19 ft was used to confirm penetration into basalt and evaluate grout mixing at the basalt interface.

4.4.2 Core Hole J (CH-J)

CH-J was located on the north side of GH-41 (grout interval from 8 to 16 ft at 6,000 psi). This area was cored to collect grout samples for contamination analysis (hole location was near CH-11, which was drilled as part of the Acid Pit Track-2 Investigation). CH-J was drilled to a total depth of 19 ft, and split-barrel samples were collected from 8 to 17 ft. The cored interval from 17 to 19 ft was used to confirm penetration into basalt and evaluate grout mixing at the basalt interface.

4.4.3 Core Hole F (CH-F)

CH-F was located on the northeast side of GH-65 (grout interval from 8 to 16.5 ft at 6,000 psi). This area was cored to evaluate a well-grouted region of the monolith. CH-F was drilled to a total depth of 17.5 ft, and split-barrel samples were collected from 8 to 17.5 ft (total depth). For Core Run No. 5 (CR-5), radioactive contamination was detected above background levels (600 counts per minute) in the sample material contained inside the drill bit. The Lockheed Martin Idaho Technologies Company (LMITCO) Radiation Control (RADCON) technician immediately shut down the drilling operation to

Figure 28. Predrilled holes through the top surface of the thrust block (Photo 98-216-1-22).

Figure 29. Lexan tubing used in the split spoon core system (Photo 98-216-1-23).

respond to the radioactive contamination. A reddish-brown discoloration was observed in the sample material; however, a closer examination could not be performed once the RADCON technician designated the sample radioactive (about 200 counts per minute above background—the RADCON technician thought that the contaminant was a beta emitter because there was no reading through the lexan tube).

4.4.4 Core Hole C (CH-C)

CH-C was located on the northeast side of GH-17 (grout interval from 8 to 16 ft at 6,000 psi). This area was cored to evaluate a well-grouted region of the monolith. CH-C was drilled to a total depth of 17 ft, and split-barrel samples were collected from 10 to 17 ft (total depth). In an attempt to improve the quality of the core recovery, drilling parameters were reduced for vibration frequency, revolutions per minute, and downhole pressure. CR-5 was drilled without a lexan tube inside the split-barrel sampler to allow for a direct examination of core recovery under adjusted drilling parameters. This sample interval consisted of broken and fragmented pieces of core sample. No solid core recovery was observed, suggesting fracturing of recovered samples during sonic drilling.

4.4.5 Core Hole K (CH-K)

CH-K was located on the north side of GH-45 (grouting interval from 11 to 16 ft at 6,000 psi). This area was cored to collect samples for contamination analysis (hole located near CH-11 drilled as part of the Acid Pit Track-2 Investigation). CH-K was drilled to a total depth of 16.5 ft, and split-barrel samples were collected from 10 to 16.5 ft (total depth). For CR-4, radioactive contamination was detected from sample material inside the core drill bit. The RADCON technician shut down the operation to survey the site, decontaminate the work area and bit, and isolate and contain the contaminated core run (sampling interval from 13 to 16.5 ft).

4.4.6 Core Hole R (CH-R)

CH-R was located on the south side of GH-44 (drilled but not grouted). This area was cored to evaluate an ungrouted void region in the monolith and for correlating geophysical data. CH-R was drilled to a total depth of 12 ft, and split-barrel samples were collected from 2 to 12 ft.

4.4.7 Core Hole S (CH-S)

CH-S was located between GH-35 (grout interval from 10 to 16 ft at 3,500 psi) and GH-36 (grout interval from 8 to 16 ft at 6,000 psi). This area was cored to evaluate the interstitial region between grout holes. CH-S was drilled to a total depth of 16 ft, and split-barrel samples were collected from 8 to 16 ft (total depth).

4.4.8 Core Hole Q (CH-Q)

CH-Q was located between GH-42 and GH-43 (not grouted, abandoned holes). This area was cored to evaluate an ungrouted region of the monolith. CH-Q was drilled to a total depth of 15 ft, and split-barrel samples were collected from 5 to 15 ft (total depth).

4.4.9 Core Hole O (CH-O)

CH-O was located between GH-55 (grout interval from 10 to 15 ft at 3,500 psi) and GH-56 (not grouted, abandoned hole). This area was cored to evaluate the northeast portion of the monolith. CH-O was drilled to a total depth of 15 ft, and split-barrel samples were collected from 5 to 15 ft.

4.4.10 Core Hole T (CH-T)

CH-T was located north of GH-8 (drilled, but not grouted), outside the planned grouted area of the monolith. This area was cored to correlate geophysical data for an ungrouted region. CH-T was drilled to a total depth of 15 ft. No split-barrel samples were collected, and all samples were retrieved into plastic sleeving.

5. TEST RESULTS

The results section examines (1) the grouting operation including the results of posttest analysis of contamination control data taken during the grouting operation, (2) temperature of the curing pit, (3) postgrouting evaluation of pit cores for leachability and grout penetration, and (4) geotechnical evaluation of the grouted pit.

5.1 Analysis of Grouting Operation

5.1.1 Grout Emplacement

The jet-grouting operation resulted in a filling of the pit with a volume of grout equal to approximately 25% of the treated volume. This is consistent with estimates of soil void space in INEEL soils.[1] The 25% estimate for grout filling comes from the following calculation:

A total of 3,295 gal of grout was injected during drilling and grouting operations. The total affected volume is approximately 14 × 14 × 7 ft or 1,372 ft^3 or 10,263 gal. Of the 3,295 gal of grout that went into the pit, some returned to the surface filling some of the void space under the thrust block. The total amount of grout returns was estimated to be 729 gal. The total available void volume under the thrust block was 2,496 gal. A total of 1,700 gal was poured into the remaining void space (800 gal with the remaining TECT grout on September 25, 1998, immediately following completion of the grouting operation; and on September 26, 1998, another 900 gal of API Type-H Portland cement was poured into the remaining space, thus essentially filling the total remaining void space). An additional estimated 66 gal of grout had been poured into the access holes using the catch can during grouting; therefore, the total estimated grout returns that entered the void space in the thrust block was the total void volume available (2,496 gal)—(poured grout from the catch can [66 gal] + poured volume from the last day of grouting [800 gal] + poured volume the next day of Type-H cement [900 gal]) and 729 gal. Therefore, the total grout that stayed in the pit was the injected volume (3,295 gal) minus the grout returns (729 gal) or 2,566 gal. This corresponds to 25% of the total volume of the treated area. Examining Track 2, the pregrouted soil was evaluated for both soil moisture content and porosity; and the average difference was 28%, meaning the soil had approximately only 28% possible void volume left prior to grouting. From a mixing standpoint, this means that of the voids in the lower 7 ft of the pit, the grouting operation essentially filled or redistributed all of them. Since there was no heave of the thrust block observed for this operation, it is assumed that the injected grout went into mixing with the soil and filling its void space.

The planned order of grouting[7] was not followed. This deviation from the test plan was primarily due to the relatively small operating envelope offered by the contamination reduction zone and the presence of tieback wires for the weather shield, which would have interfered with movement from the drill rig. For this reason, the final grouting plan was to start on the south end of the thrust block and generally work to the north one row at a time in a modified "Z" pattern. The original test plan assumed that each grout hole would be grouted from the basalt to approximately 5 ft from the top surface of the Acid Pit (meaning approximately 12 ft of total grout column). During this planning phase, the goal was to treat 100% of the contaminated zone that occurs in the bottom 12-ft section; however, examination of Track 2 shows that the bottom 6 ft contains 99% of the contaminants. This planning was performed without benefit of the cold testing summarized in Volume 1 of this report, and the true extent of grout returns during soil-only grouting was not understood. Cold testing in the Operational Readiness Pit described in Volume 1 showed that when grouting only 6-ft columns starting at 17 ft below the top surface, grout returns were virtually eliminated. Therefore, based on the extent of contamination and the desire to reduce grout returns, it was recommended to perform only a 6-ft injected interval. However, there were other programmatic constraints that made that option impossible, including the fact that the geophysics design assumed that the columns would be 12 ft high and the geophones were already emplaced outside the pit to accommodate that design. In addition, all negotiations with regulators had assumed that the 12-ft interval would be grouted; therefore, grouting started with the full 12-ft columns.

Returns became excessive after grouting the first row (grout sequence numbers 1–9, as shown in Figure 30, which shows the actual order of grouting on the holes). The first alternative was to reduce the column height to about 10 ft. When this also produced grout returns, the order of grouting was varied by first trying to obtain an every-other-hole grouting sequence and eventually choosing positions that had not been grouted, reducing the grouted height, and examining the grout returns. This explains the rather random order observed in Figure 30. As grouting progressed, it became increasingly more difficult to emplace any grout in the pit; and eventually the pressure of grouting and the length of the column were adjusted (see Table 3). It was as if the hydraulic pressure exerted by the emplaced grout had compressed the voids in the soil to the point were virtually no grout could be emplaced even under high pressure. Figure 31 shows qualitatively the general pattern of grouting followed. In this figure, it is shown that the interior ungrouted positions tended to be compressed by injection of grout into the surrounding soils. Interestingly enough, during the last day of grouting, several positions could not be grouted because the rotopercussion drill rig could not penetrate in a timely manner a cured grout layer that formed under the thrust block. The surface-cured TECT-HG grout was so hard that even a rotational drilling action with no drilling fluid could not penetrate the material without excessive bit wear. Even though there were difficulties in grouting several positions in the pit, a total grout volume was injected that equaled a void volume in the soil of about 25%.

5.1.2 Contamination Control During Grouting

Contamination control systems operated as planned throughout the grouting process. The operation started and remained clean. Both radiological and hazardous online monitoring were performed along with personnel monitoring for hazardous and radiological constituents. In addition, postgrouting evaluation of smears on the drill stem and thrust block surface was conducted for contaminants. Also, air monitoring was performed in a pattern of air monitors surrounding the grouting area. Even though contamination was observed on the drill stem and in grout returns under the thrust block, there was no migration of contaminants into worker breathing zones. The operation proceeded unencumbered by work stoppage from intervention by RADCON or industrial hygiene personnel.

5.1.2.1 Online Contamination Control Data Results. Online contamination control data monitored by industrial hygienists confirmed that contamination levels during grouting were trivial and that work could proceed without use of respirators. In addition, online measurements by RADCON technicians were never above background.

Table 6 shows the overall mercury and organic online measurements taken at the top surface of the thrust block just after the drill steel was removed for changing to another hole. The range of values for mercury at the hole varied between 0–0.061 ppm. These levels are all lower than the action levels of 0.1 ppm Hg, which would have prompted measuring Hg at the breathing level. In addition, these values are generally lower than the mercury levels at the hole during the coring used to emplace the geophysics probes in the Acid Pit, which vary from 0–0.199 ppm (see Table 7).

5.1.2.2 Posttest Evaluation of Smears, Grab Samples, and Air Monitoring Samples. The spread of contaminants from the pit to the top surface of the thrust block and beyond was measured by collecting smears, obtaining grab samples of solid material from the grout returns under the thrust block, and obtaining air filter material. Smears were collected on the top surface of the thrust block and on the drill stem following various grouting operations. Grab samples of the grout returns under the thrust block were also obtained. Finally, to assess the extent of airborne contaminant spread, high-volume air sampler filter data were obtained for all the operations and samples from the HEPA filter

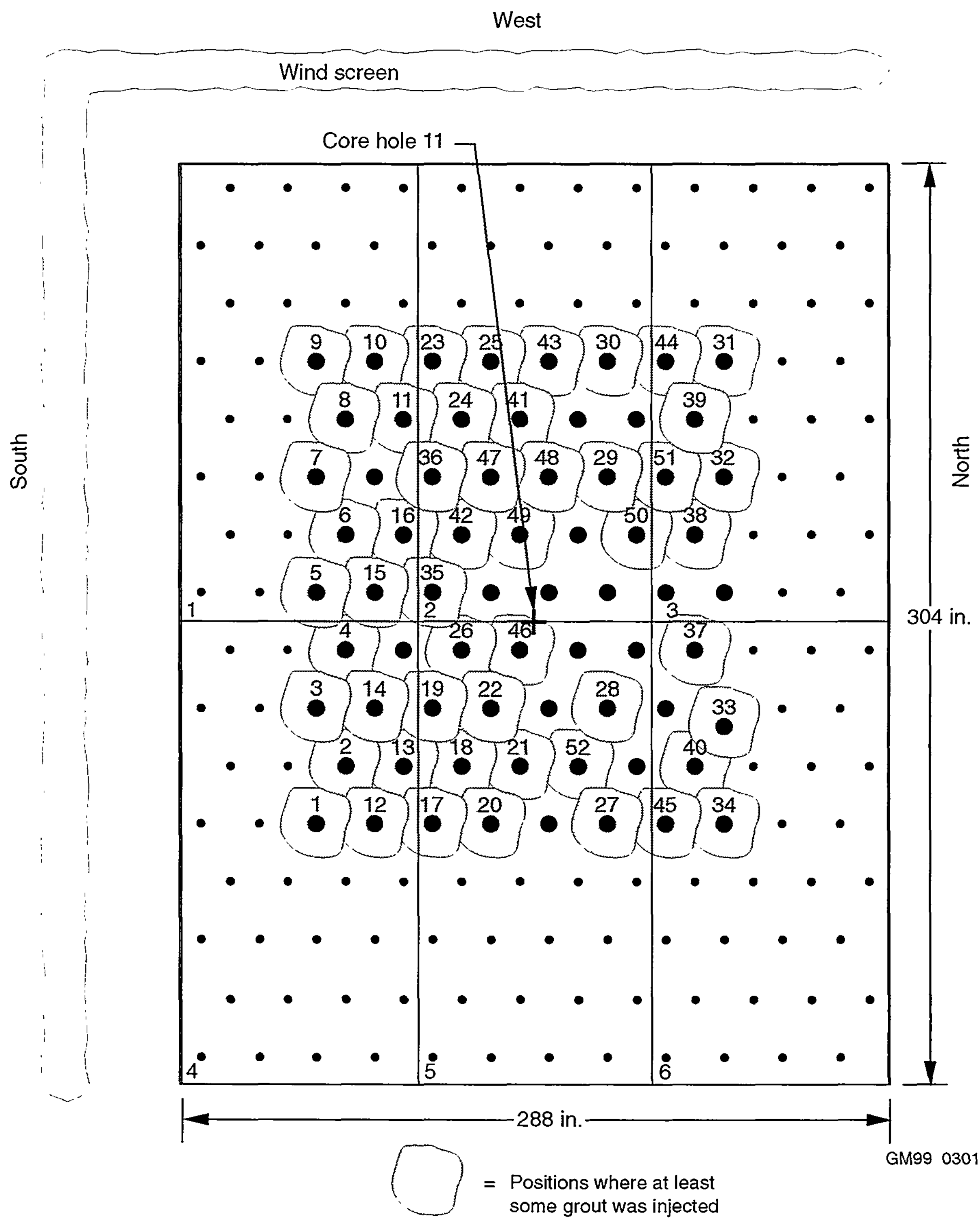


Figure 30. Order of grouting in the Acid Pit (Graphic GM99 0301).

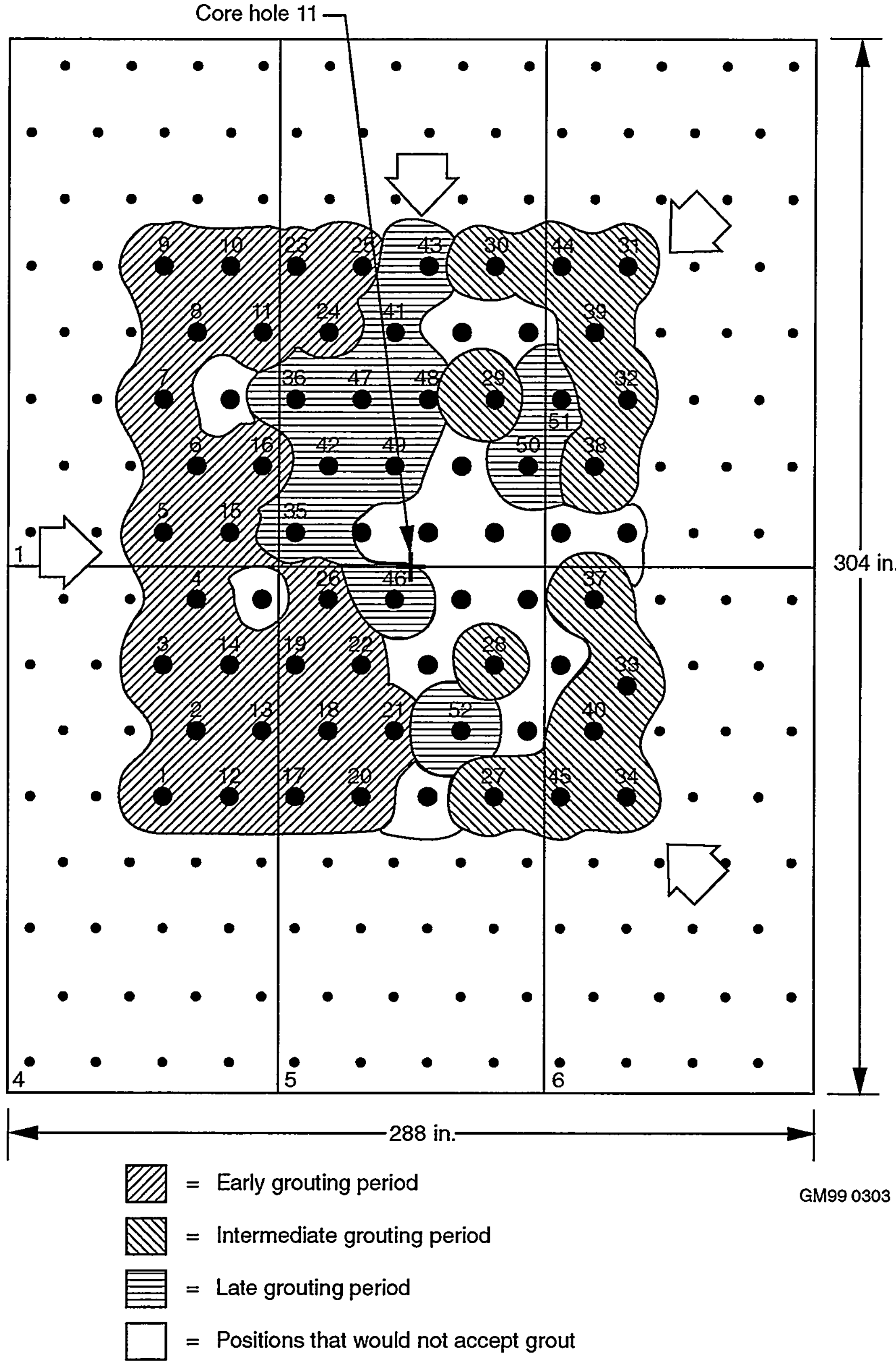


Figure 31. Compression of interior positions in the Acid Pit due to the grouting sequence (Graphic GM99 0303).

Table 6. Acid Pit Stabilization phase online mercury and organic evaluation.

Date	Time	Location (hole number)	Mercury (mg/m^3) At Hole	Organics (ppm) At Hole	Organics (ppm) Breathing Zone
09/22/97	10:15 am	Background: SE corner	0.015	0.4	—
	10:20 am	31 (pregrout)	0	0.7	—
	10:50 am	31 (postgrout)	0	0.3	—
	11:10 am	29	0	0.2	—
	11:20 am	27	0	2.5	0.7
	11:35 am	25	0.014	3	0.7
	11:50 am	23	0.003	0.4	—
	12:13 pm	21	0.029	1	—
	12:41 pm	19	0.036	0.4	—
	12:54 pm	17	0	0.7	—
	1:04 pm	15	0.003	0.4	—
	1:15 pm	13	0	0.7	—
	1.25 pm	11	0	0.4	—
	1:48 pm	32	0	2.1	0.7
	1:57 pm	30	0.009	0.3	—
	2.06 pm	28	0	0.4	—
	2.23 pm	26	0	0.7	—
	2.31 pm	24	0	0.4	—
09/23/97	8:45 am	22	0.04	0.3	—
	8:55 am	20	0.028	0.3	—
	9:05 am	57	0.011	1	0
	9:15 am	53	NR	0.3	—
	9:30 am	49	0.013	0.2	—
	9:45 am	58	0.036	1	0.6
	9:55 am	54	0.058	0.9	—
	10:05 am	50	0.09	0.3	—
	10:20 am	61	0.02	0.3	—
	10:35 am	65	0.01	0.9	—
	10:45 am	62	0.018	0.7	—
	10:55 am	45	0.038	0.6	—
	11:25 am	60	0.04	0.6	—
	11:35 am	52	0.015	0.3	—
	11:45 am	44	0.044	0.3	—
	11:55 am	36	0.031	0.4	—

Table 6. (continued).

Date	Time	Location (hole number)	Mercury (mg/m^3) At Hole	Organics (ppm) At Hole	Organics (ppm) Breathing Zone
	12:05 pm	64	0.007	0.3	—
	12:15 pm	2	0	0	—
	12:30 pm	5	0.007	0.3	—
	12:40 pm	11	0.004	0.3	—
	12:50 pm	14	0	0	—
	1:00 pm	37	0.003	0.3	—
09/24/97	9:45 am	41	0.037	0.3	—
	10:00 am	33	0.038	0.5	—
	10:10 am	9	0.038	0.6	—
	10:20 am	6	0.055	0.3	—
	10:35 am	3	0.055	0.6	—
	10:50 am	12	0.061	0.3	—
	11:05 am	54	0.042	0.3	—
	11:20 am	66	0.03	0.3	—
	11:35 am	37	0.022	0.6	—
	11:55 am	63	0.035	0.3	—
	12:10 pm	1	0.038	0.6	—
	12:12 pm	13	0.05	0	—
09/25/97	9:20 am	46	0.052	0.4	—
	9:45 am	34	0.043	0.6	—
	10:00 am	35	0.037	0.9	—
	10:15 am	42	0.032	0.6	—
	10:20 am	43	0.017	0.3	—
	10:35 am	38	0.029	0.3	—
	10:55 am	67	0.022	0.3	—
	11:15 am	40	0.026	0.3	—
	11:30 am	4	0.028	0.6	—
	12:00 pm	55	0.026	0.3	—
	12:15 pm	10	0.011	0.3	—

Note: Readings were taken in the breathing zone (~3–4 ft above hole) when measurements at hole exceeded: 0.1 ppm Hg and 1.0 ppm organics.

Table 7. Baseline Hg readings from the Acid Pit during installation of geomonitoring devices at four locations.

Date	Location	Drill Depth (ft)	Description	Mercury (mg/m^3) At Hole	Mercury (mg/m^3) Breathing Zone
8/27/97	N hole	4	—	0	—
		17–18	Core sample	0.003	—
			hole	0.124	0.099
	S hole	4	Hole	0	—
		9	—	0	—
		13	—	0	—
		17		0.179	0
			Core	0.03	
	East hole	4	Hole	0	—
		9	—	0	—
		13	—	0.199	—
		17	—	0.033	0
			Core	0	—
	West hole	3.5	Hole	0	—
		8.5	—	0	—
		13.5	—	0	—
		17.5	—	0.151	0
			Core	0	

located on the drill rig were also analyzed. All of these samples were evaluated for mercury and radiological contamination. Figure 32 shows the sampling locations for the smears and grab samples of grout returns and the relative location of three high-volume air samplers located around the operation.

5.1.2.3 Evaluation of Smears and Grab Samples. At each of the sampling locations (shown in Figure 32), immediately following the grouting operation, samples of smears on the drill stem and top surface of the thrust block were taken as well as a grab sample of the grout returns, if any. Results show that the grab samples of the grout under the thrust block and the drill stem smears have mercury contaminants well above background; however, the top surface of the thrust block remained relatively free of contaminants. Smears and grab samples were evaluated using atomic absorption for mercury and gamma spectroscopy for radionuclides. Table 8 shows an evaluation for the smears on the drill stem and thrust block for mercury analysis, and Table 9 shows the same smears evaluated for radionuclides. Table 10 shows the grab sample evaluated for mercury. Examining these tables shows that the drill stem was contaminated above background values in over half the cases. Yet, the top surface of the thrust block remained at the nondetect level for all but one sample. For that position, the level of contamination on the

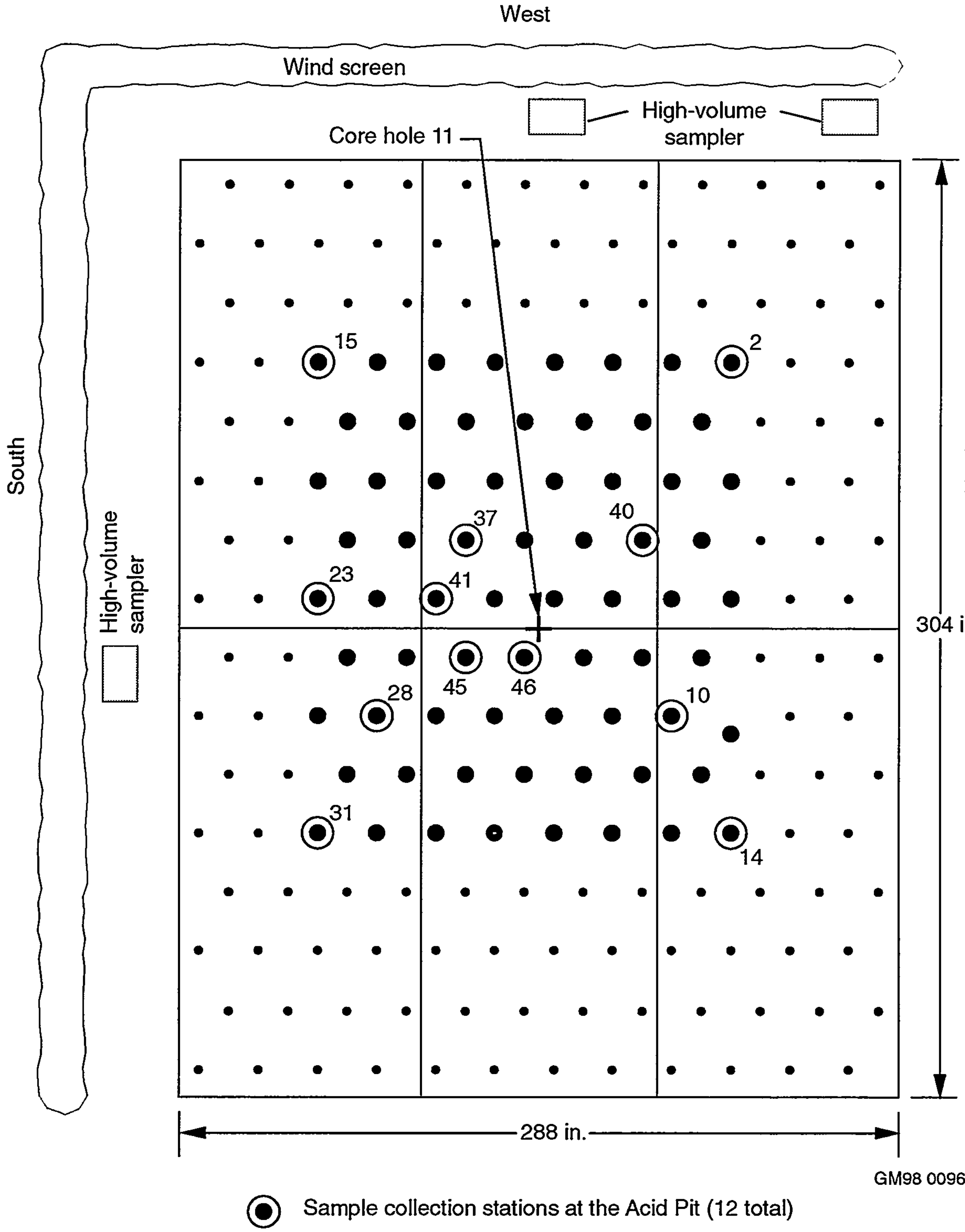


Figure 32. Location of sampling positions during Acid Pit grouting (Graphic GM98 0096).

Table 8. Evaluation of smears of mercury contamination.

Hole	Drill Stem Smear µg/100 cm^2	Thrust Block Smear µg/100 cm^2
2	0.244	Nondetect
10	0.039	Nondetect
14	0.115	Nondetect
15	Nondetect	Nondetect
23	Nondetect	Nondetect
28	Nondetect	Nondetect
31	Nondetect	Nondetect
37	0.609	Nondetect
40	0.059	0.021
41	0.056	Nondetect
45	Nondetect	Nondetect
46	0.152	Nondetect
	Average 0.182	
Background	Nondetect	Average 0.021

Detection limit is 0.020 ppm mercury

Table 9. Evaluation of smears of radiological contaminants (gamma-scan).

Hole	Drill String Smear pCi/Sample	Thrust Block Smear pCi/Sample
2	Eu-152 = 5.03 pCi/s	Nondetect
10	Co-58 = 1.54 pCi/s	Nondetect
14	Nondetect	Nondetect
15	Nondetect	Zn-65 = 4.16 pCi/s
23	Nondetect	Nondetect
28	Ra-226 = 8.79 pCi/s	K-40 = 0.211 pCi/s
31	Nondetect	Nondetect
37	Nondetect	Nondetect
40	Nondetect	Co-60 = 1.33 pCi/s
41	Ag-108M = 1.19 pCi/s Co-60 = 1.5 pCi/s Ra-226 = 3.28 pCi/s	Am-241 = 11 pCi/s K-40 = 11.94 pCi/s Ra-226 = 5.96 pCi/s
45	Nondetect	Ag-108M = 1.38 pCi/s Ra-226 = 6.03 pCi/s
46	Ra-226 = 2.86 pCi/s Zr-95 = 3.26 pCi/s	K-40 = 3.78 pCi/s

Background drill stem Ru-103 = 1.67 pCi/s

Background thrust block = nondetect

Table 10. Evaluation of grout returns for mercury contamination. Lower detection level = 0.024 ppm.

Hole	Contamination Level[a] mg/kg
2	0.723
14	1.33
15	0.118
23	0.436
28	1.13
31	Nondetect
37	1.07
40	1.75
41	0.827
45	0.731
46	0.197
	Average 0.831

a. With the dilution factor of 20:1 for TCLP testing, all of these values would pass TCLP.

thrust block was only a fraction (about 11% on average) of the drill stem values. Further examination of Table 10 shows that the grab samples of the grout returns all had mercury above the detection level for all but one sample, indicating that the grout returns were contaminated with the mercury material. In fact, for the 10 samples collected, the average value above the detection limit was 34 times; and most of the values were above the hazardous definition limit of 0.2 mg/kg. Therefore, the thrust block appears to have performed its duty in controlling the spread of contamination via grout return management, even though there were occasional (about 1 in 20 holes) excursions of grout to the surface, especially during the later phases of grouting.

Occasionally during the later phases of the grouting operation, grout returns would, in fact, come to the surface of the thrust block and require a special cleanup involving squeegees as depicted in Figures 33 and 34. These figures also show that even with the grout excursion, the contaminants remained locked in the slurry and were not available for transport to other areas, thus remaining contained. The squeegeed surface was allowed to dry, then clean plywood was placed over the area, thus removing further potential for contaminant spread. In fact, even though there were instances of contamination above detection limits below the thrust block in the grout returns and occasional excursions of grout to the surface, there were only background levels detected in the air samplers (see Table 11).

Table 11 gives the level of mercury collected on the air sampler filters in micrograms collected and micrograms per liter of air. For all levels shown in Table 11, the values are thousands of times less than the threshold limit value. It is noted that following the first day of grouting, there was an actual decrease in the micrograms of mercury per liter of air; however, during the second day of grouting, the level roughly doubled. During this second day of grouting, there were three excursions for holes 49, 50, and 52, which required the cleanup procedure shown in Figures 33 and 34. This may account for the

Figure 33. Grout returns during Acid Pit grouting (Photo 97-789-2-12).

Figure 34. Cleaning the top surface of the thrust block following grout excursion (Photo 97-789-2-13).

Table 11. High-volume air sampler data (mercury). Threshold limit value 0.025 mg/m^3 = 0.025 μg/L.

Grouting Holes	Mercury Collected (μg)	Mercury Concentration (μg/L)
1. Background (9/19/97)	0.106	1.23×10^{-6}
2. First day of grouting (9/22/97): Holes 31, 29, 27, 25, 23, 21, 19, 17, 15, 16, 18, 32, 30, 28	0.187	1.06×10^{-6}
3. Second day of grouting (9/23/97): Holes 24, 20, 22, 57, 53, 49, 58, 54, 50, 61, 65, 62, 45, 60, 52, 36, 64, 2, 5, 11, 14	0.383	2.01×10^{-6}
4. Third day of grouting (9/24/97): Holes 41, 33, 9, 6, 3, 12, 66, 37, 63, 1, 13	0.141	No data
5. Fourth day of grouting (9/25/97): Holes 46, 34, 35, 38, 40, 4, 55	0.269	1.66×10^{-6}

elevated levels for the second day; however, during the third and forth day of grouting the levels actually dropped from the second day high, which is consistent with only one excursion of grout during that period (an excursion occurred on hole 49 when grouting hole 12).

5.1.2.4 Radionuclide Results. Examination of the smears for radionuclide content shows that the smears either had nondetect values or were in the pCi/g levels, which can easily get confused with natural background values from atmospheric bomb testing.[9] Referring back to Table 9, the radionuclide content for drill string and thrust block smears is mostly at the nondetect level; however, there were several readings above the background values. The values are listed as pCi/sample, and a sample is a standard health physics smear that weighs approximately 1 g, including smeared material. Therefore, the numbers correspond on an order-of-magnitude basis with pCi/g.

Track 2 lists the following gamma-emitting radionuclides as a source term in the original core hole 11, which is basically the middle of the grouted area in the Acid Pit: Co-60—1.97 pCi/g, Cs-137—125 pCi/g, Eu-152—0.523 pCi/g, Th-234—21.8 pCi/g, Pa-234—34.4 pCi/g, and finally, U-235—1.44 pCi/g. Of this list, only Co-60 and Eu-152 were found on the smears for the drill string or the top surface of the thrust block as shown in Table 9. The cobalt found on the smears was near the source term values; however, for the europium, the value on the smear was higher than the source term, which suggests either the source term defined by Track 2 is nonhomogeneous (which is most likely) or it is a measurement of the Eu-152 from atmospheric testing. In either case, the levels are extremely low.

Interestingly enough, the Acid Pit data shown in Table 9 show no Cs-137, which had as a source term approximately 60 times the Co-60 source term. Again, nonhomogeneity of the waste is the most likely answer; however, it could be possible that the cesium has leached out of the area in the 9 years since the Track 2 was written. The highest manmade radionuclide shown on Table 9 from the Acid Pit smears is Am-241 at 11 pCi/sample. For the Track-2 core hole 11, the source term was only 1.51 pCi/g for Am-241; however, for core hole 9 (far removed from core hole 11 [see Figure 1]) the Am-241 level was as high as 52.9, again suggesting nonhomogeneity of the Acid Pit waste.

In addition to the smears on the drill stem and the thrust block, the high-volume filters were also analyzed for radionuclide content and found to display no radionuclides from the Acid Pit as shown in Table 12. The only detectable radionuclide was K-40 (40–101 pCi/sample, where a sample is the high iodine filter), which is commonly found throughout the INEEL soil at the 15–20 pCi/g range.[9] In addition

Table 12. High-volume air sampler data (composite).

	Grouting Holes	Radiological Collected on Filter (pCi/Sample)	Radiological Concentration (pCi/L)
1.	Background 9/19/97	K-40 = 40 pCi/s	4.7×10^{-4}
2.	First day grouting: Holes 31, 29, 27, 25, 23, 21, 19, 17, 15, 16, 18, 32, 30, 28 (9/22/97	K-40 = 74 pCi/s	4.2×10^{-4}
3.	Second day grouting: Holes 24, 20, 22, 57, 53, 49, 58, 54, 50, 61, 65, 62, 45, 60, 52, 36, 64, 2, 5, 11, 14 (9/23/97)	No data	—
4.	Third day grouting: Holes 41, 33, 9, 6, 3, 12, 66, 37, 63, 1, 13 (9/24/97)	Nondetect	Nondetect
5.	Fourth day grouting: Holes 46, 34, 35, 38, 40, 4, 55 (9/25/97)	K-40 = 101 pCi/S	6.2×10^{-4}

to the high-volume samplers, the HEPA filters on the drilling equipment were dismantled and evaluated for both mercury and radiological contaminants (gamma-scan). Table 13 shows that the mercury was measured at the microgram level, and there was a nondetect for the radionuclides. The mercury number cannot be compared with the allowable limit of 200 ppb levels, because the mass of the sample was not recorded. Rather, it simply shows the presence of mercury. Assuming a 10-g sample shows mercury at 100 ppb, a 1-g sample would have a mercury level of 1 ppm. Therefore, a 5-g sample of the filter material would be at the allowable limit of 200 ppb.

Table 13. HEPA filter data (mercury—radiological).

	Mercury (μg)	Radiological
Sample 1	1.01 μg	Nondetect
Sample 2	0.49 μg	Nondetect

5.2 Evaluation of Cores for Leachability and Grout Penetration

Core samples were evaluated for penetration of grout and for leachability to determine the suitability of the monolith to perform as a permanent disposal system for the Acid Pit. Figure 25 shows the overall location of the various cores relative to the various regions grouted. Some of the cores were obtained in regions where it was suspected that there should be good grout penetration and a relatively high percentage of grout to soil (i.e., positions immediately adjacent to the grouting hole). Some of the core holes were located exactly in-between grouting holes to assess whether the grout had penetrated the approximately 2 ft of space between the holes, and some of the holes were located in regions where the geophysics evaluation (discussed in a subsequent section) indicated either good or poor grout penetration.

5.2.1 Grout Penetration Study

Grout penetration was evaluated by visual examination and evaluation of the total metals analysis performed on samples from the cores.

5.2.1.1 Visual Examination. During visual examination of the cores, it became apparent that determining the pervasiveness of the TECT grout would be difficult because the grout color was close to the soil color and that the cores had been highly fractured by sonic drilling. When neat pure pockets of grout were encountered, it was obvious the grout was present. Therefore, the following discussion uses a qualitative description, assigning a percentage of grout observed, and does not necessarily agree with a more quantitative analysis offered later in the report. In general, the condition of the soil appears similar to the clean soil in the cold testing, except for a very few samples at the bottom of the pit in which a reddish-brown material (similar to oxidized iron) was encountered.

Evaluation of core samples recovered from the Acid Pit was conducted from July 7 to July 9, 1998. Core evaluation was performed at a specially equipped facility (Building 635) for handling radioactive material at the RWMC. In general, core recoveries consisted of highly fractured cores of compacted soil (clay) intermixed with either TECT fragments or soilcrete mixtures. Figure 35 shows a complete core with essentially full recovery and the highly fractured nature of the core caused by the sonic drilling process. The cores were picked apart and examined foot by foot, and a verbal description follows. Figure 36 shows detail of a core fragment with a stringer of TECT grout in the core. Depending on core hole location, concentration of TECT grout that permeated into the soil matrix ranged from less than 5% to more than 50% (qualitative description). A summary of sample description for each core hole follows.

Core Hole B (CH-B)

CH-B was located to evaluate a well-grouted region in the southeast portion of the test area (near GH-29, which corresponds to an area grouted to the 5-ft level at 6,000 psi). For CH-B, a 14-ft interval was cored for examination, and 84% of this interval was recovered. For this interval, core samples were expected to contain a high percentage of TECT. Core samples from 5 to 15 ft contained a TECT concentration ranging from 5% to 25% (visually estimated average concentration of 15%), which was lower than expected. From 15 to 16.5 ft, the TECT concentration increased to 50%, representing the highest TECT concentration from this hole. The interval from 16.5 to 17 ft consisted of a reddish-orange stained ungrouted soil that when surveyed had detectable levels of radioactive contamination (most likely a beta emitter in that survey through the lexan tube [which would shield beta] revealed no radioactivity with hand-held instruments) (Note: No mercury contamination was detected with field monitoring instruments). This interval is shown in Figure 37, with the reddish-brown material at the bottom suggesting chemical dumping in the Acid Pit. Figure 38 shows a core fragment from this region, with a high (qualitatively 50%) amount of TECT grout shown as a purplish material on the sample. The cored interval from 17 to 17.5 ft consisted of ungrouted sandy-clay, and the interval from 17.5 to 19 ft consisted of basalt rubble as shown in Figure 39. It is not clear whether the top surface of the basalt was naturally rubblized or the sonic drilling process actually rubblized the core. In either case, the core was mainly a fine basaltic powder (also shown in Figure 39), suggesting that the drilling process had rubblized the core.

Core Hole C (CH-C)

The position of CH-C was selected to evaluate a well-grouted region in the southwest portion of the test area (near GH-17, which corresponds to an area grouted to the 8-ft level at 6,000 psi). For CH-C, a 9-ft interval was cored for examination, and 100% of this interval was recovered. For this interval, core samples were expected to contain a high percentage of TECT. Except for the upper foot, core samples consisted of a TECT concentration ranging from 50% to 70% (visual qualitative estimate).

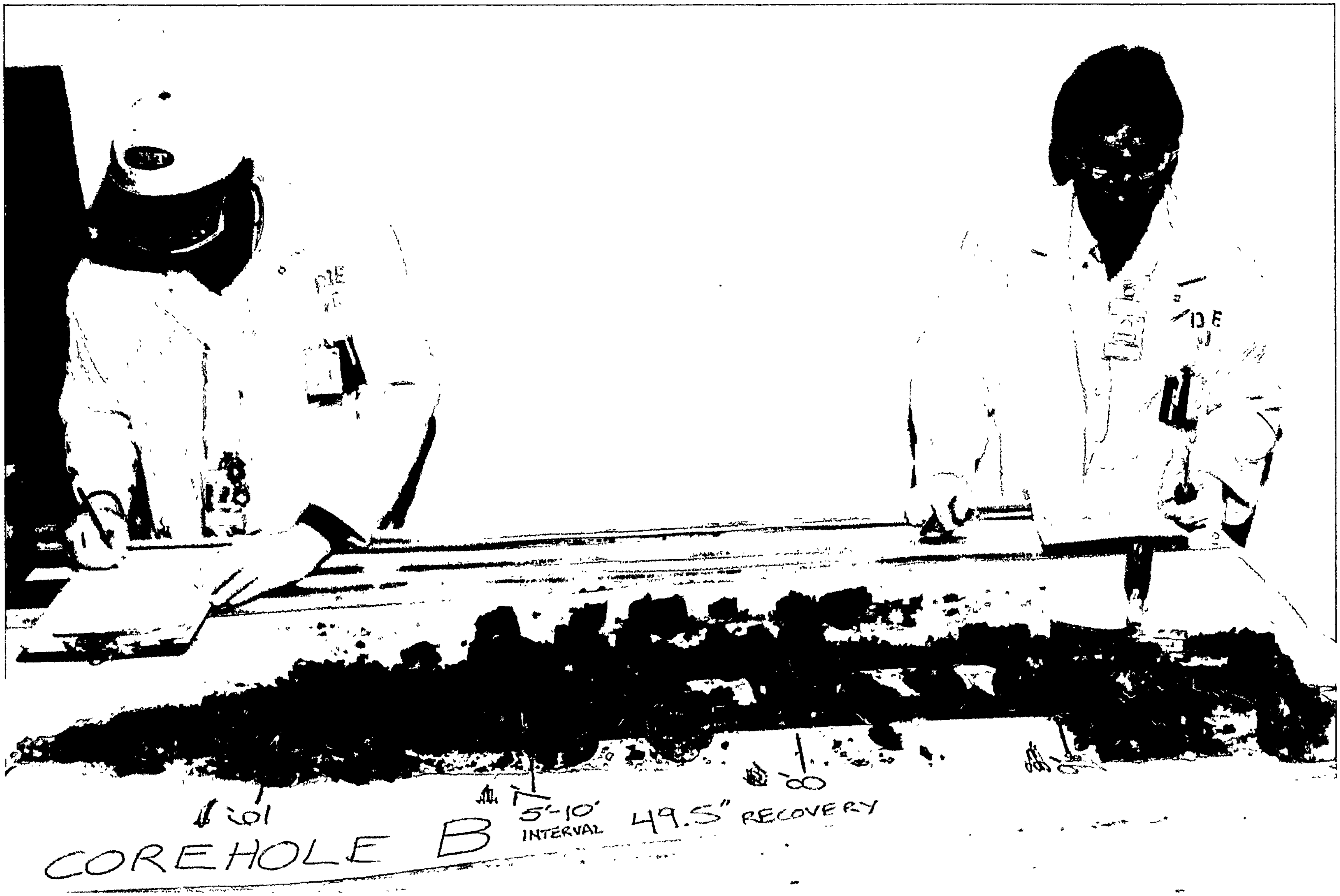


Figure 35. Example of typical core recovery during core examination, which showed high recovery and a highly fractured core (Photo 98-386-2-12).

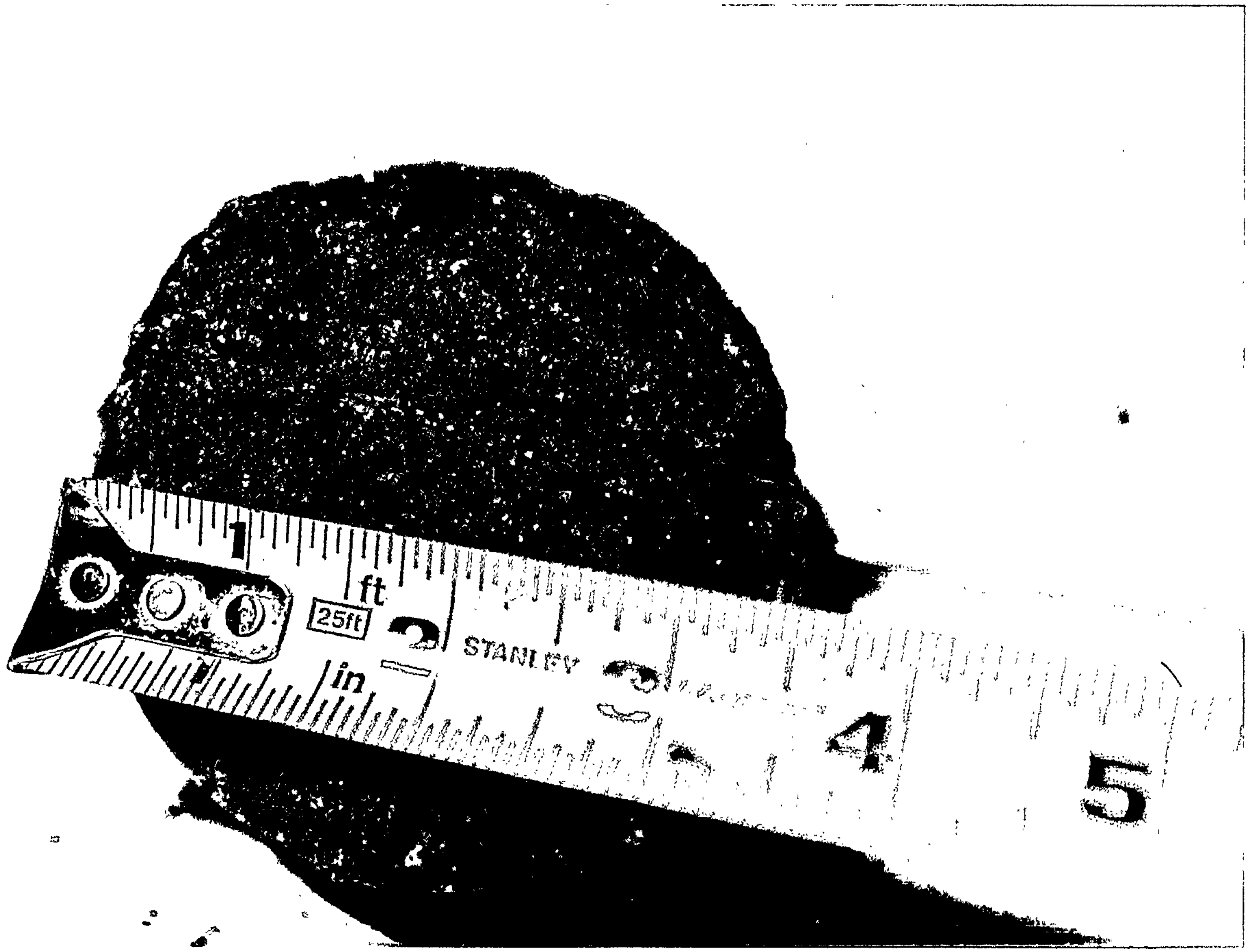


Figure 36. Detail of core fragment showing TECT stringer (neat grout) (Photo 98-386-2-9).

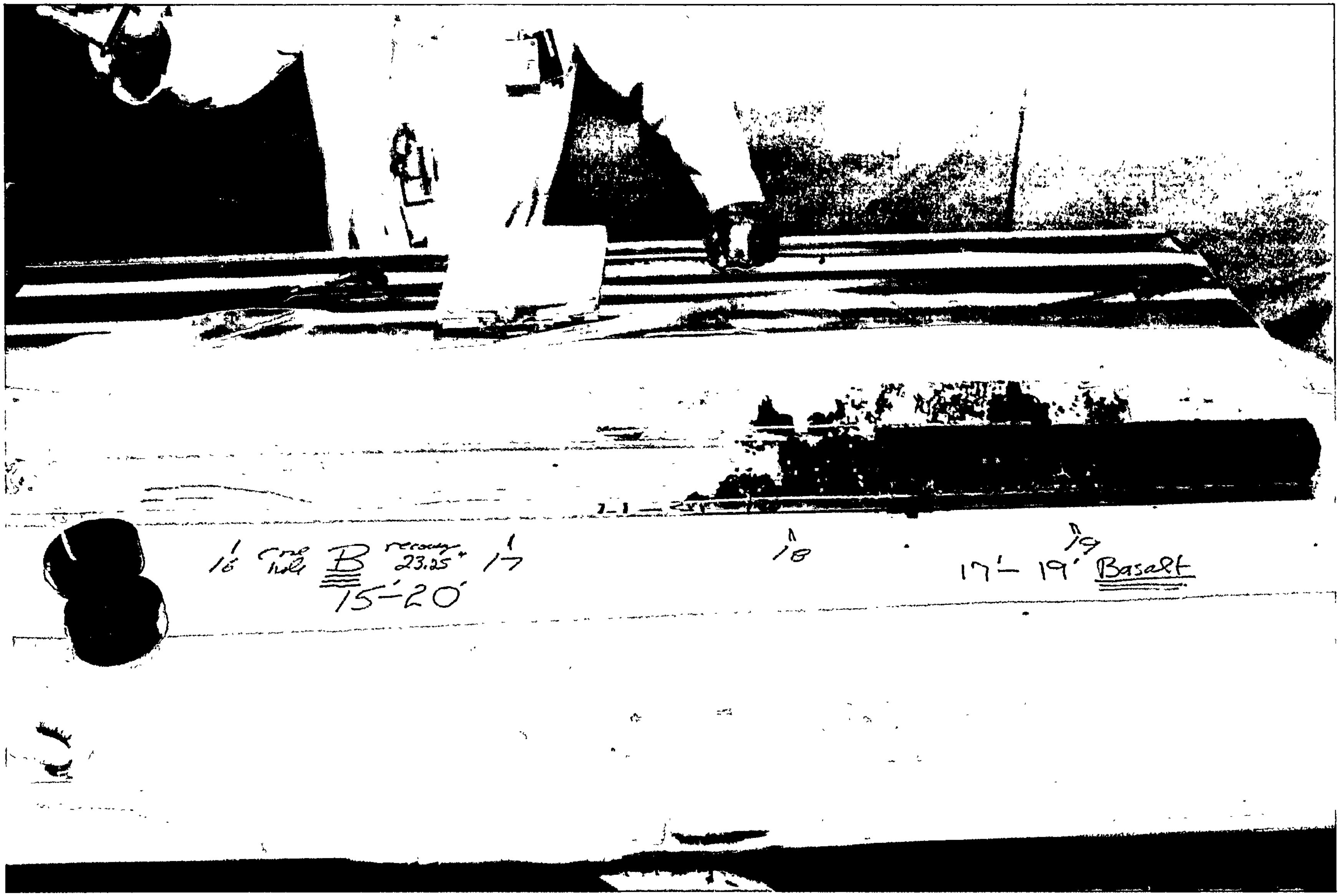


Figure 37. Core hole B (15-20 ft) showing reddish-brown material at the bottom (Photo 98-386-2-20).

Figure 38. A core fragment with high TECT content (50%) (Photo 98-386-1-3).

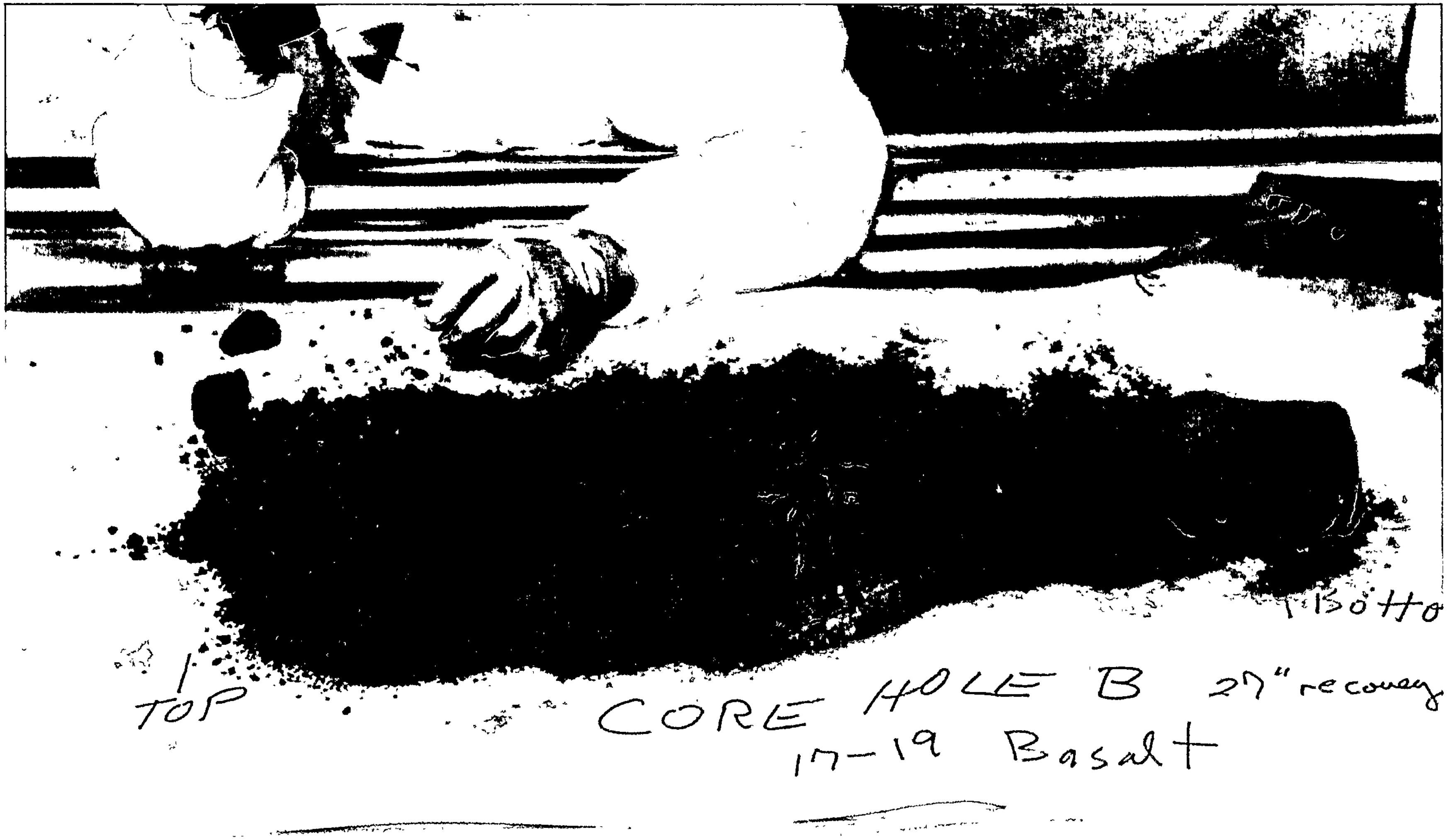


Figure 39. Core hole B basalt interface showing fractured basalt pieces (Photo 98-386-1-5).

Core Hole F (CH-F)

CH-F was located to evaluate a grouted region in the western portion of the test area. For CH-F, a 10-ft interval was cored for examination, and 88% was recovered. For this interval, core samples were expected to contain a high percentage of TECT because the core hole was adjacent to a grouted hole (GH-65). Core samples from 8 to 15 ft showed an increasing TECT concentration with depth, with the upper portion consisting of less than 5% TECT and bottom portions at 40% TECT. A well-grouted region was observed from 15 to 16.5 ft, with a TECT concentration greater than 75%. From 16.5 to 17.5 ft, the core consisted of a reddish-orange stained soil, with detectable radioactive contamination. Figure 40 shows clearly the reddish-brown stain again, suggesting the prior chemical dumping. In examination of excavated soil in areas adjacent to the SDA Cold Test Pit, no reddish-orange stained soil was observed. The soil was composed of very fine-grained sand that was ungrouted.

Core Hole J (CH-J)

CH-J was located in an area consisting of grouted holes (at variable injection pressures) and ungrouted holes. For CH-J, a 9-ft interval was cored for examination, and 100% was recovered. CH-J was drilled to collect representative samples for analytical testing. This hole was located near core hole 11 (drilled and sampled as part of the Acid Pit Track-2 Investigation), and core samples were expected to consist of variable TECT concentrations due to lower injection pressures and nearby ungrouted areas. From 8 to 16 ft, TECT concentration ranged from 10% to 40% (averaging ~30%). The sample from 16 to 17 ft consisted of an ungrouted region composed of fine-grained sand. The cored interval from 17 to 19 ft was inadvertently not retained for examination, and no evaluation of grouting conditions at the basalt/soil interface could be performed.

Core Hole K (CH-K)

CH-K was located near GH-45, which was the closest grouted hole near core hole 11 (drilled as part of the Acid Pit Track-2 Investigation). For CH-K, a 6.5-ft interval was cored for examination, and 86% was recovered. GH-45 was only partially grouted and is surrounded by abandoned or ungrouted holes. Core samples were expected to contain a lower percentage of TECT compared with areas that were considered well grouted. Overall, CH-K showed a higher than expected TECT concentration, averaging more than 50%. Figure 41 shows the core with fairly large cohesive fragments of material, and Figure 42 shows an interesting white residue in the bottom of the core. It is suspected that this is the lime material that was reported to have been used to neutralize acids placed in the pit.

Core Hole R (CH-R)

CH-R was drilled to evaluate an ungrouted region of the monolith and for correlation of geophysical data. For CH-R, a 10-ft interval was cored for examination, and only 36% was recovered. CH-R was located near GH-44, which was a troublesome grouting area (excessive grout returns) that was eventually abandoned. Core samples were expected to contain either a low percentage of TECT or absence of TECT (ungrouted). No TECT was observed in core samples from 2 to 7 ft; from 7 to 12 ft contained a TECT concentration ranging from 5% to 50%.

Core Hole S (CH-S)

CH-S was drilled to evaluate the interstitial area between GH-35 (grout interval from 10 to 16 ft at 3,500 psi) and GH-36 (grout interval from 8 to 16 ft at 6,000 psi). For CH-S, an 8-ft interval was cored for examination, and only 43% was recovered. Core samples were expected to contain low concentrations of TECT. Samples contained less than 5% TECT, which indicates that grout column development for this region was less than 24 in. in diameter.

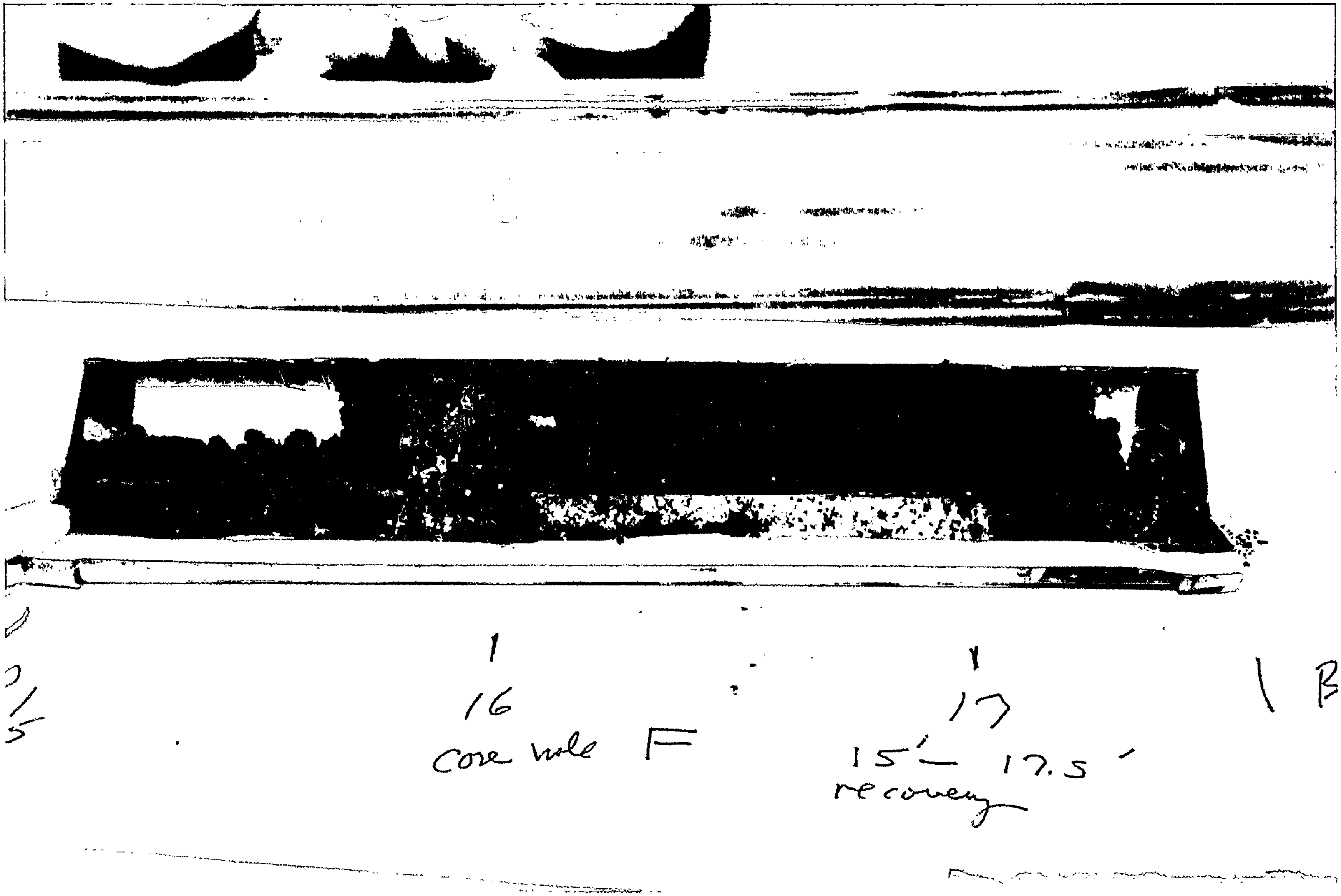


Figure 40. Core hole F at the bottom of the sample showing a reddish-brown stain—evidence of chemical dumping (Photo 98-386-1-22).

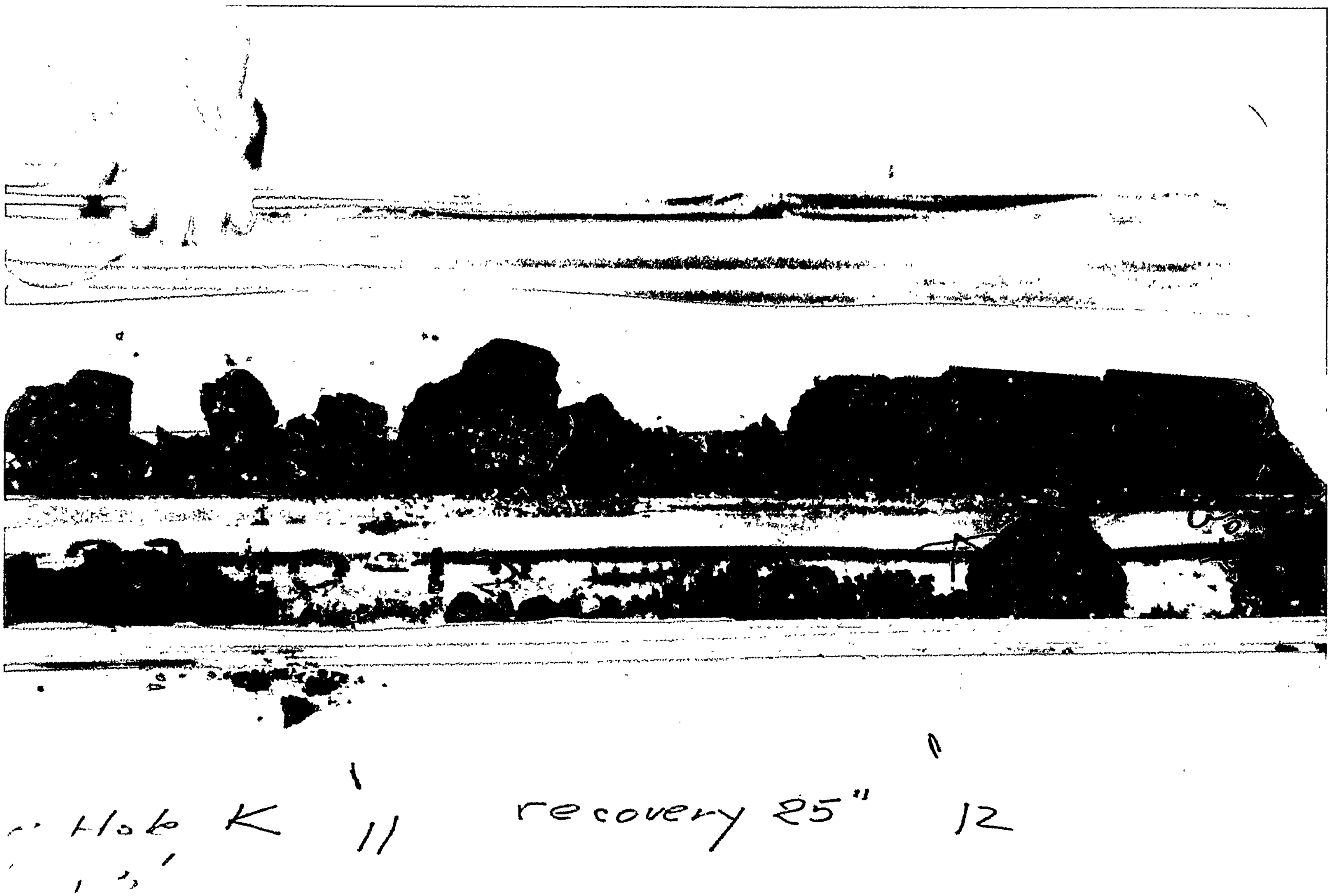


Figure 41. Core hole K showing large cohesive fragments of highly compacted clay (10-13 ft) (Photo 98-386-1-29).

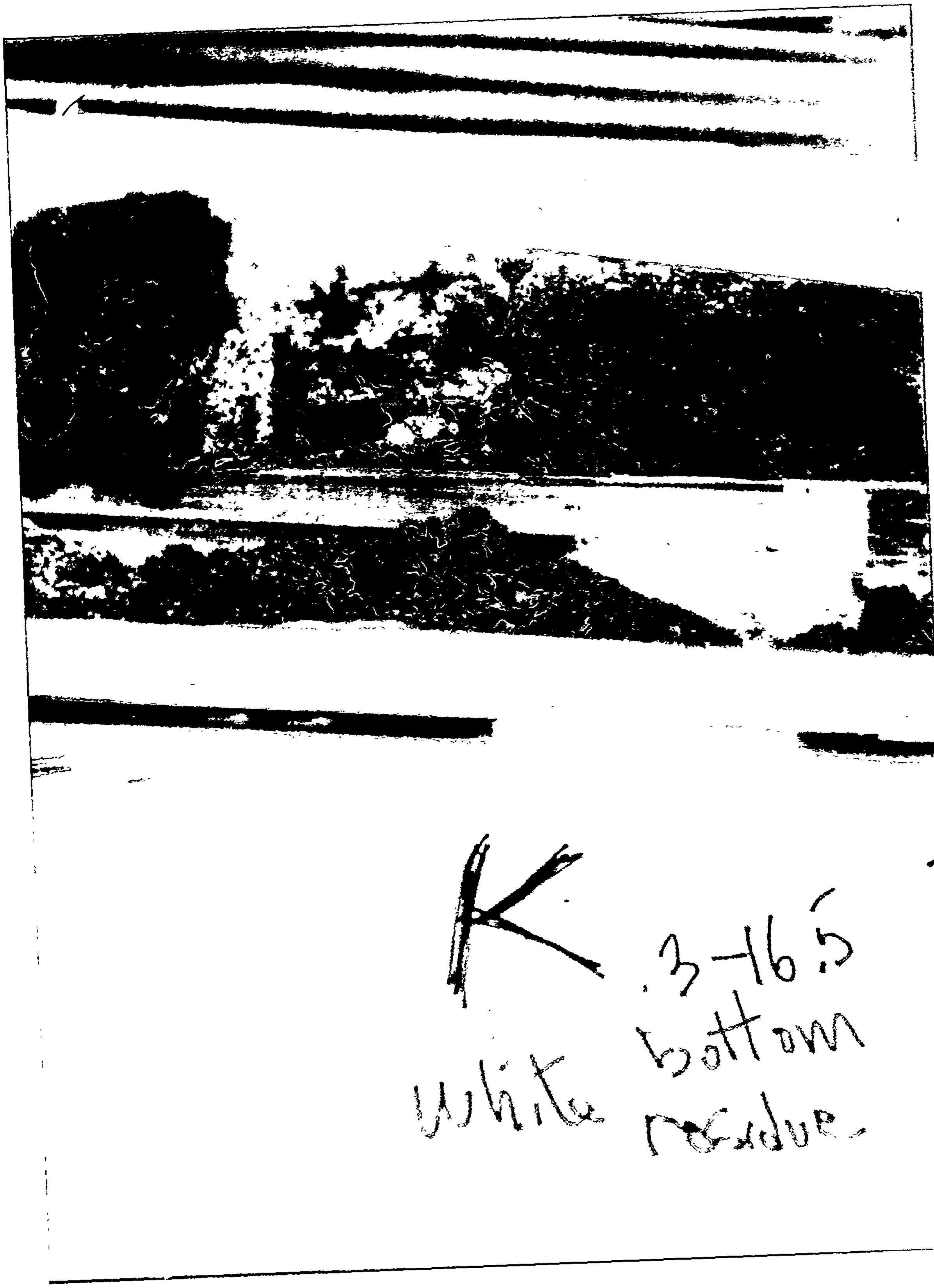


Figure 42. Core hole K showing a white residue near the bottom of the sample (13-16.5 ft) (Photo 98-386-1-32).

Core Hole O (CH-O)

CH-O was drilled to evaluate the northeast portion of the test area. For CH-O, a 10-ft interval was cored for examination, and 72% was recovered. CH-O was located between GH-55 (grout interval from 10 to 15 ft at 3,500 psi) and GH-56 (abandoned hole). Core samples were expected to contain a low percentage of TECT. From 8 to 14 ft consisted of a TECT concentration ranging from 5 to 30%; from 14 to 15 ft, the TECT concentration increased to 50%.

Core Hole Q (CH-Q)

CH-Q was drilled to evaluate an ungrouted region of the test area. For CH-Q, a 10-ft interval was cored for examination, and 45% was recovered. CH-Q was located between GH-42 and GH-43, which were abandoned holes. Core samples were expected to either contain a low percentage of TECT or be absent of TECT. From 5 to 10 ft, the core sample consisted of a TECT concentration ranging from 10 to 15%; from 10 to 15 ft, an absence of TECT was observed as expected.

Core Hole T (CH-T)

CH-T was drilled to evaluate the ungrouted region south of the test area for correlation of geophysical data. Recovered cores from CH-T were transferred to plastic sleeving, and core recovery estimations could not be determined. CH-T was located approximately 2 ft south of GH-8 (an abandoned hole), which was outside the planned test area for grout emplacement. Core samples were expected to be absent of TECT. Core samples consisted of clay with scattered thin TECT stringers at an estimated TECT concentration of less than 10%.

In general, the examination of the cores revealed little evidence of any contamination because the cores appeared like grouted soil or, in some cases, simply soil. The only exception to this is the reddish-to-brown stain near the bottom of the pit and in isolated positions a minor white residue—presumably slaked lime. Also, another general observation is that the TECT grout appears in regions where it was expected to be nonexistent, suggesting a nonhomogeneous soil structure in the Acid Pit with preferential paths for grout.

5.2.1.2 Total Metals Evaluation of the Cores. Samples of the neat grout, untreated Acid Pit soils, and soilcrete from Acid Pit cores were evaluated for total metals to aid in a quantitative determination of the pervasiveness of the grout in the treated region of the Acid Pit. The technique involved evaluating the neat grout for those metals that were excessively higher in concentration relative to their concentration in the Acid Pit soil and using these metals as marker metals. Acid Pit core data for total metals were then evaluated for these marker metals and modeled utilizing the assumption that 100% grouting meant that there was 25% of the sample volume (average available void space in INEEL soil) filled with grout. This meant that the soil, when mixed with the neat grout (soilcrete), should be higher than the surrounding untreated soil in these marker metals by a factor dictated by the model.

Table 14 gives the total metals concentrations in mg/kg for the neat grout and all of the core samples. Examination of this table shows that the neat grout has elevated concentrations compared with the grouted soil composition on four basic marker elements including calcium, iron, lead, and zinc. Table 15 further summarizes the concentration for these marker metals for the various cores (e.g., B, C, F, etc.) and also shows the neat grout concentrations. Additionally, when comparing the neat grout concentrations for the marker metals with the ungrouted soil values, it is obvious that the neat grout is also elevated in these elements as shown two ways in Tables 16 and 17. Table 16 shows data (metals evaluation for the marker metals) for soil markers from core hole 11 taken during the 1992 Track-2 evaluation. Also shown in Table 16 is the average of these concentrations for all elevations and the average deviation from the mean along with the concentration for the neat grout.

Table 14. Total metals evaluation of stabilized Acid Pit core.

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Neat grout (7-13-98)		Core B (10–15 ft)	
Al	6,870	Al	12,300
Sb	5.0	Sb	9.6
As	10.4	As	9.2
Ba	325	Ba	262
Be	0.81	Be	0.73
Cd	0.20	Cd	0.44
Ca	147,000	Ca	37,000
Cr	23.3	Cr	24.6
Co	4.5	Co	8.0
Cu	71.2	Cu	19.4
Fe	32,800	Fe	18,700
Pb	41.4	Pb	11.3
Mg	6,670	Mg	8,030
Mn	510	Mn	529
Hg	0.03	Hg	1.3
Ni	11.3	Ni	31.2
K	1,220	K	2,640
Se	0.20	Se	0.20
Si	81,500	Si	260,000
Ag	0.40	Ag	0.40
Na	2,410	Na	515
Th	0.30	Th	0.30
Va	24.6	Va	31.9
Zn	326	Zn	90.4

Table 14. (continued).

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Core B (15–17 ft)		Core C (10–15 ft)	
Al	10,100	Al	4,660
Sb	5.0	Sb	5.0
As	9.2	As	7.0
Ba	172	Ba	90.0
Be	0.6	Be	0.35
Cd	0.33	Cd	0.20
Ca	43,700	Ca	43,600
Cr	24.0	Cr	15.2
Co	5.1	Co	1.9
Cu	19.6	Cu	22.9
Fe	19,100	Fe	16,200
Pb	10.2	Pb	6.4
Mg	6,650	Mg	2,800
Mn	317	Mn	230
Hg	27.7	Hg	40.9
Ni	22.2	Ni	9.8
K	2,150	K	1,250
Se	0.20	Se	0.20
Si	149,000	Si	244,000
Ag	0.40	Ag	0.40
Na	925	Na	1,190
Th	0.30	Th	0.30
Va	25.4	Va	19.2
Zn	90.2	Zn	99.4

Table 14. (continued).

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Core C (15–17 ft)		Core C (15–17 ft)	
Al	4,070	Al	3,550
Sb	5.0	Sb	5.0
As	6.6	As	6.4
Ba	70.1	Ba	70.7
Be	0.29	Be	0.27
Cd	0.20	Cd	0.20
Ca	34,500	Ca	37,300
Cr	13.1	Cr	11.3
Co	1.5	Co	1.4
Cu	18.9	Cu	19.7
Fe	12,900	Fe	12,800
Pb	5.3	Pb	5.1
Mg	2,430	Mg	2,000
Mn	183	Mn	170
Hg	48.3	Hg	42.2
Ni	9.7	Ni	7.4
K	1,060	K	1,070
Se	0.20	Se	0.20
Si	219,000	Si	135,000
Ag	0.40	Ag	0.40
Na	957	Na	1,150
Th	0.30	Th	0.30
Va	16.5	Va	16.5
Zn	82.7	Zn	85.6

Table 14. (continued).

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Core F (14–15 ft)		Core F (14–15 ft)	
Al	4,720	Al	3,770
Sb	5.0	Sb	6.3
As	6.1	As	4.9
Ba	146	Ba	99.4
Be	0.39	Be	0.17
Cd	0.20	Cd	0.20
Ca	55,200	Ca	17,800
Cr	14.5	Cr	10.9
Co	1.5	Co	0.80
Cu	39.8	Cu	21.7
Fe	15,200	Fe	9,200
Pb	14.4	Pb	12.2
Mg	3,340	Mg	1,700
Mn	228	Mn	88.2
Hg	33.3	Hg	33.2
Ni	8.3	Ni	5.9
K	1,190	K	1,140
Se	0.20	Se	0.20
Si	134,000	Si	85,500
Ag	0.40	Ag	0.40
Na	1,280	Na	869
Th	0.30	Th	0.30
Va	16.4	Va	17.6
Zn	127	Zn	53.7

Table 14. (continued).

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Core F (15–17 ft)		Core J (8–13 ft)	
Al	3,760	Al	9,940
Sb	7.1	Sb	5.8
As	5.4	As	8.4
Ba	103	Ba	157
Be	0.25	Be	0.59
Cd	0.20	Cd	0.42
Ca	28,600	Ca	34,200
Cr	11.0	Cr	20.4
Co	1.1	Co	6.2
Cu	17.5	Cu	16.5
Fe	13,700	Fe	15,600
Pb	8.3	Pb	10.1
Mg	2,160	Mg	6,830
Mn	158	Mn	293
Hg	55.2	Hg	7.8
Ni	7.7	Ni	24.0
K	1,060	K	1,960
Se	0.20	Se	0.20
Si	288,000	Si	286,000
Ag	0.40	Ag	0.40
Na	677	Na	541
Th	0.30	Th	0.30
Va	15.4	Va	26.1
Zn	79.8	Zn	81.8

Table 14. (continued).

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Core J (13–17 ft)		Core O (5–10 ft)	
Al	3,660	Al	9,110
Sb	5.0	Sb	10
As	5.3	As	9.1
Ba	123	Ba	239
Be	0.34	Be	0.75
Cd	0.24	Cd	0.20
Ca	56,000	Ca	87,600
Cr	9.8	Cr	23.5
Co	1.6	Co	5.1
Cu	28.6	Cu	46.3
Fe	9,630	Fe	26,100
Pb	10.2	Pb	24.1
Mg	2,680	Mg	7,210
Mn	228	Mn	403
Hg	62.5	Hg	7.4
Ni	6.1	Ni	20.1
K	887	K	1,700
Se	0.2	Se	0.20
Si	127,000	Si	147,000
Ag	0.74	Ag	0.41
Na	784	Na	1,070
Th	0.3	Th	0.30
Va	14.5	Va	24.7
Zn	124	Zn	209

Table 14. (continued).

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Core O (10–15 ft)		Core Q (5–10 ft)	
Al	5,900	Al	10,500
Sb	5.0	Sb	5.0
As	6.9	As	12.1
Ba	148	Ba	187
Be	0.39	Be	0.73
Cd	0.20	Cd	0.49
Ca	56,900	Ca	66,200
Cr	14.1	Cr	26.2
Co	2.7	Co	7.9
Cu	33.5	Cu	15.8
Fe	15,300	Fe	17,900
Pb	18.6	Pb	11.6
Mg	3,410	Mg	11,200
Mn	217	Mn	363
Hg	62.5	Hg	0.20
Ni	9.2	Ni	36.1
K	1,330	K	1,680
Se	0.20	Se	0.20
Si	153,000	Si	131,000
Ag	0.40	Ag	0.40
Na	1,370	Na	935
Th	0.30	Th	0.30
Va	16.5	Va	33.9
Zn	129	Zn	101

Table 14. (continued).

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Core Q (10–15 ft)		Core R (7–12 ft)	
Al	9,360	Al	12,000
Sb	5.6	Sb	7.2
As	10.1	As	10.2
Ba	226	Ba	221
Be	0.63	Be	0.70
Cd	0.54	Cd	0.42
Ca	38,800	Ca	59,400
Cr	20.6	Cr	25.4
Co	6.5	Co	6.8
Cu	16.5	Cu	24.2
Fe	15,600	Fe	20,300
Pb	11.1	Pb	13.2
Mg	8,070	Mg	8,670
Mn	352	Mn	415
Hg	0.22	Hg	0.89
Ni	30.8	Ni	25.2
K	1,950	K	2,360
Se	0.20	Se	0.20
Si	118,000	Si	157,000
Ag	0.40	Ag	0.40
Na	204	Na	847
Th	0.30	Th	0.30
Va	26.0	Va	33.9
Zn	89.4	Zn	110

Table 14. (continued).

Analyte	Concentration (mg/kg)	Analyte	Concentration (mg/kg)
Core S (8–13 ft)		Core S (13–16 ft)	
Al	10,000	Al	9,760
Sb	9.4	Sb	8.9
As	9.4	As	10.2
Ba	175	Ba	165
Be	0.64	Be	0.62
Cd	0.43	Cd	0.41
Ca	30,000	Ca	33,000
Cr	20.2	Cr	21.0
Co	8.1	Co	6.1
Cu	16.6	Cu	17.2
Fe	161,100	Fe	15,600
Pb	10.8	Pb	11.2
Mg	7,320	Mg	7,270
Mn	394	Mn	309
Hg	2.5	Hg	3.3
Ni	27.0	Ni	27
K	2,080	K	2,100
Se	0.20	Se	0.20
Si	104,000	Si	138,000
Ag	0.40	Ag	0.40
Na	248	Na	319
Th	0.30	Th	0.30
Va	26.7	Va	25.7
Zn	81.1	Zn	87.4

Table 15. TECT marker elements for cores of the Acid Pit.

Core	Calcium (mg/kg)	Iron (mg/kg)	Zinc (mg/kg)	Lead (mg/kg)
Neat grout	147,000	32,800	326	41.4
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)	17,800	9,200	53.7	12.2
F (15–17 ft)	28,600	13,700	79.8	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

Table 16. Marker elements for Acid Pit soils (from Track-2 core hole 11) and neat TECT-HG grout.

Elevation below G.L. (G.L. = 0)	Concentration (mg/kg)			
	Calcium	Iron	Zinc	Lead
0–2 ft	65,100	20,500	80.3	14.6
4–6 ft	56,500	14,600	148	20.7
6–8 ft	32,200	12,000	86	19.1
8–10 ft	34,100	14,400	88.6	15.3
10–12 ft	35,100	19,100	108	17.7
12–14 ft	33,300	18,100	111	11.2[a]
14–16 ft	16,100[a]	4,240[a]	25.5[a]	11.8[a]
16–17.33 ft	7,580[a]	23,800	87.9	35.2[a]
Mean	42,716	17,500	101	17.48
Average deviation from mean[a]	12,055	3,285	18.6	1.97
Range Low	30,661	14,215	82.40	15.51
High	54,771	20,785	119	19.45
Neat Grout (ppm)	Calcium	Iron	Zinc	Lead
	147,000	32,800	326	400

a. Values not included in evaluation of mean and average deviation from mean as unexplainable chemical leaching or statistically invalid data.

Table 17. Average total metals in subs from core 11 (Track 2) as to elevation, along with neat grout total metals.

Elevation below G.L. (G.L. = 0)	Average Concentration (mg/kg)			
	Calcium	Lead	Zinc	Iron
5–10 ft	40,933	18.3	107	13,666
8–13 ft	34,166	17.3	94.2	15,166
10–15 ft	34,200	14.7	102	13,813
14–15 ft	16,100	11.8	25.5	4,240
15–17 ft	11,890	23.5	56.7	14,020
13–17 ft	18,993	19.4	74.8	15,380
7–12 ft	33,800	17.3	94.2	15,166
13–16 ft	24,700	11.5	68.2	11,170
Neat grout:	147,100	41.4	326	32,000

Table 17 collates the soil-only data from Table 16 and represents an average concentration for the marker metals for elevations corresponding to the Acid Pit core intervals (B, C, F, etc). Both tables show the same result in that the marker metals in the grout are significantly higher than the marker metals in the soil. Based on these data, a model was developed in which a degradation factor (DF) was calculated based on the fact that the soilcrete mixture should be increased or decreased in the amount of TECT grout marker metals depending on how well the mixing occurred. A perfect mix was where the neat TECT grout was 25% of the soilcrete. This thinking was juxtaposed onto the relative concentrations of the marker materials in the following formula: DF = (Soilcrete Marker Level-Soil Marker Level)/(Neat Grout Marker Level-Soil Marker Level). This comes from the basic equation that the soilcrete value = DF × the grout value + (1-DF) × the soil value. This means then that if the core is neat TECT, the DF becomes, for example, for the marker metal calcium: DF = 1 = (147,000-soil marker level)/(147,000-soil marker level). Furthermore, it is defined that when the DF is .25, then the soilcrete just fills the voids in a fully loaded soilcrete or 100% loaded.

Tables 18 and 19 show calculated DFs for all the postgrout Acid Pit cores determined in two different ways. Table 18 is based on the mean minus the standard deviation for the Track-2 soil values using the entire length of the core and averages to determine the marker metals (based on Table 16). This technique tends to maximize the amount of TECT that might show up in the DF calculation. As an alternative, Table 19 uses the range of elevations corresponding to the postgrouting Acid Pit cores when determining the marker metal concentrations in the pregrouted Acid Pit soil and probably represents the most realistic case (based on Table 17). In either case, it is clear that the neat grout has a DF of 1.0 and the ideal soilcrete has a DF of .25.

Comparing the DFs for the various cores shows a wide variation in values, with some exceeding the ideal of 0.25, meaning that there was neat TECT in the sample and some shown as negative. A negative value means that the soil marker metal level was higher than the soilcrete value, suggesting basically no grout in the sample. To make the evaluation of the amount of grout clearer, the values in Table 18 and 19 are normalized to making the ideal soilcrete have a DF of 100% and the neat grout equaling 400% as shown in Tables 20 and 21. For these tables, it is clear that within the cores there is a wide range of values, again reflecting fully grouted soilcrete, fully grouted with neat TECT, or not grouted at all. On an Acid Pit-wide basis, the average of all values for the various marker metals is also shown.

Table 18. Degradation percentage from fully loaded soilcretes (based on average soil concentrations) for marker elements found in cores.

Sample	Degradation Factor[a]			
	Calcium	Iron	Zinc	Lead
Neat grout	1.00	1.00	1.00	1.00
Fully loaded soilcrete	0.25	0.25	0.25	0.25
B (10–15 ft)	0.054	0.24	0.033	Negative
B (15–17 ft)	0.112	0.26	0.032	Negative
C (10–15 ft)	0.111	0.106	0.069	Negative
C (15–17 ft)	0.033	Negative	0.001	Negative
C (15–17 ft duplicate)	0.057	Negative	0.013	Negative
F (14–15 ft)	0.210	0.053	0.183	Negative
F (14–15 ft)	Negative[b]	Negative	Negative	Negative
F (15–17 ft)	Negative	Negative	Negative	Negative
J (8–13 ft)	0.034	0.075	Negative	Negative
J (13–17 ft)	0.217	Negative	0.171	Negative
O (5–10 ft)	0.489	0.64	0.520	0.331
O (10–15 ft)	0.225	0.058	0.191	0.119
Q (5–10 ft)	0.305	0.198	0.076	Negative
Q (10–15 ft)	0.069	0.075	0.028	Negative
R (7–12 ft)	0.247	0.327	0.113	Negative
S (8–13 ft)	Negative	0.101	Negative	Negative
S (13–16 ft)	0.021	0.075	0.026	Negative

a. $DF = \left[\frac{\textit{Soilcrete Marker Level} - \textit{Soil Marker Level (average)}}{\textit{Grout Marker Level} - \textit{Soil Marker Level (average)}}\right]$

b. Measures soil level higher than soilcrete level.

Table 19. Degradation percentage from fully loaded soilcretes (based on local soil conditions) for marker elements found in cores.

Sample	Degradation Factor[a]			
	Calcium	Iron	Zinc	Lead
Neat grout	1.0	1.0	1.0	1.0
Fully loaded	0.25	0.25	0.25	0.25
B (10–15 ft)	0.025	0.257	Negative	Negative
B (15–17 ft)	0.235	0.270	0.125	Negative
C (10–15 ft)	0.083	0.125	Negative	Negative
C (15–17 ft)	0.167	Negative	0.096	Negative
C (15–17 ft duplicate)	0.188	Negative	0.107	Negative
F (14–15 ft)	0.298	0.383	0.337	0.087
F (14–15 ft duplicate)	0.013	0.173	0.094	0.013
F (15–17 ft)	0.119	Negative	0.085	Negative
J (8–13 ft)	0.003	Negative	Negative	Negative
J (13–17 ft)	0.289	Negative	0.195	Negative
O (5–10 ft)	0.439	0.649	0.465	0.25
O (10–15 ft)	0.201	0.078	0.120	0.146
Q (5–10 ft)	0.238	0.221	Negative	Negative
Q (10–15 ft)	0.041	0.094	Negative	Negative
R (7–12 ft)	0.226	0.291	0.068	Negative
S (8–13 ft)	Negative	Negative	Negative	Negative
S (13–16 ft)	0.067	0.205	0.074	Negative

a. $DF = \left[\frac{\textit{Soilcrete Marker Level} - \textit{Soil Marker Level (elevation average)}}{\textit{Grout Marker Level} - \textit{Soil Marker Level (elevation average)}}\right]$

Table 20. Core marker metals analysis: percentage of a completely grouted matrix (based on soil average).

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)	21.6%	96%	13%	Negative
B (15–17 ft)	44.8%	104%	12.8%	Negative
C (10–15 ft)	44.4%	42.4%	27.6%	Negative
C (15–17 ft)	13.2%	Negative	0.5%	Negative
C (15–17 ft duplicate)	22.8%	Negative	5.2%	Negative
F (14–15 ft)	84%	21.2%	73%	Negative
F (14–15 ft duplicate)	Negative	Negative	Negative	Negative
F (15–17 ft)	Negative	Negative	Negative	Negative
J (8–13 ft)	13.6%	30%	Negative	Negative
J (13–17 ft)	86.8%	Negative	68.4%	Negative
O (5–10 ft)	195%	256%	208%	132%
O (10–15 ft)	90%	23.2%	76.4%	47.6%
Q (5–10 ft)	122%	79.2%	30.4%	Negative
Q (10–15 ft)	27%	30%	11.2%	Negative
R (7–12 ft)	98%	130%	45.2%	Negative
S (8–13 ft)	Negative	40%	Negative	Negative
S (13–16 ft)	8.4%	30%	10.2%	Negative
Average	62.25% (3 of 17 cores showed no grout)	73.5% (5 of 17 cores showed no grout)	44.76% (4 of 17 cores showed no grout)	89.8% (15 of 17 cores showed no grout)

Table 21. 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% (1 of 17 cores showed no grout)	99.7% (6 of 17 cores showed no grout)	64.1% (6 of 17 cores showed no grout)	49.5% (13 of 17 cores showed no grout)

For the values based on the average soil marker metals, the average for calcium as a marker metal had 62% DF and 3 out of 17 cores with no grout, for iron 73.5% with 5 of 17 cores showing no grout, for zinc 44.76% with 4 of 17 cores showing no grout, and for lead 89.8% with 15 of 17 cores showing no grout. Throwing out lead because it is the poorest marker metal in the TECT compared with soil and averaging these DFs results in an average DF of about 60%, compared with 100% for a fully grouted case. A better result is seen in Table 21, in which the soil marker metals where elevation weighted with an average DF of 76% compared with the perfect 100%. This attempt at a quantitative method to determine the pervasiveness of the TECT grout in the soilcrete of the cores mostly agrees with the visual examination. Cores B, F, J (lower), O, Q, and R all show relatively high levels of TECT grout by this methodology.

Comparing grout penetration by the presence of marker metals with expected penetration based on location of the core holes relative to the grout holes showed surprising results because positions that should have shown poor penetration showed, in fact, good penetration such as core holes adjacent to grout holes and vice versa.

Examining the logic for locating grout holes, it was seen that holes B, J, F, and C should all have shown good grout penetration because the core holes were close to the grout holes. In addition, cores R, Q, and O should be basically an ungrouted region in that grouting could not be performed in these areas due to excessive returns. S is an interstitial position and should have some grout, but it would be expected that the adjacent holes B, J, F, and C would have more grout. What follows is an evaluation of the marker metals relative to what should have been either good grouted areas or ungrouted areas:

Areas that should have shown good grout penetration (holes B, C, F, and J):

Examining Table 20 (or 21), it is seen that hole B shows good grout penetration for some marker metals as expected. Hole C, on the other hand, should have exhibited good penetration but showed only fair on the marker metals analysis. Hole F showed good penetration as expected by high marker metals; however, hole J (upper 8–13 ft) showed no penetration of grout, even though hole J lower (13–17 ft) showed good penetration.

Areas that should have shown poor grout penetration (holes R, Q, and O):

Core O showed the most obviously high marker metals for all four marker metals. Yet, it was a region that could not be grouted. Perhaps the reason it could not be grouted is that grout penetration from other holes preferentially entered this region because of higher porosity and when grouting was attempted, additional grout simply came up as returns and grouting was abandoned in that area. Core R similarly showed generally good grout penetration by marker metal evaluation. Hole Q upper showed good grout penetration, but the lower portions were essentially devoid of grout.

Areas that should have shown mixed grout penetration because of an interstitial core hole:

Core hole S showed very poor to no grout penetration for the upper core, and the lower core showed fair penetration.

5.2.2 Leachability Study

Samples from the cores were evaluated for leachability by using TCLP for the main contaminant of concern (mercury) and for all metals in the material. In general, examination of the results shows that the final waste form passes TCLP because the values found in the leachate of TCLP are all lower than the regulatory levels. Table 22 shows that for all the cores, the TCLP values are in the tens of ppb range, while the regulatory limit is 200 ppb. The original source term for mercury varied between 1.4 to 5,230 ppm (Reference 1, Track-2 core 11 sample). Therefore, the nominal 59 ppb in the leachate for core B, for instance, represents a large 4,500-fold reduction over the original 5,320 ppm concentration (accounting for the automatic 20:1 reduction in the TCLP process).

It is possible that the reported Track-2 mercury concentration was fairly isolated and the real average source term for mercury was actually lower. Evidence for this is that the evaluation of the Track-2 core hole 11 cores by Brookhaven National Laboratory during the mixing study (see Appendix A) reported the range of mercury in the core sample was 2.6 to 10.5 ppm. If the source term were this low, the TCLP results still show a 9-fold reduction, again considering the 20:1 dilution factor. Examining the total metals in the cores (Table 14), mercury averaged about 24 ppm, which agrees more with the Brookhaven work and represents a 20-fold reduction (from 24 ppm to 59 ppb). It is pointed out that at no time in the core visual examination was any elemental mercury found in the core. For completeness, Table 23 gives the total metals evaluation for TCLP showing that all hazardous metals except barium are at the ppb-type levels or, in other words, very small, indicating that the TECT grout either locks up the contaminants or the material has migrated away since Track 2 (early 1990s).

Table 22. 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	
Rinsate 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.

Table 23. TCLP metals analysis for cores.

	Concentrations (µg/L)							
Core Location	Arsenic	Barium	Cadmium	Chrom	Lead	Mercury	Selenium	Silver
B (15–17 ft)	23.5	6,700	8.2	4.7	1.1	58.9	5.8	4.4
C (15–17 ft)	25.6	6,850	4.8	3.5	1.1	4.5	5.5	4.4
F (15–17 ft)	26.4	8,500	9.5	5.4	1.1	14.8	4.3	4.4
F (15–17 ft) duplicate	30.5	2,940	7.5	4.8	1.1	27.8	2.3	4.4
J (13–17 ft)	44.9	10,300	6.1	2.2	1.1	10.3	6.4	4.4
O (10–15 ft)	37.6	3,480	4.9	4.5	1.1	4.5	2.2	4.4

5.3 Temperature Measurement During Curing

Temperature data were recorded from September 24 until October 22, 1997, during the monolith curing process. These data were recorded continuously, taking a reading every 30 minutes from each of the two probes. Figure 43 gives a temperature/time history of the Acid Pit. The inner probe recorded a peak cure temperature of 22.4°C (72.3°F) and decayed to 20.8°C (69.4°F) in 17 days. These data do not agree with previous data obtained from grouting in debris pits. In general, cement-based grouts cure at about 60°C and the values obtained from the Acid Pit were all lower. It is possible that the prior data were based on measuring the curing inside a monolith of buried debris and the thermocouple probe is imbedded in neat grout rather than the soilcrete of the Acid Pit.

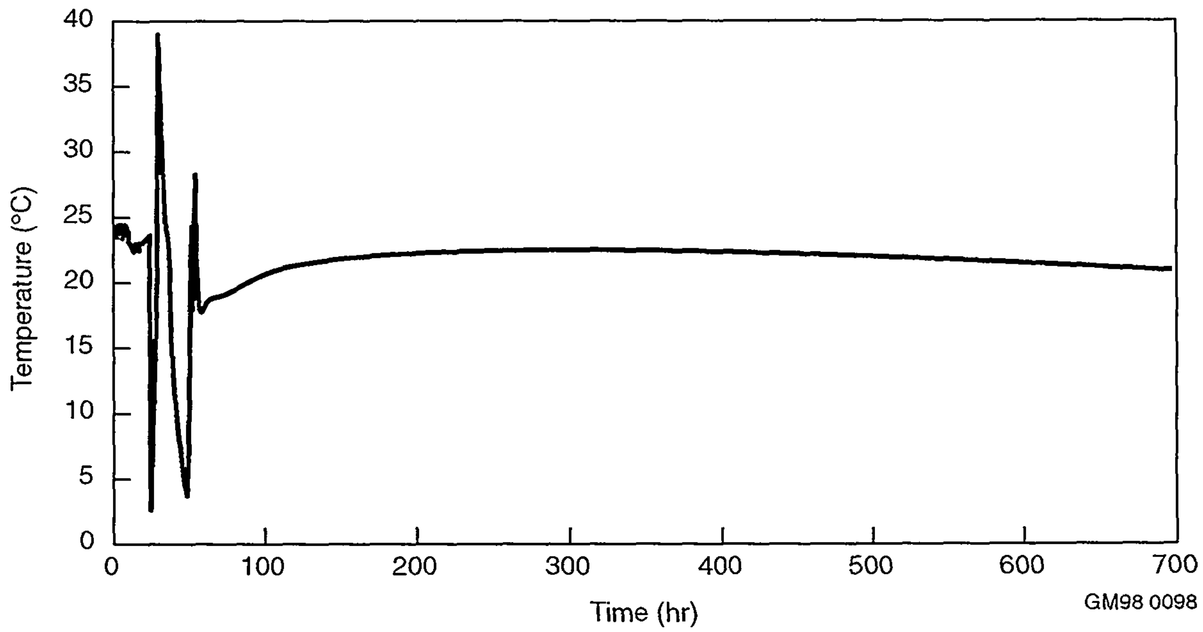


Figure 43. Internal core temperature history following Acid Pit grouting (Graphic GM98 0098).

5.4 Geophysical Verification

Seismic and electrical tomography methods were employed to nondestructively image the emplaced grout monolith at the Acid Pit. Geophysical instrumentation and verification techniques were first tested at the Cold Test Pit and then employed at the Acid Pit. The Acid Pit was instrumented using techniques known to provide sufficient sensor/ground coupling and site coverage.

5.4.1 Site Preparation

Prior to placing the Acid Pit thrust blocks, four boreholes were drilled to install the seismic source/electrical receiver boreholes. The four holes, termed Source Holes N, S, E, and W, were drilled to the basalt bed, which was approximately 16 ft below the surface. Lengths of polyethylene pipe 20 ft long, sealed at the bottom, were inserted into each hole. The boreholes were backfilled with native soil.

Twelve receiver electrodes, made from copper sulfate and plaster, were attached to the outside of the polyethylene pipes prior to insertion. Electrodes were spaced 1 ft apart and started 1 ft above the bottom end of the pipe.

No seismic receivers or source electrodes were installed prior to grouting. As a result, no baseline data could be collected. Due to time constraints, the decision was made to install the seismic receivers and source electrodes during grouting. Preliminary field observations showed this method provided excellent coupling between the geophysical sensors and the subsurface. In addition, the risk of having sensors destroyed during the grouting process was reduced.

Field conditions at the Acid Pit required the grouting parameters to be reevaluated and modified, as necessary, from hole to hole. In addition, the grouting sequence and pattern were altered from the test plan.[7] Based on the grouting data, it was expected that the northern part of the Acid Pit monolith would have a fairly large portion of ungrouted to poorly grouted soil (see Figure 23). It was also expected that similar areas, smaller in size, would be present in the monolith.

While grouting the Acid Pit, geophysical sensors were inserted into newly formed grout columns in grout holes 8, 23, 54, and 66, as shown in Figure 23, for the strings and holes 2, 4, 10, 14, 15, 20, 28, 31, 38, 41, 44, 46, 57, 60, 61, and 64 for the single sensors. This makes for a total of four 18-sensor strings and 16 single sensors emplaced in the Acid Pit. A sensor consisted of a seismic receiver (geophone) and an electrical source (stainless steel hose clamp). Single sensors were constructed using a 40-Hz geophone encased in a standard marsh case. A stainless steel hose clamp was attached to each geophone. The single sensor was then attached to a 4-ft wooden dowel for emplacement. The sensor strings consisted of a string of 40-Hz geophones hard-wired into the cable. A stainless steel hose clamp was attached to each of the geophones. Sensors were spaced 1 ft apart on the string.

The sensor strings were pushed to the bottom of the grouted column. Single sensors were only inserted to a depth of 4 ft below the thrust block surface. These sensors were considered "surface" sensors.

Following grouting and curing, seismic data were collected by lowering the elastic wave source into one of the four seismic source holes. A source wave was generated at the bottom of the source hole and recorded on the four receiver strings and "surface" geophones. The source was then raised 1 ft, and the process was repeated. Fifteen shots were made in the south, east, and west holes, and 14 shots were made in the north hole.

Electrical resistive data were collected along north-south and east-west profiles. For the north-south profile, data were collected using the north and south receiver electrodes and source electrodes. Resistive data were collected using the north source string as the source and the south source string as the receiver. The north source string was then used as the source, and the pulse was received and processed on the north and south receivers. Finally, the south source string was used as the source; and the north and south receivers received and processed the pulse. This process was repeated using the electrodes in the east-west profile.

Tomograms produced from the Acid Pit seismic data are shown in Figures 44, 45, and 46. As with the Soil Pit, higher velocities should indicate a greater concentration of grout in the subsurface. Velocities in the Acid Pit ranged from approximately 0.41 ft per millisecond (ft/ms) to 1.63 ft/ms, with the higher velocities occurring in the grouted region. Depth slices displayed in Figure 44 show an area of lower velocities in the northern portions of the tomograms. In addition, a low-velocity zone, at times surrounded by higher velocities, exists within the central portion of what would be the monolith. These low-velocity zones could be attributed to those sections of the Acid Pit that were not grouted. The north-south and east-west slices (Figures 45 and 46, respectively) depict the high-velocity region as a "box-shaped" anomaly approximately 13 ft long east to west, 14 ft long north to south, and 13 ft high. A three-dimensional representation of the high-velocity zone shows the same "box-shaped" anomaly (Figure 47). In addition, a velocity decrease (shown as a void in the velocity model) in the northern portion of the imaged region can be discerned. High velocities are also absent in the middle of the anomaly, where little to no grouting occurred.

5.4.2 Geophysical Versus Coring Data

After completing the core evaluation in July 1998, seismic tomography data collected at the Acid Pit were compared with data gathered while examining the cores. Core holes were located on the seismic tomograms. Pseudovelocity logs were constructed for each core hole using the east-west, north-south, and vertical velocity tomograms containing the core holes. These logs were then averaged to obtain a final velocity log that represented the seismic velocities one would expect to find along each core hole location. The average pseudoseismic velocity log created for each core hole was compared with the actual core descriptions made during the core evaluation.

Due to the project scope, much of the upper core runs were not examined. Consequently, comparisons focused primarily on the lower intervals. Particularly good correlations between seismic velocity and core evaluation data were present in core holes B, J, K, O, and T.

Grouting parameters and intervals indicated the Acid Pit should be well grouted in the location of CH-B. Seismic velocity data for CH-B indicated this area of the Acid Pit contained low velocities from the 7 to 17-ft interval, with a slight increase around 15.5 ft. The lower velocities indicate a poorly grouted and/or poorly compacted region, and the higher velocities indicate a higher grout content and/or an increased compaction. Evaluation of core samples from CH-B showed the interval from 7 to 14.5 ft contained little grout (approximately 0% to 25% qualitative). A slight increase in grout content, approximately 50%, was seen from 15 to 16.5 ft, and the grout content dropped to 0% from the 16.5 to 17.5-ft interval. Lower-than-expected TECT concentrations may reflect core sampling at the outer edge of the grout column (access hole for CH-B was located approximately 6 in. from GH-29).

Seismic velocity data suggest CH-J would have a higher grout content and/or compaction from 8 to 16.5 ft. Actual grout content, from the core analysis, ranged from about 20% to 40% in the 8 to 14.5-ft interval. From 15 to 16 ft, the grout content decreases slightly then increases to approximately 50% at 16.5 ft.

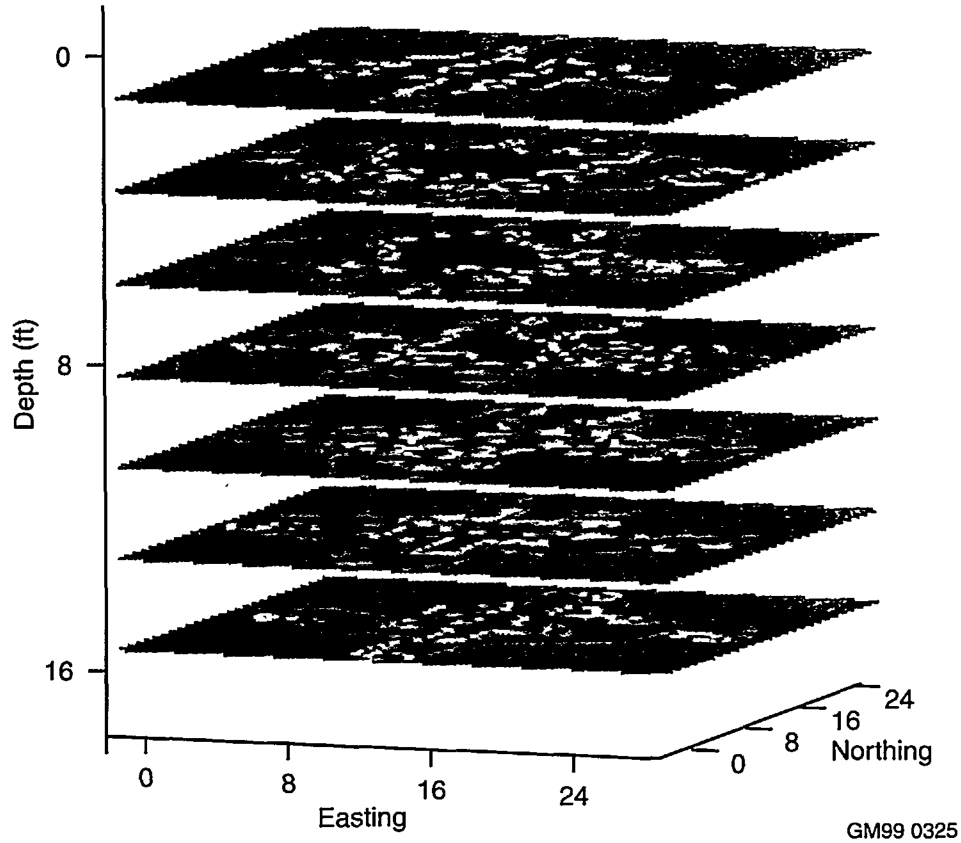


Figure 44. Depth slices (Graphic GM99 0325).

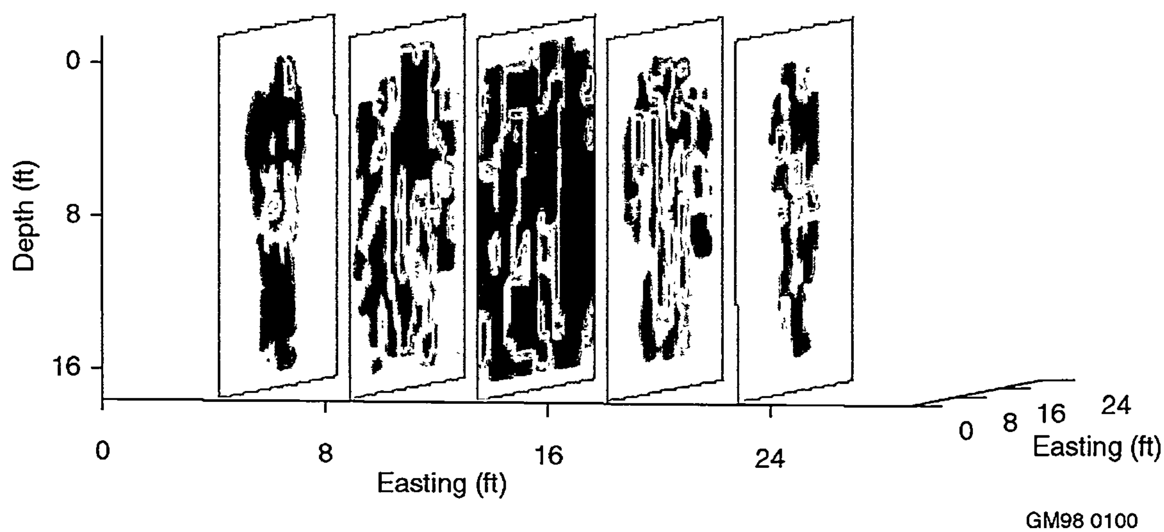


Figure 45. North-south tomograms (Graphic GM98 0100).

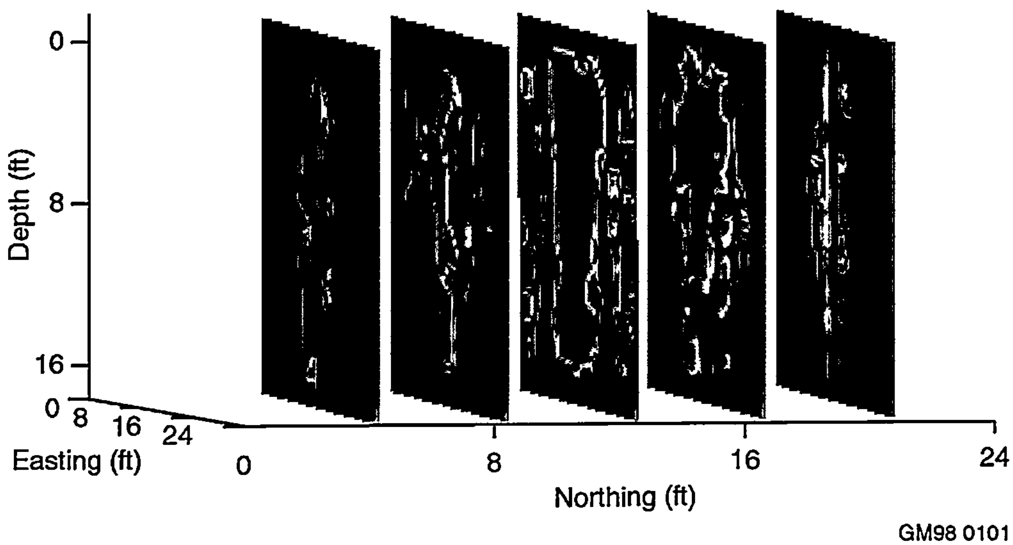


Figure 46. East-west tomograms (Graphic GM98 0101).

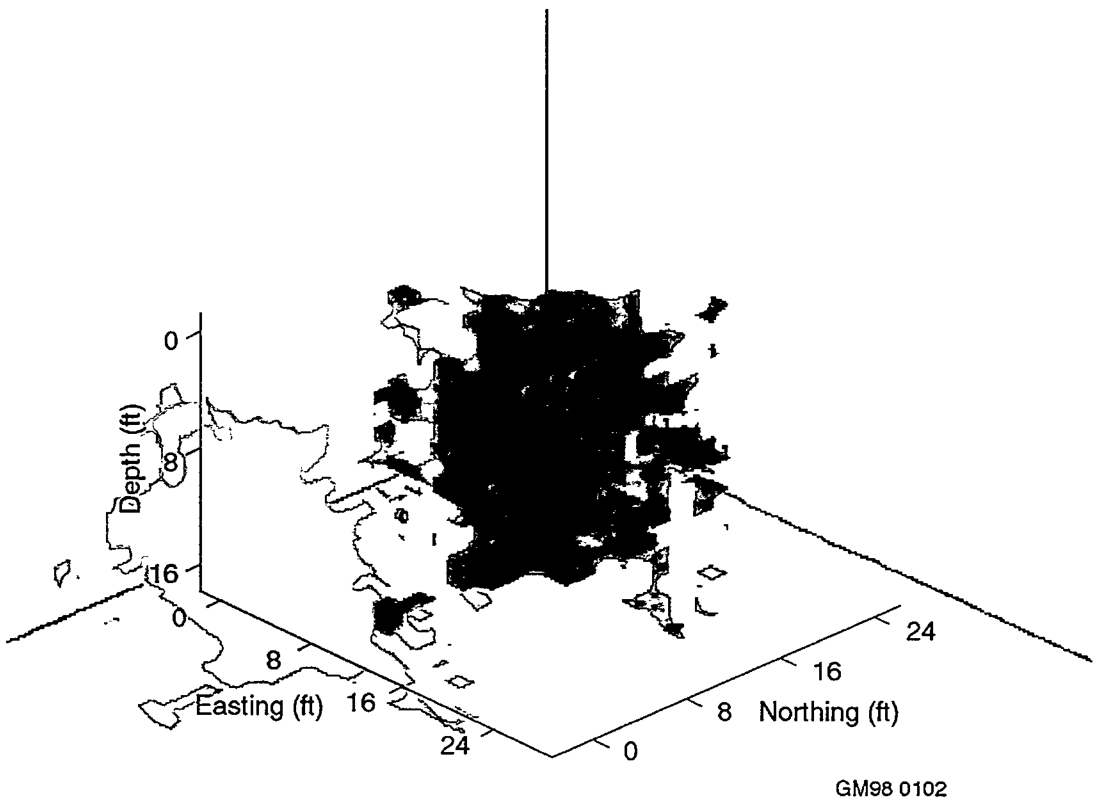


Figure 47. Acid Pit composite tomogram (Graphic GM98 0102).

High seismic velocities were prominent along CH-K from 11 to 16.5 ft. When CH-K was evaluated, the actual core revealed an approximate grout content, in this interval, ranging between 50% and 80%, with only a small portion decreasing to about 20%.

Analysis of the core from CH-O indicated the interval from 7 to 8.5 ft contained between 0% and 15% grout (visual observations). Grout content increased to about 10% to 30% from 9 to 9.5 ft. The 11 to 14.5-ft interval contained between 0% and 5% grout. Seismic velocities along this core hole increased from 7 to 9.5 ft before decreasing from the remainder of the hole.

The final core examined was from CH-T. This core hole was used as a control hole. Since it was located away from the primary grouting area, it was assumed that the hole would contain no grout and/or compacted soil. Seismic data supported this assumption, as low velocities were present along the entire core hole area. Aside from the 5 to 8-ft and 12.5 to 14.5-ft intervals that contained negligible, thin stringers of grout, the core taken from CH-T contained no noticeable amount of grout.

Seismic velocity data from the remaining five core holes (F, C, R, S, and Q) do not correlate as well with the core evaluation data. Higher velocities were not always accompanied with increased grout content. However, an accurate estimate of compaction from the grouting process could not be determined from the core evaluation. Several core holes did not extend deep enough and/or core recovery was not sufficient to complete an accurate comparison. As a result, the increased velocity could have been a result of increased compaction from grout emplacement.

5.4.3 Geophysical Summary

Seismic geophysical methods were used to nondestructively examine jet-grouted monoliths emplaced at the INEEL RWMC. The nondestructive examination included verifying the existence of the monolith as well as its location and the continuity of the monolith. This work was completed using tomograms generated from collected geophysical data.

Seismic data collected at the Acid Pit after grouting suggest the presence of the emplaced monolith. High-velocity zones, indicating the presence of grout and/or higher compaction, can be distinguished in this section. The size and shape of this high-velocity zone correspond with the grouting data collected in the field. In addition, results from the Acid Pit clearly show voids in the monolith that can be associated with zones of the Acid Pit that were not grouted and/or compacted. A fair amount of core hole data could be correlated to the seismic velocities determined at the core hole locations. Poorly correlating data may have been a result of an indeterminate estimation of the amount of in situ compaction in the Acid Pit due to grouting. High velocities in areas with no grout could have been a result of increased compaction.

5.5 Cost Estimate for Full-Scale Application

An estimate of the cost of application for this technology in a contaminated soil region of mixed waste has been evaluated. The actual cost of application of any technology in the INEEL SDA is overwhelmed by the permitting and management costs; however, an estimate can be made for application on a per cubic foot of contaminated space basis. The main variable in the cost estimate presented below is the depth of the contamination zone. For instance, the cost for the thrust block would be higher if the zone of contamination were longer in the axial direction primarily because of the requirement for a larger volume for grout returns; therefore, there are two estimates: one for a contaminated zone from 0–6 ft and another for a contaminated zone from 6–12 ft. Only the costs associated with deployment, grouting, grout, thrust blocks, operations, contamination control, and secondary waste management are included in this evaluation. The actual cost for remediation of a CERCLA site could easily be doubled or tripled for management verification and coring, and permitting of the operation. Another basis for the cost estimate is that one grout hole affects a volume of 2.18 ft^3 per vertical foot of contaminated soil (20-in. diameter column).

Grouting a 6-ft zone:
Thrust block: $150/hole
Grouting includes mobilization/demobilization: $250/hole
Grout: $20/ft
Contamination control: $20/hole
Secondary Waste Management: 0.1 ft^3 per hole @ $500/$ft^3$ = $50/hole
Totals per hole: $150 + $250 + $120 + $20 + $50 = $590/hole
This equates to $45/$ft^3$ or $1,217/$yd^3$ of waste

Grouting a 12-ft zone:
Thrust block: $250/hole
Grouting including mobilization and demobilization: $250/hole
Grout: $20/ft
Contamination Control: $20/hole
Secondary waste management: 0.1 ft^3 per hole @ $500/$ft^3$ = $50/hole
Totals per hole: $250 + $250 + $240 + $20 + $50 = $810/hole
This equates to $31/$ft^3$ or $836/$yd^3$ of waste

The cost estimate for the 12-ft column is essentially the same estimate that was made for debris pits in Reference 4. The shorter zone is more expensive per cubic foot because the cost of grouting is essentially the same for a 12-ft zone or a 6-ft zone, with essentially the same cost of grout per foot of column created. Therefore, even though the thrust block costs more for the extended volume to collect grout returns, the overall cost per foot is reduced when comparing the 12-ft hole with the 6-ft hole.

6. DISCUSSION OF RESULTS—RELEVANCE OF DATA

The most significant accomplishment of the entire treatability study was completing the operation without incident. What was left was a grouted pit with a top cap of approximately 3 ft of clean overburden, followed by reinforced concrete approximately 18 in. thick and a region of more or less grouted or compressed soil to the basalt layer. The area grouted covered the only zone of the Acid Pit that displayed in the Track-2 elevated levels of hazardous materials, namely mercury. Grouting was accomplished within 1 week, and there was no secondary wastewater generated. What follows is a discussion of the results relative to the stated objectives of the CERCLA Treatability Study and the relevance of the data to other applications. For the treatability study to be considered successful, the following objectives must be met:

Grouting Should Decrease Leachability

This objective of obtaining reduced leachability was clearly met because evaluation of the cores for mercury passed TCLP criteria. Evaluation of the Track-2 core hole 11 by Brookhaven showed that the concentrations for mercury were all above the regulatory levels (see Appendix A). Yet, the samples of the cores, which are representative of the core hole 11 region when subjected to TCLP, all showed below 200 ppb in the leachate. Interestingly enough, the original Track-2 cores showed mercury as high as 5,320 ppm, which is considerably lower than that found by the Brookhaven analysis of the same cores. This suggests that perhaps the mercury had been very localized to approximately 0.25 ft^3 of material (size of a core) in the original Track-2 study and that the remaining core sent to Brookhaven simply did not have that much mercury. In fact, the grout return grab samples all were elevated relative to background but still in the 1-ppm mercury range, which is more closely in agreement with the Brookhaven evaluation of 10 ppm as a source term.

Another example of the reduction in leachability is the potential reduction in hydraulic conductivity inherent in the technology. Enough grout was placed in the treated region that no additional grout could have been emplaced under pressure, suggesting a near complete lack of water assessable voids. The top surface of the reinforced concrete thrust block was drilled prior to the sonic coring operation and rainfall remained in the top cap holes, indicating that the approximately 18 in. of reinforced concrete and neat grout present a barrier to incident water penetration to the Acid Pit below. In addition, the Brookhaven study showed that in the laboratory the mixture of soil and TECT-HG had a hydraulic conductivity on the order of 1e-11 cm/s, which far exceeds the Nuclear Regulatory Commission value for low-level waste pits of 1e-7 cm/s.

The Resulting Monolith Should Resist Subsidence

The issue of subsidence with a contaminated soil site is almost nonexistent; however, installing an 18-in. thick cap of concrete followed by an amount of grout equal to approximately 25% void filling within the pit itself guarantees that the possibility of subsidence is moot. Laboratory studies at Brookhaven show that the compressive strength testing of the cured soil/TECT-HG mix is on the order of 2,000 psi compared with the required 50 psi value required to hold up soil. Although visual observations of the cores did not clearly reveal the presence of TECT, an examination of certain marker metals in the soilcrete mix suggested the presence of the TECT-HG grout throughout the cores. For positions difficult to grout, it would be expected to find little grout; however, the marker metal evaluation showed considerable penetration of grout in these regions. In addition, there were a few examples of a region that should show good grout penetration that did not show any. One possible explanation for this is that the general soil condition within the Acid Pit must be generally heterogeneous, and grout penetration varies widely depending on the local conditions of porosity and other density/particle size distribution parameters.

The Monolith Should Resist Degradation

Past studies for the TECT grout (similar in composition to the subject TECT-HG) showed that when subjected to 30–90 day water, base, and trichloroethane immersion testing, there was no significant loss of mass nor change in baseline compressive strength.[4]

The Monolith Is Compatible with the Surrounding Environment

The TECT-HG grout is a hematite, puzzolanic, cementitious mixture, which is chemically and mineralogically stable with the soil being grouted. Because of this compatibility, the monolith should be as stable as the existing soil.

The Grouting Operation Is Fully Implementable

Implementability was fully demonstrated by the successful completion of grouting in the Acid Pit during a September 1997 operation. Discussed below are several implementability issues associated with the operation.

Once the Cold Test Pit data were obtained (Volume 1 of this report), the process of jet grouting in a contaminated soil region of the Acid Pit was fairly straightforward. The problems with creating monoliths out of soil sites all centered on trying to mix grout and soil in a media that had few voids, which resulted in excessive grout returns and therefore contamination spread. The goal of the project was to start and work clean, and this was accomplished. Any grout flows to the surface of the thrust block during grouting of the Acid Pit were controlled by first good communication between the drilling technician and the pumping technician. If the returns became obviously excessive, pumping was immediately stopped and either the grouting parameters were changed or another hole was started. Next, the technique of using the blotter paper and the catch pan controlled excessive dripping of clean grout onto the top surface of the thrust block. In addition, using the squeegees in conjunction with laying down plywood over the affected area kept the top surface clean. Finally, reducing grouting pressure and the length of the column grouted helped stem grout returns.

As grouting proceeded, it appeared that the pit was filling with grout and there were fewer and fewer voids in the pit to accommodate grout. During the early part of the first day of operation (in the south side of the pit) grouting proceeded with only trivial grout returns, even while grouting the full 10-12 ft columns. For these positions, approximately 100 gal of grout was delivered per hole without incident. As the first row was completed (east to west) and the drill string was moved to the second row, grout returns became more common when grouting back across the row (west to east). Finally, when grouting hole 20 (see Figure 29), excessive returns caused abandonment of the hole (this was to have been the 12th hole grouted). Because of excessive returns, the drill rig was moved to the far east part of the pit and three holes in a row were grouted at an 8-ft column height without incident (grout holes 12, 13, and 14) until hole 26 was encountered, which could not be grouted without excessive returns.

At this point, it became clear that the original plan for grouting basically from the south end of the pit to the north end (row by row in a "modified Z" pattern) could not be followed without excessive grout returns, and several different techniques were used including an every-other-hole approach and skipping to complete new regions in the pit. The amount of injected grout emplaced in the pit for the first day's grouting was 1,105 gal and for the second day, 1,307 gal. For the third day, grouting was 620 gal. For the forth and final day, 263 gal. This general decline of injected grout indicated the decreasing amount of voids in the pit given that the same number of holes was attempted per day. In hindsight, it is speculated that grouting the bottom 6 ft of the pit (a region in which 99% of the contaminants reside) would most likely have been accomplished without any excessive grout returns. The reason this could be accomplished is that the potential voids in the regions above the grout zone could have absorbed the grout compression. Unfortunately, grouting the bottom contaminant zone was incompatible with the already fixed geophysics monitoring scheme, and this plan could not be considered an option.

The Extent of the Monolith Is Verifiable

The seismic geophysics technique of applying both long and short probes for the geophones in the just-grouted holes proved to be a viable technique for assessing the size of the monolith postgrouting. There was a strong correlation of the results of the examination of the cores both visually and analytically with the seismic techniques described in this report. Using this technique to assess the amount of cracking within the cured monolith will require more development.

The Monolith Is Retrievable

The monolith in the Acid Pit can be considered disposed; however, if, in the event that retrieval becomes required, the TECT-HG/soil grout matrix is certainly retrievable using industry standard retrieval equipment. During FY-96 studies,[4] a debris pit grouted with TECT grout was retrieved; however, it is cautioned that retrieval of the relatively hard TECT/soil matrix is not recommended unless necessary in that the matrix has high compressive strength, and extremely high force is necessary to break it up. In fact, using a standard backhoe would require suspending the backhoe above the monolith and dropping the bucket while breaking out no more than 4–6 in. off an exposed face. It would be impracticable to retrieve the monolith from the top down due to its dense nature. Other grouts developed in past INEEL studies[3,4] including acrylic polymers and molten paraffin are more ideally suited for stabilizing waste zones followed by retrieval.

Grouting Is Cost-Effective

The technology is cost-competitive with the soil-auger concept and other soil-mixing technologies in that the spread of contamination is minimized by the thrust block, and the operations involving augers with multiple crane manipulations at Department of Energy sites are considered dangerous and present schedule difficulties. When comparing this technology with published remediation costs of ongoing operations at TRU pits and trenches at the INEEL SDA, there is an approximate 10:1 cost savings for the in situ stabilization technology over conventional retrieval and treatment technologies. The technology is definitely on the high end of CERCLA remediation costs in that it is applicable primarily to mixed waste sites. The soil-augering technology and other soil-mixing ideas are more appropriate for nonmixed waste sites.

7. CONCLUSIONS/RECOMMENDATIONS

7.1 Conclusions

It is concluded that the monolith has been shown to have a resistance to leaching and should exhibit a resistance to subsidence thereby satisfying the treatability study's main objectives. In addition, the monolith has shown in the laboratory a demonstrable durability and is compatible with the environment. The fact that the Acid Pit work was accomplished within a week shows full-scale implementability. The geophysical evaluation shows that the presence of the monolith is verifiable. Past studies with TECT-grouted monoliths show that the monolith is retrievable, and this study shows an economic benefit over other subsurface technologies. Specific conclusions are:

- The technique of creating monoliths at contaminated soil sites by jet grouting is practical. However, adjustments to the grouting parameters for soil sites compared with grouting in buried debris sites are required. Higher grout returns were observed when grouting soil sites compared with debris pits.

- Contaminant spread during grouting was mitigated by the thrust block, catch cup and can, and HEPA-filtered shroud around the drill string.

- The TECT-HG grout showed a good chemical stabilization of the mercury contamination found in the pit, as TCLP results showed less mercury in the leachate than regulatory limits allow.

- Grout penetration can be evaluated by examining cores of the monolith for marker metals high in TECT grout but not in soil. Examination of these marker metals showed mixed results in that positions that should have exhibited poor TECT penetration showed good penetration and vice versa. However, generally, those positions that should have displayed good penetration exhibited higher levels of TECT grout.

- Soil properties affected the ability to successfully grout certain types of subsurface conditions. In the future, a geotechnical study is recommended to fully characterize the physical properties of the site for determination of grouting intervals and 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. Then, minor adjustments can be made to grouting parameters and/or techniques to optimize encapsulation of the contaminated zone.

- The cement-based TECT-HG was not completely compatible with the pumping equipment used for this project. A more extensive cleanout process had to be implemented to sufficiently remove settled components of the mixture from pumps and lines. Without this more extensive cleanout, major delays may have occurred to unplug the system.

- Comparing seismic tomography data and core evaluation data shows that seismic tomography is a practical, effective method for verifying and imaging an emplaced monolith. The technique used for this demonstration was effective in determining monolith size and shape.

7.2 Recommendations

- A more extensive subsurface characterization should be conducted to determine emplacement parameters that minimize grout returns and optimize grout column development. This information would provide a more accurate estimate of grout volume needed for emplacement to stabilize the site.

- It is recommended that a packer or plug system be employed in unused or already grouted holes to block any flow of viscous grout returns to the surface of the thrust block during grouting.

- Material mixing should be performed onsite to produce better mixtures and avoid unnecessary disposal of unused material if operational problems occur.

- Temperature measurements from previous field demonstrations[4] recorded a peak cure temperature of 55°C for the TECT grout. Lower temperatures were recorded for the monoliths emplaced at the Acid Pit (peak cure temperature of 23°C). Evaluation of core samples from the Acid Pit revealed that the TECT had properly cured. In addition, neat TECT-HG pockets in the thrust block also displayed curing. These lower-than-expected readings may have been caused by the fact that in the previous study[4] the pit contained buried debris and the thermocouple was placed in neat grout pockets, whereas in the Acid Pit the thermocouples were placed in a soilcrete mixture. The different composition may have caused a difference in measured cure temperatures.

- When compared with conventional core drilling, the sonic drilling process was faster, used no fluids for penetration, and generated no dust or drill cuttings. However, core recoveries generally consisted of fragmented samples containing rubblized TECT and compacted soil. The sonic drilling process caused fracturing of samples and, in some cases, limited the recovery of solid core sections. These poor-quality samples hindered visual determination of the percentage of grout permeation, the degree of grout mixing, and the extent of grout column development. Furthermore, only limited sections of the core could be collected for geotechnical testing. It is recommended that future drilling be conducted by less-intrusive methods and that cutting fluids be employed.

- Although not part of the technology evaluation, it was suspected that viscosity of the TECT grout had a strong effect on grout returns and monolith formation. It is recommended that a parametric study be performed involving variations in TECT grout viscosity to determine effects on grout permeation and column formation.

- For imaging the internal region of the monolith in more detail, it is recommended that higher frequencies be used.

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Appendix A

Materials Testing Phase

Appendix A

Materials Testing Phase

The Materials Testing Phase was performed as a Resource Conservation and Recovery Act (RCRA) Treatability Study due to the transferal of the investigation-derived soil samples used for this study from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program to the RCRA program. The primary objective of this phase was to conduct mixing studies with actual Acid Pit soils and candidate grout materials to aid in the selection process of a suitable grout for emplacement at the Cold Test Demonstration and Acid Pit Stabilization sites. This phase involved (1) retrieval of mercury-contaminated Acid Pit soil samples previously generated from the Acid Pit Track-2 Investigation, (2) shipment of this material to Brookhaven National Laboratory (BNL), and (3) performing mixing studies at BNL using the Acid Pit soil samples and five stabilization materials. Testing activities were presented in more detail in the *Test Plan for the Materials Testing Phase of the In Situ Stabilization Treatability Study.*

Acid Pit Sample Retrieval and Shipment

The investigation-derived soil samples were classified as RCRA waste and stored in drums at the INEEL Mixed Waste Storage Facility (MWSF), a RCRA treatment, storage, and disposal facility operated by the Waste Reduction Operations Complex (WROC). The soil materials selected for testing were derived from core holes 11 and 12, which were drilled as part of the Acid Pit Track-2 Characterization. Analytical results from these core hole samples showed the highest mercury levels at concentrations greater than 1,000 mg/kg. Table A-1 lists analytical results from the Acid Pit Track-2 Summary Report for soil sampling intervals designated for retrieval.

Tasks involved with retrieval of the Acid Pit soil samples included (1) transporting the drums from the MWSF to Test Area North (TAN), (2) retrieving selected sample material from the drums, and (3) shipping the sample material to BNL for the mixing studies. All appropriate notifications for personnel and facility were made and authorizing documents were approved before initiation of retrieval activities. Sample removal from the transferred drums was conducted at the TAN Hot Shop Extension/Annex, an approved location for handling mixed waste materials.

Acid Pit soil samples were retrieved by the MSE Technology Applications, Inc. sampling team on March 17, 1997, and shipped on March 18, 1997, to BNL. The sample containers were labeled and prepared for shipping to BNL by the MSE sampling team and an INEEL-certified shipper. After sample retrieval, equipment used was properly decontaminated and/or disposed according to specifications stated in the test plan.

Mixing Studies at BNL

The technical support provided by BNL for the mixing studies was divided into the tasks given below.

- Task I: Characterization Testing
- Task II: Test Specimen Preparation
- Test III: Performance Testing

Table A-1. Acid Pit soil sample results.

Hole No.	Depth (ft)	Mercury (mg/kg)	Metals (mg/kg)	Radionuclides (pCi/g)	Organics (µg/kg)	Nonmetal Inorganics (mg/kg)
11	14-16	1,420	None reported	*Gamma-emitting* Co-60 1.56 Cs-137 1.14 Eu-152 0.523 *Alpha-emitting* Pu-239 0.20 U-234 2.9 U-238 0.11 U-235 3.0	*Volatile* Carbon tetrachloride 24 Chloroform 18 Trichloroethane 18 Methylene chloride 170 Acetone 103 *Semivolatile* Bis(2-ethylhexyl)phthalate 5,200 Tributylphosphate 45,000	Nitrate 5,590 Sulfate 10,600 TOC 11,400
12	14-16.8	1,030	Beryllium 2.5 Aluminum 27,800 Sodium 658	*Gamma-emitting* None detected *Alpha-emitting* U-234 3.0 U-238 2.5	*Volatile* Methylene chloride 160 *Semivolatile* Bis(2-ethylhexyl)phthalate 1,040 Tributylphosphate 1,100	Nitrate 7,890 TOC 14,800 Magnesium 9073 Sodium 658

A 45-day RCRA Treatability Study notification was filed with the State of New York for performing the soil/grout tests at BNL. Samples were shipped to BNL before the 45-day approval to initiate characterization testing. Specimen preparation and performance testing did not begin until the 45-day notification had been approved. Testing methods and results are described in the following sections.

Five grouting materials were tested including two commercially available materials and three innovative materials. The two commercial grouts were Type-I and Type-H (similar to Type-V) Portland cement. The three innovative grouting systems tested were TECT, paraffin wax (WaxFix), and a special magnesium/potassium/phosphate cement (MKP). The innovative materials were formulated and provided by two different vendors. TECT (also TECT-HG, the specialized additive grout for stabilizing mercury) and WaxFix were provided by Carter Technologies of Houston. MKP was supplied by Argonne National Laboratory (ANL) in Chicago.

Task I: Characterization Testing

The objective of Task I: Characterization Testing was to characterize the mercury concentrations of the Acid Pit soils prior to performance testing. Before characterization testing, the soil was sized through a 3/8-in. sieve and screened to produce a homogeneous sample. A representative sample was collected from the composite mixture for analytical testing to determine the total mercury concentration and soluble mercury concentration. Leachate was extracted from three samples following the U.S. Environmental Protection Agency (EPA) Method SW846 1311, *Toxicity Characteristic Leaching Procedure (TCLP) Extraction.* Initial analysis of the leachate for mercury was conducted by inductively coupled plasma (ICP) spectrometer using EPA Method 200.7 Rev. 4.4 (1994) *Methods for the Determination of Metals in Environmental Samples, Supplement I. Determination of Metals and Trace Elements in Water and Wastes by ICP-AES.* Lower-than-expected concentrations of mercury were detected in the TCLP leachates. To confirm these results, additional samples of the INEEL soil were digested according to EPA Method SW846 and then analyzed. Analytical results are shown in Table A-2.

Table A-2. Mercury concentration in Acid Pit soil.

Sample Location	Mercury in Digest (ppm)	Dilution Factor	Mercury in Soil (ppm)
CH-11 (Depth 10 to 12 ft)	<0.1	25.77	<2.6
CH-12 (Depth 14 to 16 ft)	0.41	25.51	10.5
CH-11 (Depth 14 to 16 ft)	0.47	21.01	9.9

As previously stated, the purpose of the soil characterization testing was to evaluate the mobility of the mercury contamination and determine the percentage of soluble and nonsoluble mercury. Unfortunately, test results showed significantly lower concentrations of total and leachable mercury when compared with the levels reported in the Acid Pit Track-2 Summary Report. It was assumed that these lower-than-expected concentrations were due to degradation of mercury contamination while the samples were in storage. The cause of this degradation could not be determined from this study. Consequently, the mercury concentrations detected were below acceptable levels for a meaningful assessment of mercury stabilization, especially if a significant portion of the contaminant is soluble. Due to these results, MSE, Lockheed Martin Idaho Technologies Company (LMITCO), and BNL mutually agreed to artificially enhance the mercury levels to correspond to values reported in the Acid Pit Track-2 Summary Report.

Mercury enhancement involved (1) thoroughly mixing the remaining Acid Pit samples to produce a homogeneous sample; (2) adding mercuric chloride, as a soluble surrogate for mercury, to the sample to elevate the mercury concentration to approximately 1,000 mg/kg; (3) testing the sample by EPA Method SW846 7471A, *Metals/Mercury*, to verify the total mercury concentration; and (4) testing the sample for soluble concentrations of mercury according to EPA Method SW846 1311, *TCLP Extraction*, and analyze the leachate using EPA Method SW846 7470, *Mercury*.

Three samples of spiked soil were tested to check if the mercury concentration of soil was acceptable. Mercury concentrations in the three spiked samples ranged from 878 to 1,004 parts per million (ppm) for an average concentration of 927 ppm. This value, slightly lower than expected, may represent loss of mercury due to volatilization.

BNL researchers informed the project team that the stabilization properties for the proposed grout mixtures potentially would not stabilize elevated mercury levels to below the TCLP standard (for mercury less than 0.2 ppm). BNL recommended adding a binding agent to each of these grout mixtures to potentially improve the stabilization properties for mercury. To determine the best additive, two series of tests were run in which the sorption of mercury by each of the additives was assessed. These tests are described in detail in the *Materials Testing for In Situ Stabilization Treatability Study of INEEL Mixed Waste Soils*. Sorption results for the first series of tests are listed in Table A-3.

These results indicated that sodium sulfide, hematite, and iron powder outperformed the other materials for stabilization of soluble mercury. Based on these results, a second series of tests was run using sodium sulfide, hematite, and iron powder additives. This second series of testing involved evaluation of the behavior of these additives in the presence of mercury-spiked soil samples. Three samples were prepared with one sample set used as a reference, a second sample set mixed with the iron compounds, and a third sample set mixed with sodium sulfide. Sample sets were tested according to the TCLP protocol, with the exception of reduced sample mass and volume to conserve the spiked soil. The concentration of mercury in the reference sample set was 23.9 ppm, which exceeded the TCLP limit of 0.2 ppm. Results were similar for the sample set mixed with the iron, with the mercury concentration of

Table A-3. Sorption of mercury with additives.

Additive	Source	Weight (g)	Volume (mL)	Mercury Start (µg/g[a])	Mercury End (µg/g)	Mass of Mercury Sorbed (µg/g)
Clinoptilolite	Teaque Minerals	1	40	52	51.6	16
Fly Ash, Type F	Detroit Edison	1	40	52	33.4	744
Sodium Sulfide	Reagent	1	40	52	0.72	2,050
Hematite	P. Shaw	1	40	52	1.98	2,000
Diatomaceous earth	Vortex Diatom Filter Powder	1	40	52	41.1	440
Fe_2O_3 (red)	Fisher	0.5	9	34	13.4	370
Iron powder	Electrolytic reagent	0.5	9	34	0.6	600
Limonite	Ward's	0.5	9	34	3.2	554
Fe_3O_4(black)	Alfa Products	0.5	9	34	4.4	533

a. µg/g—micrograms per gram.

22.4 ppm in the leachate. The concentration of mercury in the sample set mixed with sodium sulfide was below the detection limit of 0.1 ppm. Based on these results, it was decided to add sodium sulfide to the WaxFix, TECT, and Portland cement grout mixtures. The researchers at ANL developed the MKP grout mixture to stabilize a wide variety of contaminants, including mercury. Carter Technologies developed a variation of the TECT mixture to stabilize mercury called TECT-HG. Therefore, besides testing the grout mixtures for TECT, WaxFix, and Portland cements (Type-I and Type-H) with and without sodium sulfide, TECT-HG and MKP were tested without the addition of sodium sulfide.

Task II: Test Specimen Preparation

The purpose of Task II: Test Specimen Preparation was to prepare test specimens for performance testing. Test specimens were mixed according to grout/soil (mercury-enhanced) formulations listed in Table A-4.

Two test specimen sets were prepared. Sample Set 1 consisted of soil mixed with (1) Portland cement Types-I and -H without additives, (2) WaxFix and TECT without additives, and (3) TECT-HG and MKP. Sample Set 2 consisted of soils mixed with Portland cement Types-I and -H, TECT, and WaxFix, with sodium sulfide as a binding agent. The TECT grouts were mixed in a high shear mixer. The Portland cements and WaxFix were mixed by hand. The MKP cement samples were prepared by ANL personnel during a visit to BNL.

Each prepared grout mixture was introduced into a cylindrical polyvinyl chloride (PVC) pipe mold measuring approximately 26 to 35 cm in length and 3.8 cm in diameter. Prepared test specimens were allowed to cure for the industry-recommended 30 days. At the end of 30 days, the molds were cut into 7.6-cm lengths using a wet-masonry saw with a diamond-impregnated blade. The PVC casing was then removed from each individual sample. The samples were measured, weighed, and numbered and then stored in 100% relative humidity until tested for compressive strength. Table A-5 lists the sample identification numbers for each grout mixture and types of tests performed.

Table A-4. Grout/soil mixing formulations.

Grout Type	Grout (mL)	Soil (g)
TECT	110	per 100
Paraffin	45	per 100
Type-H Portland	90	per 100
Type-I Portland	90	per 100
Phosphate Cement	50	per 100

Table A-5. Test specimen sets and associated testing requirements.

Grout Type	Sample Number	Mixture Specification	Total Compressive Strength Samples	Total TCLP Samples[a]
MKP	5-1 5-2 5-3	No binding agent	3	2
TECT	4-1 4-2 4-3	No binding agent	3	2
	7-1 7-2 7-3	Sodium sulfide additive	3	2
	2-1 2-2 2-3	Special mixture (TECT-HG)	3	2
Paraffin	1-1 1-2 1-3	No binding agent	3	2
	6-1 6-2 6-3	Sodium sulfide additive	3	2
Type-H Portland Cement	10-1 10-2 10-3	No binding agent	3	2
	9-1 9-2 9-3	Sodium sulfide additive	3	2
Type-I Portland Cement	3-1 3-2 3-3	No binding agent	3	2
	8-1 8-2 8-3	Sodium sulfide additive	3	2

a. Compressive strength samples were used for TCLP analyses of mercury.

Task III: Performance Testing

The objective of Task III: Performance Testing was to evaluate the grout properties through a series of two standard tests. Except for WaxFix, compressive strength measurements were performed on test specimens following American Society for Testing and Materials (ASTM) C-39, *Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens.* The test specimens for WaxFix were compression tested according to ASTM D-695, *Standard Test Method for Compressive Properties of Rigid Plastic.* The grout/soil mixtures were compression tested in triplicate, and average compressive strength results are given in Table A-6.

After compressive strength testing, specimen fragments were collected and subjected to TCLP analyses for mercury. Duplicate samples were tested according to the EPA Method SW846 1311 for TCLP Extraction and EPA Method SW846 method 7470, *Mercury* (Mercury in Liquid Wastes Manual, Cold Vapor Method). Analytical results are listed in Table A-7.

Table A-6. Average compressive strengths.

Grout Type	Average Compressive Strength (psi)
WaxFix	140
WaxFix with sodium sulfide	140
Portland Type-I	1,600
Portland Type-I with sodium sulfide	1,050
Portland Type-H	610
Portland Type-H with sodium sulfide	640
TECT	2,210
TECT with sodium sulfide	1,900
TECT-HG	1,880
MKP	140

Table A-7. Average mercury concentrations in TCLP leachate.

Grout Material	Average Mercury Concentration (µg/L)
WaxFix	630
WaxFix with sodium sulfide	13.1
TECT	175
TECT-HG	26.7
TECT with sodium sulfide	0.65
Type-I Portland	600
Type-I Portland with sodium sulfide	0.3
Type-H Portland	350
Type-H Portland with sodium sulfide	0.4
MKP	565
Reagent Blank	0.3

Evaluation of Test Results and Material Selection for Field Demonstrations

Seven criteria were developed to facilitate the selection of an appropriate stabilization material for field demonstration testing. Information from Task III was used as part of this selection process. Table A-8 lists these evaluation criteria (ranked highest to lowest) with corresponding performance standards (acceptance criteria). Critical criteria for grout selection were specified as contaminant stability and implementability. If a grout material did not meet the performance standard for either of these two criteria, then it was not considered any further in the selection process.

Data used for evaluation of Level-1 criteria were obtained from the following sources: (1) BNL data produced by the mixing studies, (2) demonstration findings from the Innovative Subsurface Stabilization Project conducted at the INEEL in Fiscal Year (FY) 1996, and (3) existing data. Level-2 criteria were derived from (1) existing/historical data and information obtained from material vendors, (2) test results performed at BNL in FY-96, and (3) test results from previous demonstrations conducted at the INEEL (see Section 3). Table A-9 is a summary of the evaluation data for each of the grout materials. A discussion of these results follows.

Level-1 Criteria

Of the as-received materials tested, only the TECT-HG passed the TCLP limit for mercury (0.2 ppm or 200 ppb). When sodium sulfide was added, all materials passed TCLP. The next-best results were obtained from the TECT without sodium sulfide, which averaged below the 200-ppb level. However, one sample was borderline at 200 ppb, which indicates a potential for failure.

Use of the additive profoundly reduced the concentration of mercury in the TCLP leachate, with all concentrations significantly below the 200-ppb standard. Both types of Portland cement containing the sodium sulfide additive had releases of mercury that were no greater than the reagent blank for the analysis, indicating that mercury concentrations were below the laboratory detection limit. The TECT had only slightly higher mercury concentrations in the leachate; the difference between the TECT material and the Portland cements, as far as TCLP leaching is concerned, is negligible. The Portland cements without additives, WaxFix without additives, and MKP did not pass TCLP testing; therefore, they were not considered any further in the selection process.

During the Innovative Subsurface Stabilization Project conducted in FY-96, TECT, WaxFix, and Portland Type-H cement were successfully injected using high-pressure jet grouting to produce competent monoliths that encapsulated buried waste. Portland Type-I cement had been successfully jet grouted in previous INEEL demonstrations.

Destructive examination of these test pits showed that the TECT grout produced a competent monolith with minimal grout returns. The WaxFix produced a competent monolith with good grout permeation into the buried waste but generated a large volume of returns. The Portland Type-H cement was grouted in two test areas: one using an 18-sack mix and the other using a 16-sack mix. The higher sack mix produced more returns when compared with the 16-sack mix; however, both were significantly less than the WaxFix emplacement. For the exposed monolith created by the 16-sack mixture, poorly grouted regions were observed, which were inferred to represent areas where the grout reacted with sodium sulfate (used as a simulator for nitrate salt).

Table A-8. Criteria for grout selection.

Criteria	Performance Standard
Level-1 Criteria	
Contaminant Stability	Pass/Fail—Leachable mercury concentration of 0.2 ppm or less
Implementability	Pass/Fail—Ability to pump the material using jet-grouting techniques
Structural Integrity	Compressive strength at greater than 50 psi
Economics	Material cost per gallon, cost ranked lowest to highest
Level-2 Criteria	
Permeability	Goal—Hydraulic conductivity of less than 10^{-7} cm/s
Durability	Relative degree of degradation
Verification monitoring	Ability of using geophysical techniques to verify the integrity of the emplaced grout

Table A-9. Summary of evaluation data for stabilization material selection.

Evaluation Criteria	MKP	TECT	WaxFix	Portland-I	Portland-H	Comments
Level-1 Criteria						
Contaminant Stability (ppm)*	0.565	1—0.178 2—0.001 3—0.027	1—0.630 2—0.013	1—0.601 2—BDL	1—0.35 2—BDL	TCLP analysis for mercury BDL—Below detection limit Mercury TCLP Standard = 0.2 ppm
Implementability	Not tested	Yes	Yes	Yes	Yes	Based on results from the Innovative Subsurface Stabilization Project for FY-96
Structural Integrity (psi)*	145	1—2,207 2—1,902 3—1,876	1—143 2—141	1—1,603 2—1,048	1—612 2—643	Unconfined compressive strength EPA > 50 psi
Economics—includes supervision labor (material cost)	~$5.00/gal	1—$8.40/gal 2—$8.50/gal 3—$8.50/gal	1—$9.50/gal 2—$9.60/gal	1—$2.50 2—$3.00	1—$3.50 2—$4.00	Based on vendor quotes and historical data.
Level-2 Criteria						
Permeability (cm/s)	3.1×10^{-7}	$<2 \times 10^{-11}$	$<2 \times 10^{-11}$	10^{-7} to 10^{-8}	10^{-7} to 10^{-8}	Information from previous studies
Durability (MPa)@	Base-line: 8.3 Wet-Dry: 3.0	Base-line: 20.5 Wet-Dry: 13.5	Base-line: nm Wet-Dry: nm	Base-line: 45.2 Wet-Dry: 36.1	Base-line: 45.2 Wet-Dry: 36.1	Information from previous studies
Verification Monitoring	Not tested	2	3	1	1	MKP not tested, but ceramic material. Assume would be comparable to Portland cement if cures properly.

1—Material without binding agent
2—Material with binding agent
3—Specialized formulation
MKP—magnesium/potassium/phosphate
* Average value
@ Comparison of compressive strength
nm—Not measured

The EPA considers a stabilized material with a strength of 50 psi to have satisfactory compressive strength (USEPA OSWER Directive, No. 9437.00-2A) to provide a stable foundation for impermeable caps and cover materials. All the materials passed this compressive strength standard of 50 psi. The highest strength values were obtained for the TECT mixtures, with the Portland cements being only slightly less in strength than the TECT grouts. The TECT grout mixtures and Portland cements were an order of magnitude greater in strength than the WaxFix. WaxFix and Portland Type-H showed relatively no change in strength properties between the mixtures with and without additives. TECT and Portland Type-I mixtures with additives showed strength decreases on the order of 15% and 35%, when compared with the mixtures without additives.

Cost for the TECT and WaxFix are generally twice as high as the Portland cements. Furthermore, based on 1996 results, because of the high-density properties of TECT, more material was emplaced (up to 25% more) compared with the monoliths created using Portland cements and WaxFix grout mixtures. Material volume estimates and associated costs are given in Table A-10.

As seen in Table A-10, cost of the estimated volume of TECT material for emplacement during the field demonstrations would be three times higher than the Portland cements.

Level-2 Criteria

As previously stated, data for Level-2 criteria were primarily obtained from a BNL study conducted in 1996. This study focused on the TECT, WaxFix, and MKP with limited information for Portland cement (Portland Type-II). Because of similarities in Portland cement properties, test results from the BNL study were used in the evaluation process for the Portland Type-I and Type-H cements.

The hydraulic conductivity of test specimens was measured using flexible wall perimeters following ASTM D-5084. Hydraulic conductivities were low for all grout/INEEL soil mixtures. Hydraulic conductivity values for the TECT and WaxFix specimens were below the instrument detection limit of 2×10^{-11} cm/s. The Portland cement specimens tested an average hydraulic conductivity value of approximately 10^{-7} cm/s, which infers higher composite void space and porosity in the grout/soil mixture.

Wet-dry cycling was conducted to simulate natural stresses applied over time and evaluate the resistance of the stabilized mixtures to degradation due to external environmental stresses. No standards are currently established for determining whether stabilized material has passed this durability test. Except for WaxFix, grout mixtures were tested for wet-dry cycling following ASTM D-4843, *Wetting and Drying Test for Solid Wastes*. After cycling, the mechanical integrity of the specimens was determined using ASTM C-39. Variable results were obtained following wet-dry cycling. The TECT mixtures showed hairline cracking and slight compositional changes, which indicate general retention of the sample's physical integrity. The TECT/INEEL soil mixture exhibited hairline cracking after just one wet-dry cycle; however, this initial cracking never increased. After cycling, the TECT/INEEL soil mixture showed a strength loss of 34%.

Values for the Portland cements were taken from previous studies conducted at BNL using Portland Type-II cement, which were assumed to be similar to Portland cements subjected to this study. The Portland cement samples showed modest hairline cracking and a significant reduction in strength, indicating stresses may affect the internal integrity of the monolith.

From the geophysical studies performed in FY-96, Portland cement samples showed the most favorable and WaxFix the least favorable imaging properties for geophysical evaluation. However, differences between the TECT and Portland cements were minimal when compared with the WaxFix.

Table A-10. Grout volume and cost estimate for field demonstrations.

Grout Type	Cold Test Demonstration	Acid Pit Stabilization	Total Volume	Estimated Cost
TECT	8,000 gal	17,000 gal	25,000 gal	$212,500
WaxFix	6,000 gal	13,000 gal	19,000 gal	$182,400
Portland Type-H	5,000 gal	13,000 gal	18,000 gal	$72,000
Portland Type-I	5,000 gal	13,000 gal	18,000 gal	$54,000

Material Selection

Based on the comparative analysis of the above criteria (see Table A-9), TECT-HG was selected as the most appropriate material for grout emplacement for the Cold Test Demonstration and Acid Pit Stabilization phases. Although TECT-HG did not significantly outperform the Portland cements, the TECT-HG was selected for the following reasons:

- Passed TCLP for stabilizing soluble mercury contamination
- Proven implementability as demonstrated by FY-96 work at the Cold Test Pit
- Processed higher strength properties
- Was more durable
- Had a significant reduction in hydraulic conductivity.

Other factors favoring the selection of TECT-HG were:

- Development of competent monoliths based on core evaluation and field permeability testing conducted in FY-96.
- TECT-HG, as an iron oxide cement-type material, has the potential to stabilize a wider range of contaminants (i.e., metals, chlorinated solvents, etc.) than the Portland cements (the next best material).
- As demonstrated in FY-96, TECT can stabilize liquid organic sludges, sulfate compounds, and a variety of waste forms (i.e., organic sludges, salts, paper, wood, cement and metal fragments, etc.).
- TECT-HG developed by the grout supplier required only a minor addition of a stabilizing agent for mercury. The vendor claimed this addition should not affect the implementability of the mixture using jet-grouting techniques to create a competent monolith. Although less than 5% of sodium sulfide was added to the total volume of the other mixtures, unless field implementability tests were performed, it was unknown if this additive would affect the jet groutability of these mixtures.

MSE proceeded to subcontract with Carter Technologies to supply TECT-HG for the grout emplacement phases of the treatability study. Based on product information provided by the grout developer, TECT-HG is a high-performance cementitious grout designed for block encapsulation of buried waste by the jet-grouting process. TECT-HG is a proprietary two-component system consisting of solid and liquid components with a binding agent for mercury stabilization. The low-viscosity grout was formulated to allow mixing and delivery in conventional concrete mixer trucks.

TECT grout remains liquid longer than Portland cement slurries (the material is jet groutable for at least 12 hours), and when cured, the material hardens into a dense, low-permeability solid resembling a kiln-fired ceramic. The grout has a low heat of hydration and is formulated to tolerate and stabilize small amounts of organic contamination. The product hardens in approximately 1 day when mixed with soil. However, after approximately 12 months of curing, the grout approaches its final matrix condition, which is thermodynamically stable and highly resistant to chemical and physical degradation.